INVENTORY LEVEL CHANGE BEFORE AND AFTER THE GREAT EAST JAPAN EARTHQUAKE: IMPLICATIONS FOR JUST-IN-TIME

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ABSTRACT

Just-in-time (JIT) is an excellent Japanese management technique. However, it has received criticisms about its limitation during unexpected disasters, especially after the Great East Japan Earthquake. Some companies prefer to stock as a countermeasure to the damage sustained by supply chains. Though the earthquake had a significant effect, is such a decision appropriate? How did Toyota Motor Corporation (the originator of JIT) behave in this situation? In this study, we address these question through an investigation of the inventory turnover of Toyota and its suppliers. We analyze the inventory turnover using statistical tests. Our results support the tendency of companies to increase inventory possession after an earthquake. However, a particular company showed a tendency to decrease its inventory. Considering the situation of all the suppliers when evaluating inventory control is necessary because the analysis is conducted at the supply chain level.

Keywords: just-in-time, inventory level change

INTRODUCTION

In March 2015, Toyota Motor Corporation (hereafter called Toyota) reported an annual net profit of 2 trillion yen, making them the first Japanese company to do so. They have sustained high sales for a long time. One of the things that helped with Toyota's success was a way of thinking called just-in-time (JIT). Several researchers in various fields, such as business administration,

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production control, distribution, and operations research, have studied JIT (also known as the Toyota Production System). Extensive research from the management accounting perspective has also been conducted (Cooper, 1995; Cooper & Slagmulder, 1999; Johnson & Broms, 2008). Despite the volume of prior research that suggested the effectiveness of JIT, determining whether the essence of this methodology has been explained clearly in the context of accounting is difficult. For instance, while many companies recognize that the Toyota Production System is one of the best practices, very few of them have introduced this methodology. In addition, JIT has received several criticisms, such as suppliers face extreme disadvantages because they are required to be highly efficient and they face limitations during sudden disasters. We discuss the latter case in this study. The concept of reducing the quantity of inventory, which is one of the most important concepts in JIT, could stop the product supply when an unexpected disaster/ event occurs.

Such incidents have been witnessed before, and the Great East Japan Earthquake in March 11, 2011 comes to mind quite often, in the context of supply chains. In other words, JIT involves a trade-off from the business continuity perspective, and it downplays a risk.

Japan is known as an earthquake-prone country. Thus, all areas in Japan are required to be prepared for earthquakes. The Great Hanshin Earthquake in 1995 and the Chuetsu[1] earthquakes in 2004 and 2007 are still fresh in the memory of the Japanese people. In addition, rumors about the imminent occurrence of a Tonankai[2] earthquake have been going around. Meanwhile, high-intensity earthquakes have occurred in New Guinea, Philippines, Pakistan, China, Iran, Indonesia, and Taiwan over the past few years, and in Nepal in 2015. Earthquakes have a direct and serious influence on the lives of the people living in the affected area. Moreover, earthquakes have an indirect adverse effect on many countries and areas because of the destruction of resources and long period of industrial stagnation. This was evident after the Great East Japan Earthquake, where supply chains were impaired.

Some companies tend to favor stock as a countermeasure to the damage sustained by supply chains. In short, they find holding a greater

1 The area belonging to Niigata prefecture.

2 The peripheral area of Shizuoka, Aichi, and Mie prefectures.

volume of inventory than before necessary to provide for unexpected conditions. However, this practice contradicts a key JIT concept. Does this mean that the earthquake influenced JIT? In this study, we investigate whether the Great East Japan Earthquake influenced JIT. In particular, we explore whether the perception on inventory possession has changed using accounting information.

In addition to Toyota, we include the affiliates that constitute Toyota's supply chain in the analysis. We indicate that the approach toward inventory in the supply chain is debatable. This is why we include the affiliates in the analysis. In other words, even if a company increases or decreases its stock volume, the total stock volume in the supply chain may not fluctuate if another company in the chain absorbs the fluctuation. This idea is based on a financing research in the context of improving the cash conversion cycle in the supply chain.

The rest of this paper is organized as follows. First, we present an overview of the extant literature. Subsequently, we perform an inter-industry comparison, focusing on operating income, and an inter-company comparison in the automotive industry, where damage was greater than the mean. We then analyze the inventory turnover period in the Toyota Group. Finally, we consider the comparative results and conclude with directions for future research.

LITERATURE REVIEW

Supply Chain Disruption and Financial Performance

In this section, we review the studies conducted by Hendricks and Singhal that presented the changes in various financial indicators and stock prices before and after supply chain disruptions. Hendricks and Singhal (2005, 2012) surveyed over 800 cases of supply chain disruptions from 1989 to 2001 in the United States. The supply chain in the United States was disrupted by various factors, including manufacturing problems or parts shortages. The time spans of their analyses were 3 years, that is, the year before a disruption and 2 years after it. To control the differences in terms of company size or industry, they assigned a value to a company that has experienced a supply chain disruption and compared it to companies

with similar enterprise-wide performance trends. The results of their survey showed that compared to the previous year operating income decreased by 107%, sales growth decreased by 7%, total cost increased by 11%, return on sales (ROS) decreased by 114%, return on assets (ROA) decreased by 92%, and inventory increased by 14%. In addition, they pointed out that approximately two years were required to recover from the effect of the supply chain disruptions on profitability, sales growth, and costs and inventories.

