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PRODUCTION CAPACITY CHANGE IN INDUSTRIAL SECTORS OF HACHINOHE CITY DUE TO THE 2011 TOHOKU TSUNAMI

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ABSTRACT

This study focuses on a production capacity change in industrial sectors due to the 2011 Tohoku tsunami, generated by the 2011 off the Pacific coast of Tohoku earthquake. The authors highlight the coastal area of Hachinohe city which was damaged and inundated by the earthquake and the tsunami. The main method of the investigation is collecting the fact data for the activities of 10 industrial sectors from the public announcements, newspaper articles and information published. The result shows that the estimated amount of economic damage is approximately 114.5 billion Japanese yen as the production capacity change in the industrial sectors of the area due to the earthquake and the tsunami. The estimated amount of the economic damage is equivalent to approximately 95 % to the amount of the stock damage in the city.

INTRODUCTION

Tsunami inundation causes the stock damage, such as damage on infrastructures, destruction of industrial plants, deprivation of in-stock items, collapse of residences and the others. Tsunami fragility curves (TFCs) are available to estimate the fragility of the facilities against tsunami (Mas et al. 2012), and it is possible to evaluate the stock damage with the proper TFCs, and spatial data of the facilities in high resolution and the tsunami inundation map in fine-grid mesh.

The tsunami also causes the flow damage, such as production decrease in the industrial sectors, economic loss in the commercial sectors and the others. Because there are difficulties to evaluate the flow damage in estimating the amount of the production and time period until the recovery of the objective activities, analysing the fact of the flow damage due to the 2011 Tohoku tsunami is important to improve the estimation methods.

The industrial sectors play important roles in the economic activities, but less information

is available to the public for analysing the flow damage in high resolution spatially because many industrial sectors belong the private business activities.

The size of the factory is the relatively easy accessible information of the property information of industrial companies, if aerial photos or maps in high resolution are available. Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan published the technical manual and shows a typical method to evaluate the stock and the flow damage. The method shown is a simple method using constant coefficient of transformation from the number of employees to economic loss per day for the industrial sections in view of the estimation of the economic loss of business suspension (MLIT 2005). The method is easy enough to estimate, but the constant coefficient should have variations depending on the area characteristics, the category of industry, degree of technical innovation and the other factors.

The manual of MLIT also shows a table of the days of business suspension in the range from 6.0 days for the minimum to 45.2 days for in the maximum, depending on the inundation depth of the flood. Kajitani et al. shows a figure of a production capacity change from the day of the disaster to 180 days after the disaster of the the 2011 off the Pacific coast of Tohoku earthquake. The values of the production capacity of the industrial sector are approximately 0.4 at the day of disaster, approximately 0.9 at the 60 days after the disaster, and approximately 0.95 at the 180 days after the disaster. The curve line which draws the relationship between the production capacity in the vertical axis and the days after the disaster in the horizontal axis is concave down in the figure. These results are the result of the questionaries in Miyagi and Iwate prefecture mainly for the area affected by the earthquake, not for the area affected by the tsunami. It seems to be important to survey and to draw the line of the production capacity change for the area affected by the tsunami.

INDUSTRIAL SECTORS AFFECTED BY TSUNAMI AND THEIR ANNUAL SALES

Industrial Sectors in Tsunami Inundation Area

Hachinohe city is one of the major industrialized cities in the northern Japan. The maximum tsunami height was approximately 6 - 8 m in the Hachinohe city, Aomori prefecture (The 2011 Tohoku Earthquake Tsunami Joint Survey Group 2012).

At the first, the authors digitized the maximum inundation area maps of the 2011 Tohoku tsunami in Hachinohe city (Haraguchi and Iwamatsu 2011) into the line-shape file, using the GIS software, ArcMap Ver. 10.3 of ESRI Japan Corporation. The digital map data for the building shape, including industrial factories and residences, is introduced from the CD-ROM of Z MAP TOWN II (Zenrin Co., LTD) to the GIS software. By overlapping the maximum inundation area maps on the building shape map, the authors picked up 283 the large size buildings, e.g. a building of which amount of the floor area is more than 1,000 m^2 for 1st floor, in the tsunami inundation area. The floor area of 283 building is 858,880 m^2 in total.

