

**Analyzing Inter-firm Relationships:**  
**An Empirical Study on Japanese Keiretsu Networks**  
(企業間関係分析：  
日本の系列ネットワークに関する実証研究)

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An Empirical Study on Japanese Keiretsu Networks**

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## **Abstract**

Among academics, practitioners and the popular press, there is general consensus that the resurrection of Japan as a formidable and dominant force in the global economy can largely be ascribed to the array of family-owned inter-firm alliance networks and institutions known as keiretsu. Collectively, keiretsu networks, in general, and automotive keiretsus, in particular, which comprise and play an extremely dominant role in the Japanese economy, compete with one another to vie for market share and profits. The performance of Japanese auto manufacturers, such as Toyota, Mazda and Nissan, and member firms within their respective keiretsu, have significantly improved due to sophisticated production system technologies, highly productive workers, and recurring transaction relationships with other partners in their respective network organizations. Indeed, one possible determinant of their success, arguably, could be attributed to keiretsus, which is a unique organizational form as it provides a solid platform for firms to cement strategic alliances with their partners virtually encompassing their entire supply chain.

In general, the intensification of global competition over the last two decades and the proliferation of supply chains geographically have had a significant impact on the administration and inter-relational dynamics among member firms in Japanese keiretsus. In particular, the strong ties among automobile manufacturers and their respective supplier partners witnessed significant “loosening,” which was attributed to an “external event” known as the financial crisis of 2008—an event also referred to as the Great Recession. More specifically, keiretsus have manifested a “loosening” of ties among their strategic network partners with many firms breaking generational norms by simultaneously engaging in exchange relationships with non-member firms that lie beyond their family network boundaries—behavior that traditionally is considered discordant and incompatible with the spirit and philosophical underpinnings of keiretsu norms. As a case in point, automobile manufacturers are currently known to engage in collaborative research and development activities with their competitors—behavior once considered even more inconceivable.

Having gained prominence in the Japanese economy over the last 70 years, keiretsus have only sustained attention in the popular press as the subject of news and anecdotal discussions. In stark comparison, scholarly studies published in academic journals that advance our knowledge of the nature of keiretsus as well as shed light on the interrelationships among member-partners has only recently started to sustain attention of academic scholars. Albeit scant, the academic research on the systematic body of knowledge on Japanese keiretsus is fragmented as well as disjointed.

While still considered nascent, and owed to the paucity of theoretical and empirical research,

the purpose of this dissertation is to partially address this gap in the literature by examining the nature of relationships and ties among member firms in Japanese alliance networks that have recently undergone fundamental changes. Using data drawn from a sample of automotive Japanese firms constituting a keiretsu, this thesis reports the findings of three separate, independent and distinct empirical investigations that examine the extent to which corporate performance—as manifested by sales revenues and profits—are impacted by (a) Fragility, (b) Degree, and (c) Momentum, which embody inter-firm relationships and ties among member firms. The occurrence of the inter-relational structural changes noted above within keiretsu systems provided the impetus for this dissertation, which begged the following research questions: What is the status quo of automotive keiretsus? Are transactional relationships in keiretsus still associated with increasing corporate performance? Owing to the paucity of research, answers to these questions are not readily available in the literature. Thus, to augment the extant knowledge in this field and documenting answers to these larger research questions, this dissertation partially makes a contribution by bridging this gap in our understanding of keiretsus. Towards that end, this dissertation utilizes novel approaches and methodologies, such as Data Envelopment Analysis, Graph Theory and Limited Cycle Theory, to shed light on the key determinants of corporate performance based on which strategic management implications are identified and directions for future investigation are proffered.

As preliminary studies, I have published a couple of papers on transactional and capital networks. The research on transactional network reports the results of a study that shed light on the linkage between inter-firm transactional relationships and corporate performance [16]. The empirical investigation reveals that: (1) Keiretsu is a flexible, highly adaptive organizational form; its scale is prone to modifications in response to changes in economic conditions; (2) Transactional relationships continue to be a significant predictor of increasing profits for keiretsu partners even in the aftermath of the 2008 financial crisis. Recently, research has shed light on how fundamental changes to capital relationships in Japanese alliance systems have affected corporate performance [17]. Thus, this research reports the results of a study that collected data on cross-shareholdings that shed light on the relationship between inter-firm capital relationships and corporate performance. The empirical investigation reveals that: (1) As a flexible, highly adaptive organizational form, keiretsu scale changes as a response to economic conditions; (2) Capital relationships remain a significant determinant of increasing profits for keiretsu partners even after the bubble burst in the 1990s.

This dissertation is structured into five chapters as follows: Chapter 1 explains the background



and the purpose of the dissertation, and investigates the literature of corporate strategy and network studies. A survey of the relevant literature reveals that a plethora of network analytic facets, such as degree, eigenvalue, density, block, cluster, have been developed and employed to further our understanding of network structures. To extend our understanding of network systems, additional dimensions need to be identified that shed light on the dynamic processes among individual member nodes within network structures.

Specific to the context of networked systems, Chapter 2 proposes a new concept of fragility. Specifically, it develops and empirically tests a mathematical model of fragility from the standpoint of how ties among network members significantly influence corporate performance, thus uniquely contributing to extant knowledge. Using data drawn from a sample of two well-known network organizations, Mazda and Toyota, this chapter attempts to shed light on the relationship between degree, fragility and corporate performance. Degree is defined as the number of nodes that connect with it directly. The fragility is a measure index of the brittleness of the relationship between any two nodes. The investigation confirms the validity of the new concept as well as enabling a contrast of the network structures of Mazda and Toyota. Based on the findings, the managerial implications are discussed, the study limitations are identified and directions for further research are suggested.

