DSSR

Discussion Paper No.93

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Takeru Sugasawa

January, 2019

Data Science and Service Research
Discussion Paper

Center for Data Science and Service Research
Graduate School of Economic and Management
Tohoku University
27-1 Kawauchi, Aobaku
Sendai 980-8576, JAPAN

Impacts of constructing flood control dams on industrial investments in downstream regions in the case of Shiga Prefecture

Takeru Sugasawa†

Abstract

There is the possibility that disaster risks prevent regions from developments through decreases in incentive to investments. We investigate the impacts of constructing flood control dams on location decision of industries in their downstream areas. To analyze the relationship, we focus on four flood control dams and 50 municipalities in Shiga prefecture, a suburban area located in middle-western Japanese main island, between 1965 and 2000. We conduct event study analyses, and find that constructing the flood control dams significantly increased the number of manufacturing plants of industries requiring large amount of physical capital in downstream areas. We consider that since physical capital requires long periods to recover their establishment costs, manufacturing category strongly depending on physical capital would sensitively react to the reduction of flood risks. We also find that the number of commerce stores increased in the dams' downstream areas. However, the effects required more than 10 years to be observed after the completion of flood control dams. We interpret that commerce industry could receive positive effects only after increases in manufacturing plants, because commerce industry receive the effects of decreases in flood risks through increases in manufacturing plants' demand for materials or tools to do their production activities.

1. Introduction

Flood disasters have caused serious damages to human economic activities. For instance, Toyota plants in Thailand experienced a large-scale flood in July 2011, and they lost production opportunities of approximately 260,000 cars.[1] In June 2018, floods in Guanajuato State in middle Mexico hit Honda plants, and monetary damages accumulated of more than 50 billion yen.[2] Ways to reduce natural disaster risk and damages remain an important theme.

† Graduate School of Economics and Management, Tohoku University (tel: 090-8478-3247, e-mail: takeru.sugasawa@gmail.com)

[1] According to Toyota's company history, 75 years of TOYOTA.

[2] We refer to the article by Asahi Shimbun in August 2018.

Disaster risk is known to affect industrial investment activities. Gourio (2012) focuses on the impacts of natural disasters on regional economic activities using the real business cycle model and suggests that larger disaster risk reduce the investment amount.

In terms of capital structure, disaster risk decrease expectations for physical capital's return and prevent firms from investing in physical capital with low mobility (Skidmore and Toya: 2002). To determine the reason for the decreases in investments in physical capital, Kahn (2005) focuses on 73 countries between 1980 and 2002. He finds that physical capital received larger damages than human capital from natural disasters, especially in developed countries. Since physical capital requires long periods to recover establishment costs, higher disaster risk would decrease industrial agents' incentives for investments in physical capital. From the above discussions, public investments decreasing disaster risk may affect regional investment activities and industrial locations.

In a study focusing on the effects of public investments aiming to reduce regional disaster risk, Boustan, Kahn and Rhode (2012) investigate the impacts of floods and hurricanes in the United States between the 1920s and the 1930s. They find that the areas where the New Deal's public investments were conducted to reduce flood risk achieved higher population growth than the areas hit by hurricanes. From the discussion, we consider that economic agents consider the reduction in disaster risk when deciding their locations. However, they do not focus on the impacts of flood control dams on the regional industrial location and investment activities.

In this study, we investigate the impacts of constructing flood control dams on industrial location decisions in their downstream areas by using Shiga Prefecture's municipality-level data between 1965 and 2000. In the period, four flood control dams were constructed in Shiga Prefecture, and the industrial locations in their downstream areas received the effects of decreases in flood risk.

Municipalities in Shiga Prefecture are appropriate for our empirical study for two reasons. First, since the prefecture is landlocked and almost all of its border is composed of mountains, municipality geographical characteristics have only small differences. Second, almost of the municipalities are contained in downstream areas of completed or suspended control flood dams. From the characteristics, we assume that the municipalities in Shiga Prefecture are different only in the periods of the construction of dams located in their upstream area. Utilizing the difference in their periods of constructions, we conduct event study analyses.

From our analyses, we find that the reduction in flood risk increased the number of manufacturing plants in downstream areas, and the magnitude is larger in the basic materials as well as the processing and assembling categories, both of which require large amounts of physical capital. For this reason, we consider that manufacturing plants in categories requiring larger amounts of capital tend to have higher

price elasticity in response to disaster risk and more sensitively react to reduction in flood risk than categories requiring smaller amounts of capital.

We also find that plants in the basic materials category, requiring the largest amounts of physical capital of the three categories focused on in the study, increased investments in tangible capital after constructing flood control dams. However, their number of employees was not affected by the reduction in flood risk. For this reason, we interpret that since human capital has higher mobility than physical capital, manufacturing plants tend to invest in human capital compared to physical capital even with the disaster risk. Therefore, constructing flood control dams would not have significant effects on the number of employees in the downstream areas. Our analyses suggest that economic agents decide industrial locations considering disaster risk, and public investments reducing disaster risk would attract industries. The structure of this paper is as follows. Section 2 describes the previous studies relating to our investigation. Section 3 explains the characteristics of Shiga Prefecture, our empirical target, and the flood control dams in it. Section 4 describes our estimation models and variables. Section 5 describes the results of the event study and interpretation. Section 6 is the conclusion.

2. Previous Study

This chapter describes previous studies relating to the impacts of disaster risk on investment activities and industrial location decisions. Skidmore and Toya (2002) examine the impacts of natural disasters on countries' capital, productivity and economic growth by focusing on 89 countries and find that countries frequently experiencing natural disasters tend to increase investments more in human capital than in physical capital. In terms of impacts of flood disasters, Leiter, Oberhofer and Raschky (2009) focus on the impacts of European flood disasters occurring between 1950 and 2007 on capital structure. They find that firms located in the hit areas tend to prefer intangible assets to tangible ones.

Although many studies investigate the relationship between natural disasters and industrial investment activities, almost all of them focus only on the effects of happened disasters, not on the effects of countermeasures to natural disasters. Public investments decreasing disaster risk may affect industrial investment activities and locations. As a previous study focusing on the effects of public investments aiming at reducing regional flood risk, Boustan, Kahn and Rhode (2012) investigate the impacts of floods and typhoons in the United States between the 1920s and the 1930s. They find that the areas where the New Deal's public investments were conducted to reduce flood risk achieved higher population growth than the areas hit by typhoons, and the effects are observed in long-term.

From the discussion, economic agents would decide their locations or investment activities considering the regional disaster risk. However, there are no previous studies focusing on the impacts of flood control dams on regional industrial locations and investment activities.

3. Shiga Prefecture and Flood Control Dams

To investigate the relationship between reduction in flood risk and manufacturing activities, we focus on the case of Shiga Prefecture and four flood control dams in it. In this chapter, we describe the characteristics of Shiga Prefecture relating to flood risk.

3.1. Shiga prefecture and Lake Biwa

As the estimation sample, we focus on municipalities in Shiga Prefecture between 1965 and 2000. In this section, we describe the geographical and industrial characteristics of Shiga Prefecture.

Shiga Prefecture is a landlocked prefecture in the Kinki region located in central/western of Japan's main island. As an important geographical characteristic, Shiga Prefecture contains Lake Biwa, the largest freshwater lake in Japan. One hundred nineteen rivers flow into Lake Biwa, and only one river, Yodo River, flows out from it. Figure 1 is a map of Japan showing the location of Shiga Prefecture in red and Lake Biwa in blue.

Figure 1. The Location of Shiga prefecture and Lake Biwa

From those geographical characteristics, Shiga Prefecture has experienced many and serious flood disasters. Since only the Yodo River flows out from Lake Biwa, flood disasters easily occur if sediment accumulates along the river's bottom. In terms of the seriousness of the flood disasters, the large-scale flood in 1896 overwhelmed all of the central area of Otsu City and approximately 80% of Hikone City, and the flood water did not recede until approximately three months later according to the report by Shiga Prefecture. Table 1 shows the human and industrial damages as well as main cities hit by each flood in Shiga Prefecture between 1895 and 2013. The period included 34 floods with 2,264 human casualties and 227,401 damaged buildings.[3] Figure 2 shows the number of floods each municipality experienced between 1895 and 2013. From the map, we can observe that sites hit by floods are distributed all over Shiga Prefecture. The large risk of flood disasters would have prevented industries in Shiga Prefecture from investments in capital weak in disasters, such as physical capital.

