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Murakami, Hideki

Yanagida, Akiko

(Citation)
神戸大学経営学研究科 Discussion paper,2014・15

(Issue Date)
2014-07

(Resource Type)
technical report

(Version)
Version of Record

(URL)
https://hdl.handle.net/20.500.14094/81008081

Graduate School of
Business Administration

KOBE UNIVERSITY

ROKKO KOBE JAPAN

2014-15

IMPACTS OF EAST-JAPAN'S DISASTER ON PRODUCTION OF A SMALL —MEDIUM CARDBOARD MANUFACTURER IN FUKUSHIMA

Hideki Murakami　Akiko Yanagida

Discussion Paper Series

Chapter XX

IMPACTS OF EAST-JAPAN'S DISASTER ON PRODUCTION OF A SMALL －MEDIUM CARDBOARD MANUFACTURER IN FUKUSHIMA

Hideki Murakami and Akiko Yanagida

Abstract This paper analyzed the impact of the earthquake, tsunami, and explosion-disaster at the Fukushima nuclear power plant in March 2011 on a small-medium cardboard manufacturer's production and transportation systems. We first estimated the Cobb-Douglas production function to determine the change pre- and post-disaster using time-series monthly data from January 2010–December 2012 (35 months); we found few structural changes to the input ratio in the company's production system. We then performed statistical analyses to investigate changes in the cargo flow originating at the firm and shipped to devastated/non-devastated destinations. The results indicated that the disaster affected cargo flow only to the coastal area devastated by the tsunami or contaminated by nuclear radioactivity. Since the demand for cardboard is a "derived demand" of agriculture and relatively light industries, this finding suggests that these industries were not unduly impacted by the disasters, and that the disaster's effects may be overemphasized.

Keywords East-Japan earthquake, small-medium firm, production function

XX.1. Introduction

East Japan experienced a historical disaster in March of 2011. The Asahi newspaper reported in 2011 that about sixteen thousand people were dead and three thousand are still missing.

In addition to these human disasters, many industries and infrastructures were damaged. These disasters are classified into three categories depending on the cause of the damage. The first is the earthquake itself, the second is the tsunami that caused the greatest damage along the coast, and the third is the radioactive disaster generated by the explosion of the nuclear electric plants. Damaged infrastructure was restored in accordance with its importance and necessity, and

Mail to:H.Murakami
Kobe University, Graduate School of Business; Tohoku Kogyo
e-mail: hidekim@panda.kobe-u.ac.jp

individual industry has also been revived. However, people are still forbidden from entering or staying in the areas contaminated by radioactivity. While these areas comprise only a part of the Fukushima prefecture, it seems that many people in other areas of Japan and outside in other countries still have misconceptions about the nuclear contamination. The contamination spread only to limited areas in the Fukushima prefecture, and economic activities were quickly restored immediately following the earthquake.

There have been many studies and reports on issues related to the Fukushima disaster (Kushida, 2012; Holt et al., 2012;, Conferences Proceedings of the STS Forum on the 2011 Fukushima/East Japan Disaster, UC Berkeley, May 11-14, 2013). However, all of them have dealt with the disaster itself, for example, scientific analyses of radioactive contamination, or time-series reports about political and institutional responses. Few studies have conducted economic analyses, since many businesses in Fukushima closed down operations, and there was insufficient data for a rigid analysis using economics or statistics.

This paper is the first to do an economic analysis highlighting a small-medium manufacturer of cardboard in the Fukushima area. The purpose of this study was to investigate whether the production activities of a manufacturer in the Fukushima prefecture was changed after the disaster by estimating (1) the production function and change in the ratio of input share, and (2) regional-area specific logistics activities of the firm by time-series analyses. The methodology combined microeconomics and econometrics, using 35 months of data. In the next section, we demonstrate the impact of East-Japan's disaster on regional small-medium enterprises and discuss the remedies enacted by the Japanese public sector, such as national and regional government to alleviate the effects on companies. In Section 3, we present an overview of the demographic issues and the damage to Fukushima Prefecture. Section 4 presents the empirical models and dataset. In Section 5 we show and discuss the empirical results, followed by future perspectives in Section 6.