Additionally, they investigated the difference in the performances of six industries[3] classified by their SIC code. They showed that a negative effect on the performance of all these industries existed. The decline in operating income and sales in the wholesale and retailing industries was smaller than those in the other industries because a different trend across industries seemed to exist. However, the authors concluded otherwise. Moreover, all the companies belonged to the processing industry (foods, tobacco, textiles, lumber, wood, furniture, paper, and chemicals), and manufacturing industries were not examined because their sample size was small. Thus, additional investigation can still be performed. Therefore, we investigate whether the results in the context of American companies are evident in Japanese companies after the 2011 earthquake.

Just-In-Time (JIT) and Disruptions

Various opinions about the relation between JIT and contingency exist. The Toyota Production System aims for lean manufacturing, and the lean supply chain of JIT may increase the risk of disruptions during disasters to achieve this (Whitney Luo & Heller, 2013). Possessing a large inventory as a safeguard against disruption could help avoid shutdowns (Tomlin & Wang 2010). However, this is not an entirely sound strategy in normal times because it prevents the early manifestations of problems, which is one of the characteristics of a production system. Moreover, the JIT competitiveness of supply and demand coordination continues (Monden, 2012). Long-term vulnerability and redundancy of low inventory levels is a trade-off and corporations must decide which one to prioritize (Sheffi, 2005). Thus, companies may have advantages in increasing or decreasing their inventories. In other words, they need to decide whether to emphasize

3 The six industries were natural resources, processing, high technology, transportation, wholesale and retail trade, and services; these provided a certain sample size.

the benefits of a lean production mechanism or prepare for an emergency. Thus, whether Toyota changed their perception after the earthquake or not is an important issue.

RESEARCH METHOD

The research subjects of this study are Toyota, which is an end-product manufacturer, and 10 companies, which constitute Toyota's supply chain. They form the "Toyota Group," which includes the companies that are established or financed by Toyota Motor Corporation or Toyota Industries Corporation and are non-consolidated. These companies are equivalent to a Tier 1 company (see Appendix 1).

We extract the cost of goods sold and the inventory from the financial statements and quarterly reports of each company and calculate the turnover period of the inventory, which is calculated by dividing the total amount of inventory by the cost of goods sold per day.[4] The amount of inventory is regarded as the sum of raw materials, work in progress, and finished products. The amount of inventory used is the value of the average beginning-of-quarter and end-of-quarter, while the cost of goods sold per day is calculated from the average values from the first quarter of fiscal year 2008 to the fourth quarter of fiscal year 2014. Therefore, we focus on how many days the companies held their inventories based on cost price.

The main objective of this study is to examine whether the inventory turnover period increased after the earthquake or not. This is to determine if the following hypothesis is correct: "Inventory turnover period did not fluctuate either before or after the earthquake." We use regression analysis to examine the variations in the inventory turnover period of each company before and after the disaster, which is linearized by a least-squares method. In addition, we conduct a statistical test to determine whether a real difference between the averages of the two groups exists using paired *t*-test.

4 Sales could be used in the calculation of inventory days; however, while considering the number of days of stock, the total inventory should be calculated by dividing the average daily sales volume. Similarly, it is theoretically correct to use the cost of goods sold, calculated by multiplying the manufacturing cost, rather than sales, which is calculated by multiplying the unit price. Therefore, we use the cost of goods sold as the divisor in this study. See Okamoto et al. (2008, pp.45-46).

We set the study periods to the first quarter of fiscal year 2008 to the third quarter of fiscal year 2010 (4.1.2008–12.31.2010; 11 samples), that is, before the earthquake, and from the second quarter of fiscal year 2011 to the fourth quarter of fiscal year 2014 (7.1.2011–3.31.2015; 15 samples), that is, after the earthquake. All the listed companies were required to submit quarterly reports as per the Financial Instruments and Exchange Act in fiscal year 2008. The earthquake occurred on March 11, 2011; therefore, we excluded the fourth quarter of fiscal year 2010. In addition, the purpose of this research is to survey the time series transition in inventory possession. We do not intend to examine the circumstances in the aftermath of the earthquake. Therefore, we exclude the first quarter of 2011 from the survey because the sales situation during this quarter can be presumed abnormal.[5]

In the statistical analysis related to the averages, we set the period from the second quarter of fiscal year 2011 to the fourth quarter of fiscal year 2013 (7.1.2011–3.31.2014; 11 samples) as the period after the earthquake because we need to condition the data to perform the test of average with a pair of specimens.