Improving efficiency is an important issue in corporate management. Although many tools to measure efficiency have been developed, Chapter 3 proposes a new approach known as dynamic network-based Data Envelopment Analysis (DEA) as an even more effective tool for examining inter-firm relationships. More specifically, dynamic network-based DEA makes it possible to detect system-wide effects when marginal changes in related phenomena occur. This new approach was illustrated using data gathered from Mazda's Yokokai keiretsu to reveal the impact that transactions among member firms in the network have on sales revenue. Managerial implications in the formulation of corporate strategy are discussed. Study limitations are identified and directions for future research are proffered.

Many theories and models of corporate strategy have been published in the past century. For example, Porter's theory of competitive advantage [52], Barney's Resource based view [53], and Mintzberg's 5Ps concepts [1], are considered as the most representative studies in this field. Tenets from these theories, such as managerial resources, cost competition, organizational structure and bargaining power of suppliers and buyers, are discussed in this literature. The basis of this thought stems from two seminal books: *The Art of War*, and *On War* written by Chinese military strategist, and philosopher Sun Tzu in the late sixth century BC and Prussian military

thinker Carl von Clausewitz in 1827, respectively [55, 56]. In contrasting these two theses with current strategic theories, discussions on momentum, an important concept, have been sparse, although in the context of current management strategies the pivotal nature of momentum recently has been operationalized and discussed in research on marketing, and finance. Thus, Chapter 4 reviews the literature associated with corporate strategy, and proposes a new approach of acceleration to measure momentum based on limited cycle theory. Consequently, this research endeavor contributes to extant thought on automobile manufacturers by: 1) Defining momentum, 2) Discussing the nature of the relationship between momentum to its external environment, and company scale, 3) Ascertaining the momentum period, and 4) Proposing a four-cell matrix model composed of momentum and company scale for judging a firm's position. Additionally, the relationship between momentum and the impact of 2007-2008 financial crises is addressed. Based on the findings, the study limitations are identified and directions for further research are suggested.

Finally managerial implications, study limitations and suggestions for future research of the dissertation are offered in Chapter 5.

## Acknowledgements

Over the Ph.D. course of the three years that I was working on this dissertation, I have tremendously benefitted from the valuable contributions a number of researchers and colleagues have made in the form of comments and directions on improving earlier drafts of my thesis and for assisting me throughout the Ph.D. program and especially during the dissertation stage. As I am deeply indebted for their guidance and suggestions, I would like to express my gratitude to all of them. In particular, I would like to thank the members of my doctoral committee at Hiroshima University, Professor Katsuhiko TAKAHASHI, Professor Naoto YORINO, and Professor Ichiro NISHIZAKI. A large measure of thanks is owed to Professor Katsuhiko TAKAHASHI and Associate Professor Katsumi MORIAKWA, who provided a plethora of constructive suggestions, technical assistance, and support, that I feel greatly improved the quality of this dissertation.

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## **Chapter 1 Introduction**

### **1.1 Introduction**

The term strategy, which has been around for a long time, has been frequently been used by organizational scholars. For instance, Mintzberg's perspective of strategy comprises of five Ps: planning, pattern, position, perspective, and ploy [1]. And Chandler asserted that strategy can be defined as the "determination of the basic long-term goals and objectives of an enterprise, the adoption of course of action and the allocation of resources necessary for the carrying out of these goals" [2]. Strategy formation is an important phase in corporate making process. Of the plethora of studies that have focused on strategy formulation, two aspects are noteworthy: coordination of managerial resources within firm and establishment of rational relationships with outside shareholdings. Evidently, as inter-firm relationships with external constituents are important, the network perspective can effectively increase our collective understanding of the dynamics between network members. Recent investigations on inter-firm relationships have focused on examining centrality [3], the relationship between corporate governance and closeness [4], firm centrality measurement of transaction and cross-shareholdings and capacity index analysis [5, 6].

Japanese automobile manufacturers still show signs of performing at a significantly higher level than their global counterparts. This could possibly be due to the sophisticated technologies deployed for their production systems, highly productive employees, and continuous transaction relationships with other member-partners in the keiretsu network. Possibly, one explanatory factor contributing to their success could be their unique organization forms –the keiretsu– which provides a strong platform to forge strategic alliances with their parts suppliers, as well as collaboration in research and development with other automobile makers. In the aftermath of the 1990s economic bubble, the strong interrelationships between car producers and their automotive parts suppliers in the keiretsu network underwent a significant transition referred to as "keiretsu loosening". Moreover, the 2008 financial crisis is also known to have a significant impact on keiretsu. After the financial crisis—also known as the great recession of 2008— strong ties between automobile manufacturers and their supplier partners underwent significant change, which were manifested by the "loosening of network" ties that were attributed to "external influences" [7-10]. However, these structural changes are anecdotal in nature due to the paucity of research on current state of interrelationships among member firms in the extant literature on keiretsu. Consequently, this begs finding answers to research questions, such as: What is the status quo of automotive keiretsus? Are transactional relationships in keiretsu still associated with improved corporate performance? To augment knowledge, this dissertation makes a contribution

to our understanding of keiretsu by documenting answers to these questions.

This dissertation examines the nature of relationships among member firms of a keiretsu, which typifies a network organization. The focus of this dissertation is to describe recent fundamental changes in the nature of Japanese alliance networks known as keiretsu. Drawing data from a sample of firms constituting a keiretsu, this dissertation reports the findings that investigates empirically the relationship between these changes and corporate performance. More specially, the performance of Japanese auto manufacturers, such as Toyota, Mazda and Nissan, among others, has significantly improved due to sophisticated production system technologies, highly productive workers, and recurring transaction relationship with other partners in their network organization, respectively. One possible determinant of their success could be attributed to the unique organizational form of the keiretsu as it provides a solid platform to forge strategic alliances with their suppliers as well as collaborative research and development activities with other competitive automobile manufacturers.

The purpose of this dissertation is to examine the interrelationships between corporate behaviors, such as fragility and momentum and their effect on corporate performance—as manifested by sales revenues and profits. This dissertation proposes three new approaches to shed light on the key determinants of corporate performance based on which managerial implications of corporate strategy are identified and directions for future investigation are proffered.