XX.2. Government's response to the disaster and descriptive statistics of revival of small-medium firms in Tohoku afterwards

In this section we survey the Japanese government's actions to relieve the effects of the disaster on small-medium firms in the Tohoku district. According to Japan's Small-Medium Enterprise Agency, the following financial plans were announced to assist all small-medium companies in the immediate aftermath of the disaster on March 13th 2011. Actions included granting loans as high as eighty million yen without collateral, extending the period of redemption from seven to nine years, lowering the bid rate by 0.9%, and offering indirect subsidies from national government to small-medium companies via local government.[1] These financial remedies have been revised and updated, and may now be granted to those who restart their businesses either in their original location, or where they had to move due to the high density of radioactivity.

Having received this aid from national and local governments, small-medium companies have shown slight signs of recovery according to the statistics officially published by the Organization for Small & Medium Enterprises and Regional Innovation, Japan. Using these statistics, we analyzed whether and to what extent the small-medium companies of Tohoku had been revived as of 2013.

Fig.XX.1 shows the time-series changes in the number of small-medium manufacturers in the pre- and post-disaster period. The data are from the second quarter (April-June) of each year.

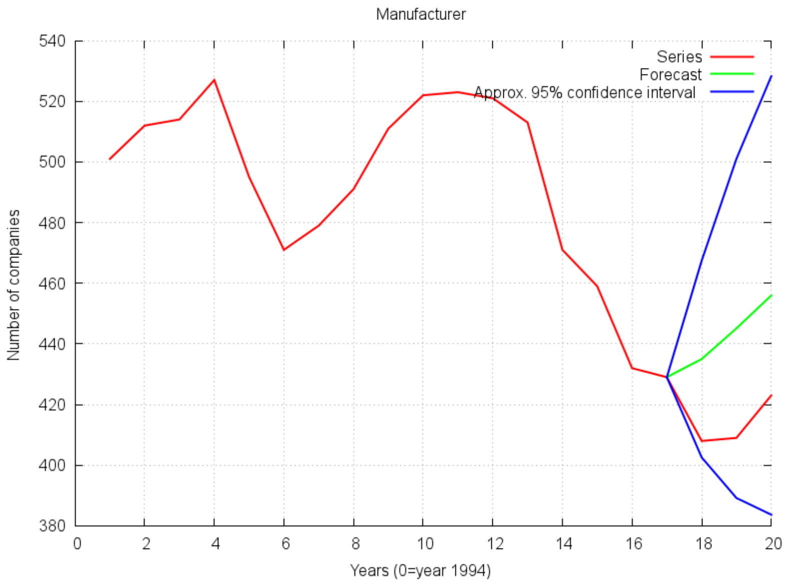

Fig.XX.1 Time-series changes in the number of small-medium manufacturers in Tohoku

Note: the vertical axis shows the number of manufacturers and on the horizontal axis, zero represents 1994 and 20, 2013.

According to Fig.XX.1, the number of small-medium manufacturers showed a downward trend in each business cycle. “Series” refers to data that were actually observed. These manufacturers produced high-quality, high-price goods for export from Narita worldwide, especially to East and Southeast Asia. As can be seen in the figure, the recession caused by the 1998 currency crisis in Asia strongly affected export activities (time unit 6). Another bottom was apparently

[1]Information from the home page of the Small Medium Enterprise Agency accessed 3rd April, 2014. http://www.chusho.meti.go.jp/keiei/antei/2011/110313TohokuGekijinShitei.htm

caused by the Tohoku disaster in 2011 (time unit 17). Fig.XX.1 reveals that the drop in the number of firms in the year following the disaster was almost in line with the lower bound of the 95% confidence interval. The curve then began to climb in 2011-12 (time units 17-18), and indeed the recovery has since accelerated from (2012-13; time units 19-20), but is still much smaller than the forecasted value for these twenty years.[2]