Shiga Prefecture is suitable for our analyses because of the uniform geographic characteristics among its municipalities. As discussed above, Shiga Prefecture is landlocked, and almost all of the prefectural border consists of mountains. These conditions mean industrial structures differ little as a result of the natural characteristics shared among municipalities, which enables us to clearly observe the impacts of constructed flood control dams on their downstream areas.

In terms of industrial characteristics, manufacturing industries have prospered in Shiga Prefecture. In 2015, products from manufacturing industries comprised 41.1% of GDP of Shiga Prefecture, the largest share in Japan's 47 prefectures.[4] Lake Biwa plays a role as a large-scale source of industrial water, and municipalities located in surrounding regions receive its advantages. Since manufacturing industries tend to require large amounts of water resources for cooling and cleaning machines, manufacturing plants are attracted to surrounding (or downstream) areas of Lake Biwa to receive the benefits of better access to the rich industrial water.

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[3] Human casualties consist of 208 deaths, 2,045 injured and 11 missing. Building damages are divided by 2,687 complete destructions, 15,829 partial destructions, and 116,458 inundations.

[4] Using data from the Report on the Prefectural Account by the Cabinet Office (2015).

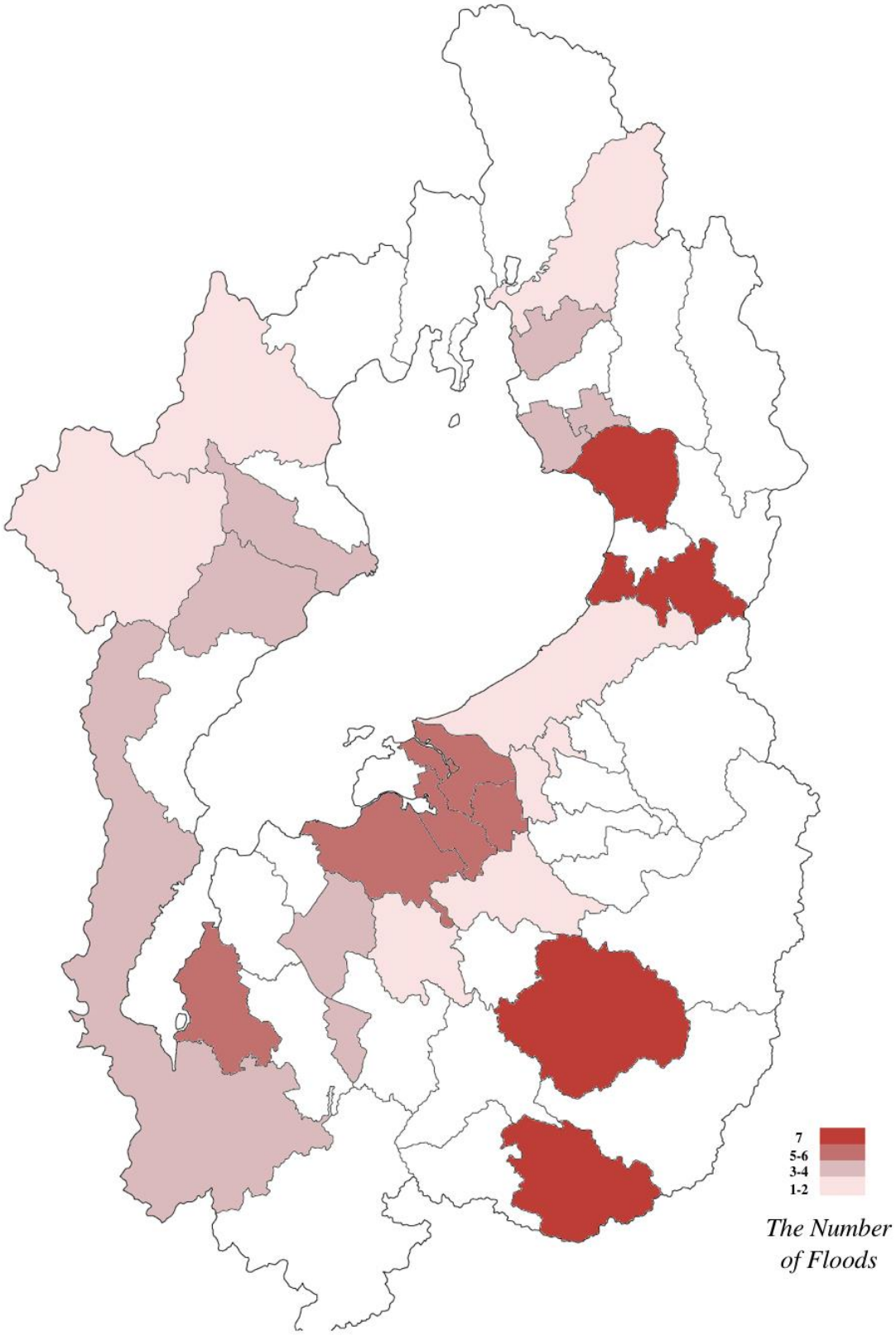


Figure 2. The Number of Floods in Each Municipality between 1895 and 2013

Table 1. Flood Damage by Year in Shiga Prefecture

	Human Damages			*Building Damages*			
Year	*Death*	*Missing*	*Injured*	*Complete Destructions*	*Partial Destructions*	*Inundations*	*Main Municipality Experienced Flood*
1895							Nagahama City
1896	29	5	79	3,000	32,501	55,391	Omihachiman City
1916							Gokashou Town
1917				7	55	3,539	Omihachiman City
1934	47		641	681	921		Kusatsu City
1938	6		1	24		1,862	Gokasho Town
1941		1	1	30		4,738	Otsu City
1944							Ryuo Town
1950	7	1	76	297	854	52	Torahime Town
1953	88	4	640	589	1,357	41,575	Koga Town
1954							Kusatsu City
1958	2		3	7	244	1,758	Koga Town
1959	20	0	132	375	1,381	45,251	Maibara Town
1961	3		438	610	3,388	807	Toyosato Town
1963							Kutsuki village
1965	3		19	63	7,415	13,944	Nagahama City
1967							Kusatsu City
1968							Hino Town
1971							Maibara Town
1972							Torahime Town
1975			2	2	24	103	Torahime Town
1982			1	2	16	1,221	Adsuchi Town
1990	1		2		174	1,608	Nagahama City
1998							Nagahama City
1999							Imadsu Town
2004	1		1		6	41	Otsu City
2008						214	Nagahama City
2013	1		9	10	718	546	Takashima Town
Total	208	11	2,045	5,697	49,054	172,650	

3.2. The flood control dams in Shiga prefecture

This section describes the flood control dams in Shiga Prefecture. An important public work conducted in Shiga Prefecture is the Lake Biwa Comprehensive Development (LBCD) project. It is a large-scale and multipurpose project led by the national and Shiga Prefecture's governments to develop surrounding regions of Lake Biwa between 1972 and 1997. The project contained many kinds of works, such as constructing dams to reduce floods damages, promoting agriculture and manufacture in surrounding regions, and protecting the natural environment of Lake Biwa. The total monetary costs of the project were approximately 1.9 trillion yen. Of that, Shiga prefectural and municipal governments bore approximately 1.3 trillion yen, the national government bore approximately 430 billion yen, and the rest was borne by organizations receiving benefits from the project.

As the works aiming to reduce disaster damages, the LBCD project included the construction of seven flood control dams and 59 small barriers against landslides. In terms of flood control dams, however, only

four of the seven dams were completed, and the rests were suspended in the 21th century. Therefore, some municipalities are not yet protected by flood control dams, and we can observe the impacts of the dams by comparing the downstream areas of the completed and the suspended dams. The small barriers against landslides are not the focus of this study, because we focus on the effects of reducing the risk of flood disasters. Table 2 describes the period of construction of each flood control dam and the numbers and names of municipalities located in the downstream areas.