## **1.2 Outline of the Dissertation**

This dissertation is structured around five chapters, as follows: Chapter 1 explains the background and the purpose of the dissertation, and investigates the literature of corporate strategy and network studies. Chapter 2 proposes a new concept of fragility. Specifically, it develops and empirically tests a mathematical model of fragility from the standpoint of how ties among network members significantly influence corporate performance, thus uniquely contributing to extant knowledge. Using data drawn from a sample of two well-known network organizations, Mazda and Toyota, This chapter attempts to shed light on the relationship between degree and fragility. The investigation confirms the validity of the new concept as well as enabling a contrast of the network structure of Mazda and that of Toyota. Chapter 3 proposes a new approach known as dynamic network-based Data Envelopment Analysis (DEA) as an even more effective tool for examining inter-firm relationships. More specifically, dynamic network-based DEA makes it possible to detect system-wide effects when marginal changes in related phenomena occur. This new approach was illustrated using data gathered from Mazda's Yokokai keiretsu to reveal the impact that transactions among member firms in the network have on sales revenue. Chapter 4 reviews the literature associated with corporate strategy, and proposes a new approach of momentum. The momentum is a measure expressing the motion of a firm, equal to the value of acceleration based

on limited cycle theory in this research. Consequently, this research endeavor contributes to extant thought on keiretsu by discussing the nature of the relationship between momentum to its external environment, and company scale, ascertaining the momentum period, and proposing a matrix model composed of momentum and company scale for judging a firm's position. Finally managerial implications, study limitations and suggestions for future research of the dissertation are offered in Chapter 5.



## **Chapter 2 Measuring Fragility using the Entire Degree in Network Systems**

### **2.1 Introduction**

As in sociology and psychology, many mathematical models have been developed to increase our understanding of the organizational sciences. For instance, relative to the prominence of keiretsu organizations, which play a dominant role in the Japanese economy, researchers have not devoted much attention on conducting empirical investigations to increase our understanding of these networks. While studies on keiretsu have garnered greater attention and empirical studies have started to emerge in scholarly research journals, still these investigations can be considered fragmentary and sparse [7-13]. Being an additional organizational form within the context of networked structures, more recently dimensions, such as influence [4, 14], centrality [5], transactional relationships [15, 16], capital relationships [17], Euclidean distance [18], and capacity [6], have revealed the static nature of relationships among individual actors relative to other members within the whole network. However, dynamic processes are considered to be even more salient in the organizational sciences and allied fields. A review of the literature suggests that newer models and paradigms illustrating the dynamic processes between network participants are more desirable. Accordingly, this chapter proposes, measures and illustrates how the new concept of fragility, which is theoretically grounded as well as rooted in a systematic repeated trial and error assessment, has an impact on degree and corporate performance.

Drawing data from two well-known network organizations, Toyota's Kyohokai from 2004 to 2007, and Mazda's Yokokai from 2004 to 2012, the purpose of this research endeavor is to calculate and ascertain the relationship between fragility, degree and sales revenue, thus confirming the validity of new model. Furthermore, the relationship between fragility and corporate performance is also assessed, which forms the basis of the managerial implications discussed in the manuscript. More specifically, this chapter makes a unique contribution to extant thought by: 1) Defining the concept of fragility, 2) Discussing the nature of the relationship between degree and corporate performance, and 3) Empirically testing the dimensional differences between fragility and corporate performance. Thus, this empirical investigation enables Mazda's networked organization to be compared and contrasted with Toyota's network constellation.

This chapter is structured as follows. Section 2 reviews the literature focusing on network analysis. In Section 3, the chapter explicates the models of degree and fragility and data collection

with a couple of hypotheses. Discussion of our findings based on the results management implications are identified in Section 4 and Section 5 respectively. Directions for further research are proffered in the final section.

## **2.2 Background and Literature Review**

As noted earlier, indexes, such as influence, centrality, transactional relationships, capital relationships, Euclidean distance, and capacity, have been used widely in empirical research to measure different dimensions of organizational networks. Comprising a most basic facet of centrality, degree was firstly proposed by Niemen [19] in his research on organizational constellations. Simply put, degree is defined as the number of links incident upon a node in a graph. In real society, most of the relationships between members are considered to be mutual. Furthermore, nodes within a network are known to interact with each other. Consequently, direction with weight have been commonly employed to analyze different phenomena within social networks. In this context, Freeman proposed a new index of entire degree, which identifies the centrality of the whole network [20].

Ito and Sakamoto proposed a new approach to identify the importance of each individual node based on Freeman's model [21]. More recently, Park and Chen applied centrality indexes to analyze organizational structure and performance of Panasonic [22-23]. Ogata used soreness index to identify the formation of accounting standardization [24-25]. More recently, Akiyama studied inter-organizational relationships using network indexes such as degree and structure holes [26]. Furthermore, Borgatti discussed centrality and network flows and developed a new approach to identify the key players optimally diffusing or disrupting or fragmenting the network by removing the key nodes [27, 28]. However, noted that much more research is necessary to fully understand keiretsu constellations. Although the relationships between network member firms can be manifest in the form of equity ties, personal ties, transactional ties and workflow ties, this chapter examines transactions within a network to reveal the nature of the relationships between business ties and corporate performance. More specifically, owed to the sparsity of knowledge, this investigation contributes to the literature by advancing a new procedure for measuring the interrelationships between members of a keiretsu by suggesting the new concept of fragility to be a determinant of corporate performance.

## **2.3 Models and Data Collection**

Two model are applied in this chapter: degree and fragility.

### **2.3.1 Models**

Degree, as one of the basic indices of centrality, is considered as the basic index in network

analysis. It can be calculated as follows [19].

$$C_D(p_k) = \sum_{i=1}^n a(p_i, p_k) \quad (1)$$

where

$i \neq k$ ;

$n$ : data number;

$a(p_i, p_k) = 1$  if and only if  $p_i$  and  $p_k$  are connected by a line; (the percentage data are adopted in this chapter.)