The building shape map includes not only the building shape but also names of tenant of the building, the company's name. By using the latter information and 'the street view' function of Google Earth Ver. 7.15.1557, provided by Google Inc., the authors identified the company's name for each building. 53 buildings is unclear its company's name. Finally, the authors picked up 230 buildings with their company's name, 748,171 m^2 of the floor area in total.

Ministry of Internal Affairs and Communications (MIC) of Japan provides the table of 'the Standard Industrial Classification of All Economic Activities' (SIC) Rev. 13 (MIC 2013). MIC categorise all of the economic activities of Japan into 99 categories of sectors, and lists SIC ID numbers, 1 - 99, and their sector's name respectively. Authors identified and gave SIC ID number to the 230 buildings on the basis of their company's name.

Because SIC's target is all economic activities, SIC includes the industrial sectors (SIC ID number: 09 - 32) and the non-industrial sectors (SIC ID number: 01 - 08 and 33 - 99). Authors picked up the 155 building of the industrial sectors, SIC ID number 09 - 32, from the 230 buildings.

Many industrial companies have several buildings in the target area, then the authors integrated the buildings into one column with summing up the values of the floor area the buildings into one value.

Finally, the authors got the list of 60 companies of the industrial sectors in the inundation area of Hachinohe city due to the 2011 Tohoku tsunami, with SIC ID number. The floor area is 543,611 m^2 in total, and it is equivalent to the 63 % of the floor area of all buildings, 858,880 m^2. The 60 companies are categorized into the 10 industrial sectors, shown in **Fig. 1**.

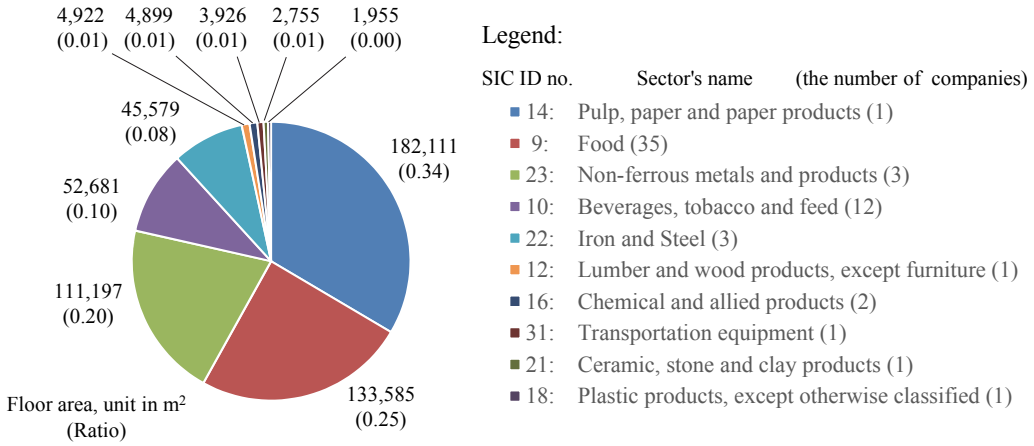


Fig. 1 Floor area of the 60 companies of the10 industrial sectors of Hachinohe city in the inundation area due to the 2011 Tohoku tsunami

Annual Sales of the 10 Industrial Sectors in 2010

Amount of Annual sales is one of the fundamental index of private company's activity. The authors searched the fact data for the amount of annual sales of the 60 companies from the fact data CD-ROMs of 2011-2015 published by a book publishing company (Toyo Keizai Inc.), the documents published by the government, the official websites of the company, and the others (see **Appendix A**).

The tsunami event was happen in 2011, and it is necessary to correct or estimate the values in 2010 for 60 companies respectively because amount of annual sales after 2011 should be affected by the event strongly, and economic conditions and other conditions should be changed before and after the event.