ANALYSIS AND FINDINGS

Effect on Corporate Performance before and after the Earthquake

Prior to the analysis, we present the damage caused by the Great East Japan Earthquake to various industries. We compare the financial performance a year before and after the earthquake for each industry to examine the differences in the effects that each endured. Specifically, using the industry average of the unconsolidated financial data published by the Development Bank of Japan (2012), we investigate the variations in value in fiscal year 2010 (a year before the earthquake) and in fiscal year 2011 (a year after the earthquake). The compared items show variability in the rate of operating income, ROS, and ROA, following Hendricks and Singhal (2005, 2009, 2012). However, we simply compare these items with the average value from the previous year, whereas previous studies used the values to compare benchmark companies for each case. In view of the scale of the earthquake, similar industries are expected to have been affected

5 See report of the first quarter 2011 (Toyota Motor Corporation, 2011, p.5.).

correspondingly, except for regional disparities. Therefore, we examine the industrial trend based on actual values. The industries are sorted in descending order according to the rate of variability of operating income, as shown in Table 1.

Table 1: Rate of Variability of Financial Measures by Industry

Type of Industry	Operating Income	ROS	ROA
Electricity	–185.04%	–183.85%	–45.48%
Transportation Equipment	–148.21%	–147.77%	–22.47%
Printing	–129.00%	–131.36%	–220.93%
Other Manufacturing	–72.49%	–70.38%	–108.12%
Electrical Machinery	–53.90%	–50.70%	–201.21%
Iron and Steel	–49.53%	–50.40%	–101.60%
Ceramic, Stone and Clay Products	–35.99%	–33.54%	–53.17%
Manufacture of Gas	–35.41%	–43.04%	–41.67%
Non-ferrous Metal	–30.66%	–29.44%	–27.00%
Plastic Products	–24.28%	–23.94%	22.05%
Transport	–20.74%	–20.53%	–43.97%
Fisheries	–16.83%	–21.98%	–53.83%
Textile	–12.86%	–13.79%	12.60%
Pulp and Paper	–11.99%	–11.69%	1402.82%
Chemical	–10.56%	–10.39%	12.74%
General Machinery	–6.53%	–8.47%	–15.36%
Real Estate	–4.31%	0.17%	–34.43%
Construction	–2.93%	–6.36%	–30.03%
Food	–1.00%	–2.38%	59.35%
Mining	2.62%	11.04%	67.37%
Rubber Products	2.69%	–4.29%	–13.09%
Information and Communication Electronics	3.31%	0.69%	3.09%
Retail	4.34%	6.07%	–3.84%
Services	6.35%	5.10%	13.95%
Fabricated Metal Products	12.84%	9.57%	112.09%
Precision Instruments and Machinery	16.39%	14.25%	–29.55%
Wholesale	27.14%	18.94%	17.85%
Petroleum	137.29%	104.74%	79.93%

Profit and profitability decreased significantly in many industries, especially in the electricity, transportation equipment, and printing industries. However, some industries benefited, such as the petroleum and wholesale sectors. For the industries that witnessed a significant downturn, the influence of increased fuel costs and a decrease in electricity sales are evident. Furthermore, the decrease in nuclear power caused deterioration in the electricity industry, while the business environment suffered because of self-restraint on advertisements in the printing industry (Tokyo Electric Power Co., Inc., 2012, p.13; Toppan Printing Co., Ltd, 2012, p.16; Dai Nippon Printing Co., Ltd, 2012, p.13). Although supply chain disruptions are not reflected in these results, many industries suffered because of the earthquake. In particular, the damages to transportation equipment, electrical machinery, and iron and steel industries were relatively severe, which is consistent with the findings of Tokui, Arai, Kawasaki, Miyagawa, Fukao, Arai, Edamura, Kodama and Noguchi (2012), who reported that the automotive industries suffered more severe damage compared to the food and beverages, chemical products, iron and steel, general machinery, and electronic components industries. Automobile manufacturers are the main companies that constitute the transportation equipment industry. Therefore, the automotive industry should be targeted in this analysis.[6]

Inventory Turnover Period of Three Car Manufacturers

In this section, we discuss why we focus on Toyota. Figure 1 presents a comparison of the three major car manufacturers in Japan, namely, Toyota, Nissan, and Honda, in terms of inventory turnover period in days, which is calculated by dividing the total amount of inventory by the cost of goods sold per day. Notably, the value of the average beginning-of-quarter and end-of-quarter is used as the amount of inventory, while the cost of goods sold per day is calculated from the average values from the first period of fiscal year 2010 to the fourth period of fiscal year 2012, following Hendricks and Singhal (2005). Thus, we seek to eliminate the difference in the scale of sales of each company that does not reflect the changes in sales volume. As shown in Figure 1, the inventory turnover period was 40–60 for Nissan, 45–65 for Honda, and just 30–35 for Toyota. Toyota was clearly more

6 In the automotive industry, where the supply chain does not have the structure of a pyramid but that of a diamond, the number of firms increases when moving upstream in the supply chain. Therefore, the effects of the decentralization of suppliers that are assumed by downstream manufacturers do not work well, and the damage increases (Sakaguchi and Makino, 2011, pp.81-82).

stable with fewer variations, while Nissan and Honda had slightly larger variations. In addition, the inventory turnover period in Nissan tended to increase throughout the entire period, while that in Toyota increased slightly after the first quarter of fiscal year 2011. Honda's inventory turnover period fell until the second quarter of fiscal year 2011, but increased subsequently.

