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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

This study is the first attempt to examine the impacts of a natural disaster at the plant level, focusing on the Great Hanshin-Awaji (Kobe) earthquake, which occurred in 1995 and affected numerous plants in Kobe city. In this study, I use plant-level data to re-examine the creative disaster hypothesis, which states that natural disasters enhance growth of firms or plants in stricken areas. I employ the matching method together with the difference-in-difference (DID) approach to reveal the quake's effects. While most country and firm-level evidences support the creative disaster hypothesis, this study shows that the plants that survived in Kobe's most devastated districts faced severe negative effects from the quake in terms of employment and value added growth during the subsequent three years.

1. Introduction

The Great Hanshin-Awaji (Kobe) earthquake, which occurred on January 17, 1995, is one of the largest natural disasters in Japanese history. The death toll reached 6,437,[2] and the number of injured was 43,792 (Hayashi, 2011). Furthermore, 182,751 buildings were completely destroyed. Such devastation 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, approximately 2.1% of Japan's GDP.[3]

This study aims to investigate the impacts of natural disasters on plant growth, focusing on the Kobe quake. Previous studies on natural disasters such as Leiter et al. (2009) confirm the creative disaster hypothesis, which posits that natural disasters enhance the growth of firms or plants in the affected areas. The Kobe quake presents an ideal case for testing this hypothesis because it was unexpected and affected a large industrial area.

In this study, I employ plant-level data as well as the difference-in-difference (DID) and matching techniques. The empirical results of this study show that the surviving plants in Kobe experienced lower employment and value added growth during the three years following the quake than plants in unaffected areas, although some did experience higher capital growth.

The remainder of this paper is organized as follows. In Section 2, I review the literature and explain the creative disaster hypothesis. In Section 3, I explain the methodology. Section 4 provides a description of the data used in this study together with an overview of the quake's economic impacts on plants in Kobe. In Sections 5 and 6, I present the results. Finally, Section 7 presents the conclusion.

2. The creative destruction hypothesis

Natural disasters usually have negative impacts on the economy: they are highly prone to destroying physical and human capital as well as public infrastructure. In the case of the Kobe quake, many studies have reported substantial economic loss (Hayashi, 2011; Hondai and Uchida, 1998).

However, several empirical studies have reported a positive correlation between the frequency of natural disasters and long-run economic growth. Skidmore and Toya (2002) investigated the long-run impact of natural disasters upon growth for the period 1960–1990. They found that the frequency of climatic disasters is positively correlated with human capital accumulation, total factor productivity (TFP) growth, and GDP per capita growth.

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[2] The death tolls of the great Kanto quake (1923) and Great East Japan quake (2011) were 105,000 and 15,845, respectively.
[3] See, for example, Hayashi (2011), Horwich (2000), and Sawada and Shimizutani (2007, 2008) for more details on the economic aspects of the Kobe quake.

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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	4197	(100.0)	105,227	(100.0)	1010.6	(100.0)	1466.8	(100.0)
1994	525	(12.5)	41,874	(39.8)	646.2	(63.9)	919.7	(62.7)
1995	3308	(78.8)	88,207	(83.8)	885.5	(87.6)	1299.6	(88.6)
1996	3215	(76.6)	83,274	(79.1)	869.1	(86.0)	1267.6	(86.4)
1997	3111	(74.1)	81,862	(77.8)	931.4	(92.2)	1288.2	(87.8)
1998	3137	(74.7)	80,456	(76.5)	980.2	(97.0)	1352.2	(92.2)

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

The positive economic effect of natural disasters is termed creative destruction (Cuaresma et al., 2008) or creative disasters (Leiter et al., 2009). The term reflects the positive correlation that can be interpreted as evidence for the hypothesis 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.[4] However, no study in the literature so far has found a positive relationship between a geological disaster such as a quake and economic growth. In other words, the creative disaster hypothesis has not yet been supported by an empirical study in the case of geological disasters.