The 6 companies of the 30 companies has the fact data of the amount of annual sales in 2010. The rest of 24 companies has no direct data of the annual sales in 2010, and the authors estimated the value. In the estimation, four types of the estimation method were adopted. The first method was applied to the company's ID No. 12-36 (see **Appendix A**). The linear relation between the value of the floor area and the amount of the annual sales is estimated based on the three fact data before the event, the company's ID No. 3, 10, 11. The approximate algorithm adopted was the least-square fitting. The second method was applied to the company's ID No. 38 - 54. The linear relation between the value of the floor area and the amount of the annual sales is estimated based on the fact data of 2013 or 2014. And the estimated values are corrected from the value of 2013 or 2014 to the value of 2010. The third method was applied to the

company's ID No. 55 - 57 and 60. The method is the similar to the method of MLIT which was already introduced in 'Introduction' section. And the constant coefficients for the estimation were introduced from the Census of Manufactures in 2010 conducted by Ministry of Economy, Trade and Industry of Japan (Aomori prefecture 2010) and the 2011 Basic Survey on Small and Medium Enterprises conducted by the Small and Medium Enterprise Agency of Japan (SMEA 2011).

Finally, the authors got the estimated annual sales in 2010 of 60 companies of the industrial sectors in the inundation area of Hachinohe city due to the 2011 Tohoku tsunami. The estimated annual sales in 2010 is 368.7 billion yen in total. **Fig. 2** shows the annual sales in 2010 of the industrial sectors of Hachinohe city in the inundation area due to the 2011 Tohoku tsunami.

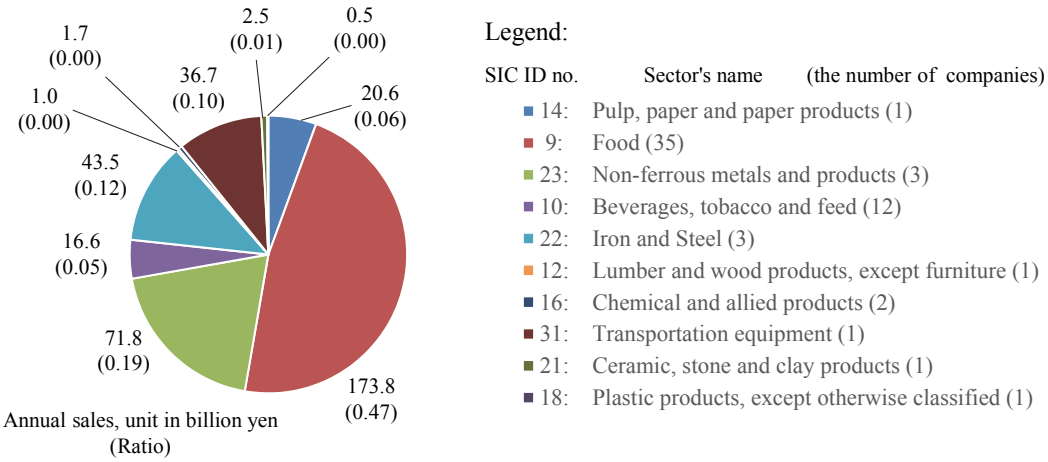


Fig. 2 Annual sales in 2010 of the industrial sectors of Hachinohe city in the inundation area due to the 2011 Tohoku tsunami

PRODUCTION CAPACITY CHANGE

Production Capacity Recovery Rate

The authors searched the fact data for the production capacity recovery of the 60 companies. The data needs two items: date and the production capacity recovery rate. If the value of the rate equals 0, it means no production at that time. In contrast, if the value of the rate equals 1, the production capacity is completely recovered and in the same level of the production before the tsunami event. In some cases, the value of the production capacity recovery rate is more than 1, because of increasing production, capacity investment and development of production capacity, and the other reasons.

The fact data sources are the news articles from 14th March 2011 to 6th March 2014 provided by the local newspaper company, Daily Tohoku Shimbun Inc., and the official websites of the company. The numbers of the fact collected were 30 articles and pages in total, for 15 companies. The 30 facts are related to the 5 industrial sectors, SIC ID nos. = 10, 14, 22, 23 and 31. In contrast, there were no fact collected for the rest 5 industrial sectors, SIC ID nos. = 9, 12, 16, 18 and 21. To collect fact data from these 5 industrial sectors is remain an issue in this survey.