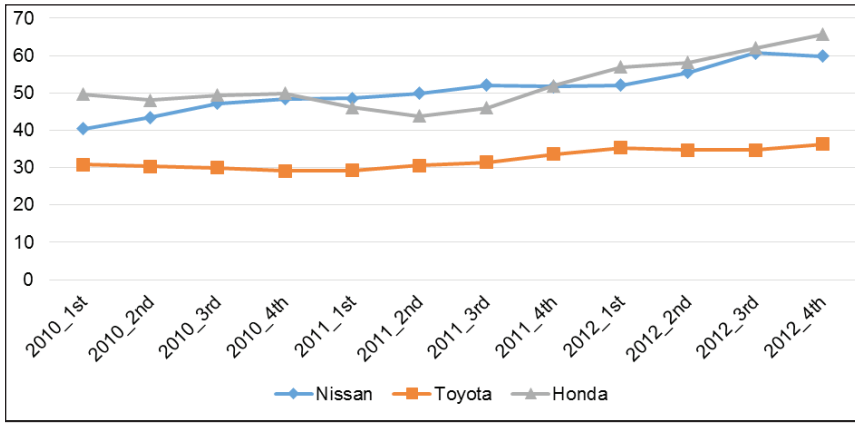

Figure 1: Inventory Turnover Period of Three Major Car Manufacturers in Japan

Figure 2 shows the inventory turnover period in the form of a line graph. The turnover increased around the fourth quarter of 2008, which must have been influenced by the decrease in the volume of sales and the cost of goods sold because of the economic downturn precipitated by the bankruptcy of the Lehman Brothers. The increase from the fourth quarter of fiscal year 2010 to the first quarter of fiscal year 2011 indicates the influence of the decrease in sales caused by the earthquake.

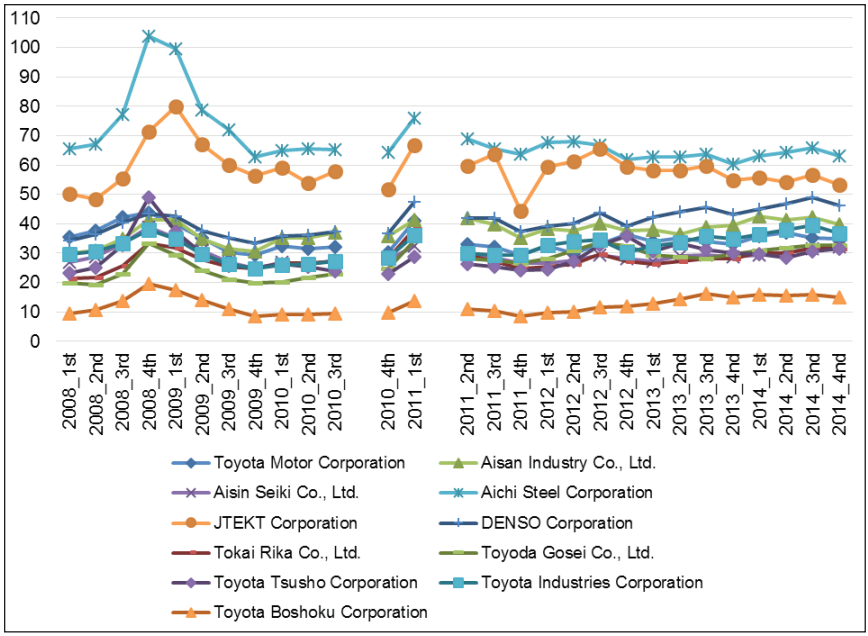

Figure 2: Inventory Turnover Period (Whole Period)

The results of the regression analysis are presented in Table 2. During the period before the crisis, only Toyota Motor Corp. and Toyota Industries Corp. witnessed a decrease in their turnover, at a .05 significance level. The slopes of most of the other companies are negative but nonsignificant. In contrast, the statistics vary in the period after the crisis. The inventory turnover period increase in Toyota Motor Corp., Aisin Seiki, Denso, Tokai Rika, Toyota Industries Corp., and Toyota Boshoku at a .01 significance level and in Toyoda Gosei and Toyota Tsusho at a .05 significance level. However, a decrease in turnover is evident in the case of the JTEKT Corp., at a .05 significance level.[7]

7 Aichi Steel Corp. also witnessed a decrease in its turnover; however, it is nonsignificant.

Table 2: Results of Regression Analysis

	Before the Earthquake		After the Earthquake	
	slope	**P-value**	**slope**	**P-value**
Toyota Motor Corporation	–1.001	0.023	0.325	0.006
Aisan Industry Co., Ltd.	0.207	0.608	0.190	0.152
Aisin Seiki Co., Ltd.	–0.579	0.180	0.243	0.005
Aichi Steel Corporation	–1.401	0.331	–0.290	0.040
JTEKT Corporation	0.198	0.838	–0.306	0.318
Denso Corporation	–0.249	0.461	0.574	0.000
Tokai Rika Co., Ltd.	0.259	0.477	0.317	0.007
Toyoda Gosei Co., Ltd.	–0.177	0.699	0.282	0.025
Toyota Tsusho Corporation	–0.664	0.398	0.400	0.041
Toyota Industries Corporation	–0.791	0.040	0.627	0.000
Toyota Boshoku Corporation	–0.427	0.249	0.525	0.000

Finally, the analysis results related to the difference in the averages are presented in Table 3. The mean significantly increases in Toyoda Gosei at a .01 significance level, in Aisan Industry and Denso at a .05 level, and in Toyota Industries Corp. at a .1 level. In contrast, the mean significantly decreases in the JTEKT Corp., at a .05 significance level. The actual value of the inventory turnover period of each company is shown in Appendix II.