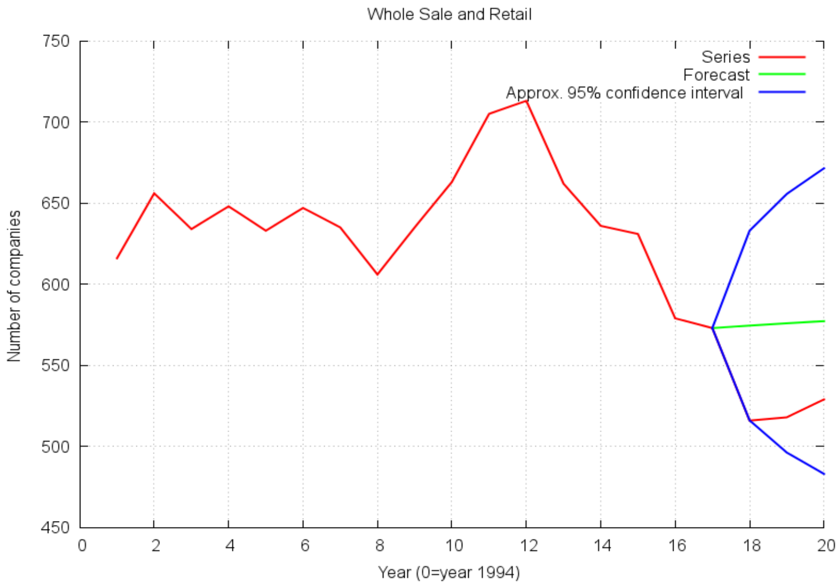

Fig.XX.2 Time series changes in the number of small-medium wholesalers and retailers in Tohoku

Note: the vertical axis shows the number of manufacturers; on the horizontal axis, zero represents 1994, and 20, 2013.

Fig. XX.2 shows the time trend for wholesalers and retailers.[3] The curve looks similar to that for manufacturers, but the degree and speed of the recovery were smaller. This may be because national and local governments offered smaller subsidies and other financial assistance to industries that did not require a lump-sum investment for their recovery, and because the amount of merchandise and agricultural products decreased significantly, especially in the areas devastated by the tsunami and contaminated by radioactivity from the damaged nuclear power plant.

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2 The time-series analysis of the change in the number of manufacturer follows AR(2). We obtained the following result by the Box-Jenkins method. The constant is 75.20 with t=1.44, the parameter of t-1 is -1.41 with t=12.87, that of t-2 is -0.563 with t=5.00, and adjusted R-square is 0.833.

3 The time-series analysis of the change in the number of wholesalers and retailers follows AR(1). We used the same method as for manufacturers, and obtained the result that the constant is 43.48 with t=0.65, the parameter of t-1 is -0.927 with t=8.84, and adjusted R-square is 0.703.

XX.3. Outlook for Fukushima, the disaster, and the surveyed firms

Fukushima Prefecture is the third largest prefecture in Japan in terms of width[4], and has a population of about two million.

Fig. XX.3 Fukushima Prefecture

Note: Blue square denotes Aizu Wakamatsu, the triangle Koriyama, the circle Fukushima-city, and the pentagon Iwaki (Onahama port is in Iwaki city). Area “A” is Aizu, “B” is Naka-dori, and “C” is Hama-dori.

Generally, the prefecture is divided into three parts based on demographic and governmental factors.[5] The first is the “Hama-dori” (coastal corridor), the second the “Naka-dori” (central corridor), and the third the “Aizu” district. Of these three districts, Naka-dori is the most thriving, with two large cities—Fukushima city and Koriyama city. Koriyama, the center of business activities, is larger than Fukushima in terms of population. Fukushima Airport is located 20 minutes from Koriyama, and east-west and north-south bound highways cross in the city. The Hama-dori region, meanwhile, used to be prosperous due to coal mining, and four nuclear power plants are located on the central coast in this area. The international container seaport along Onahama city is connected to Koriyama by a highway and national road No. 49. The Aizu area is far from the pacific coastal area and is full of historical areas called “small Kyoto”, where there are many famous temples. Overall, Fukushima prefecture ranks high in terms of producing high-value products like semi-conductors, which are exported from Narita Airport, as well as farm products such as vegetables, almost all kinds of fruit, and high-quality Japanese rice and rice wine (sake). In a sense, Fukushima is better than any other prefecture in terms of agricultural products.