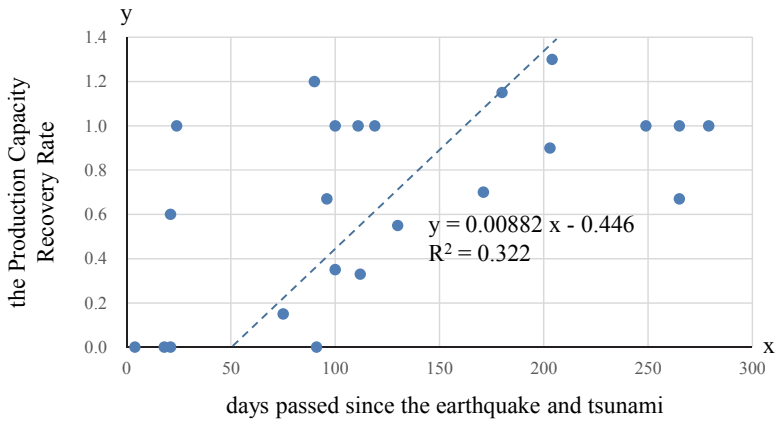
Fig. 3 (1) to (6) show the relationship between the production capacity recovery rate and the days passed since the earthquake and tsunami event for overall data and the 5 industrial sectors, respectively. The broken line of each figure is the linear relation between the x-axis and the

y-axis, and the approximate algorithm adopted was the least-square fitting. It is obvious that the R^2 values are not good for Fig. (1), (3) and (5). Although these R^2 values are quite low, in the range between 0.208 and 0.322, the authors adopt the result in this study because there is no alternative facts available. It is an important issue to solve in the future. There can be the problem in assumption that the fitting line is the linear shape, but the fitting line can be the quadratic curve shape or higher dimensional curve shape.

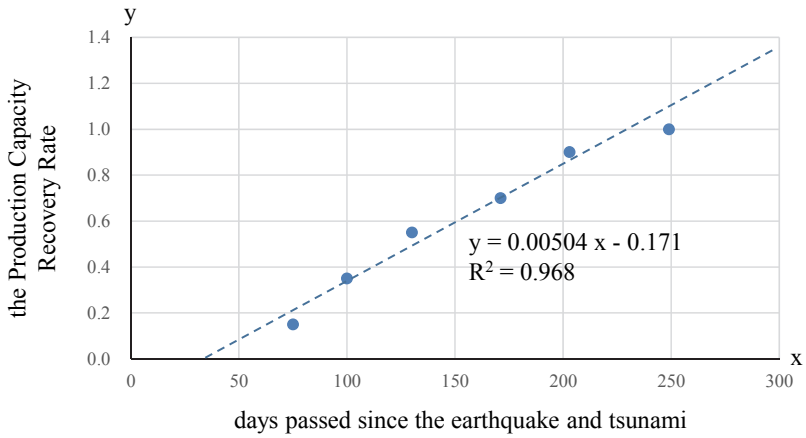
The point where the broken line and the y=1.0 crosses tells the estimated day when the production capacity recovers completely. According to Fig. (1) to (6), it is estimated the complete recovery is at the 164, 232, 174, 83, 157 and 265 days passed since the earthquake and tsunami, respectively. These days are 22nd Aug., 29th Oct., 1st Sept., 2nd June, 15th Aug. and 1st Dec. of 2011, respectively.

In Fig. (1), it is easy to calculate the areas of the trapezium, e.g. the surrounded area of two lines and the two axis, such as y = 0.00882 x - 0.446, y=1.0, y =0 and x = 0. After the calculation, the value of the area is divided by 365, finally it gives 0.295. This value is the production capacity change rate in a year.

In the same manner, Fig. (2) - (6) give 0.364, 0.342, 0.108, 0.307 and 0.392.