Table 3: Paired *t*-test

	Average Inventory Turnover Period in Days		*t*-Test	
	Before the earthquake	**After the earthquake**	***p*-Value (one sided test)**	***t*-Value**
Toyota Motor Corporation	35.43	32.97	0.123	1.231
Aisan Industry Co., Ltd.	34.79	38.45	0.015	–2.515
Aisin Seiki Co., Ltd.	29.68	28.25	0.192	0.912
Aichi Steel Corporation	74.73	64.73	0.014	2.556
JTEKT Corporation	59.98	58.59	0.324	0.470
Denso Corporation	37.52	41.68	0.010	–2.741
Tokai Rika Co., Ltd.	26.60	27.29	0.306	–0.524
Toyoda Gosei Co., Ltd.	23.13	29.42	0.001	–4.398

	Average Inventory Turnover Period in Days		*t*-Test	
	Before the earthquake	After the earthquake	*p*-Value (one sided test)	*t*-Value
Toyota Tsusho Corporation	29.42	29.21	0.473	0.069
Toyota Industries Corporation	29.71	32.48	0.054	–1.763
Toyota Boshoku Corporation	12.04	11.95	0.478	0.056

DISCUSSION

The results of the analyses seem to support the hypothesis: inventory turnover period fluctuates after the earthquake. We present arguments in favor of this conclusion. First, a clear difference is acknowledged in the variations in inventory turnover period before and after the earthquake. Although the tendency to decrease before the earthquake cannot be explicitly stated (because many companies did not have significant results), we show that it remains at the same level. Moreover, the tendency to increase is not confirmed. The increase in turnover around the fourth quarter of fiscal year 2008 may have been caused by the cost of goods sold (the denominator in the calculation), which is the result of the global recession precipitated by the Lehman Brothers' bankruptcy in 2008. Although the amount of inventory also decreases during the same period, the decline in the cost of goods sold is more pronounced. We deduce that the companies attempted to adjust the amount of inventory in response to the change in demand. However, they were unable to absorb the remarkable decrease in unit sales or they expected the decrease in unit sales to be a short-term fluctuation and continued to produce in anticipation of future sales.

Second, the inventory turnover period increased in all the surveyed companies in the period from the fourth quarter of fiscal year 2010 (including the day of the earthquake) to the first quarter of fiscal year 2011. This was caused by the increase in stock with the production stop in factories and part suppliers and the decrease in sales (cost price) that occurred because of the reduction in domestic demand. However, most of the surveyed companies

are concentrated in the Chubu region around the Aichi prefecture, and they did not have to dispose of their stock because of the direct influence of the earthquake or tsunami.

After July 2011, when the production system is mostly restored (which is one of the most noticeable periods in this research), the increase in inventory turnover period is significant. Over half the companies show significant increases, at a .01 significance level.

In terms of the long-term influence of supply chain distortions, our results support the conclusions of prior studies. However, we cannot ignore the fact that the turnover of two companies decrease after the earthquake, namely, the Aichi Steel Corp. and the JTEKT Corp. In particular, the decrease in turnover of the Aichi Steel Corp. is statistically significant. Both these companies held stock for approximately 55 to 70 days, while the other eight companies (except Toyota Boshoku, which held remarkably little stock) changed stock within 25 to 50 days. Thus, these two companies held relatively more stock compared to the other companies in the group (see Figure 2 and Appendix 2). That is, no company simply decided to increase the quantity of stock or to increase the inventory turnover period compared to the situation before the earthquake. Apart from the question of whether the tendency to increase inventory is intentional or not, the standard seems to converge from 40 to 50 days in the Toyota Group. Thus, this indicates that the tendency to increase inventory after the earthquake does not contradict the key concept of JIT, rather, risk aversion (to prepare for an emergency such as a production stop) is considered more than before.

Finally, we narrow down the companies that show noticeable fluctuation based on the results of the paired *t*-test. Four companies, namely, Aisan Industry, Denso, Toyoda Gosei, and Toyota Industry, show tendencies to increase inventory, while the Aichi Steel Corp. shows a marked tendency to decrease compared to the other companies. The findings of this study could be validated through further inspections of these companies.

CONCLUSIONS

In this study, we examine the tendency of inventory possession before and after the Great East Japan Earthquake. The inventory turnover period decreases in the period before the earthquake according to the consolidated accounting information of the Toyota Motor Corp.. In contrast, a significant tendency to increase inventory turnover period is evident after the earthquake. Though the average number of days decreases, the result is nonsignificant. Meanwhile, the tendency to increase inventory possession is evident after an earthquake in most of the companies that constitute the supply chain of the Toyota Motor Corp. Moreover, one company increased the mean of the inventory turnover period significantly. However, the company that had relatively more stock showed a tendency to decrease.

