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Recovery from the Mega-quake in Japan:
Evidence from Manufacturing Firms

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Recovery from the Mega-quake in Japan: Evidence from Manufacturing Firms

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Abstract
Firms which seriously suffered from the mega-quake in the East Japan in 2011 vary in the period to recover from the disaster. This paper examines what factors prolonged the periods for their recovery, using an original survey of disaster-hit firms in Tohoku area. While the cutoff of electrical power, industrial water supplies and transport network prevented the firms from recovering at the early time just after the quake, our estimated result, based on quantile regression, reveals that the severing of the supply chain significantly prolonged the period for their recovery.

Keywords: quake, recovery, supply chain, quantile regression

JEL classification: L60, Q54

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1. Introduction

The magnitude 9.2 quake and over 20-meter tsunami that struck the Tohoku region on March 11, 2011 wiped out in a flash precious lives and property of residents along the coast. Also, the reactor accident and subsequent radioactive contamination at Fukushima No. 1 nuclear power plant of Tokyo Electric Power Company kept many citizens far away from their living area. As the damage from the disaster to the citizens of Tohoku was enormous, it is still hard to say that they have recovered.

In addition to the fishing and marine products processing industries which received crushing blows from the tsunami, the Great East Japan Quake also had a huge impact on manufacturing firms in the Tohoku region. In March 2011, immediately after the disaster, output of the mining and manufacturing industry fell to 65.8 on the seasonally adjusted index of industrial production (IIP), using 2005 as 100. But it is notable that by September, half a year later, IIP had risen to 88, the recovery further progressed, and by March 2012, just one year after the disaster, it had reached 99.6 in Tohoku area. Compared with the 95.4 IIP for the nationwide mining and manufacturing, Figure 1 shows that as long as the mining and manufacturing, the output in the disaster area had returned to nearly nationwide levels during one year. Compared to the slow recovery from the destructive blows the tsunami dealt to citizen's lives and to the fishing and marine products processing industry, as well as from the impact of nuclear power plant radiation on the lives of local citizens, the recovery from the disaster on the mining and manufacturing was relatively rapid.

All industries and firms in the mining and manufacturing category have not recovered at the same pace. Many plants in the basic materials industry including nonferrous metals, pulp and paper industries, are located on the Pacific Coast of the Tohoku region. For these industries, many of the raw materials, intermediate goods and products are heavy in weight and the use of port facilities is essential for transporting them. Since many manufacturing plants are located in coastal areas, they were doubly impacted by the quake and tsunami. Hit by a devastating blow, they were forced to stop operating. In the Tohoku region there exist a number of manufacturing plants for the transportation equipment, machinery and electronics components industries. Since these industries use overland freight to transport raw materials, intermediate goods and products, many of their factories are located, not in the coastal regions, but near the highway in central zone of Tohoku. Industries sited in this interior region were fortunate in escaping damage from the tsunami.

Figure 1

Differences in plant locations resulted in differences in disaster damage, which in turn caused variations in the period and expense required to restore output after the disaster. Obviously, the greater the disaster damage the larger the impact on output. But the impact of drops in production by disaster-hit firms on their nationwide output cannot all be explained by the level of disaster damage. By looking at IIP (with 2005 = 100) we found a dramatic difference in the effects of the disaster on national production between basic materials manufacturers and processing and assembly manufacturers. For basic materials manufacturers severely hit by the tsunami, the impact on their nationwide production was relatively small. On the other hand, transportation equipment manufacturers and electronics parts and devices manufacturers, even though unaffected by the tsunami, suffered extremely high impacts to their nationwide production, even if the share of their production in the Tohoku region was not extremely high. The differences in the period for recovery also cannot be explained by the level of disaster damage. The production in the basic materials industry recovered in V shape and had returned to pre-disaster levels one year after the disaster. Considering the seriousness of the initial damage, we can say that, compared to the transportation equipment industry and the electronic parts and devices industry, the recovery of the basic materials industry was not prolonged. Clarifying the factors that gave rise to these differences is important for promoting recovery speed from quakes.

As long as we know, there have been few attempts, however, to analyze the factors impacting the process of firm's recovery from the large natural disaster. One reason is a lack of firm-level data of the activities of disaster-hit firms, in spite of the importance of firm-level data. To overcome this limitation, in December, 2011 RIETI conducted "A Survey of Firm Damage Caused by the Great East Japan Quake" which covers the damage and recovery of the plants which suffered from the Great East Japan Quake[1]. It is the first large-scale survey of disaster-hit plants to investigate firm's disaster and recovery. The analysis of this paper is based on this survey.

Our research makes two contributions to the studies of the disasters caused by the East Japan Great Quake. The first one is to clarify what factors prevented firms from their recovery, by focusing on the damage of infrastructure. In the contemporary economy, in which the division of manufacturing processes is well advanced, it is essential to clarify the impact of the cutoff of the supply chain on the resumption of operations by disaster-hit firms. Up till now, however, there are no studies on this issue except Henriet et al. (2012) and Hamaguchi (2013). The second contribution is to investigate the relationship between the supply chain and the period needed for operational resumption. We clarify, using the quantile regression method, how the cutoff of the supply chain differently affected the period of recovery among firms differing in their recovery periods.

The structure of this paper is as follows. The next section surveys previous studies related to natural disasters. Using IIP, the third section observes the different period of recovery from the East Japan Great Quake

[1] The survey was conducted with a cooperation of Professors N. Hamaguchi and Y. Todo.

among industries and their impact on the nationwide economy. The fourth section introduces the data of recovering firms suffered from the Great Quake by depicting the cumulative distribution function. Section 5 estimates the impact on the period of operational restart, of the variables including the cutoffs of supply chain as well as the cutoffs of the electricity, the water supply, the transportation network. The last section concludes.

2. Literature

As is surveyed by Cavallo and Noy (2009), there have been studies of natural disasters. They assert that the impact of natural disasters is not necessarily negative to the economy. Skidmore and Toya (2002), using cross-country data, showed that countries with a high frequency of disasters experienced large gains in human capital accumulation, as well as in total factor productivity (TFP)[2]. But their cross-sectional analysis among nations has a lack of evidence to show the causality between natural disaster and the economy. Leiter et al. (2008), using European firm-level panel data, analyzed the impact of floods on the accumulation of capital, labor, and the growth of value-added with an evidence for the causality between the natural disaster and the economy. They discovered that firms in flood-afflicted areas had a high rate of capital and labor growth, floods had a negative impact on the productivity growth in general, but in firms with a high proportion of intangible capital this negative impact was relatively small.