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4 For more detail, please access the prefectural official website (accessed 29th March, 2013).

5 The three prefectures were merged into their current status in 1876. See Fig. 5.

However, the radioactivity contaminated the land and agricultural products around the power plants and the areas northeast of them. These include the cities and towns along the Pacific coast and the inland areas between the coast and Naka-dori. As of now, it is still forbidden to enter or stay in several towns, and the previous inhabitants are only allowed to pass through to monitor their properties and prevent theft. In terms of traffic routes, national trunk route No. 6, which originates in Tokyo and passes along Hama-dori (coastal aisle), has been shut down around the power plants so that all traffic must use route No. 4 that passes Naka-dori.

The data used in this study was obtained from Tohoku Kogyo Co., Ltd, which mainly provides cardboard and wrapping services. The company was founded in 1972 and is located in Koriyama city. As of April 2012, it employed about 100 people, and its current capital stock is 0.8 million USD (assuming one USD = 100 yen). It obtained ISO9001 in January 2005.

XX.4. Model for Estimating Structural Change in Production

We investigated the effect of the East Japan disaster on the Tohoku Kogyo Co.'s production structure. In our analysis, we introduced the "post-disaster dummy variable" both on the constant term and slopes of input variables, as well as other "shock dummy variables". The production function of a general form is defined as Eq.(1):

$$Q = f(x_1, x_2, x_3, IIP, time, \Sigma_t D_t, post\ disaster) \quad (1)$$

where Q is the amount of final goods, $x_1, x_2,$ and x_3 are units of input (in-process goods, labor inputs [*extra* hours in addition to fixed hours per month], and utilization of electric power), *IIP* is indices of industrial production of the Fukushima Prefecture, and D_t is a group of dummy variables: t=2011.3 and 2011.4, and $D_{2011.3}$ and $D_{2011.4}$ are the dummy variables for the disaster month and the next month; *post disaster* is a dummy variable that takes 1 for the post-disaster period, and *time* is a variable to remove the time trend. Among the input variables, "in-process (intermediate) goods" (*IPG*) have different characteristics from other inputs. Since IPG also require labor, energy inputs, and so on, we had to estimate a production function of IPG simultaneously with the production function of final goods. The *IPG* function worked as follows. When estimating this system of production function, we needed to impose the restriction that $\alpha_1 + \alpha_2 = 1$ *and* $\alpha'_1 + \alpha'_2 = 0$, following microeconomic theory.

$$\log(\text{IPG}) = \alpha_0 + (\alpha_1 + \alpha'_1 DDis)\log(Labor) + (\alpha_2 + \alpha'_2 DDis)\log(Energy) + (\alpha_3 + \alpha'_3 DDis)\log(IIP) + \alpha_4 DDis + \alpha_5 D_{2011.3} + \alpha_6 D_{2011.4} + \alpha_7 \text{time} + \text{e} \quad (2)$$

$$\log(\text{FG}) = \beta_0 + (\beta_1 + \beta'_1 DDis)\log(\widehat{IPG}) + (\beta_2 + \beta'_2 DDis)\log(Transportation) + \beta_3 DDis + \beta_4 D_{2011.3} + \beta_5 D_{2011.4} + \beta_6 \text{time} + \text{u} \quad (3)$$

A description of the variables used in Eq.(2) and (3) is given in Table.XX.1; "e" and "u" are terms of random disturbance.