Table 2. Construction of Flood Control Dams between 1965 and 2000

The Names of dams	The Periods of constructions	The Number of Municipalities in the Downstream Areas and their Names	
Ishidagawa Dam	Between 1963 and 1969	2	Imadsu, Shinasahi Town
Oodsuchi Dam	Between 1966 and 1987	8	Moriyama City, Ritto, Chuzu, Yasu, Ishibe, Kousei, Minaguchi, Tsuchiyama, and Koga Town
Usogawa Dam	Between 1971 and 1979	5	Hikone City, Koto, Taiso, Echigawa, and Toyosato Town
Anegawa Dam	Between 1977 and 2002	6	Nagahama City, Santo, Ibuki, Azai, Torahime, and Biwa Town
Niu Dam	Started in 1980, but Suspended in 2014	6	Torahime, Kohoku, Biwa, Takatsuki, Kinomoto and Yogo Town
Kitagawa Dams	Started in 1989, but Suspended in 2012	3	Otsu City, Kutsuki and Adogawa Town
Seritani Dam	Started in 1992, but Suspended in 2009	2	Hikone City, and Taga Town

Figure 3 shows the locations of flood control dams in Shiga Prefecture and their downstream areas. The red areas are municipalities contained in downstream areas of flood control dams. We can observe that municipalities in downstream areas of completed or suspended flood control dams distribute throughout Shiga Prefecture. We consider that no selection occurred for the public investment's decision in any planned or completed construction of flood control dams, only in regions frequently hit by flood disasters. From Figures 2 and 3, we can observe many municipalities have experienced many flood disasters, but these disasters are contained in downstream areas of suspended flood control dams. From the above discussions, we assume that the location of each dam and the timing of its construction or completion were not selected.

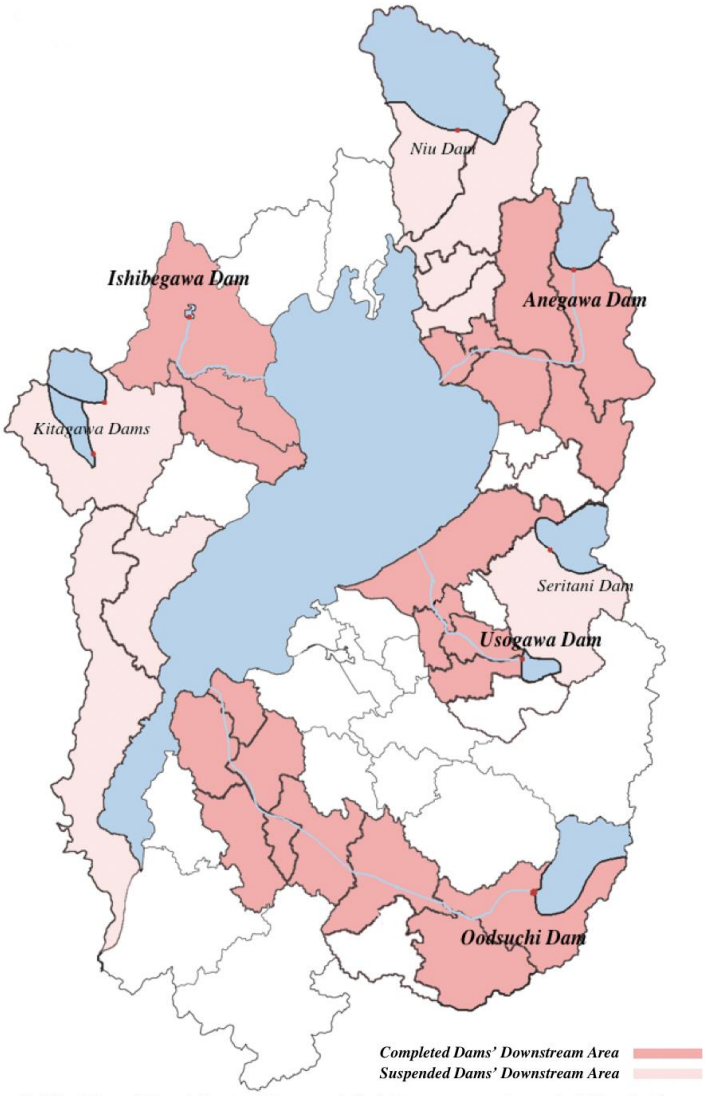


Figure 3. The Map of Flood Control Dams and their Downstream Areas in Shiga Prefecture

The flood control dams have reduced flood damages in the downstream areas. For instance, Ishidagawa Dam, which began operation in 1969, prevented floods in the case of the season's 23rd typhoon in 2004 by controlling for inflows of water downstream. In this case, the dam controlled approximately 1,133,000 tons of water, and were the Ishidagawa Dam not in existence, approximately108 tons of water would have overflowed into the downstream areas.[5] In addition, according to Table 1, which describes damages from each flood in Shiga Prefecture, we can observe the strong decreases in human casualties and building damages by flood disasters after 1960s, the period when flood control dams began to be operational. In terms of numerical value, approximately 99.2% of human casualties and

5 The reference is from the report by Shiga Prefecture in 2004.

97.9% of building damages concentrate in the period before 1970. From this data, we consider that the flood control dams in Shiga Prefecture decreased the risk of flood disasters in their downstream areas.

We consider that manufacturing industries requiring large amounts of physical capital sensitively react to a change of the disaster risk. Manufacturing industries have invest heavily in physical capital with low mobility to develop new products and improve productivity. Therefore, manufacturing industries would be affected by the constructed flood control dams in Shiga Prefecture.

Figure 4 shows the transition of the number of manufacturing plants across Japan, prefectures in the Kinki region without Shiga Prefecture, and Shiga Prefecture.[6] Each value is divided by the value in 1980. From the figure, we can observe that although the number of manufacturing plants in Shiga Prefecture appears similar to Japan as whole and the other prefectures in the Kinki region before 1990, its growth rates become larger than the other two categories between 1990 and 2000. Therefore, we consider that the public investments aimed at reducing disaster risk activated manufacturing industries in Shiga Prefecture, and they received an advantage compared to the other regions. That result would contribute to the prosperity of manufacture in Shiga Prefecture, with the largest share of manufacturing products to total GDP among Japanese prefectures.

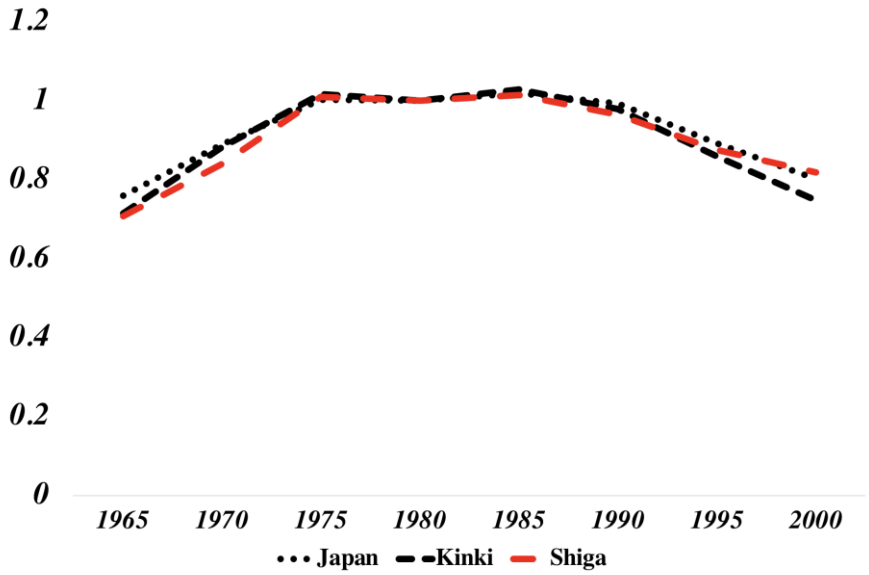
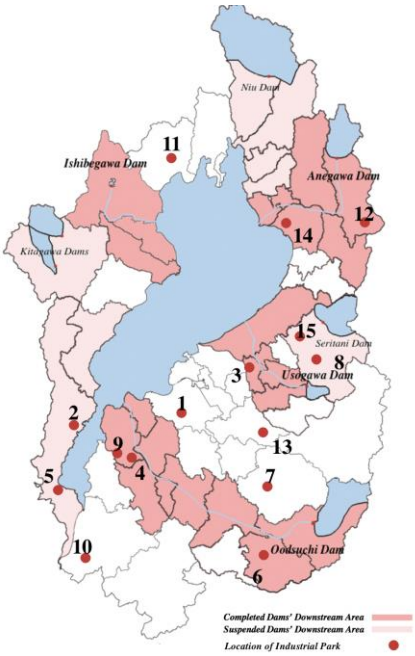


Figure 4. Growth of the Number of Plants (1980=1)

Regional governments may decide locations of manufacturing plants through establishing industrial parks. We check whether regional governments in Shiga Prefecture established industrial parks especially in downstream areas of completed flood control dams. If manufactural plants location are decided by

6 The Kinki region comprises Mie, Shiga, Osaka, Kyoto, Hyogo, Nara and Wakayama prefectures, and we refer to the Census of Manufactures by the MEIT of each year to observe the number of their manufacturing plants.

prefectural government, we cannot observe clear effects of flood risk reduction on economic agents' locations. Shiga Prefecture Land Development Corporation is a public agent aiming to expand public lands through establishing industrial parks in Shiga Prefecture. Figure 5 shows the locations and establishment periods of industrial parks in Shiga Prefecture by the corporation between 1960 and 2000. We observe that industrial parks were established in not-downstream areas of flood control dams and the establishment pace did not largely change even after completion of the dams. From the fact, we consider that Shiga Prefecture did not attempt to especially develop the downstream areas of flood control dams.