We should reserve that in short-run, the impact of natural disasters on the economy is negative. For example, using data from Central America and the Caribbean, Strobl (2012) found that hurricanes lower the production in the damaged region by 0.83%. It is therefore extremely important to investigate what factors mitigate the negative impact of natural disasters. Kahn(2005), Toya and Skidmore (2007), and Noy (2009) show that factors

[2] It is noted that Skidmore and Toya study (2002), using cross section micro-data, also has the weakness of not revealing a strict causality between natural disasters and the economic growth.

such as country-specific features, economic and social institutions are important to determine the degree of damage caused by a natural disaster. Kahn(2005) demonstrated that the richer the country, the fewer its deaths from a natural disaster. Toya and Skidmore (2007) also found that the higher a country's income level, educational standard and the market openness to trade, the smaller its damage from natural disasters. Noy (2009) showed that countries with a high level of literacy, per-capita income, government expenditure and market openness were better able to protect their macro-economies from the negative impacts of a devastating natural disaster.

In Japan there have been studies of the Great Hanshin-Awaji Quake. Toyoda (1996) and Horwich (2000) provided a general description of the disaster by the quake. Sawada and Shimizutani (2007, 2008) examined the effects of the quake on the consumer's behavior. Meanwhile, the manufacturer's perspective has been examined in a series of studies by researchers at Kobe University. For example, the research of Hondai and Uchida (1998) precisely calculated the cost of quake damage to Kobe's manufacturing industry. Uesugi (2012), a pioneer study analyzing the Great Hanshin-Awaji Quake using firm-level data, showed a significant rise in the post-quake bankruptcy rate of disaster-zone firms that had business relationships with financial institutions in afflicted areas. It also confirmed the decline of plant and equipment investments by the firms in disaster-zone that had business relationships with financial institutions in afflicted areas. There have not been attempts to investigate the factors impacting the process of firm recovery from the Great East Japan Quake at the firm level yet, except the research by Hamaguchi (2013),

3. Restoration of Disastrous Industries

The pulp and paper industry located on the Tohoku coast received devastating blow from the tsunami. Output in the Tohoku region fell to 20%

of its pre-disaster level in March, 2011. In spite of it, the nationwide production in the industry did not drop so largely. When it hit bottom in March 2011, nationwide output was still 90% of the pre-disaster level. Furthermore, even though output in the Tohoku region suffered a devastating blow, Figure 2 shows that the recovery afterward was v-shaped and in one year the output had returned to pre-disaster levels. The non-ferrous metal output in the Tohoku region suffered a devastating blow in March, 2011, falling to 50% of its pre-disaster level. But the drop of nationwide output in non-ferrous metal industry was not so large. When it hit bottom in March, 2011, nationwide output was at 80% of its pre-disaster level. The production of non-ferrous metals industry also had a v-shaped recovery from the disaster and in one year returned to pre-disaster levels.

Figure 2

The effect of decreased production in transportation machinery and electronics industries on the nationwide production was different from basic material industries. As Figures 3 and 4 show, the production level of the transportation machinery and electronics industries in the Tohoku region also suffered a hard blow in March, 2011, sliding to 60% of its pre-disaster level. In spite of relatively small decline of production compared to the basic materials industry, the outputs in both the Tohoku regions and Japan as a whole fell in parallel to 60% of pre-disaster levels. In other words, in processing and assembly industries the impact of the disaster in Tohoku spread at once to the country as a whole.

Figure 3 and Figure 4

In nationwide production levels between industries, we can see that the decline of the processing and assembly industry (transportation machinery, electronics parts) was greater than that of the basic materials industry (pulp and paper, non-ferrous metals). We cannot say, however that this was due to the Tohoku region's high share of nationwide production. Its share of nationwide industrial value-added in 2010 was 9% for pulp and paper and 17% for non-ferrous metals. On the other hand, its share of electronics parts was 12% and for transportation machinery only 3%[3]. Tohoku's share of the processing and assembly industry did not extremely exceed that of the basic materials industry.

The production network causes the reason why the fall of production in Tohoku differently spread to the nationwide production between two industries. In the basic materials industry, as the production process is completed within the site, the damage of plant did not have an impact on other unaffected plants through the supply chain of intermediate goods. Unaffected firms have been able to substitute for affected plants. On the other hand, in the processing and assembly industry, production shutdowns by disaster-affected firms possibly served, through the supply chain, to restrict production of non-affected firms. The cutoff of supply chain gives rise to restrict the production of other firms which did not even suffer from the disaster.

4. Period for Recovery

4.1 Analytical Framework

The cost and time needed for firm's recovery will obviously differ depending on the severity of the disaster. In addition, the supply chain defined by the transaction of intermediate goods between upstream and downstream firms affects them. In the case of disaster-hit firms connected through the supply chain to business partner firms even unaffected by the disaster, a drop in

[3] A significant upward trend of transportation machinery in Tohoku after the quake is notable. It was due to "Toyota effect." Toyota established the East Japan Automobile Company, a large-sized assembly subsidiary of Toyota, in the inland area of Tohoku just before the mega-quake and began to operate two months after the mega quake. The operation of Toyota East Japan led the recovery of local parts suppliers in the region.

production by disaster-hit firms leads to a demand or supply shortage of intermediates goods to partner firms. A disaster-caused decline in production by partner firms may restrict production of non-disaster-hit firms. Thus the period needed for recovery of firms under the supply chain gets longer than the firms not involved in the supply chain. The disaster-hit firms are linked to others in Tohoku through supply chain which may have generated a downward spiral, leading to prolonging the production recovery by business partners. To confirm this hypothesis, we statistically identify how largely the production recovery of firms in Tohoku was prolonged by the supply shortage of intermediate goods from their business partners through the cutoff of supply chain.[4]

4.2 Data

The Survey of Firm Damage Caused by the Great East Japan Quake, RIETI conducted in December 2011, covers the plants of manufacturing firms in the disaster-afflicted areas (Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Tochigi prefectures). For the 2,117 plants that responded to the survey, Table 1 categorizes damage causes into the two of quake and tsunami, while dividing degrees of damage into four categories: (i) no destruction, (ii) part destruction, (iii) half destruction, and (iv) complete destruction, while giving the numbers of plants falling into each category. The number of disaster-hit plants suffering part or more severe destruction by the quake was 1,376, while the disaster-hit plants reporting part or more severe destruction from the tsunami was 115. Of these, 58 plants suffered part or more severe destruction from both the quake and tsunami. The number of plants suffering part or more severe destruction from either the quake or tsunami

[4] In addition, there is another approach from non-afflicted firms. For example, there is the method of directly evaluating how drops in production by afflicted firms that possess a supply chain impact the production of non-afflicted partner firms. In that case, it is necessary to have information concerning the production of non-afflicted firms and the networks between non-afflicted and afflicted firms, as well as information on the damage to business partners. But since the purpose of this analysis is to specify the factors that hinder the recovery of disaster-hit firms, we have not used this method.

was 1,433, while 684 plants reported no destruction. It reports that fewer plants were damaged by the tsunami than by the quake.