Table XX.1. Description of variables

Variables	Explanations
IPG	The square meters of containerboards produced in one month. These are cut folded and assembled into boxes.
FG	The square meters of final goods (boxes dispatched to customers). Not all the IPGs are assembled into boxes. Defective goods are disposed of, and some containerboard is kept in stock to match supply to demand.
Labor	Extra working hours added to regular working hours. The data are aggregate for all employees in one monthly totals.
Energy	Monthly consumption of electric power (kw)
IIP	Indices of industrial production of Fukushima Prefecture (average=100)
Transportation	The number of cargo trucks engaged in carrying final goods
DDist	The 3.11 disaster dummy variable that takes 1 for 2011.5 – 2012.12 and 0 for the rest)
$D_{2011.3}$	The dummy variable that takes 1 for March 11, 2011 (to see the month of disaster)
$D_{2011.4}$	The dummy variable that takes 1 for April 11, 2011 (to see the next month's effect)
time	Time trend in logarithm

When we estimate this production function, we need the pre-assumption that the firm operates efficiently under circumstances of perfect competition. This assumption may not be true for our case if we estimate the production function of all (i.e., the aggregate) sections of a firm, but here we could assume efficiency under perfect competition since every single activity of the production-line division was strictly monitored by the production management division. If we admit that the firm operates under imperfect competition, the estimation of production function would still be useful, but the degree of homogeneity would be less than one.[6]

There is a tremendous variety of functional forms for production function according to a survey by Griffin et al. (1987).[7] Among them, the translog function is widely used for the estimation of cost functions in the transportation industry (Caves et al., 1984; Fisher and Kamarshen, 2003). Indeed, translog production function is flexible enough to approximate the form of function precisely. The drawbacks of the translog function, on the other hand, are that it has so many variables, including squared and cross terms. Therefore, introducing "slope dummy variables" into the translog would make the function very complex. To avoid this problem, we used a simple Cobb-Douglas form for specifying the functional form of production function.

In estimating this system equation, we first carried out the regression of IPG function and obtained the estimate value of in-process goods, $\widehat{IPG}$, by OLS with heteroskedasticity robust standard error. We then let $\widehat{IPG}$ be the instrument variable, and regressed FG on $\widehat{IPG}$, *Transportation*, *time*, and other dummy variables. In the estimation, we considered the existence

6 See Bruno (1978).

7 Griffin et al.(1987).

of heteroskedasticity, auto-correlation, and normality of random disturbances' distributions. In order to check the existence of concerns that might cause inefficiency, we carried out the Breusch-Pagan/Godfrey (BPG) test, Durbin Watson test, and Jarque-Bera normality test. Eq.(2) had no problem with regard to these concerns, but in Eq.(3) we detected the existence of auto-correlation by the Durbin-Watson statistic (it was 1.068). Therefore, we estimated Eq.(3) using the AR(1) model. In addition, we estimated the manufacturer's cargo dispatching activities from Koriyama to Hama-dori and compared them to those in other regions. The descriptive statistics are shown in Table XX.2.

Table XX.2. Descriptive Statistics of continuous variables

Variables	*FG* (squared meter)	*IPG* (squared meter)	*Labor*	*Energy* (kw/month)	*IIP*	*Transp.*
N	35	35	35	35	35	35
Average	1058414.2	1152943.4	864.5	68818.9	86.6	390.7
S.D.	146449.3	173053.7	331.5	10766.1	8.4	76.7
Min	812604.7	908908.8	111.5	45798.2	63.2	267
Max	1395830.3	1624970.1	1726.8	94372.0	103.2	593
Median	1047587.0	1113479.1	862.6	68118.2	87.6	372

XX.5. Empirical Results

XX.5.1. Production function

First, we estimated the system of production functions. The production function of IPG is shown in Table.XX.3.