Code	Year	Name of Dams	Periods of Dam Construction
1	1961		
2	1965	Kitagawa Dams	1989-2012
3	1965	Usogawa Dam	1971-1979
4	1967	Odsuchi Dam	1966-1987
5	1967	Kitagawa Dams	1989-2012
6	1970	Odsuchi Dam	1966-1987
7	1971		
8	1972	Seritani Dam	1992-2009
9	1980	Odsuchi Dam	1966-1987
10	1983		
11	1985		
12	1985	Anegawa Dam	1977-2002
13	1988		
14	1989	Anegawa Dam	1977-2002
15	1989	Seritani Dam	1992-2009

Figure 5. Location and Establishment Periods of Industrial Parks in Shiga Prefecture

From the above discussions, the municipalities in Shiga Prefecture are desirable for our event study analyses from the perspectives of a uniform geography, the non-selection of location and completion timing of control flood dams, and the holding of prosperous manufacturing industries requiring large amounts of physical capital weak in disasters. In the next chapter, we describe our estimation model of the event study and data we use.

4. Empirical Strategy and Data

4.1. Empirical strategy

We create panel data and estimate the impacts of constructing flood control dams on industrial locations in downstream regions, controlling for the time invariant characteristics of municipalities. Since the timing of constructions differs by dam, we adopt an event study model. The estimation model is as follows:

$$\text{NumberPlants}_{\text{it}} = \alpha_{it} + \beta \mathbf{DownStream}_{\boldsymbol{i}} \times \mathbf{ConstDams}_{\boldsymbol{ti}} + \eta_i + \sigma_t + \varepsilon_{it}. \quad (1)$$

$\text{NumberPlants}_{\text{it}}$ is a variable indicating the number of manufacturing plants in municipality i in year t. We define $\mathbf{DownStream}_{\boldsymbol{i}}$ is the vector of dummy variables that become one if municipality i is contained in the downstream area of each flood control dam. $\mathbf{ConstDams}_{\boldsymbol{ti}}$ is the vector of year dummies which becomes one if the construction of each flood control dam is completed in year t. Therefore, the product of $\mathbf{DownStream}_{\boldsymbol{i}}$ and $\mathbf{ConstDams}_{\boldsymbol{t}}$ becomes one only when the construction of the dam located upstream of municipality i is completed. Since no municipalities in Shiga Prefecture are contained in multiple downstream areas of dams, the product is only zero or one. η_i indicates the municipality fixed effects. σ_t indicates the year fixed effects. ε_{it} is the error term, which comes from the time variant characteristics of municipality i.

4.2. Data

This section describes the data used in our analysis. First, we clarify each dam's downstream area.

The definition of municipality by the Japanese government is the smallest unit of administrative districts, and it is composed of cities, towns, villages, and specified districts.[7] Shiga Prefecture has 50 municipalities composed of 7 cities, 42 towns and one village in 2000. In 1960, Shiga Prefecture had an additional three towns, but they were merged with other cities. We control for the merges by adding each variable of merged municipalities before the merges.

We define the downstream areas of flood control dams as municipalities through which the river passes where the flood control dams were constructed. Between 1965 and 2000, Shiga Prefecture saw the construction of seven flood control dams, three of which were completed in the period.

As $\text{NumberPlants}_{\text{it}}$, we adopt the natural logarithm of the total number of manufacturing plants, the natural logarithm of the number of manufacturing plants with fewer than 299 employees, and the natural logarithm of the number of manufacturing plants with more than 300 employees. To obtain data relating to the number of manufacturing plants in each municipality and year, we refer to the Census of Manufacturers released by the Ministry of Economy, Trade and Industry.

Table 3 represents the summary statistics and describes the number of manufacturing plants divided by the scale of employees they hire. The sample is classified by municipalities that are downstream areas of the flood control dams completed between 1965 and 2000, that are not downstream areas and that were

[7] In 2012, 1,747 municipalities existed in Japan. These comprised 786 cities, 754 towns, 184 villages, and 23 districts in the Tokyo metropolitan area.

intended to be downstream areas but the project was suspended.[8] From the table, we can observe that the mean and standard deviation of each variable show similar values between downstream areas of completed and suspended flood control dams. Therefore, we consider that flood control dams located only in upstream areas with evolved manufacturing industries had no tendency to be completed.

Table 3. Summary Statistics

	Not Downstream Areas				*Downstream Areas of Suspended Dams*				*Downstream Areas*			
	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
Number of Plants	70.6	55.8	9	284	91.8	133.2	6	589	96.0	136.8	6	589
Number of Plants with fewer than 299 Employees	69.7	54.6	9	273	90.5	131.2	6	582	94.8	134.8	6	582
Number of Plants with more than 300 Employees	0.81	1.86	0	11	1.29	2.19	0	9	1.13	2.22	0	9
N	280				120				120			
Municipality	35				15				15			

5. Results

This section describes the results of our estimation by the event study. Table 4 shows the estimation results.

In the table, columns (1) – (3) use all of the municipalities in Shiga Prefecture as the estimation sample, and columns (4) – (6) are the results of estimations adopting only the municipalities contained in downstream areas of completed flood control dams and downstream areas of suspended dams as the sample. If we compare the municipalities located in downstream and not downstream areas of flood control dams, the results may reflect heterogeneities other than the existence of the dams in their upstream areas. For instance, a project constructing dams could target areas of regional importance for political or economic reasons. To control for the heterogeneities, we conduct an event study analysis only using municipalities in downstream areas of completed and suspended flood control dams. As stated above, Table 3 shows that downstream areas of suspended dams have more similar values of each dependent variable than municipalities that are not in downstream areas of the dams.

First, we describe the results of columns (1) – (3) using all of the municipalities in Shiga Prefecture as the estimation sample. Column (1) adopts the natural logarithm of the number of manufacturing plants as the dependent variable, and the coefficient is positive with one percent significance. The magnitude is that constructing flood control dams increased the number of manufacturing plants by approximately 24.1

[8] The downstream areas of suspended flood control dams are also contained in areas that are not downstream.

percentage points in the downstream areas. Column (2) uses the natural logarithm of the number of manufacturing plants with fewer than 299 employees as $\mathrm{NumberPlants}_{it}$. The coefficient is positive with one percent significance. The magnitude is that flood control dams increased manufacturing plants with fewer than 299 employees by approximately 23.8 percentage points in the downstream areas. Column (3) shows the result of the estimation using the logarithm of the number of manufacturing plants with more than 300 employees, and its coefficient is positive and insignificant. This result suggests that the construction of flood control dams does not have significant effects on the number of manufacturing plants with more than 300 employees in the downstream area.

Columns (1) and (2) are consistent with our hypothesis that constructing flood control dams reduces the risk of flood and promotes the entry of new plants in downstream regions. On the other hand, column (3) does not support the hypothesis. According to the Survey of Factory Location Trends by the MEIT (2001), the average number of employees of newly established manufacturing plants was approximately 52 in 2000. From the fact, we consider that the establishment of manufacturing plants with more than 300 employees occurs rarely even in regions with small disaster risk, and they were not significantly affected by constructed flood control dams.

Furthermore, we focus on the results of columns (4) – (6). Column (4) adopts the natural logarithm of the number of manufacturing plants as the dependent variable, and the coefficient is positive with one percent significance. The magnitude is that constructing flood control dams increased the number of manufacturing plants by approximately 29.0 percentage points in the downstream areas. Column (5) uses the natural logarithm of the number of manufacturing plants with fewer than 299 employees as $\mathrm{NumberPlants}_{it}$. The coefficient is positive with one percent significance. The magnitude is that flood control dams increased manufacturing plants with fewer than 299 employees by approximately 28.8 percentage points in the downstream areas. Column (6) shows the result of the estimation using the logarithm of the number of manufacturing plants with more than 300 employees, and its coefficient is positive and insignificant. From the results, we consider that constructing flood control dams had positive impacts on the number of manufacturing plants in the downstream areas.