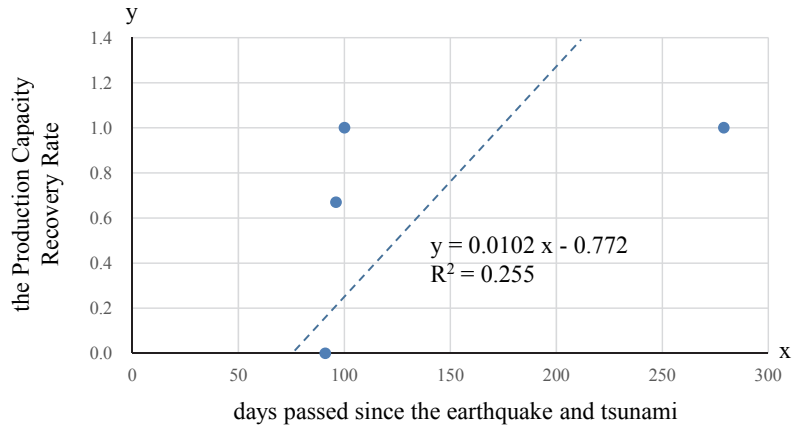


(1) Overall data

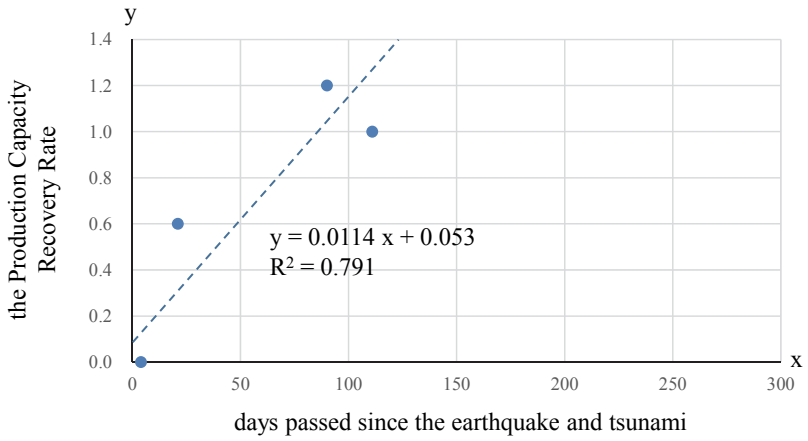


(2) Pulp, paper and paper products (SIC ID no. =14)

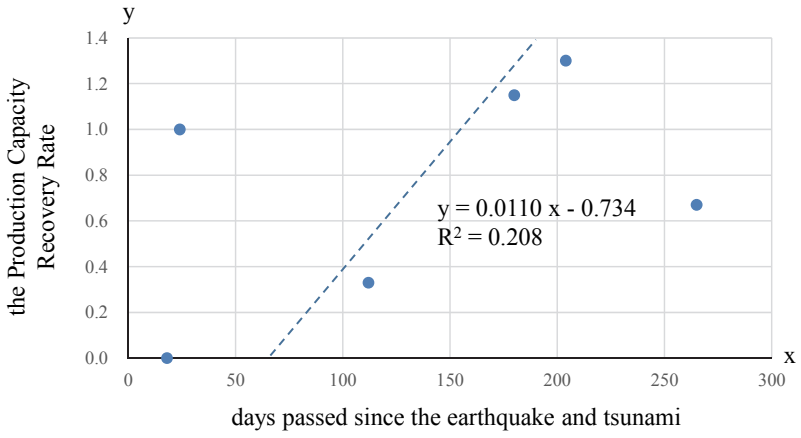
Fig. 3 Production Capacity Recovery Rate



(3) Non-ferrous metals and products (SIC ID no. =23)