The plants are classified into eight groups according to the condition of their recovery: (1) Returned to original condition, (2) Expect to recover, (3) Moved plant, (4) Plan to move plant, (5) Exit from business, (6) Expect to exit from business, (7) Have merged with or been acquired by another firm, and (8) Other. The numbers of plants in each category are shown in Table 2. Of the 2,117 plants, 1,380, two-thirds of the total, have recovered, or while 15 plants have either moved or plan to move, and five have stopped operations, an extremely small number. From these figures, we find how fast the speed of the recovery is while we have to note that the survey was carried out only eight months after the disaster, then the firms that had suffered a severe blow or whose recovery had been delayed may not have answered the survey. Further there may not have been enough time to decide on a plant move, closure or merger/acquisition. We have to note a possible bias to recovery in the survey population.

Table 2

4.3 Period for Restoration from Disaster

In this section we examine the distribution of periods needed for the resumption of post-disaster operations (referred to below as "shutdown period"). Figure 5 shows the cumulative distribution of plants' shutdown periods. Plants with a shutdown period of five days or less accounted for 35%, from five to ten days, 65% and 30 days or less, 90%. Considering the scope of the quake disaster, plants resumed operations at an astonishing speed.

Figure 5

Next, we examine the relationship between the degree of damage and the shutdown period. Figure 6 categorizes the degree of damage into part destruction, half destruction, and complete destruction, while showing the cumulative distribution of plant numbers for the shutdown period in each category. As expected, the cumulative distribution curve shifts to the right in line with the severity of the destruction, while the shutdown period tends to lengthen. Thirty days after the disaster, 90% of the plants with part destruction and 80% of the plants with half destruction had resumed operations, while only 35% of those reporting complete destruction had. The Figure shows that the degree of natural damage determined operational resumption periods fundamentally.

Figure 6

Not a few disaster-hit plants received financial support from the national and local governments to help them resume operations. Figure 7 classifies plants in ones who did or did not receive public support, while showing the cumulative distribution of plants according to the time needed to resume operations. Plants that received public support had longer shutdown periods than those that did not. This does not indicate the causality between public support and plant shutdown periods. We should explain that the plants with long shutdown periods were heavily impacted by the quake and that public support went preponderantly to plants with the severest damage.

Figure 7

For disaster-hit plant to resume operations, external resources must be provided to the firms from outside. Using the RIETI survey, we investigated how the outside resources affected the shutdown periods, including the cutoff of electrical supplies, the usability of industrial water supplies, ways of transport, and cutoff of supply chains (i.e., production shutdowns at parts and materials suppliers). Figure 8 shows the cumulative distribution of plants regarding the length of shutdown periods, for each of the four outside factors. The impact of electrical supply cutoffs was the shortest, followed by cutoffs of industrial water supplies and means of transport, while supply chain cutoffs caused the longest shutdown periods. Of the plants forced to shut down operations for causes other than supply chain cutoffs, 90% of the disaster-hit plants resumed operations within 30 days, while only 60% of the plants impacted by supply chain cutoffs were able to restart operation in the same period. This shows that supply chain cutoffs resulted in the longest operational shutdowns.

Figure 8

5. Determinants of Shutdown Periods

5.1 Empirical Estimation

In the case of operations of disaster-hit plants shutting down due to supply chain cutoffs, cutoffs of electricity, industrial water supplies and means of transportation may also have affected the shutdown period of operation simultaneously. Figure 8, although showing the cumulative distribution of operational resumptions period for each factor, did not identify the impacts for each factor. In this section by controlling for other factors than supply chain cutoff which have impacted plants simultaneously, we statistically estimate how the resumption of operations at the disaster-hit plants was affected by supply chain cutoffs. The effect is estimated by following equation:

$$(1) \qquad Y_i = X_i\beta + \varepsilon_i$$

where the dependent variable Y_i is the number of days that plant i needed to restart operations after the disaster, the explanatory variable X_i includes the number of days for which the intermediated goods supply from suppliers was cut and the control variables. The control variables include the numbers of days when electrical power, industrial water, and means of transport were respectively cut to plant *i* as well as the dummy variable indicating whether plant *i* was damaged by the tsunami or not (with damage by the tsunami = 1); the variable indicating the degree of disaster damage to plant i (with part destruction = 1, half destruction = 2 and complete destruction = 3); the dummy variable equaling 1 in the case of plant *i* having a Business Continuity Plan prior to the disaster; the dummy variable equaling 1 in the case of plant *i's* firm headquarters being located outside the disaster-hit prefecture; the dummy variable equaling 1 in the case of plant *i* receiving only private aid; the dummy variable equaling 1 in the case of plant *i* receiving both private and public aid; and plant *i's* scale, including total sales and numbers of employees. Table 3 shows the descriptive statistics for each variable.

Table 3

The estimated results, based on OLS method, are shown in Table 4. Plants that suffered tsunami damage or complete destruction or received public and private support were slow to resume operations. Also, we find that other factors delaying the resumption of operations include cutoffs of electrical power and industrial water supplies. The Table also shows that, even after controlling for these factors, the damage to business partners causing the cutoffs of supply to plant *i* significantly lengthened the period needed to resume its operations.

Table 4

5.2 Quantile Regression

The cumulative distribution function for shutdown periods in Figure 8 indicates that supply chain cutoffs are the biggest factor in lengthening operational shutdown periods. On the other hand, though the estimated results from OLS indicate that impact from supply chain cutoffs is significant in some extent, they also show that, compared with impacts from cutoffs in electrical power or industrial water supplies, the size and significance of the effect of supply chain cutoffs on the period needed for operational resumption are not so large. We find a gap between the cumulative distribution function and the estimated coefficients. To explain the gap between the two results, we hypothesize that factors determining operational shutdown periods have varying impacts on plant restoration, according to the length of the shutdown. For example, a cutoff in the supply chain may not impact a plant with a relatively short operational shutdown, but a supply chain cutoff may strongly impact a plant experiencing a long shutdown of operations. If this hypothesis is verified, the cumulative distribution function in Figure 8 indicating that supply chain cutoffs lengthen the shutdown period the most of all factors can be consistently explained.