Table 4. Results of the Event Study

	All Municipalities in Shiga Prefecture			*Downstream Areas of Completed or Suspended Dams*		
	Total Manufacturing Plants	*Manufacturing Plants with fewer than 299 Employees*	*Manufacturing Plants with more than 300 Employees*	*Total Manufacturing Plants*	*Manufacturing Plants with fewer than 299 Employees*	*Manufacturing Plants with more than 300 Employees*
	(1)	(2)	(3)	(4)	(5)	(6)
Downstream Area Dummy × After Completion Dummy	0.241***	0.238***	0.108	0.290***	0.288***	0.0730
	(3.089)	(3.116)	(1.296)	(3.550)	(3.600)	(0.800)
Municipality Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Constant	3.690***	3.715***	0.411***	3.767***	3.791***	0.479***
	(62.68)	(65.42)	(11.69)	(47.94)	(50.00)	(9.871)
N	400	400	400	240	240	240
R-squared	0.404	0.402	0.112	0.418	0.415	0.137
Number of code_num	50	50	50	30	30	30

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As a way of investigating the impacts of flood risk' reduction on manufacturing industries, the amount of the impacts on industries may differ by their investment tendencies. To investigate the effects of manufacturing industries' investment activities on industries' reactions to the constructed flood control dams, we divide manufacturing industries and compare the effects they received from reduction in flood risk.

The Japanese Census of Manufactures classifies 21 types of manufacturing into three categories: the basic materials, the processing and assembling, and the life-related industries.[9] The basic materials industry is composed of industries manufacturing products used by other manufacturers such as iron, coal, lumber and paper. The processing and assembling industry is composed of industries manufacturing processing products such as cars, televisions and clocks. The life-related industry is composed of industries related with necessities of human living such as food, clothes and furniture. The amount of capital required to do their production activities differs among manufacturing categories. Table 5 shows the number and share of manufacturing plants categorized by their manufacturing categories and amounts of capital in 1998 in all of Japan.[10] From the table, we can observe the tendency for the basic material category to consistently occupy the largest share among classes of manufacturing plants holding capital

[9] The Census of Manufactures by the MEIT classifies manufacturing types into three categories: basic materials industry (manufacture of lumber and wood products; manufacture of pulp, paper and paper products; manufacture of chemical and allied products; manufacture of petroleum and coal products; manufacture of plastic products; manufacture of rubber products; manufacture of ceramic, stone and clay products; manufacture of iron and steel; manufacture of non-ferrous metals and products; and manufacture of fabricated metal products), processing and assembling industry (manufacture of general purpose machinery; manufacture of electrical machinery; manufacture of transportation equipment; and manufacture of high precision machinery), and life-related industry (manufacture of food; manufacture of beverages, tobacco and feed; manufacture of textile mill products; manufacture of furniture; printing; manufacture of leather tanning and leather products; and miscellaneous manufacture).

[10] We refer to the Census of Manufactures (1999) by the MEIT to obtain the data.

more than 30,000,000 yen, and the share of the life-related category is the smallest among the three categories. We consider that manufacturing plants in categories requiring larger amounts of capital have higher price elasticity to disaster risk and more sensitively react to reduction in flood risk than categories requiring smaller amounts of capital.

Table 5. The Number and Share of Manufacturing Plants Categorized by their Manufacturing Types and Amounts of Capital

	All	less than 30,000,000 yen	between 30,000,000 - 50,000,000 yen	between 50,000,000 - 100,000,000 yen	between 100,000,000 - 300,000,000 yen	between 300,000,000 - 1,000,000,000 yen	more than 1,000,000,000 yen
Basic Material Category	107,592	84,666 (78.7)	8,339 (7.8)	5,764 (5.4)	2,996 (2.8)	2,088 (1.9)	3,739 (3.5)
Processing and Assembling Category	80,759	65,293 (80.8)	5,375 (6.7)	4,312 (5.3)	1,825 (2.3)	1,352 (1.7)	2,602 (3.2)
Life-Related Category	98,193	84,186 (85.7)	5,903 (6.0)	3,892 (4.0)	1,706 (1.7)	987 (1.0)	1,519 (1.5)

The share of plants in parentheses (%)

To investigate the difference of effects from constructing flood control dams among industrial categories, we conduct an event study using an estimation model as follows:

$$\begin{aligned}\mathrm{NumberPlants}_{ijt} &= \alpha_{it} + \beta\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \\ &+ \gamma\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{Basic}_j \\ &+ \theta\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{Processing}_j \\ &+ \varphi\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{LifeRelated}_j + \eta_i + \sigma_t + \varepsilon_{it}.\end{aligned}$$

(2)

$\mathrm{NumberPlants}_{ijt}$ is a variable indicating the number of manufacturing plants in industry category j, in municipality i, in year t. Basic_j is a dummy variable that becomes one if industry j is a basic materials industry. $\mathrm{Processing}_j$ is a dummy variable that is one when industry j is a processing and assembling industry. $\mathrm{LifeRelated}_j$ is a dummy variable that becomes one if industry j is a life-related industry. We omit miscellaneous manufacturing industries from the life-related category and regard it as the baseline of our results, and we represent the impacts of constructing flood control dams on miscellaneous manufacturing industries by β in the estimation model. Table 6 shows the summary statistics of the sample.

Table 6. Summary Statistics of the Number of Plants Classified by the Manufacturing Categories

	Not Downstream Areas				*Downstream Areas*			
	mean	sd	min	max	mean	sd	min	max
All Categories								
Number of Plants	15.09	33.94	0	592	14.59	17.05	1	117
Number of Plants with fewer than 299 Employees	15.27	33.85	0	566	14.31	16.84	0	116
Number of Plants with more than 300 Employees	0.33	1.37	0	26	0.27	0.57	0	3
N	413				591			
Municipalities	3				4			
Manufactural Type	21				21			
Basic Material Category								
Number of Plants	9.31	18.06	0	313	8.10	8.07	1	42
Number of Plants with fewer than 299 Employees	9.43	18.27	0	310	7.94	8.01	0	42
Number of Plants with more than 300 Employees	0.14	0.50	0	5	0.16	0.38	0	2
N	183				268			
Municipalities	3				4			
Manufactural Type	10				10			
Processing and Assembling Category								
Number of Plants	13.56	23.14	0	177	19.27	25.01	1	117
Number of Plants with fewer than 299 Employees	13.70	22.21	0	157	18.57	24.59	1	116
Number of Plants with more than 300 Employees	0.96	2.19	0	20	0.70	0.87	0	3
N	78				114			
Municipalities	3				4			
Manufactural Type	4				4			
Life-Related Category								
Number of Plants	23.38	47.75	0	592	21.75	18.37	1	77
Number of Plants with fewer than 299 Employees	23.63	47.55	0	566	21.40	18.15	1	77
Number of Plants with more than 300 Employees	0.49	1.77	0	26	0.35	0.69	0	3
N	152				209			
Municipalities	3				4			
Manufactural Type	7				7			

Table 7 describes the results of the estimation analyzing the difference in the impacts of constructing flood control dams on the number of downstream areas' manufacturing plants among manufacturing categories. As the dependent variables, columns (1) – (2) adopt the natural logarithm of the number of manufacturing plants, columns (3) – (4) use the natural logarithm of the number of manufacturing plants with fewer than 299 employees, and columns (5) – (6) use the logarithm of the number of manufacturing plants with more than 300 employees. Columns (1), (3) and (5) show the results of estimations that do not

control for the heterogeneities coming from manufacturing types, and columns (2), (4) and (6) control for the heterogeneities by using cross-terms.[11]

The coefficient of column (1) is negative and insignificant. The result suggests that constructing flood control dams does not affect the number of manufacturing plants. In column (2), the coefficient of the cross-term is negative with five percent significance, that of the cross-term using the basic materials category dummy is positive with one percent significance, that of the coefficient of the cross-term using the processing and assembling category dummy is positive with 10% significance, and that of the cross-term using the life-related category dummy is positive and insignificant. The results suggest that the number of manufacturing plants in the basic materials and in the processing and assembling categories increased after completion of the dams, but those in the life-related category did not see any effects from dam completion. The magnitude is that the construction of flood control dams increased the number of manufacturing plants in the basic materials category by approximately 26 percentage points in downstream areas. In the processing and assembling category, reduction in the risk from flood increased the number of plants by approximately 48.5 percentage points. In addition, the number of plants in miscellaneous manufacturing industries decreased by approximately 30.0 percentage points after constructing flood control dams in downstream areas.