$a(p_i, p_k) = 0$  otherwise.

Fragility is a physical term that characterizes how rapidly the dynamics of a material slow down as it is cooled toward the material transition<sup>i</sup> [29]. Accordingly, fragility, which is defined as the ratio of the entire degree of and the entire degree after removing a specific node, is mathematically expressed as:

$$F(p_i) = \frac{C_D(p_i^-)}{C_D} \quad (2)$$

where

$C_D$ : Entire degree of a given network;

$C_D(p_i^-)$ : Entire degree after removing node  $p_i$ .

The equation of the entire network is defined as below [20].

$$C_D = \frac{\sum_{i=1}^n (C_D(p^*) - C_D(p_i))}{n^2 - 3n + 2} \quad (3)$$

where

$$C_D(p^*) = \max_i C_D(p_i) \quad (4)$$

### 2.3.2 Data Collection

Widely considered as successful examples of prominent Japanese networked organizations, data were drawn from Toyota's Kyohokai and Mazda's Yokokai from 2004 to 2007 to establish the status quo of keiretsu as well as longitudinally ascertain changes in their keiretsu structure.

Japanese keiretsu (e.g., Toyota, Nissan, and Mazda's networks) are known to comprise multifarious members. It is widely acknowledged that firms are reluctant to share financial information about themselves and their members due to confidential considerations that may have competitive implications. Moreover, key informants from the focal member firms have to painstakingly research and provide relevant data from their management information systems, which is extremely time consuming and expensive. Further complicating these matters is that the data have to be cross-validated from other member firms within each respective network. Moreover, the longitudinal data were even cross-validated from on-line financial databases, thus enhancing the reliability of the data set. As a result of this albeit onerous task, a complete set of valid, reliable and useable data were only available for the specified 2004-2007 period from Toyota's Yokokai and Mazda's Kyohokai.

Both of these keiretsu organizations include singletons, which refers to a partner firm in the keiretsu that has no relationship with other member firms. However, singletons were removed from the data set because they have no impact on the calculation of network indexes.

Data on Toyota's Kyohokai and Mazda's Yokokai from 2004 to 2007 to establish the status quo of keiretsu and ascertain changes in its structure in the aftermath of the 2008 financial crisis have been drawn from the publications of the Japan Auto Parts Industries Association and Automotive Parts Publishing Company as well as telephone interviews and personal interviews [30-37].

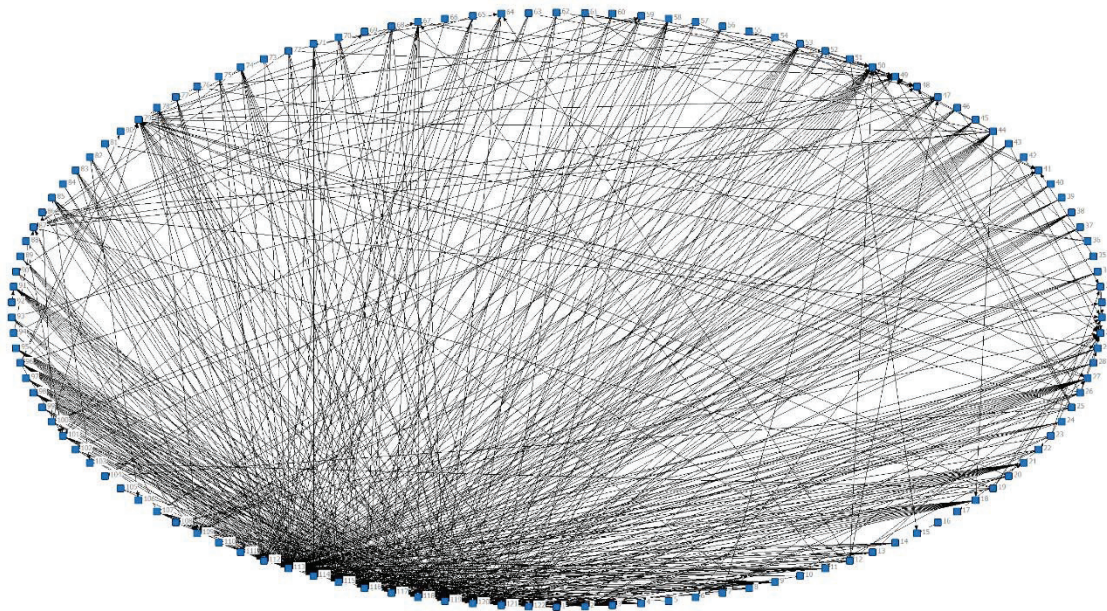
The relevant information about the Yokokai and Kyohokai is reported in Table 1.

Table 1 Firms in Yokokai and Kyohokai.

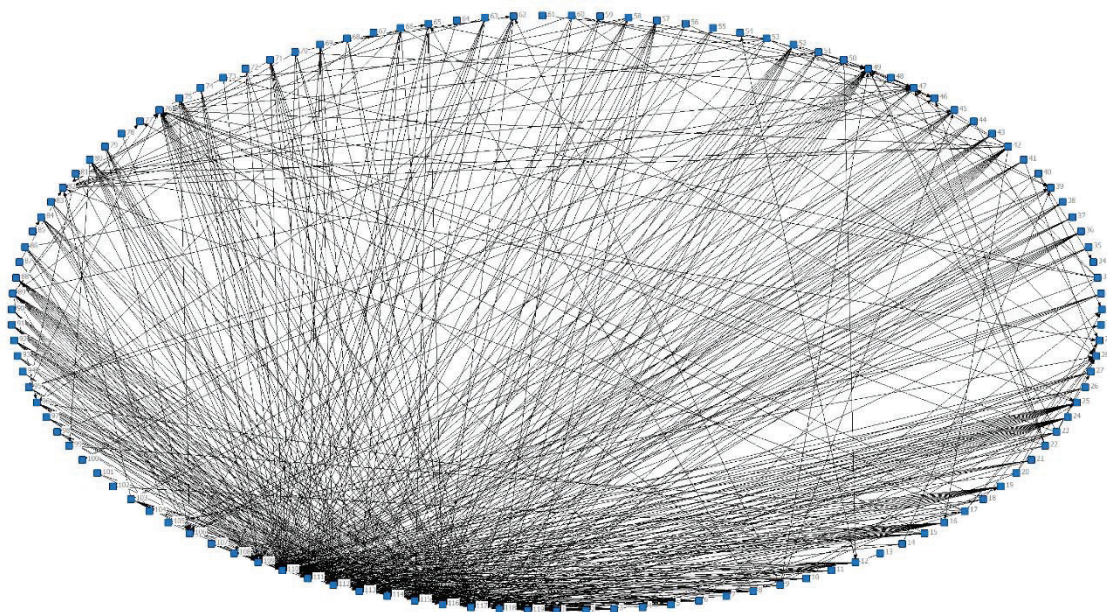
	Firms in Yokokai			Firms in Kyohokai		
	Total	Firms connected with each other	Singleton	Total	Firms connected with each other	Singleton
2004	188	91	97	215	122	93
2005	191	102	89	216	119	97
2006	190	98	92	213	120	93
2007	189	85	104	213	112	101