We, using the quantile regression method, estimate statistically the impact of the supply chain, following Greene(2012) and Koenker and Hallock(2012). The equation for estimation is as follows:

$$(2) \qquad Q(Y|X,q) = X'\beta_q \text{ s.t. } \Pr ob\left[Y \le X'\beta_q | X\right] = q,\ 0 < q < 1.$$

The coefficient is estimated so as to minimize the function below, corresponding to the value of parameter q.

$$F_n(\beta_q|Y,X) = \sum_{i:Y_i \geq X_i'\beta_q}^{n} q|Y_i - X_i'\beta_q| + \sum_{i:Y_i < X_i'\beta_q}^{n} (1-q)|Y_i - X_i'\beta_q| \tag{3}$$
$$= \sum_{i=1}^{n} g(Y_i - X_i'\beta_q|q)$$

where $g(\varepsilon_{i,q}|q) = \begin{cases} q\varepsilon_{i,q} & \text{if } \varepsilon_{i,q} \geq 0 \\ (1-q)\varepsilon_{i,q} & \text{if } \varepsilon_{i,q} < 0 \end{cases}$, $\varepsilon_{i,q} = Y_i - X_i'\beta_q$

We estimate the coefficient β corresponding to the differing value of q. That is, for the estimation, we change the weight assigned to a plant with shutdown period by changing the value of parameter q.

As for the restoration period, Table 5 shows the quite interesting estimation results as follows:.

(i) In the case of a relatively brief operational shutdown (that is, when q is less than 0.5), electrical power supply cutoffs had a big impact on recovery time. On the other hand, supply chain cutoffs did not have a significant impact on operational shutdown periods.

(ii) In the case of a lengthy operational shutdown (that is, when q is more than 0.5), electrical supply cutoffs did not have a significant impact on recovery, but supply chain cutoffs had a large and significant impact on the length of operational shutdown periods.

(iii) The impact of firm scale (as measured by the total sales and the number of employees) on operational shutdown periods was significant only in the case of lengthy shutdowns, while tending to shorten shutdown periods. A possible interpretation for this is that, in the case of plants with lengthy shutdown periods, the bigger the plant the greater the use of internal resources to invest for recovery which will shorten the recovery period. On the other hand firms of the smaller size has insufficient internal resources to invest for recovering, then did not easily recover.

(iv) The estimation results for other control variables are consistent with the results in Table 4.

The quantile regression results above clearly evidenced that plants with brief operational shutdowns did not have their recovery impacted by supply chain cutoffs, but plants with lengthy shutdowns were severely impacted by them, slowing their recovery.

Table 5

6. Conclusion

Two years passed after the Great East Japan Quake. In average the industrial production has recovered to pre-quake levels in the Tohoku region, but for some firms recovery has been slow. In this paper, using data from an original survey of disaster-hit firms conducted eight months after the Great East Japan Quake, we attempted to identify the factors hindering the recovery of firms from the quake.

Comparing the basic materials industries with the processing and assembly industries, we find that, despite major tsunami damage, the basic materials industries suffered only a small negative impact to its nationwide output, compared to the processing and assembly industries. For sectors of the processing and assembly industries not even damaged by the tsunami, the impact of production decreases on nationwide output was rather large. This paper finds that this impact from the disaster was generated through the damage of supply chain. This also affected the recovery process. Based on the survey data, the results of our estimation reveal that, not only exogenous factors such as the size of the damage and cutoffs of electrical power, industrial water and transports, but also business transaction factors, such as supply chain cutoffs, have lengthened the period of recovery from the disaster.

Since the magnitude of the impacts hindering recovery differs depending on the length of the recovery period, the estimated results on simple OLS is not sufficient for identifying the real effects. Previous research on natural disaster damage did not consider the heterogeneity of firms with differing recovery periods, Instead, this paper, using the quantile regression method, has shown that factors impeding recovery differ depending on the recovery period needed. The result of estimation has positively proven that electrical supply cutoffs dealt a big blow to plants with relatively short recovery periods, but on the other hand, supply chain cutoffs had a major impact on plants needing long times to recover. As far as the authors know, these findings are a first.

Before ending, we reserve the generalization of our analytical results. It may be possible that the survey population on which our analysis is based may be biased. Here we would like to point out two concerns. One has to do with the representativeness of the responding firms. Among the disaster-hit firms responding to this survey many had relatively smooth recoveries. But firms that suffered severe damage may not have had the leeway to respond to this sort of survey. Another concern has to do with the survey period. The survey was conducted eight months just after the disaster. Even if firms had recovered from the quake in the short term, its impact on their long-term output was not yet clear. Factories attempting to make a full-fledged recovery may move to a new location or undergo a merger or acquisition. Further investigation of these issues remains.

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Figure 1. Index of Industrial Production (Manufacturing, 2005=100)