Columns (3) and (4) show basically the same results as columns (1) and (2). In column (3), the coefficient of column (3) is negative and insignificant. The coefficients of column (4) show that the coefficient of the cross-term is negative with five percent significance, that of the basic materials category dummy is positive and one percent significant, and that of the cross-term using $\mathrm{Processing}_j$ is positive with 10% significance. The coefficient of the cross-term with the life-related category dummy is positive and insignificant. In basic materials manufacturing, the magnitude suggests that flood control dams increased the number of manufacturing plants with fewer than 299 employees by approximately 26.0 percentage points in downstream areas. On the other hand, the number of plants with fewer than 299 employees in the processing and assembling category increased by approximately 51.6 percentage points after the completion of flood control dams. The number of plants in miscellaneous manufacturing industries with fewer than 299 employees decreased by approximately 31.2 percentage points after constructing flood control dams in downstream areas.

The coefficient of column (5) is positive and insignificant. The result suggests that constructing flood control dams does not affect the number of manufacturing plants with more than 300 employees. The

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[11] In columns (1), (3) and (5), manufacturing category dummy variables, Basic_j, $\mathrm{Processing}_j$, $\mathrm{LifeRelated}_j$ become zero in estimation model (3).

result suggests that constructing flood control dams tends to increase the number of large-scale manufacturing plants. In column (6), the coefficient of the cross-term containing Basic_j is positive and insignificant, and that of the cross-term with the processing and assembling category dummy is positive with 10% significance. In addition, the coefficient of the cross-term with LifeRelated_j is negative and insignificant. The results suggest that the construction of flood control dams increased the number of manufacturing plants with more than 300 employees in the processing and assembling category. In the basic material and life-related categories, the number of manufacturing plants with more than 300 employees was not affected by the flood control dams. The magnitude is that flood control dams increased the number of manufacturing plants with more than 300 employees of processing and assembling category by approximately 2.72 percentage point in downstream areas.

Table 7. Results of the Event Study using Samples Classified by Manufacturing Categories

	Total Manufacturing Plants		Manufacturing Plants with fewer than 299 Employees		Manufacturing Plants with more than 300 Employees	
	(1)	(2)	(3)	(4)	(5)	(6)
Downstream Area Dummy × After Completion Dummy	-0.00716	-0.300**	-0.0110	-0.312**	0.0211	0.00640
	(-0.0568)	(-2.957)	(-0.0863)	(-2.879)	(1.881)	(0.165)
Downstream Area Dummy × After Completion Dummy × Basic Materials Cateory Dummy		0.260***		0.260***		0.0325
		(4.217)		(4.164)		(0.505)
Downstream Area Dummy × After Completion Dummy × Processing Category Dummy		0.485*		0.516*		0.0272*
		(2.082)		(2.315)		(2.045)
Downstream Area Dummy × After Completion Dummy × Life-Related Category Dummy		0.226		0.232		-0.0149
		(1.917)		(1.729)		(-0.668)
Municipality Fixed Effects	Y	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y
Constant	2.022***	2.022***	2.009***	2.010***	0.126***	0.126***
	(26.77)	(26.69)	(26.80)	(26.70)	(6.476)	(6.472)
N	1,004	1,004	1,003	1,003	1,003	1,003
R-squared	0.073	0.085	0.065	0.079	0.012	0.013
Number of code_num	145	145	145	145	145	145

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The results in Table 7 consistently suggest that the flood control dams had positive effects on the number of plants in the processing and assembling category in downstream regions, and it did not affect the number of plants in the life-related category. We consider that the different reaction to the reduction in flood risk comes from the heterogeneity of their capital holdings. From Table 5 we can observe that the

tendency of a life-related category's share of plants to have a large amount of capital is smaller than it is for the other manufacturing categories. Only in the class of plants with capital less than 30,000,000 yen is the share of the life-related category higher than the others. From the data, we consider that life-related manufacturing plants tend to demand smaller amounts of capital than plants in the other manufacturing categories and have lower price elasticity for flood risk than the other types.

In Table 7, the total number of plants and the number of plants with fewer than 299 employees receive significantly positive effects from constructing flood control dams, but the number of plants with more than 300 employees in the basic material category was not affected. In terms of these plant types, we consider that since basic material manufacturers tend to require large amount of capital, they sensitively react to the reduction in flood risk. Our interpretation is consistent with Table 5, suggesting the tendency that basic material manufacturers hold larger amounts of capital than plants in the other categories.

On the other hand, regarding plants with more than 300 employees, each municipality has only approximately 0.15 plants with more than 300 employees in the basic material category on average, and the point is noticeably small compared to the other categories according to Table 6. From this fact, we consider that basic material manufacturing plants do not require as many employees, and the number of large-scale plants in the category did not increase even after the reduction in flood risk.

We consider that flood control dams can also affect industrial location which are not downstream areas. Increases in manufacturing plants in downstream areas of flood control dams might be resulted from decreases in ones in not downstream areas. Figure 5 shows the transition of the number of manufacturing plants in a whole of Japan, downstream areas of flood control dams in Shiga Prefecture, and not downstream areas of flood control dams in Shiga Prefecture. We observe that the number of plants increased after beginning of the LBCD project in downstream areas of the flood control dams. On the other hand, the number of manufacturing plants in not downstream areas of the flood control dams did not increase after 1975. In addition, the level suggests similar level to one of as whole of Japan even after the flood control dams were completed. From the data, we consider that the increases of manufacturing plants in downstream areas of flood control dams were not resulted from decreases in one in surrounding areas.

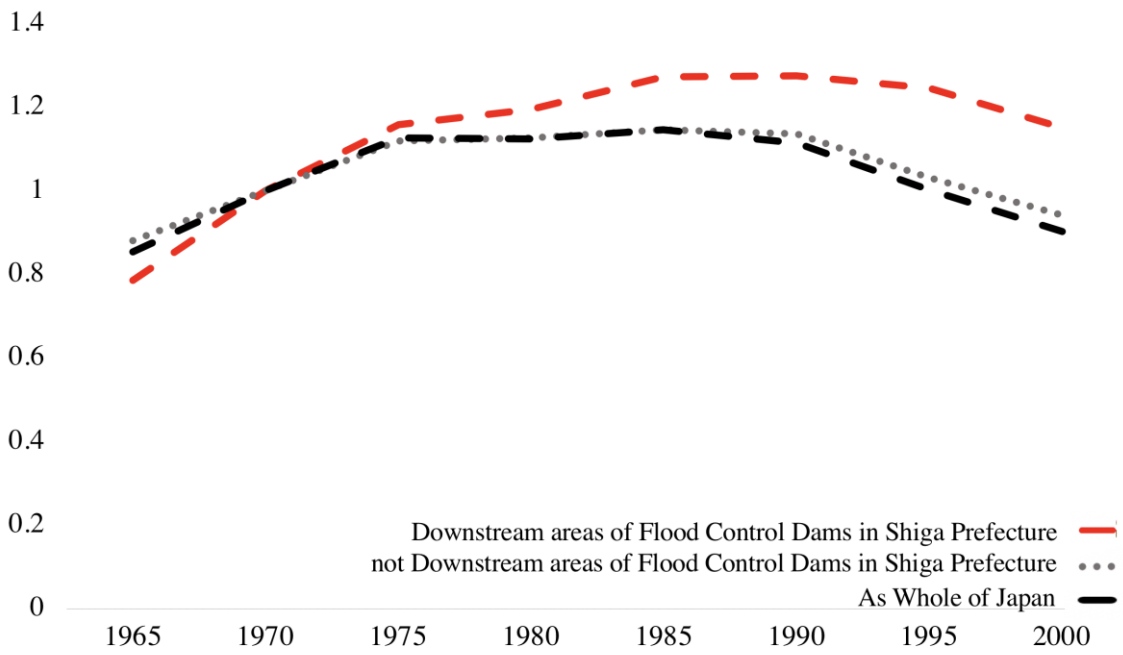

Figure 6. Growth of the Number of Plants (1970=1)

A question remains whether the amount of investments by manufacturing plants increased after constructing flood control dams in the downstream areas. To investigate the point, we conduct an event study focusing on the impacts of constructing flood control dams on the amount of investment. The estimation model is as follows:

$$\begin{aligned}\mathrm{Capital}_{ijt} &= \alpha_{it} + \beta\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \\ &\quad + \gamma\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{Basic}_j \\ &\quad + \theta\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{Processing}_j \\ &\quad + \varphi\mathbf{DownStream}_i \times \mathbf{ConstDams}_t \times \mathrm{LifeRelated}_j + \eta_i + \sigma_t + \varepsilon_{it}. \quad (3)\end{aligned}$$

$\mathrm{Capital}_{ijt}$ contains two types of capital: physical and human. As the indicator of physical investment, we use the natural logarithm of the amount of average investment by plants. To measure the amount of human capital held by plants, we adopt the natural logarithm of the number of employees, and the natural logarithm of the amount of income per employees. By the constraint of data, the indicator of physical

capital is limited to manufacturing plants with more than 20 employees, and the measures of human capital archive only manufacturing plants with more than four employees. We obtain data from the Census of Manufactures from 1965 to 2000.