A diagrammatic representation of the inter-firm transactional relationships of Toyota's Kyohokai and Mazda's Yokokai from 2004 to 2007 is illustrated in Figure 1 and Figure 2 respectively. The node means the firm, and the arc means the transaction.



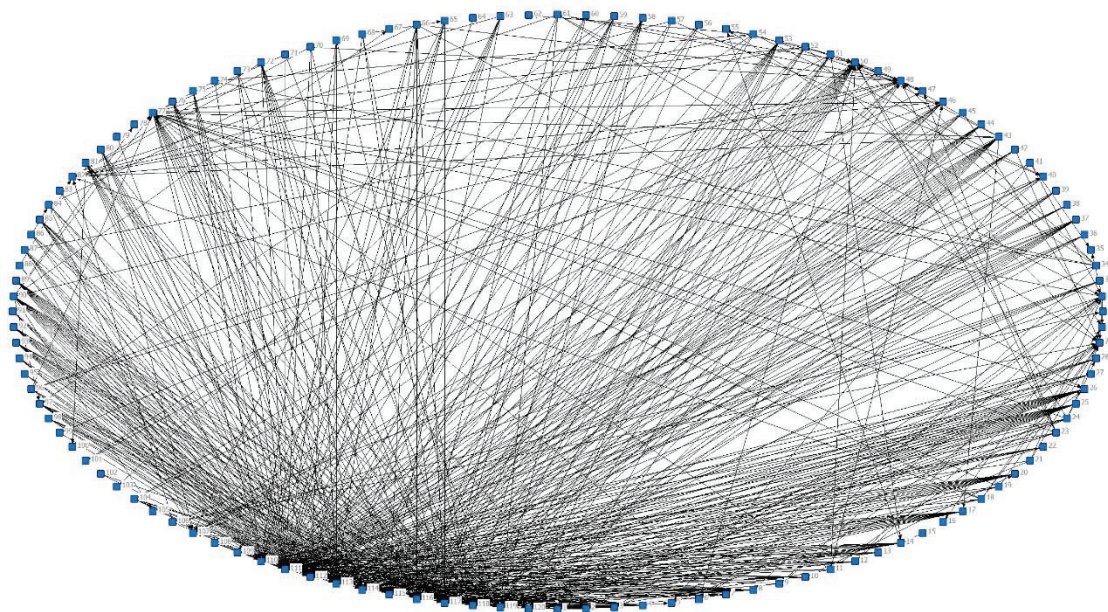


2004

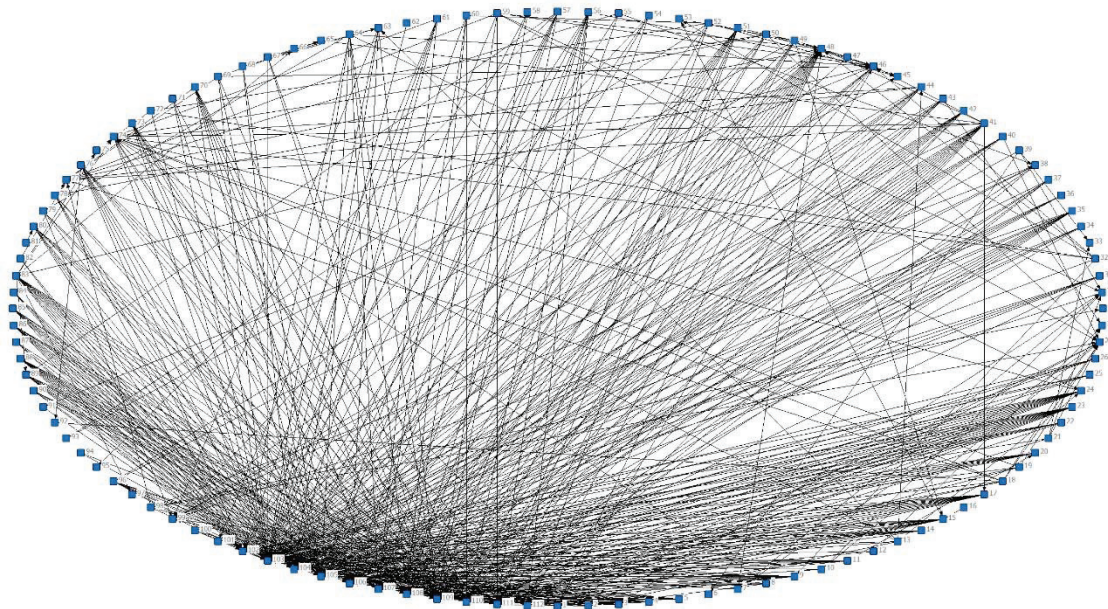


2005





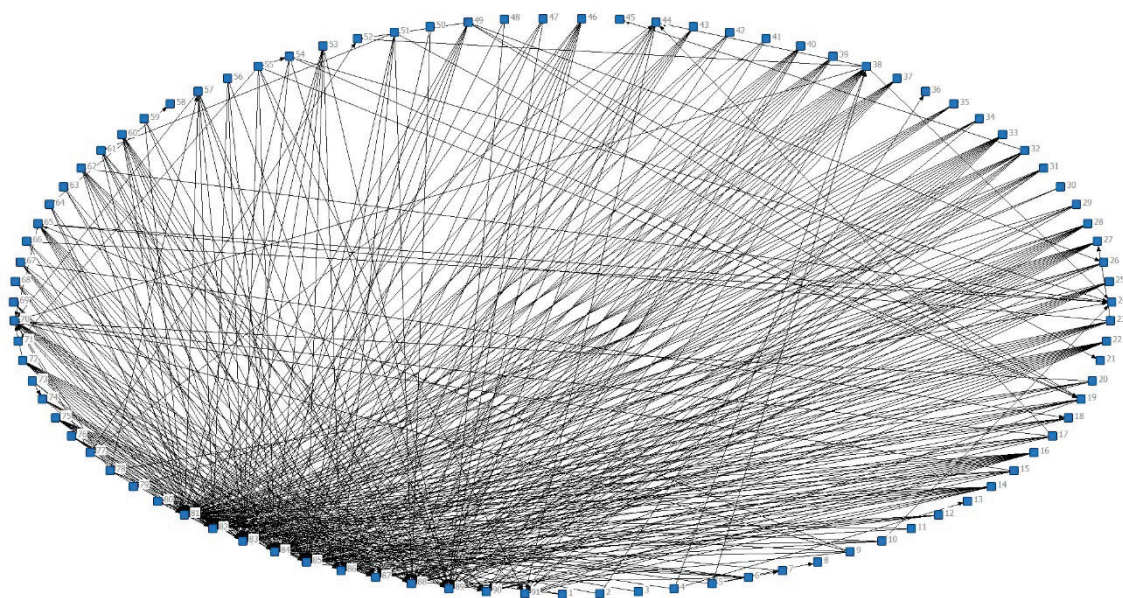
2006



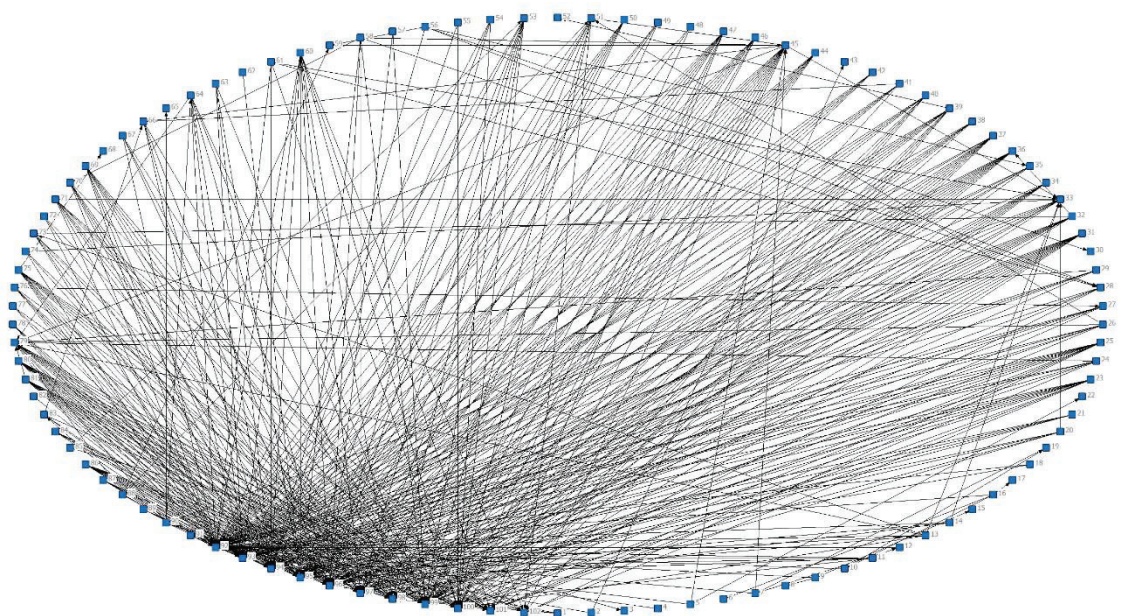
2007

Figure 1 Transaction Networks of Kyohokai from 2004 to 2007.