In view of these results, we need to consider the situation of all suppliers when evaluating inventory control because the analysis is conducted at the supply chain level,. Moreover, results such as those in the context of the Toyota Group must be regarded as an indication of the transformation or evolution of the JIT methodology. In other words, JIT may be required to determine the most suitable inventory level after considering the management of a wide range of suppliers in the supply chain, the procurement of a variety of parts, elements, such as correspondence to an unexpected situation, and so on in the future.

Finally, we discuss the limitations of this study and present directions for future research. In this study, we are not able to collect and examine information related to what kind of inventory was increased or to examine whether the targeted value of the inventory turnover period existed and whether the rate of increase was controlled. In addition, the future transition is not clarified, that is, whether the tendency to increase reaches the ceiling or converges. To address these limitations, continuous and qualitative research would be required. Moreover, the data that we collected for the statistical analysis are restrictive, and the number of samples is limited. Future research could validate the findings of this study through multidirectional analysis using other techniques.

REFERENCES

Cooper, R. (1995). *When Lean Enterprises Collide: Competing through Confrontation*, Boston: Harvard Business School Press.

Cooper, R., & Slagmulder, R. (1999) *Supply Chain Development for the Lean Enterprise: Interorganizational Cost Management*, Portland: Productivity, Inc.

Development Bank of Japan (2012). *Handbook of Industrial Financial Data 2012*. Tokyo: Japan Economic Research Institute Inc.

Hendricks, K. B. & Singhal, V. R. (2005). Association between Supply Chain Glitches and Operating Performance. *Management Science*, *51*(5), 695-711.

Hendricks, K. B. & Singhal, V. R. (2009). How much the confusion of SCM. *Logi Biz, 8*(10), 14-19.

Hendricks, K. B. & Singhal, V. R. (2012). The Effect of Supply Chain Disruptions on Corporate Performance. In P. Kouvelis, L. Dong, O. Boyabatli and R. Li (eds.), *The Handbook of Integrated Risk Management in Global Supply Chains*, (pp. 51-78). New Jersey: John Wiley & Sons.

Johnson, H. T., & Broms, A. (2008). *Profit beyond Measure: Extraordinary Results Through Attention to Work and People*. Free Press.

Monden, Y. (2012). *TOYOTA Production System: An Integrated Approach to Just-In-Time Fourth Edition*. USA: CRC Press.

Okamto, K., Hiromoto, T. Obata, H. & Hiki, F. (2008). *Management Accounting,* Tokyo: Chuo Keizaisha.

Sakaguchi, T. & Makino, N. (2011). *When the Earthquake! Procurement and Purchasing Departments of the Company Has Moved Like This—True Risk Hedge in the future*, Nikkan Kougyo Shinbunsha.

Sheffi, Y. (2005). *The resilient enterprise: Overcoming vulnerability for competitive advantage*. Cambridge, MA: The MIT Press.

Tokui, J., Arai, N., Kawasaki, K., Miyagawa, T., Fukao, K., Arai, S., Edamura, K., Kodama, N. & Noguchi, N. (2012). Economic Impact of the Great Eats Japan Earthquake ― Comparison with Past Disasters, Disruptions Effect of the Supply Chain, The Impact of Power Supply Constraints. *RIETI Policy Discussion Paper Series*, 12-P-004.

Tomlin, B. & Wang, Y. (2012). Operational Strategies for Managing Supply Chain Disruption Risk. In P. Kouvelis, L. Dong, O. Boyabatli and R. Li (Eds.), *The Handbook of Integrated Risk Management in Global Supply Chains*, (pp. 79-102.). New Jersey: John Wiley & Sons.

Whitney, D, E., Luo, J. & Heller, D. A. (2013). Supply Chain Disruption Risk and Recovery: Temporary Diversification and Its Limits, *Manufacturing Management Research Center Discussion Paper Series*, No.434.

Annual and Quarterly Reports

Aisan Industry Co., Ltd., Annual and Quarterly Reports from 2008 to 2014.

Aisin Seiki Co., Ltd. , Annual and Quarterly Reports from 2008 to 2014.

Aichi Steel Corporation, Annual and Quarterly Reports from 2008 to 2014.

Dai Nippon Printing Co., Ltd (2012) Annual Report.

Denso Corporation, Annual and Quarterly Reports from 2008 to 2014.

Honda Motor Co., Ltd., Annual and Quarterly Reports from 2010 to 2012.

JTEKT Corporation, Annual and Quarterly Reports from 2008 to 2014.

Nissan Motor Co., Ltd., Annual and Quarterly Reports from 2010 to 2012.

Tokai Rika Co., Ltd. , Annual and Quarterly Reports from 2008 to 2014.

Tokyo Electric Power Co., Inc. (2012) Annual Report.

Toppan Printing Co., Ltd (2012) Annual Report.

Toyoda Gosei Co., Ltd. , Annual and Quarterly Reports from 2008 to 2014.

Toyota Boshoku Corporation, Annual and Quarterly Reports from 2008 to 2014.