Table 3. Production function of in-process goods (paper-sheets)

Variable Name	Coefficient	t-ratio	p-value
Labor input	0.238	3.418	0.002
Labor input*post disaster	-0.180	-1.802	0.083
Energy input	0.762	10.950	0.000
Energy input*post disaster	0.180	1.802	0.083
Indices of Industrial Production (IIP)	0.658	3.909	0.001
IIP*post disaster	-1.300	-3.314	0.003
Post disaster dummy for constant	5.118	2.755	0.011
Dummy for March 2011	0.220	2.580	0.016
Dummy for April 2011	0.789	4.995	0.000
Time trend	-0.040	-1.695	0.102
CONSTANT	0.957	1.343	0.191
R-square adjusted=0.504, F(7,27)=5.326 (P-Value=0.001)			
Durbin Watson Statistics=1.690			
BPG test for heteroskedasticity: Chi-square=4.023 with d.f=10, P-Value=0.946			
JARQUE-BERA NORMALITY TEST- CHI-SQUARE(2 DF)=1.384 P-VALUE= 0.501			

Before the disaster, the input ratio[8] of labor and energy was 24:76; after. it changed to 6:94. This result is consistent with the fact that the firm dismissed part-time employees and reassigned a number of employees to other firms in the same group (*keiretsu*) after the disaster, and so production became much less labor-intensive. Post-disaster, it appeared that *IIP* no longer affected the production of IPG (parameter=0.658-1.300=-0.642 with t-ratio=-1.842).

The parameters of the three "disaster dummy variables" were positive and statistically significant. The dummies for March and April 2011 were significant because Tohoku Kogyo increased its production on behalf of other firms that were seriously damaged and unable to produce after the disaster. Despite inter-firm rivalry before disaster, businesses collaborated with each other to restore the industry following the disaster.

The post-disaster dummy was also positive and significant. Tohoku Kogyo and the firms that were not significantly damaged increased production to respond to the increased demand for cardboard for packing rescue-goods needed by people in the devastated regions and those who escaped from places contaminated by radioactivity with the aid of the compensating funds from Tokyo Denryoku (Tokyo Electric Power Company), which was responsible for the management of the nuclear power plant. In other words, both firm's budget and iso-quant curves shifted up, and the input ratio also changed. In addition, Tohoku Kogyo merged with another factory in the adjacent region post-disaster. This means that if we had a "capital-stock variable" in our production function, its parameter would have increased after the disaster. However, each element of a "capital-stock variable" takes the same value before disaster, changes once at the time of disaster, and then takes the same value again. So, it could be expected that the variable would have shown a result similar to the 0/1 binary variable, and the mixed effect of this and the compensation from the Tokyo Denryoku appears in the parameter of the Post disaster dummy in Table 3. Considering the evidence of Tohoku Kogyo and the result of Fig.1 in section 2 that tells us that the number of firms decreased significantly after the disaster, it is inferred that small-medium manufactures that survived the disaster increased production to compensate those which damaged firms would have produced.

The production function of final goods is shown in Table.XX.4. The "*DDist*" variable, which was not statistically significant, was dropped to improve the efficiency.

Table XX.4. Production function of final goods

Variable Name	Coefficient	t-ratio	p-value
IPG (estimate)	0.783	8.837	0.000
IPG (estimate)*post disaster	0.001	0.424	0.672

[8] If we use the standardized average of inputs, the input share ratio with negative signs is the technical rate of substitution.

Transportation	0.217	2.449	0.014
Transportation*post disaster	-0.001	-0.424	0.672
Dummy for March 2011	0.102	2.429	0.015
Time trend	0.031	2.374	0.018
CONSTANT	1.527	2.230	0.026
R-square adjusted	0.907		
Estimation method	Instrument variable		

According to Table XX.4, the input ratio of IPG and Transportation had been about 78.3:21.7, and was largely unchanged post-disaster (78.4:21.6), and the null hypotheses that $\beta_1+\beta_1' = 0$ and $\beta_2+\beta_2' = 0$ were rejected with asymptotic $x^2_{d.f=1}$ =78.795 and 5.966, respectively. Considering the results in Tables 3 and 4, the shares of exogenous inputs are shown in Table.XX.5.