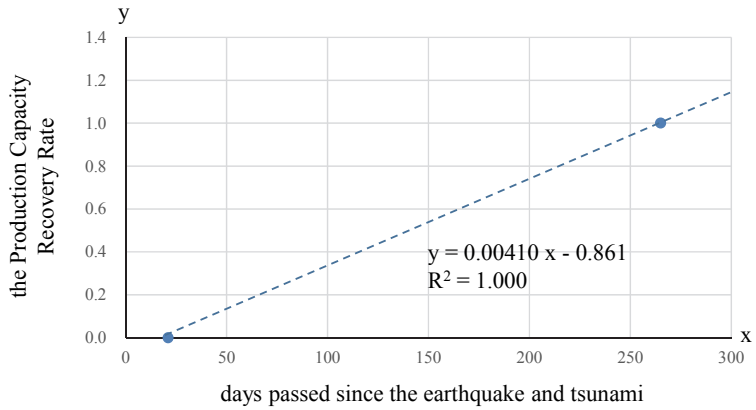


(4) Beverages, tobacco and feed (SIC ID no. =10)



(5) Iron and steel (SIC ID no. =22)

Fig. 3 Production Capacity Recovery Rate



(6) Transportation equipment (SIC ID no. =31)

Fig. 3 Production Capacity Recovery Rate

Production Capacity Change

The amount of stock damage was approximately 121 billion Japanese yen due to the earthquake and the tsunami, according to the announcement document of the city office at the end of the year 2011 (Hachinohe City Office 2011).

To evaluate the production capacity change needs the two values: the annual sales in 2010, the result of the 2nd subsection of the 2nd section, and the production capacity change rate in a year, the result of the 1st subsection of this section. The multiplication of the two values gives **Table 1**. For the sectors SIC ID nos. = 9, 12, 16, 18 and 21, there were no direct data of the production capacity change rate, therefore the value for overall case (**Fig. 3**(1)) is applied.

The estimated amount of economic damage is approximately 114.5 billion Japanese yen as the production capacity change in the industrial sectors of the area due to the earthquake and the tsunami. The estimated amount of the economic damage is equivalent to approximately 95 % to the amount of the stock damage in the city.

Table 1 Production Capacity Change in Industrial Sectors of Hachinohe City due to the 2011 Tohoku Tsunami

SIC ID no.	Sector's name	Annual Sales in 2010 (billion yen)	Production Capacity Change Rate in a Year	Production Capacity Change due to tsunami (billion yen)	Ratio
14	Pulp, paper and paper products	20.6	0.364	7.5	0.065
9	Food	173.8	0.295	51.3	0.448
23	Non-ferrous metals and products	71.8	0.342	246	0.214
10	Beverages, tobacco and feed	16.6	0.108	1.8	0.016
22	Iron and Steel	43.5	0.307	13.4	0.117
12	Lumber and wood products, except furniture	1.0	0.295	0.3	0.003
16	Chemical and allied products	1.7	0.295	0.5	0.004
31	Transportation equipment	36.7	0.392	14.4	0.126
21	Ceramic, stone and clay products	2.5	0.295	0.7	0.006
18	Plastic products, except otherwise classified	0.5	0.295	0.1	0.001
Total		368.7		114.5	1.000

CONCLUSIONS

This study focuses on a production capacity change in industrial sectors due to the 2011 Tohoku tsunami, generated by the 2011 off the Pacific coast of Tohoku earthquake. The authors highlight the coastal area of Hachinohe city which was damaged and inundated by the earthquake and the tsunami. The main method of the investigation is collecting the fact data for the activities of 10 industrial sectors from the public announcements, newspaper articles and information published. The result shows that the estimated amount of economic damage is approximately 114.5 billion Japanese yen as the production capacity change in the industrial sectors of the area due to the earthquake and the tsunami. The estimated amount of the economic damage is equivalent to approximately 95 % to the amount of the stock damage in the city.

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APPENDIX A

Table A.1 Annual sales of the 60 companies of the10 industrial sectors of Hachinohe city in the inundation area due to the 2011 Tohoku tsunami