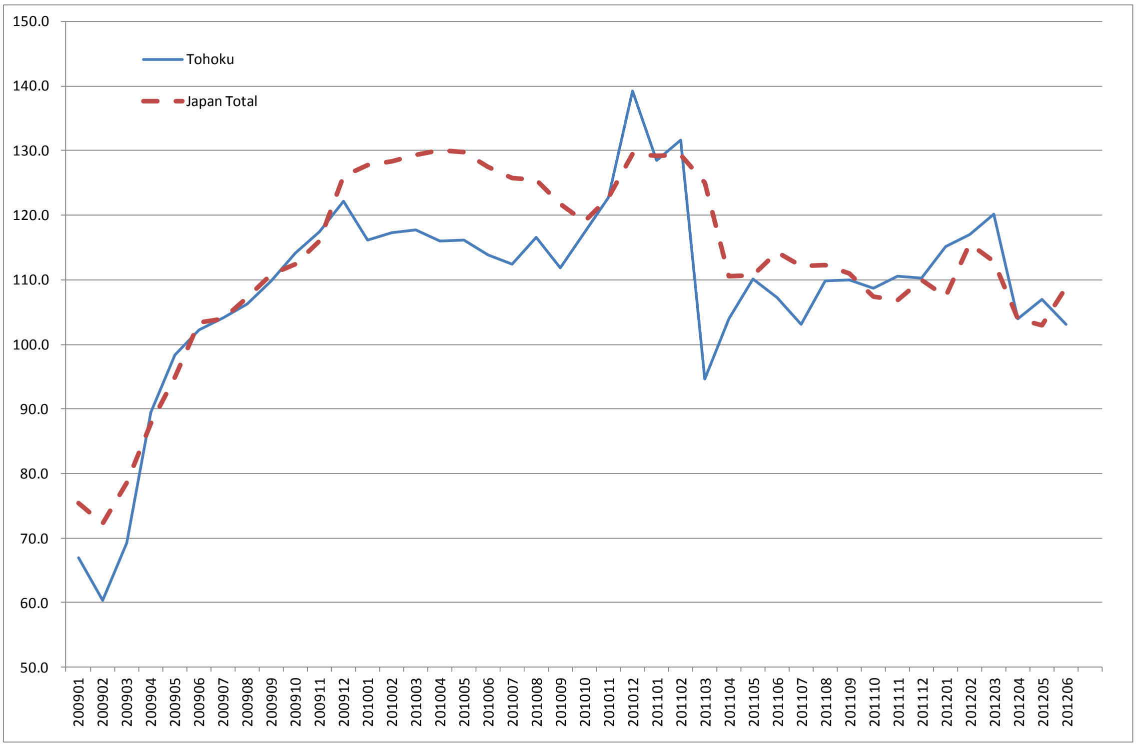

Figure 2. Index of Industrial Production (Paper & Pulp Industries, 2005=100)

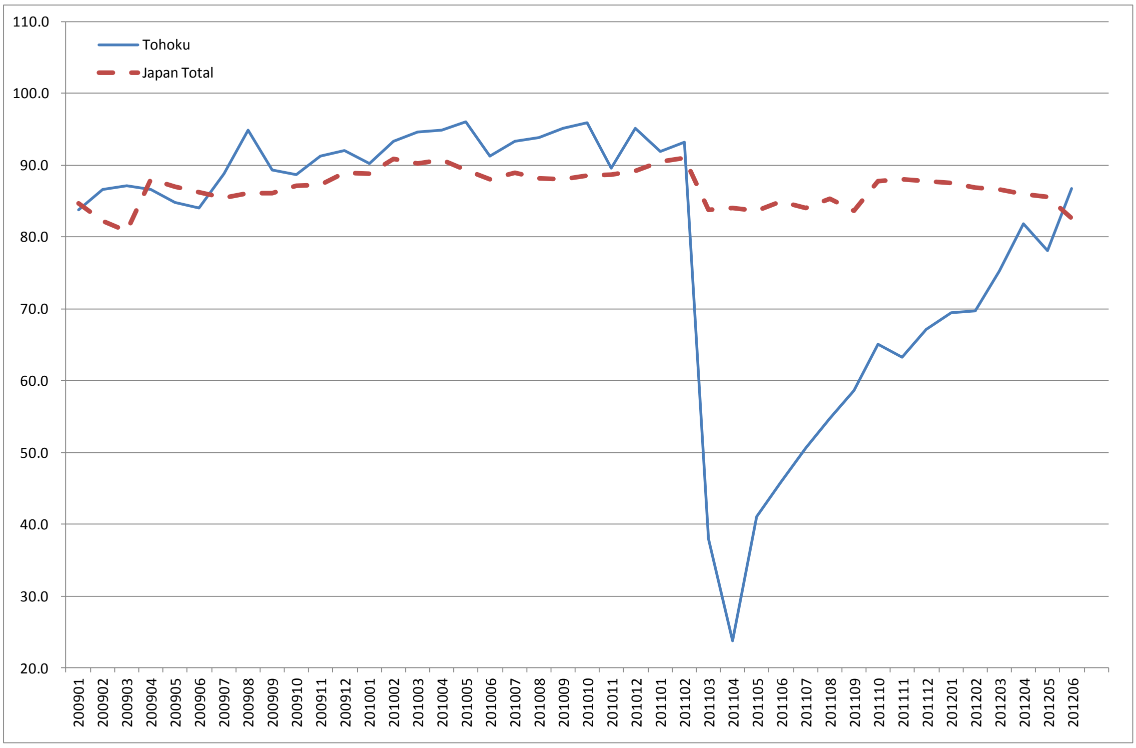

Figure 3. Index of Industrial Production (Transportation Machinery, 2005=100)

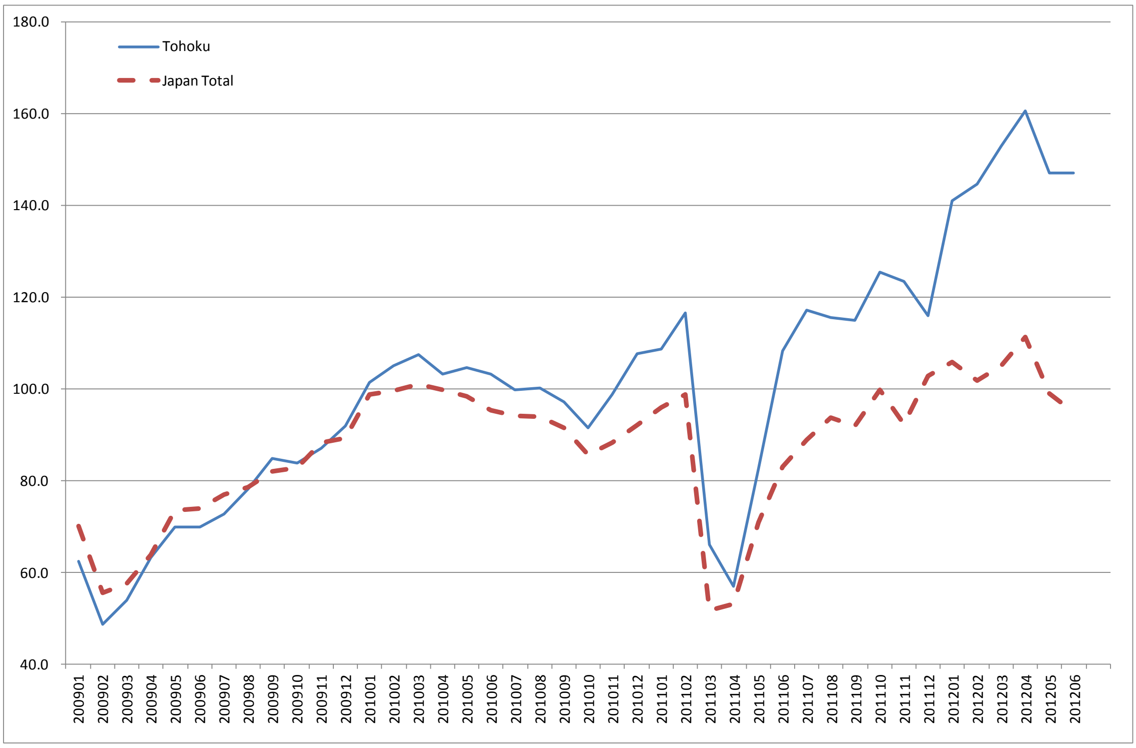

Figure 4. Index of Industrial Production (Electronics and Device Industries, (2005=100)