Table.XX.5. Comparison of input shares for the production of final goods

	Labor	Energy	Transportation
Pre-disaster	0.186	0.597	0.217
Post-disaster	0.045	0.739	0.216

The labor and the energy shares were computed by multiplying their parameters in the IPG function by the parameter of $\widehat{IPG}$ in Eq.(2). This computation makes sense as long as both IPG and FG functions are properly estimated. Bruno (1978) stated that both depended on the assumption that the double deflated value-added (FG) production functions correctly measured marginal productivities of primary factors as long as intermediate goods (IPG) relative to gross output remain constant.[9] Since our model followed the assumption of this proposition, we consider the parameters to show the proper values.

Since our analysis focused on a mostly automated production line, the labor share was extremely small. Post-disaster, the input share of transportation (trucks utilized) was almost unchanged. The firm should have spontaneously reduced the input of logistics since it was forbidden by the government from passing along a few local and thin-density contaminated routes, but there is little evidence it did so.

XX.5.2. Destination-specific analysis of disaster's effect on the delivery of final goods

We will now investigate how the delivery of final goods was affected by the natural disaster using statistical methods. According to Table 6, it appears that the amount of dispatched final goods did not change from pre- to post-disaster. This was supported by the estimate results of Table 4 that the "*DDist*" variable was not statistically significant and could be omitted.

To turn to a destination-specific case, Fig.XX.4 depicts the change in traffic flow from Koriyama-city to Hama-dori (Iwaki-city and Naraha-town).

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9 See Bruno, *op.cit.*

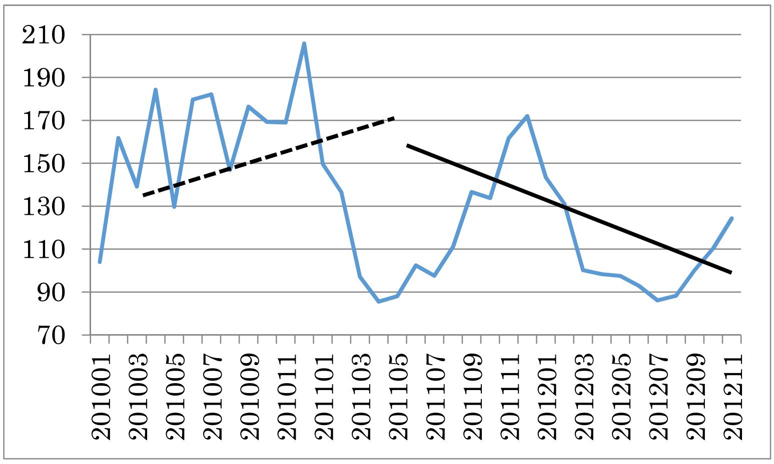

Fig.XX.4. Traffic flow of final goods to Hama-dori (Iwaki-city and Naraha-cho)

Note: The dotted and bold lines are linear-approximations. The dotted line depicts the pre-disaster situation and the bold the post-disaster.

Usually, cargo traffic decreases in winter due to the off-peak demand for vegetables. Despite this fact, cargo traffic had been trending up when the disaster took place. Actually the IIP elasticity of cargo traffic had been 0.854 (t statistics=3.133), but it became -0.146 and statistically insignificant. This implies that before the disaster the traffic to Hama-dori was increasing despite the seasonal change in demand, but after the disaster the traffic had little to do with the economic boom/recession index, i.e., *IIP*.

In addition, although the peak demand was in accordance with the peak of the output of agriculture, the cyclical span was wider and deeper than before the pre-disaster. One of the reasons for this is that rescue and emergency goods were provided in large deliveries with a time lag in between. This implies that goods were not supplied in a timely fashion, i.e., when they were really needed.

Finally, we investigated the traffic flow from Koriyama-city to Aizu Wakamatsu-city, Kitakata-city, and Inawashiro-town pre- and post-disaster. These cities are located to the west of Koriyama-city, within a four-hour drive of Hama-dori.[10]

Fig. XX.5 shows the traffic flow with a linear approximate line. There were seasonal cycles based on the harvest of vegetables and fruits from early in summer to autumn, and a weak upward trend over the observed time duration.

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[10] Time for using highways is partially included.