The contribution of this study to the existing literature is twofold. First, it employs plant-level data. Skidmore and Toya (2002) employed cross-country macroeconomic data, and Leiter et al. (2009) employed European firm-level data. Neither of these types of data can capture the pure effects of natural disasters since they include unaffected plants and regions. Even if positive effects from natural disasters are observed at the country or firm level, the direct impacts on plants in the affected area can be negative. From the viewpoint of policymakers in the affected area's local government, the effect on plants in their area is the primary concern. To the best of my knowledge, no study has thus far used plant-level data to investigate the effects of natural disasters.

Second, this study employs the matching technique to control for pre-quake plant characteristics. After matching plants in the affected area with those in unaffected areas, this study compares their growth paths. This method will yield more precise impacts of natural disasters. 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 attempt to provide evidence on the precise impacts of natural disasters at the plant level.

3. Empirical strategy

This study employed two empirical methods to examine the impact of the Kobe quake on plant growth: first, a simple DID estimation, following Leiter et al. (2009) and second, the matching method.

Treated (affected) plants were distinguished from nontreated (nonaffected) plants on the basis of their location since plant-level damage information is not available. Plants in Kobe were classified as treated plants and those in other areas as nontreated 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 were excluded from the analysis.

3.1. Difference-in-difference (DID) estimation

Using DID estimation, plants in the most devastated area of Kobe were compared with those in other major cities designated by government ordinance (*seirei shitei toshi* in Japanese). These include Kyoto, Nagoya, Yokohama, Kitakyusyu, Sapporo, Kawasaki, Fukuoka, Hiroshima, Sendai, and Chiba.[5] Following Leiter et al. (2009), the following DID equation was estimated:

$$\ln y_{isr,t} = \eta_0 + \beta_1 * \ln y_{isr,1993} + \beta_2 * kobe_{ir} + \beta_3 * after_t + \beta_4 * (kobe * after)_{ir,t} + industry_{is} + \epsilon_{isr,t}, \quad (1)$$

where i, s, r, and t represent 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 the log of employment (number of workers) and log of capital. I included their initial 1993 values, $\ln y_{isr,1993}$, as one explanatory variable, following Leiter et al. (2009).[6] Further, $kobe_{ir}$ 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—the year in which the Kobe quake occurred. Therefore, $(kobe * after)_{ir,t}$ is the DID dummy that captures the effects of the Kobe quake. Finally, $industry_{is}$ is an industry fixed effect and $\epsilon_{isr,t}$ is an error term.

Based on the Cobb–Douglas production function, the log of value added was regressed as follows:

$$\ln v_{isr,t} = \delta_0 + \delta_1 * \ln k_{isr,1993} + \delta_2 * \ln l_{isr,1993} + \delta_3 * kobe_{ir} + \delta_4 * after_t + \delta_5 * (kobe * after)_{ir,t} + industry_{is} + \eta_{isr,t}, \quad (2)$$

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 the log of capital and log of employment, respectively. The last term, $\eta_{isr,t}$, is an error term. As indicated by Leiter et al. (2009), the coefficient of DID dummy, δ_5, captures the productivity effects of the disaster.

3.2. Matching method

The matching method was employed to compare plants in the affected area with those in unaffected areas to evaluate the quake's

[4] Siodla (2012) also studied the positive impacts of disasters but focused on urban redevelopment.

[5] The choice of these cities as the control group appeared arbitrary. Therefore, plants from the entire area of Japan were selected except the Kobe and surrounding areas when the matching method was employed. This study employed the matching method to address the selection bias, while DuPont and Noy (2014) adopted the synthetic control method to avoid potential bias arising from the selection of the control group.

[6] In the literature on firm growth such as Angelini and Generale (2008), using the lagged dependent variable at the period $t - 1$ as an explanatory variable is common practice. This type of partial adjustment model identifies the quake's incremental impact. This study, however, followed Leiter et al. (2009) and used the initial value prior to the quake to estimate its cumulative impact to make it easier to compare the results from the DID estimation with those from the matching method.