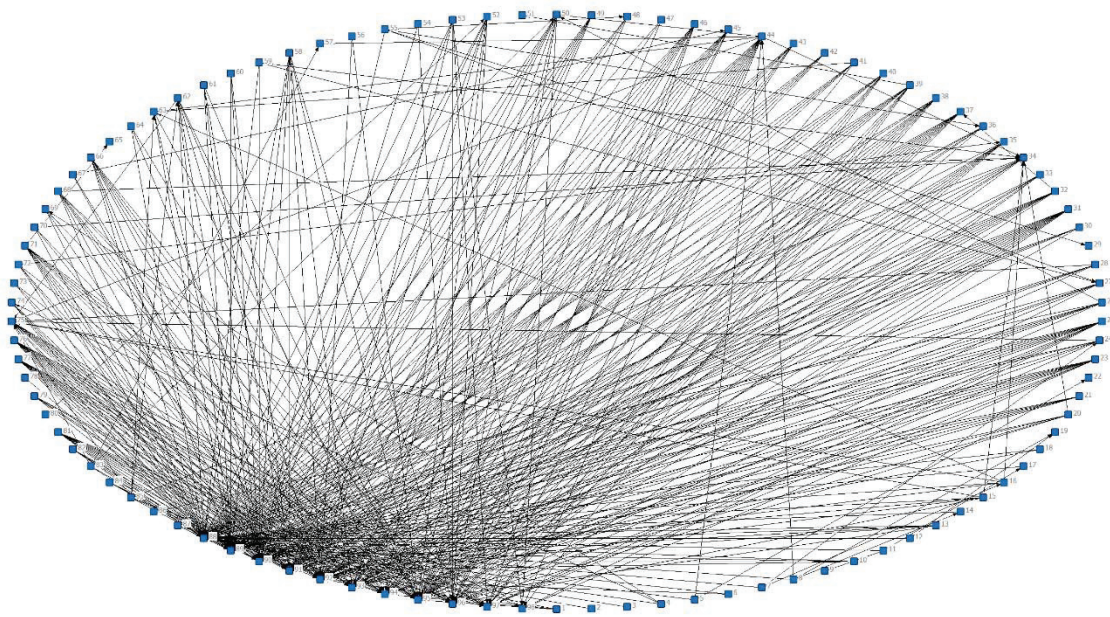


2004

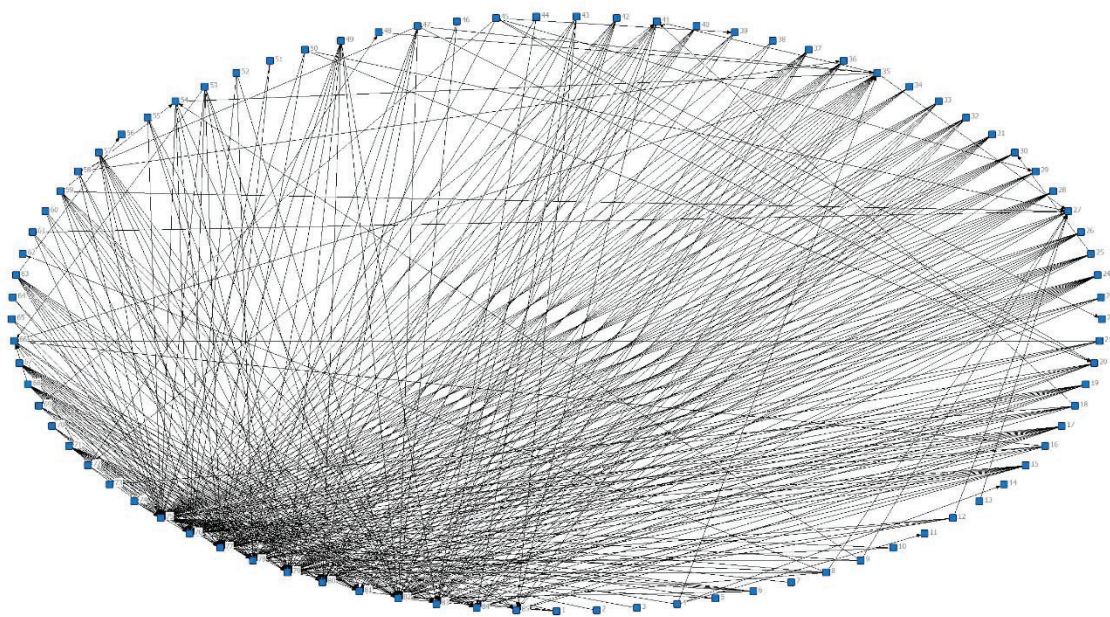


2005





2006



2007

Figure 2 Transaction Networks of Yokokai from 2004 to 2007.

The nodes express the firms and the connection line means the transactions between each peer firms.

I put all data in a matrix table. Table 2 shows the transactional data in Yokokai.



Table 2 Yokokai Network Matrix Data in 2006<sup>ii</sup> (Selected part).

	...	63	64	65	66	67	68	69	70	71	72	73	74	75	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
4	...	0	0	0	0	0	0	14.5	0	0	0	0	8.1	0	...
5	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
6	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
7	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
8	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
9	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
10	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
11	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
12	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
13	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
14	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
15	...	0	0	0	0	0	0	0	0	0	0	0	0	1	...
16	...	1.5	0	0	0	0	0	0	0	0	0	0	0	2	...
17	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
18	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
19	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
20	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
21	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
22	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
23	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
24	...	0	0	0	0	0	0	0	0	0	0	0	0	71.2	...
25	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
26	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
27	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
28	...	0	0	0	0	0	0	0	0	0	0	0	0	76.5	...
29	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
30	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
31	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
32	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...

Table 2 Yokokai Network Matrix Data in 2006 (Continued).

	...	63	64	65	66	67	68	69	70	71	72	73	74	75	...
33	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
34	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
35	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
36	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
37	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
38	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
39	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
40	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
41	...	5.5	0	0	0	0	0	0	0	0	0	0	0	0	...
42	...	0	0	0	0	0	0	0	0	0	0	0	0	0	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

In Table 2, the amount in  $(i, j)^{th}$  cell means the firm in  $i^{th}$  column sells parts to the firm in  $j^{th}$  row, or the firm in  $j^{th}$  row purchases parts from the firm in  $i^{th}$  row. For instance, Asmo Co., Ltd. (No. 24), a parts manufacturer of windshield wiper and power seat motor, sells its 71.2 percent parts to Denso (No. 75). As such, the cell between Asmo Co., Ltd. and Denso is 71.2 percent. In other words, Denso purchases parts from Asmo Co., Ltd. and it occupy 71.2 percent of Asmo Co., Ltd.'s total sales revenue.

In an asymmetric network, two indexes of out-degree and in-degree should be calculated. In transactional network, the value of degree is the percentage of transaction of parts maker  $i$  with any other firms. Accordingly, out-degree means parts maker  $i$  sells parts to other firm  $j$  and/or auto makers, and in-degree refers to parts maker  $i$  purchases parts from other firm  $k$  and/or auto makers. For instance, NSK Ltd. (44), an enterprise specializing producing bearing, purchases parts of anti-vibration rubber from Kurashiki Kako Co., Ltd. (5), and sells its products to auto makers, such as Mazda (88) and Toyota (89). Therefore, out-degree is associated with sales revenue while in-degree is associated with sales revenue indirectly. Thus, selling parts to keiretsu members will increase sales revenues while buying parts from other firms in the same keiretsu will be associated with greater sales revenue indirectly. Accordingly, the following hypotheses are posited.