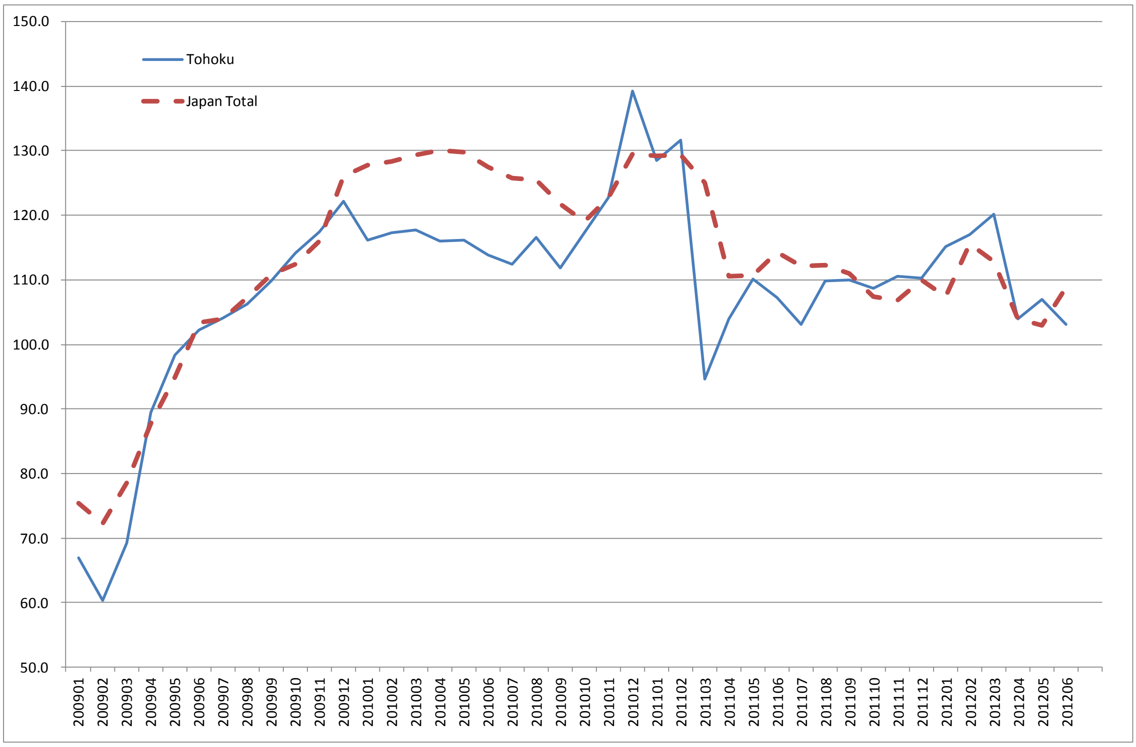

Figure 5. Cumulative Distribution of Plants and Period of Operational Shutdown

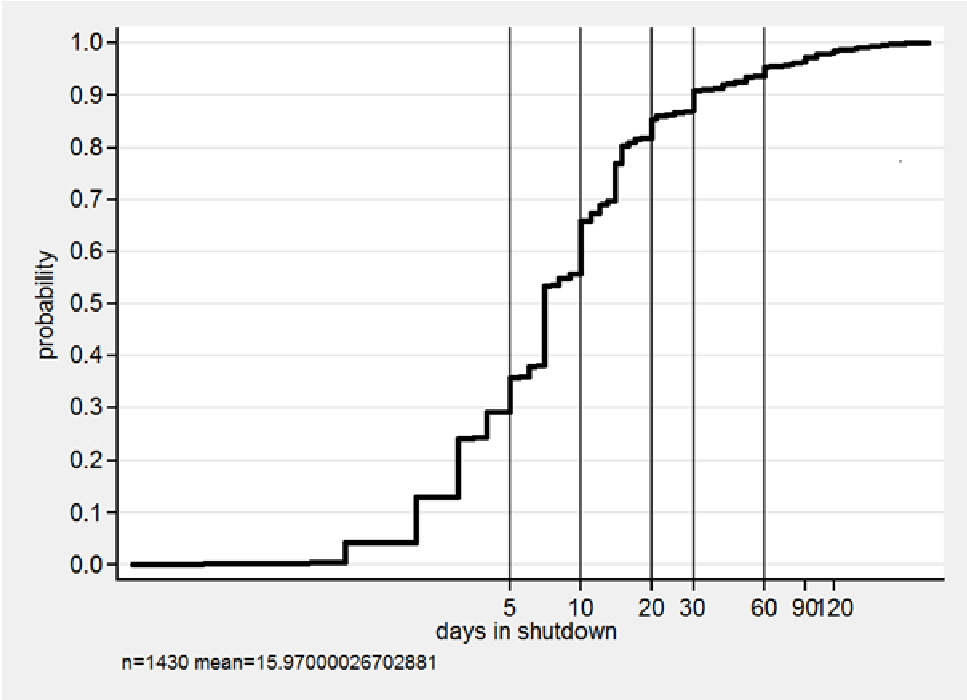

Figure 6. Cumulative Distribution of Plants and Period of Operational Shutdown

(by Degree of Damage)