SIC ID no.	Company's ID	Annual sales (billion yen)	Year	Data source/ sources
14	1	N/A	-	-
9	2	4.0	2014	Doc. published by the Gov.
	3	13.4 - 14.8	2007- 20014	Toyo Keizai Inc.
	4	5.5	2014	official website
	5	2.0	2012	official website
	6	0.1	2012-2014	Doc. published by the Gov.
	7	5.8	2014	official website
	8	0.9	2014	websites of the local news company and the others
	9	4.6	2013	websites of the local news company and the others
	10	14.1 - 15.6	2010 - 2014	Toyo Keizai Inc.
	11	2.0	2008	websites of the local news company and the others
	12-36	N/A	-	-
23	37	5.5 - 6.4	2010 - 2013	Toyo Keizai Inc. websites of the local news company and the others
	38	45.9 - 55.9	2012 - 2014	Doc. published by the Gov.
	39	N/A	-	-
10	40	4.4 - 4.6	2012 - 2014	Toyo Keizai Inc.
	41	0.4	2014	Doc. published by the Gov.
	42	0.5	2014	Toyo Keizai Inc.
	43	0.4	2012 - 2014	Toyo Keizai Inc.
	44 - 51	N/A	-	-
22	52	40.0 - 53.4	2011 - 2014	Doc. published by the Gov.
	53	0.3	2014	websites of the local news company and the others
	54	N/A	-	-
12	55	N/A	-	-
16	56	0.4 - 0.6	2012 - 2014	Doc. published by the Gov.
	57	N/A	-	-
31	58	14.7 - 36.7	2006 - 2014	Toyo Keizai Inc.
21	59	2.0 - 2.7	2006 - 2012	official website
18	60	N/A	-	-

* N/A : not available

APPENDIX B

Fig.2 shows the estimated result applying with the "hybrid" method, e.g. the values of the annual sales for 60 companies are the results of combination of the four method (see '**Annual Sales of the 10 Industrial Sectors in 2010**' subsection of the 2nd section). In this "hybrid" method, results derived by using both of the fact data and the statistical data.

Fig. B.1 shows the estimated result applying with the "simple" method. All values of the annual sales is estimated by the third method in the 2nd subsection of the 2nd section, e.g. NO fact data, shown in **Table A.1**, is used, and all values of the annual sales is simply estimated only with the statistical data from 'the Census of Manufactures in 2010' and 'the 2011 Basic Survey on Small and Medium Enterprises'.

The estimated annual sales in 2010 is 138.2 billion yen in total. This estimated value of "simple" method is equivalent to approximately 37 % to the estimated annual sales of "hybrid" method.

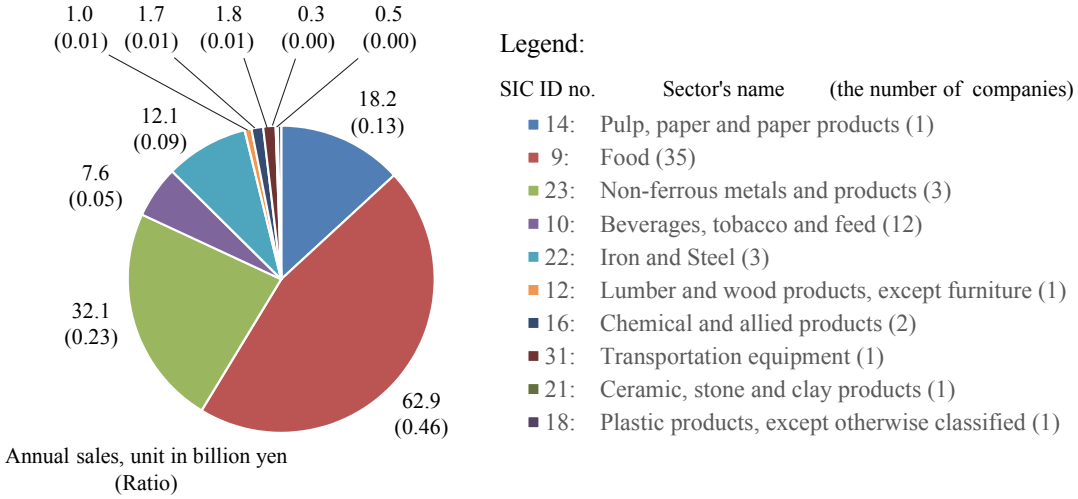

Fig. B.1 Annual sales in 2010 of the industrial sectors of Hachinohe city in the inundation area due to the 2011 Tohoku tsunami, estimated with "simple" method

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