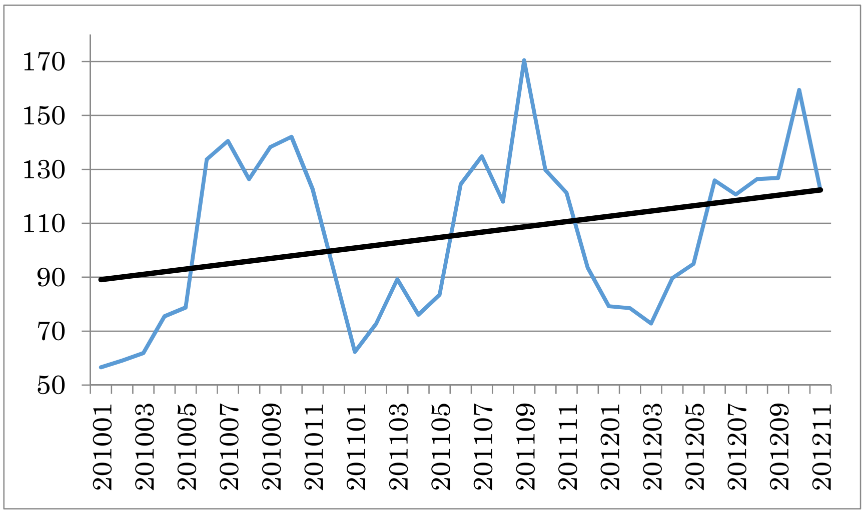

Fig.XX.5. Traffic flow of final goods for the west (Aizu Wakamatsu, Kitakata, and Inawashiro)

The reason for this upward trend was that the firm relocated their fleet of trucks from Hama-dori to the Aizu Wakamatu district, where they could expect more stable demand. In order to investigate the character of traffic fluctuation further, we applied a brief time-series analysis. If we assume that this fluctuation curve follows an AR(1) model, the parameter is 0.848 with t -value=5.908. The hypothesis that this parameter equals unity (i.e., the hypothesis of random walk) cannot be rejected (t-value=1.062) before the disaster. After the disaster, the parameter changed to 0.619, and two hypotheses that the parameter equals zero and one are rejected with t-value=3.501 (reject at 1% level) and 2.155 (at 5% level). This implies that the post-disaster fluctuation was stationary. In the case of the entire time span, the parameter is 0.742 and both hypotheses that the parameter equals zero and one are rejected at 1% and 5% levels (t-value=6.750 and 2.347, respectively). This result is close to that of the post-disaster case. In summary, the fluctuation followed an AR(1) process pre- and post-disaster for the entire duration, and after the disaster, it was converging to stationary. Considering this result, our conclusion is that the fashion of fluctuation has not changed over time. According to the firm's data, the volume of dispatched final goods for the northern area (Sendai-city, Fukushima-city and Nihonmatsu-city etc.) and southern area (Shirakawa-city, Ishikawa-county and Yabuki-town) has not substantially changed, either.

XX.6. Conclusion

This empirical study of a cardboard manufacturer, Tohoku Kogyo, highlighting the production structure and direction-specific cargo flow before and after the disaster, concludes that the production structure became energy-intensive but did not otherwise change in terms of the transportation input. It is also inferred that Tohoku Kogyo increased its production on behalf of the firms that had been damaged by the disaster. In terms of the direction-specific cargo flow, only the flow to Hama-dori seems to have been affected. Since the demand for cardboard is a “derived demand”, mainly from the agriculture sector, this result suggests that the agriculture and other industries that need this firm’s cardboard have also been recovering from the disaster. In short, it appears that the degree of the disaster has been partially overemphasized beyond the reality: of course small-medium industry just started to revive only recently, especially, but it appears that undamaged small-medium firms have been active and have tried to produce more than the disaster occurred.

Since our analysis is limited to the case of a single manufacturer, our study can be regarded as a preliminary analysis only. Our next step will be to continue to research other manufacturers that are recovering and prepare to disclose their evidence.

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