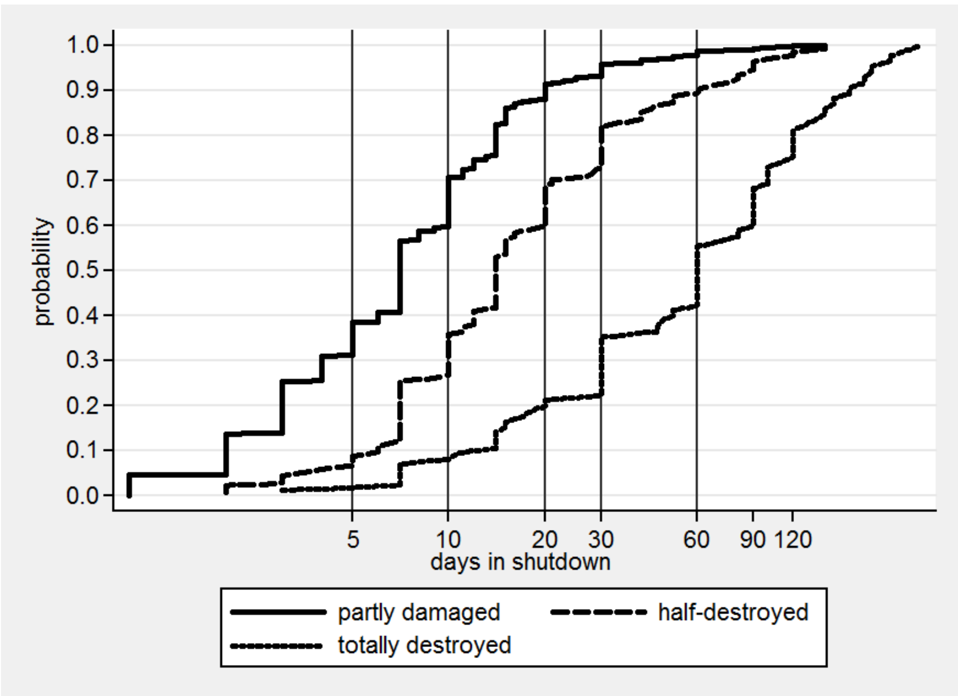

Figure 7. Cumulative Distribution of Plants and Period of Operational Shutdown (by Public Support)

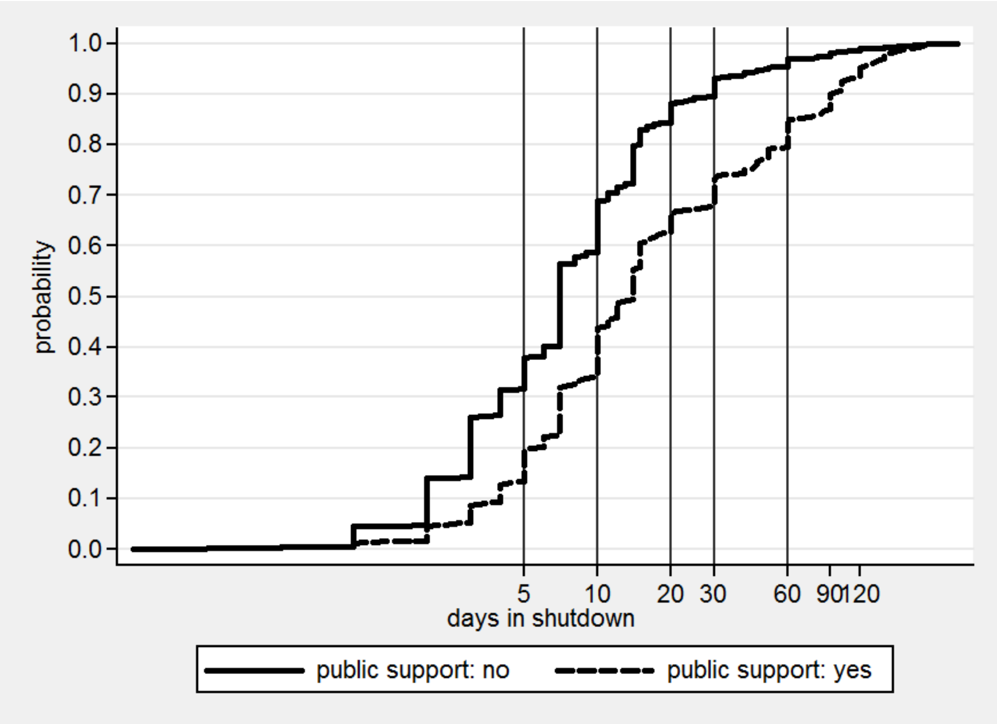

Figure 8. Cumulative Distribution of Plants and Period of Operational Shutdown (by Factors Prolonging Recovery)

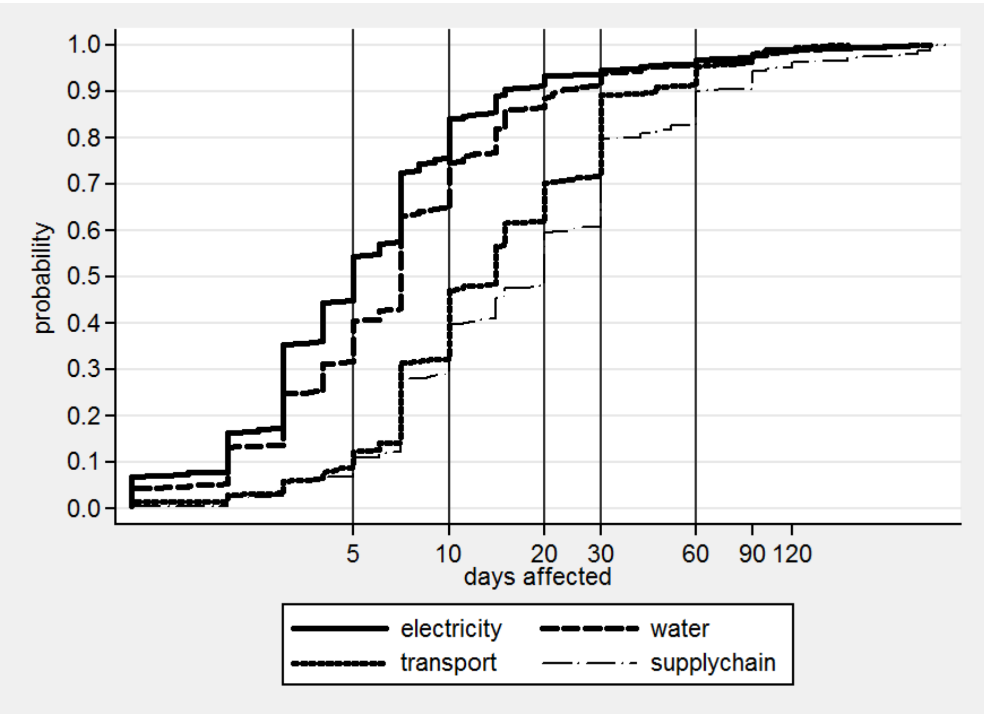

Table 1. Number of Disaster-hit Plants

	Destruction by Quake				
	No	Part	Half	Complete	Total
Destruction by Tsunami					
No	684	1,177	117	24	2,002
Part	5	12	2	0	19
Half	8	6	9	0	23
Complete	44	18	1	10	73
Total	741	1,213	129	34	2,117