Toyota Industries Corporation, Annual and Quarterly Reports from 2008 to 2014.

Toyota Motor Corporation, Annual and Quarterly Reports from 2008 to 2014.

Toyota Tsusho Corporation, Annual and Quarterly Reports from 2008 to 2014.

APPENDIX

Outline of the Companies

	Annual sales (2014, unit of one million yen)	Sales to Toyota (2014, percentage of its sales)	Regular employee	Business segments/ Main products	Outline	Main domestic factory (Prefecture)	Main foreign subsidiary (Country)
Toyota Motor Corporation	25,612,836	-	344,109	Automotive operations, financial services	Began research of automotive in Toyota Industries Corporation in 1933. Independent in 1937.	Aichi, Shizuoka, Osaka, Tokyo, Miyagi, Fukuoka	Canada, Thailand, U.S., Indonesia
Aichi Steel Corporation	240,647	12.24%	4,617	Automotive parts such as steel material, castings, electromagnetic goods	Independent in 1940 from Toyota Industries Corporation.	Aichi, Gifu	U.S., Thailand, China
Aisan Industry Co., Ltd.	212,676	50.50%	8,521	Automotive parts such as fuel pump modules, throttle body, canister	Founded for the purpose of munitions production in 1938. Launched auto parts manufacturing (such as carburetors) in 1945.	Aichi	South Korea, China, Indonesia, India, U.S., Czech Republic
Aisin Seiki Co., Ltd.	2,963,971	32.37%	94,748	Automotive parts such as engine, drive train, brakes, chassis, body	Founded Aichi Industrial Co., Ltd. and Shinkawa Industrial Co., Ltd. (core automotive parts manufacturer) merged in 1965.	Aichi, Toyama, Fukui	U.S., China, Thailand, Indonesia

	Annual sales (2014, unit of one million yen)	Sales to Toyota (2014, percentage of its sales)	Regular employee	Business segments/ Main products	Outline	Main domestic factory (Prefecture)	Main foreign subsidiary (Country)
Denso Corporation	4,308,754	24.97%	146,714	Powertrain (engine and gasoline injection parts), electron, heat, information safety, (information and communication, driving safety, electrical control), motor	Independent in 1940 from Toyota Motor Corporation.	Aichi, Mie	U.S., Italy, Hungary, Czech Republic, Thailand, Korea, Indonesia, China, Brazil
JTEKT Corporation	1,355,992	16.66%	43,912	Machinery, furniture and fixtures (steering, drive system components, bearings), machine tool	Founded in 1921, started bearing production.	Osaka, Aichi, Tokushima, Tokyo, Kagawa, Nara, Mie, Saitama	Thailand, U.S., Brazil
Tokai Rika Co., Ltd.	452,195	29.60%	17,348	Automotive parts such as switches, seat belt, key lock, shift lever	Started manufacturing and selling automotive switch in 1948	Aichi, Gifu	Thailand, U.S., China, Czech Republic
Toyoda Gosei Co., Ltd.	727,846	25.62%	34,754	Automotive and optoelectronics (LCD backlight and LED lamps)	Independent in 1949 from Kokka Industrial Co., Ltd.	Aichi	Mexico, Canada, Thailand, Australia, China, U.K., Czech Republic
Toyota Boshoku Corporation	1,305,502	29.28%	41,509	Automotive parts such as seat fabric, airbag, bumper	Established in 1918. Merged with Toyota Motor Corporation in 1943, independent again in 1950.	Aichi, Gifu, Shizuoka	U.S., China, Indonesia, Thailand, Australia, Vietnam, Turkey, South Africa, France

	Annual sales (2014, unit of one million yen)	Sales to Toyota (2014, percentage of its sales)	Regular employee	Business segments/ Main products	Outline	Main domestic factory (Prefecture)	Main foreign subsidiary (Country)
Toyota Industries Corporation	2,166,661	31.97%	52,523	Sell the vehicle or engine for Toyota. Development of the important components of hybrid vehicles and fuel cell vehicles	Founded in Aichi Prefecture for the preparation of the automatic loom that Sakichi Toyoda invented, in 1926.	Aichi	U.S., China, Germany
Toyota Tsusho Corporation	8,663,460	5.70%	53,241	Metal, global parts and logistics, automotive, machinery, energy and plant projects, chemicals, electronics, food, life industry	Founded inherited the Commercial department of Toyoda Sangyo Co., Ltd. in 1948.	Aichi	Russia, U.S., Norway