Table 8 describes the estimation results. Column (1) uses the natural logarithm of the amount of average investment as the dependent variable. In column (1), the coefficient of the cross-term between $\mathbf{DownStream}_i$ and $\mathbf{ConstDams}_t$ is negative and insignificant. The coefficient of the cross-term containing the basic materials category dummy is positive with five percent significance. The magnitude is that the amount of average investment by plant in the basic materials category increased by 69.4 percentage points. The coefficients of the cross-terms using the processing and assembling category as well as the life-related category dummies are positive and insignificant. The results suggest that constructing the flood control dams did not affect the amount of investment by plants in the processing and assembling as well as the life-related categories.

From the results, we can observe that constructing flood control dams increased physical investments only for plants in the basic material category. The result is consistent with our above discussions, suggesting that flood control dams have larger impacts on basic material manufacture, which require large amounts of capital to produce. We consider that since plants in the processing and assembling as well as the life-related categories sufficiently held physical capital even before completed the flood control dams, they did not receive significant effects from the reduction in flood risk

Column (2) adopts the natural logarithm of the number of employees in plants with more than four employees as the explained variable. The coefficient of the cross-term between the downstream area dummy and the after dams' completion dummy is positive and insignificant. The result suggests that the number of employees in miscellaneous manufacture was not affected by the flood control dams. The coefficient of the cross-term containing the basic materials category dummy is negative and insignificance, and that of the cross-term using the processing and assembling category dummy is positive and insignificant. The result suggests that constructing flood control dams did not have any impacts on the number of employees in the basic materials or the processing and assembling categories. The coefficient of the cross-term containing the life-related category is negative with 10% significance. The magnitude suggests that employees in life-related manufacture decreased by 22.6 percentage points after the completion of flood control dams.

The results show that constructing flood control dams does not have positive and significant effects on the number of manufacturing employees. For this reason, we consider that since human capital has larger mobility than physical capital, manufacturing plants tend to invest in human capital compared to physical capital even with the risk of disaster, and the number was not affected by flood control dams. A

confusing point remains that the number of employees in the life-related category significantly decreased after constructing the flood control dams. Since the amount of investments by plants in the life-related category received positive but insignificant effects, we interpret that some plants in the life-related category decreased their employees and shifted to be capital-intensive after the reduction in flood risk.

Column (3) uses the natural logarithm of the amount of wage per employee as Investment_{ijt}. The coefficients of the four cross-terms are positive and insignificant. The result suggests that the flood control dams did not affect the amount of wage per employee of manufacturing plants.

From the discussions, we conclude that reduction in disaster risk increases the amount of investment in plants requiring large amounts of physical capital to produce. The result is consistent with our above results suggesting that plants in the basic materials as well as the processing and assembling categories increased their number of plants after the construction of flood control dams.

Table 8. Results of the Event Study focusing on the Amounts of Investment

	(1)	(2)	(3)
	ln (the Average Amount of Investment by Plants)	ln (the Number of Employees of Plants with more than 4 Employees)	ln (the Amount of Wage per Employee of Plants with more than 4 Employees)
Downstream Area Dummy × After Completion Dummy	-0.872 (-1.88)	0.210 (1.589)	0.0119 (0.351)
Downstream Area Dummy × After Completion Dummy × Basic Materials Category Dummy	0.694** (3.48)	-0.114 (-1.299)	0.0308 (1.764)
Downstream Area Dummy × After Completion Dummy × Processing Category Dummy	0.635 (0.79)	0.0767 (0.391)	0.0577 (1.072)
Downstream Area Dummy × After Completion Dummy × Life-Related Category Dummy	0.813 (0.90)	-0.226* (-1.995)	0.0296 (0.419)
Municipality Fixed Effects	Y	Y	Y
Year Fixed Effects	Y	Y	Y
Constant	3.10*** (5.81)	5.487*** (78.67)	3.539*** (74.17)
N	649	798	766
R-squared	0.405	0.045	0.950
Number of code_num	137	122	121

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In addition, the increases in manufacturing plants and investment may have impacts on non-manufacturing industries in surrounding areas, because other industries could receive positive effects

through increases in manufacturing industries' demand for materials or tools to do their production activities. To investigate the point, we focus on commerce industry located in the downstream areas.

We investigate the impacts of constructing flood control dams on commerce industries in downstream areas. The effects would require a time lag to appear. For this reason, we consider that the reduction in flood risk indirectly affects commerce industry, and the effects would occur only after increases in manufacturing plants or investment in downstream areas. To examine the time lag, we conduct an estimation using cross-terms between each year dummy and each downstream area dummy. The estimation model is as follows:

$$\mathrm{Store}_{\mathrm{it}} = \alpha_{it} + \beta\mathbf{Year_t} + \gamma\mathbf{DownStream}_{\boldsymbol{i}} \times \mathbf{Year}_{\boldsymbol{t}} + \eta_{\mathrm{i}} + \sigma_t + \varepsilon_{it}. \quad (4)$$

As the dependent variable, we use the natural logarithm of the number of stores in municipality i in year t. We obtain data for the number of stores in each municipality by referring to the Statistical Handbook of Shiga Prefecture between 1960 and 2000. Table 9 shows the summary statistics of commerce industries in Shiga Prefecture, and they are classified into each downstream area of flood control dams.

$\mathbf{Year}_{\boldsymbol{t}}$ is the vector of year dummy variables every five years between 1965 and 2000, and the value in 1960 is omitted and regarded as the baseline. As the sample, we adopt municipalities that are downstream areas of the flood control dams completed or suspended after 1965.

Table 9. Statistical Statuses of the Commerce Industry in each Dam's Downstream Area

	Downstream Areas of Ishidagawa Dam				*Downstream Areas of Odsuchi Dam*				*Downstream Areas of Usogawa Dam*				*Downstream Areas of Suspended Dams*			
Year	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max	mean	sd	min	max
The Number of Stores																
1960	149.5	55.9	110	189	206.6	138.8	83	446	413.6	661.1	106	1,596	358.0	642.3	52	2,331
1970	178.5	79.9	122	235	257.9	155.0	111	558	440.0	654.1	125	1,609	394.6	739.5	50	2,726
1980	206.0	75.0	153	259	330.7	210.2	102	716	449.2	674.5	122	1,655	461.4	943.4	45	3,534
1990	201.5	98.3	132	271	380.9	242.3	114	779	473.0	756.2	113	1,825	441.6	929.6	13	3,460
2000	177.5	71.4	127	228	392.6	267.8	127	814	430.8	681.0	105	1,648	414.6	869.5	39	3,258
The Amount of Stock (1,000,000 yen)																
1960	51.5	3.4	30	73	71.0	66.7	12	201	204.8	353.7	15	834	192.8	427.1	10	1,447
1970	278.0	166.3	160	396	434.3	317.7	123	979	942.7	1,698.8	66	3,970	851.8	1,929.5	35	6,413
1980	986.8	578.3	578	1,396	2,302.5	2,067.0	391	5,399	3,094.4	5,536.9	340	12,988	3,186.2	7,373.6	79	26,353
1990	1,293.5	748.5	764	1,823	3,682.0	3,268.1	738	9,570	5,364.6	9,535.0	625	22,402	4,143.1	9,618.3	92	34,369
2000	1,892.5	1,247.5	1,010	2,775	4,923.5	4,987.4	698	14,224	6,031.5	10,950.8	660	25,602	5,115.0	12,246.5	93	45,204
N		2				8				5				15		
Municipality		18				72				45				135		

Table 10 describes the results of analyses using estimation model s (4) and (5). Columns classified in (1) show the result of estimation model (5). The left area of column (1) describes the coefficients of cross-terms between year dummy variables and Ishidagawa Dam's downstream area dummy. The coefficients are consistently positive and become significant after 1975 without 1985 and 1995. The magnitudes show that the number of stores in Ishidagawa Dam's downstream area increases by between 15.9-39.1 percentage points compared to the other areas. The central area of column (1) shows the

coefficients of cross-terms between year dummies and the downstream area dummy of Odsuchi Dam. The coefficients are positive, and become five percent significant after 1985. The magnitudes are that the number of commerce plants increases by between 60.3-64.2 percentage points in downstream area of Odsuchi Dam compared to the other areas. The right area of column (1) represents the coefficients of cross-terms between $\mathbf{Year}_t$ and Usogawa Dam's downstream area dummy. The coefficients are consistently positive but not significant. The result suggests that the number of stores in the downstream area of Usogawa Dam were not affected significantly by constructing flood control dams.