Table 2. Stage of Recovery

Stage of recovery	Number of plants	Share	Cummulative share
No	597	28.20	28.20
Returned to original condition	1380	65.19	93.39
Expect to recover	75	3.54	96.93
Moved plant	5	0.24	97.17
Plan to move plant	10	0.47	97.64
Exit from business	2	0.09	97.73
Expect to exit from business	3	0.14	97.87
Have merged with or been acquire	3	0.14	98.02
Other	42	1.98	100.00
Total	2117	100.00	

Table 3. Description of Statistics

variable	N	min	mean	max	s.d.
ln shutdown periods	1437	0.000	2.247	5.707	0.959
dummy for tsunami	2117	0.000	0.054	1.000	0.227
degree of destruction: part=1, half=2, complete=3	1454	1.000	1.243	3.000	0.571
dummy for BCP	2117	0.000	0.085	1.000	0.280
dummy for headquarter outside	2117	0.000	0.011	1.000	0.106
ln cutoff of electrical power	1978	0.000	1.282	5.707	1.055
ln cutoff of water supply	2005	0.000	0.792	5.802	1.150
ln cutoff of supply chain	1867	0.000	1.604	5.903	1.641
ln cutoff of transport	1844	0.000	1.317	5.802	1.432
dummy for private support only	2117	0.000	0.185	1.000	0.388
dummy for private & public support	2117	0.000	0.088	1.000	0.284
ln sales in 2010	1691	2.944	9.400	17.910	1.507
ln workers in 2010	1963	0.000	3.061	7.021	1.021

Table 4. Results of Estimation (OLS)

	OLS	
	(1)	(2)
dummy for tsunami	0.695***	0.704***
	[0.140]	[0.127]
degree of destruction	0.562***	0.510***
	[0.061]	[0.057]
dummy for BCP	-0.156*	-0.164*
	[0.088]	[0.084]
dummy for headquarter outside	0.127	0.083
	[0.332]	[0.302]
ln cutoff of electrical power	0.119***	0.125***
	[0.038]	[0.035]
ln cutoff of water supply	0.066**	0.062**
	[0.026]	[0.025]
ln cutoff of supply chain	0.034*	0.032*
	[0.019]	[0.018]
ln cutoff of transport	-0.006	0.003
	[0.023]	[0.021]
dummy for private support only	0.134**	0.130**
	[0.066]	[0.062]
dummy for private & public support	0.239***	0.263***
	[0.089]	[0.086]
ln sales in 2010	-0.026	
	[0.018]	
ln workers in 2010		-0.045*
		[0.026]
R square	0.447	0.450
N	698	797

(Note) * significant at 10%; ** significant at 5%; *** significant at 1%

Table 5. Results of Estimation (Quantile Regression)

	q					q				
	0.10	0.25	0.50	0.75	0.90	0.10	0.25	0.50	0.75	0.90
dummy for tsunami	0.410***	0.564**	0.698***	0.896***	0.960***	0.543*	0.675***	0.738***	0.743***	0.674***
	[0.146]	[0.244]	[0.196]	[0.226]	[0.232]	[0.286]	[0.231]	[0.228]	[0.194]	[0.179]
degree of destruction	0.361***	0.444***	0.518***	0.586***	0.617***	0.284***	0.374***	0.451***	0.568***	0.620***
	[0.112]	[0.104]	[0.059]	[0.088]	[0.127]	[0.097]	[0.072]	[0.048]	[0.063]	[0.109]
dummy for BCP	-0.099	-0.075	-0.124	-0.238	-0.225	-0.073	-0.1	-0.122	-0.149**	-0.181
	[0.084]	[0.068]	[0.143]	[0.190]	[0.207]	[0.076]	[0.109]	[0.134]	[0.073]	[0.111]
dummy for headquarter outside	0.588***	0.385***	0.139	0.061	-0.083	0.427***	0.338*	0.141	0.012	-0.056
	[0.061]	[0.078]	[0.127]	[0.329]	[0.472]	[0.111]	[0.178]	[0.096]	[0.259]	[0.391]
ln cutoff of electrical power	0.243***	0.347***	0.218**	0.077	0.003	0.278***	0.331***	0.230***	0.11	-0.007
	[0.053]	[0.063]	[0.091]	[0.057]	[0.063]	[0.064]	[0.038]	[0.086]	[0.072]	[0.058]
ln cutoff of water supply	0.04	0.014	0.046**	0.043	0.100***	0.055	0.032	0.034	0.047	0.089***
	[0.043]	[0.037]	[0.023]	[0.037]	[0.036]	[0.055]	[0.035]	[0.031]	[0.036]	[0.018]
ln cutoff of supply chain	-0.004	0.006	0.031**	0.066***	0.079***	0.002	0.013	0.029	0.054**	0.074**
	[0.018]	[0.012]	[0.016]	[0.023]	[0.029]	[0.031]	[0.020]	[0.019]	[0.026]	[0.033]
ln cutoff of transport	0.033	0.042*	0.026	-0.022	-0.058	0.034	0.041	0.032	-0.005	-0.072**
	[0.023]	[0.025]	[0.025]	[0.042]	[0.041]	[0.022]	[0.026]	[0.025]	[0.014]	[0.032]
dummy for private support only	0.157*	0.141***	0.151*	0.088**	0.185	0.093	0.074	0.173	0.101	0.197***
	[0.095]	[0.050]	[0.083]	[0.041]	[0.126]	[0.091]	[0.099]	[0.111]	[0.074]	[0.058]
dummy for private & public support	0.385***	0.274***	0.238	0.231***	0.143	0.402***	0.221**	0.280**	0.242***	0.245***
	[0.126]	[0.078]	[0.154]	[0.067]	[0.088]	[0.038]	[0.110]	[0.123]	[0.088]	[0.069]
ln sales in 2010	0.01	-0.034**	0.009	-0.006	-0.048***					
	[0.032]	[0.017]	[0.028]	[0.023]	[0.018]					
ln workers in 2010						-0.038	0.009	0.004	-0.038	-0.089***
						[0.044]	[0.046]	[0.060]	[0.039]	[0.030]
Pseudo R square	0.271	0.289	0.254	0.290	0.376	0.284	0.295	0.260	0.292	0.369
N	698	698	698	698	698	797	797	797	797	797

(Note) * significant at 10%; ** significant at 5%; *** significant at 1%