APPENDIX 2

Inventory Turnover Period

	2008_1st	2008_2nd	2008_3rd	2008_4th	2009_1st	2009_2nd	2009_3rd	2009_4th
Toyota Motor Corporation	35.4857	37.6975	42.2927	43.7947	39.7535	35.2431	30.1462	29.2438
Aisan Industry Co., Ltd.	29.9889	30.8134	34.9261	41.2046	41.1771	34.9886	31.4876	30.5235
Aisin Seiki Co., Ltd.	26.9093	28.7992	33.5035	38.9141	35.0670	30.8213	26.9594	24.9102
Aichi Steel Corporation	65.5082	66.9312	77.2881	103.8456	99.4604	78.7461	72.0533	62.6830
JTEKT Corporation	50.0799	48.4623	55.5676	71.3366	79.8803	67.1024	60.1390	56.3799
Denso Corporation	34.2843	36.4639	40.4734	43.4753	42.6436	37.6021	35.1298	33.2451
Tokai Rika Co., Ltd.	21.5535	21.5598	25.6864	33.3082	31.7166	27.7526	25.5149	24.9020
Toyoda Gosei Co., Ltd.	19.8218	19.2718	23.0807	33.4527	29.2843	24.0855	20.9851	19.7366
Toyota Tsusho Corporation	23.1559	24.9882	32.7575	48.9232	37.3691	30.1132	25.6216	24.9461
Toyota Industries Corporation	29.7186	30.6029	33.4651	37.8743	34.9488	29.5461	26.3361	24.6966
Toyota Boshoku Corporation	9.4696	10.5348	13.6024	19.6532	17.5656	14.0233	11.1144	8.6117

	2010_1st	2010_2nd	2010_3rd	2010_4th	2011_1st	2011_2nd	2011_3rd	2011_4th
Toyota Motor Corporation	32.4692	31.5444	32.0231	30.2203	41.1064	33.1080	32.2781	29.3589
Aisan Industry Co., Ltd.	35.2934	35.2253	37.0096	35.8683	41.2872	41.8287	39.6475	35.2170
Aisin Seiki Co., Ltd.	26.8968	26.2125	27.4360	27.8504	32.5223	29.6866	28.3990	26.5742
Aichi Steel Corporation	64.7957	65.4110	65.3391	64.4418	75.9330	68.8352	65.6072	63.8163
JTEKT Corporation	58.9697	53.9296	57.9522	51.8114	66.8272	59.6301	63.7251	44.5378
Denso Corporation	35.7785	36.2303	37.3949	36.7808	47.3577	41.8573	42.0248	37.3917
Tokai Rika Co., Ltd.	26.7594	26.6490	27.1485	28.0410	38.1130	29.5135	27.3293	24.6649
Toyoda Gosei Co., Ltd.	20.2122	21.6860	22.8609	24.8324	34.1982	28.1346	27.6828	26.5968
Toyota Tsusho Corporation	26.4491	25.4738	23.8744	22.9983	28.6691	26.4255	25.3867	24.1244
Toyota Industries Corporation	26.1022	26.3117	27.1655	28.5982	36.0365	29.9926	29.2889	29.4583
Toyota Boshoku Corporation	9.2391	9.1556	9.5104	9.7168	13.7219	10.8617	10.2588	8.6458

	2012_1st	2012_2nd	2012_3rd	2012_4th	2013_1st	2013_2nd	2013_3nd	2013_4nd
Toyota Motor Corporation	32.5461	29.9489	33.0915	36.3862	33.9070	35.1612	33.8210	33.0750
Aisan Industry Co., Ltd.	38.1388	37.6136	40.1952	37.7753	37.8454	36.3464	38.7399	39.5652
Aisin Seiki Co., Ltd.	26.5296	27.6446	29.3905	28.2988	27.1807	29.0329	29.3336	28.7233
Aichi Steel Corporation	67.6475	67.8680	66.6170	61.9078	62.9279	62.7341	63.7999	60.2543
JTEKT Corporation	59.5009	61.2000	65.5214	59.3107	58.3007	58.3220	59.6592	54.7781
Denso Corporation	39.3065	40.1112	43.6708	39.0516	42.1179	44.1717	45.5434	43.2389
Tokai Rika Co., Ltd.	25.5320	26.2556	29.6427	27.3123	26.4360	27.1877	28.1517	28.2056
Toyoda Gosei Co., Ltd.	28.2474	30.9108	33.7896	32.3180	29.5109	28.7526	27.9994	29.6856
Toyota Tsusho Corporation	24.5994	27.1471	32.7477	35.6811	30.7305	33.2154	31.2247	30.0648
Toyota Industries Corporation	32.7499	33.8197	34.7000	30.2805	32.5720	33.7194	35.6932	35.0064
Toyota Boshoku Corporation	9.8449	10.1357	11.7218	11.8361	12.6977	14.3004	16.0622	15.0951

	2014_1st	2014_2nd	2014_3nd	2014_4nd
Toyota Motor Corporation	35.9418	36.9113	35.2524	34.8550
Aisan Industry Co., Ltd.	42.5725	41.4729	42.3561	39.8896
Aisin Seiki Co., Ltd.	29.3371	30.1425	31.3821	32.1354
Aichi Steel Corporation	63.1817	64.3045	65.9390	63.0911
JTEKT Corporation	55.7635	54.2264	56.6038	53.2916
Denso Corporation	45.1044	46.7916	48.8911	46.3037
Tokai Rika Co., Ltd.	30.1854	29.9935	31.7852	31.5091
Toyoda Gosei Co., Ltd.	31.0465	31.7346	32.6363	32.6053
Toyota Tsusho Corporation	29.7917	28.4644	30.6163	31.4038
Toyota Industries Corporation	36.5159	37.9768	39.6093	36.6990
Toyota Boshoku Corporation	15.7711	15.5293	16.0280	14.9001