Regarding the results of column (1), we consider the relationship between the coefficients and the periods of flood control dam construction. As described in Table 2, Ishidagawa Dam was constructed between 1963 and 1969, Odsuchi Dam was constructed between 1966 and 1987, and Usogawa Dam was constructed between 1971 and 1979. We compare the periods to the results of column (1) in Table 10 and find that the impacts of constructing flood control dams on the number of stores in downstream areas becomes statistical significance approximately five years after the completion of the dam (in the case of Ishidagawa Dam), or later in the construction phase (in the case of Odsuchi Dam). The case of Ishidagawa Dam is consistent with our hypothesis that the impacts of flood risk' reduction on commerce industries in downstream areas requires a time lag to appear because the effects occur only after increases in manufacturing plants or investment in surrounding areas. However, the positive impacts of constructing Odsuchi Dam on the number of stores in downstream area appeared in 1985, before the completion of the dam. For this reason, we consider that since the dam's construction took a long time, 21 years between 1966 and 1987, people in the downstream area would expect the decreases in flood risk, and the effects appeared even before the completion.

On the other hand, the right area of column (1) consistently shows positive and insignificant effects of flood control dams on downstream regions. For this reason, we interpret that the downstream area of Usogawa Dam contains Hikone City, the core city of East Shiga Prefecture, and many commerce stores were present even before the construction of Usogawa Dam. From Table 9, we can observe the tendency that the average number of stores of Usogawa Dam's downstream area is larger than the other areas, but the value did not change greatly between 1960 and 2000. From this fact, we consider that the commerce industry of Usogawa Dam's downstream area was developed even before the construction of Usogawa Dam, and additional demand resulted from increases in manufacturing plants or investments.

In addition, to check our hypothesis that the impacts of the reduction in flood risk on commerce industries in downstream areas appear after the increases of manufacturing plants in downstream areas, we conduct estimation model (5) using the natural logarithm of the number of manufacturing plants as the dependent variable. We can observe the number of plants in each municipality between 1965 and 2000,

and we regard the 1965 values as our results' baseline. Since Ishidagawa Dam was completed in 1969, we cannot observe the changes in the number of manufacturing plants in the downstream area between before and after the completion. Therefore, we conduct the estimation using only the downstream areas of Odsuchi and Usogawa Dams as $\mathbf{DownStream}_i$.

Column (2) in Table 10 shows the estimation results. The left area of the column describes the coefficients of cross-terms between year dummy variables and Odsuchi Dam's downstream area dummy. The coefficients are consistently positive with one percent significance. The magnitudes show that the number of manufacturing plants in Odsuchi Dam's downstream area increases by between 37.6-88.7 percentage points compared to the other areas, and the magnitude becomes larger over time. The right column shows the coefficients of cross-terms between the year dummy variable and the downstream area dummy of Usogawa Dam. The coefficients are positive, and become 10% significant after 1990. The magnitudes are that the number of manufacturing plants increases by between 37.7-42.5 percentage points in the downstream area of Odsuchi Dam.

From the results in the central area of column (1) and the left area of column (2), we can observe that the increases in the stores in Odsuchi Dam's downstream area occurred after the appearance of the impacts of the construction of Odsuchi Dam on downstream areas' manufacturing plants. This result is consistent with our hypothesis that the reduction in flood risk affects commerce industries in downstream areas after the appearance of the impacts of the flood risk' reduction on the manufacturing industry. Regarding Usogawa Dam, from the right area of column (2), although the coefficients become significant after 1990, the magnitude becomes large in 1975 compared to 1970, and the statistical significance is approximately 12%. We consider that the manufacturing industry in Usogawa Dam's downstream area expected a forthcoming reduction in flood risk between the periods of Usogawa Dam's construction, leading to a tendency to increase their plants or investment, but the amount was not sufficiently large to be statistically significant. From the right area of column (1), we can observe that the coefficients become large after 1985, from approximately 0.085 in 1980 to 0.244 in 1985. We interpret the change of coefficient in the commerce industry as the result of spillover effects from the manufacturing industry: the spillover effects required approximately 10 years to be observed, but the magnitude was not sufficiently large to be significant.

From the above discussions, we conclude that the reduction in flood risk activates non-manufacturing industries in downstream areas through increases in manufacturing plants and investment. Public investments reducing regional disaster risk could improve the regions' economic activities of many kinds of industries in the long term.

Table 10. Spillover Effects of Flood Risk Reduction on the Number of Commerce Shops

	ln (the Number of Commerce Shops)			*ln (the Number of Manufacturing Plants)*	
	(1)			(2)	
	Downstream Areas of Ishidagawa Dam	*Downstream Areas of Odsuchi Dam*	*Downstream Areas of Usogawa Dam*	*Downstream Areas of Odsuchi Dam*	*Downstream Areas of Usogawa Dam*
Year1965	0.0395	0.0324	0.0886		
×Downstream Dummy	(0.437)	(0.309)	(0.789)		
Year1970	0.0910	0.187	0.103	0.376***	0.0946
×Downstream Dummy	(1.002)	(1.353)	(0.819)	(2.894)	(0.858)
Year1975	0.159*	0.293	0.104	0.484***	0.264
×Downstream Dummy	(1.909)	(1.538)	(0.798)	(2.810)	(1.661)
Year1980	0.227**	0.351	0.0848	0.536**	0.267
×Downstream Dummy	(2.205)	(1.680)	(0.616)	(2.708)	(1.421)
Year1985	0.337	0.612**	0.244	0.655***	0.312
×Downstream Dummy	(1.525)	(2.060)	(0.988)	(2.951)	(1.661)
Year1990	0.391*	0.691**	0.246	0.743***	0.382*
×Downstream Dummy	(1.944)	(2.412)	(1.161)	(3.162)	(1.767)
Year1995	0.168	0.603**	0.145	0.828***	0.377*
×Downstream Dummy	(1.546)	(2.425)	(0.996)	(3.492)	(1.726)
Year2000	0.222*	0.642**	0.107	0.887***	0.425*
×Downstream Dummy	(1.992)	(2.490)	(0.696)	(3.616)	(1.793)
Municipality Fixed Effects		Y		Y	
Year Fixed Effects		Y		Y	
Constant		5.132***		3.767***	
		(82.77)		(53.44)	
N		270		240	
R-squared		0.218		0.537	
Number of Municipalities		30		30	

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

We empirically investigate the relationship between constructing flood control dams and manufacturing agglomeration in downstream areas by focusing on the case of Shiga Prefecture between 1965 and 2000 using municipality-level data. From the results of our event study, we find that the reduction in flood risk increased the number of manufacturing plants in downstream areas, but the impact is limited to manufacturing types requiring large amounts of physical capital to do their production activities: the basic materials as well as the processing and assembling categories.

We also find that plants in the basic materials category, requiring the largest amount of capital among the three categories focused on in the study, increased their investments in physical capital after constructing flood control dams, but the number of their employees did not increase. From the result, we conclude that manufacturing plants exposed to flood risk tend not to invest in physical capital with lower mobilities than human resources.

In addition, reduction in flood risk affected not only the manufacturing industry but also the commerce industry in downstream areas, and the effects required 10 years or more to be observed. For

this reason, we consider that the commerce industry could receive positive effects through increases in manufacturing industries' demand for materials or tools to do their production activities, but that becomes clear only after manufacturing plants or investments increase.

Our estimation results show that constructing flood control dams promotes manufacturing agglomeration in downstream areas, and the magnitude becomes large in industries needing larger physical capital. Developments of flood control dams could stimulate downstream areas' economic activities, in spite of governments not anticipating the effects. In the long term, large-scale public investments aiming to reduce regional disaster risk could improve the regions' economic activities.

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