H1: *Higher levels of out-degree is associated with increased sales revenue.*

H2: *Higher levels of in-degree is associated with increased sales revenue.*

Fragility could be considered as a concept of structural importance. High fragility means the entire degree after moving a specific node  $i$  is larger than the entire degree. Node  $i$  is a weak point if the entire degree after moving the node  $i$  is larger than the entire degree including the node  $i$ . Therefore, if a member of the keiretsu, which is considered to be vulnerable, is removed from the constellation, the value of degree of the keiretsu is reduced, which, in turn, can negatively impact sales revenues. Thus, the following hypothesis is proposed:

*H3: Higher levels of fragility is associated with lower sales revenue.*

## **2.4 Results and Discussions**

The results of degree and fragility and the relationship between degree and sales revenue, and fragility and sales revenue will be discussed.

### **2.4.1 Sales Revenue and Out-degree and In-degree**

Using regression model, the relationship between out-degree and in-degree as determinants of sales revenue has been tested. The results of out-degree-sales revenue and in-degree-sales revenue regression models is shown in Table 3. Table 3 shows the results of regression models between out-degree, in-degree and sales revenue of Yokokai and Kyohokai from 2004 to 2007. Out-degree and in-degree are the explanatory variables of sales revenue, a description variable in the model.

Table 3 shows that all Partial regression coefficients of in-degree are statistically significant while out-degree are not significant except for Kyohokai in 2004. Thus, evidently in-degree has a statistically significant impact on sales revenue. In contrasting the results of Yokokai, the correlation coefficients as well as the coefficients of determination are higher. Thus, it can be inferred that the regression model of Kyohokai has stronger power to explain the relationship between in-degree and corporate performance—as measured by sales revenue. Hence, the results with regard to H1 show that there is no association between out-degree and sales revenues. However, H2 is verified because there is a strong association between sales revenue and in-degree. Specifically, Table 3 indicates that the difference between Yokokai and Kyohokai looks similar, but different in-degree.

### **2.4.2 Sales Revenue and Fragility**

Fragility can also help distinguish the difference between Yokokai and Kyohokai. The results of fragility-sales revenue regression model is shown in Table 4.

Table 3 Results of Out-degree and In-degree-Sales Revenue Regression Model.

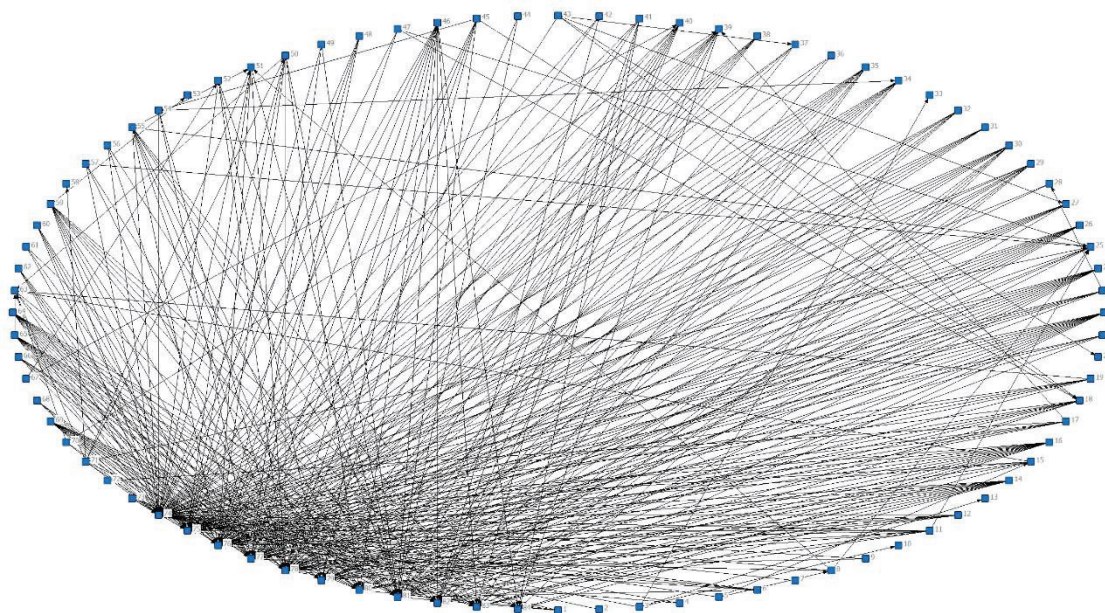
	Models							
	Yokokai				Kyohokai			
	2004	2005	2006	2007	2004	2005	2006	2007
Out-degree regression								
Partial coefficient	5153.17	1724.58	-8079.95	-15695.40	-7537.79	-4468.46	-3779.68	-3619.42
Standard coefficient	0.06	0.09	-0.10	-0.14	0.11	-0.06	-0.05	-0.04
t value	0.86	1.50	-1.04	-1.60	-2.75	-1.55	-1.27	-0.98
Probability	0.39	0.14	0.30	0.11	0.01	0.12	0.21	0.33
Correlation coefficient	-0.49	-0.39	-0.43	-0.32	-0.47	-0.44	-0.44	-0.45
Partial correlation coefficient	0.10	0.16	-0.12	-0.81	-0.26	-0.16	-0.13	-0.10
In-degree regression								
Partial coefficient	14162.85	7124.583	9322.69	20726.5	6465.41	8166.00	9597.79	11958.24
Standard coefficient	0.90	0.92	0.65	0.61	0.87	0.91	0.92	0.92
t value	11.97	15.26	6.99	6.78	21.16	22.54	24.73	23.34
Probability	0	0	0	0	0	0	0	0
Correlation coefficient	0.86	0.86	0.70	0.66	0.92	0.92	0.94	0.94
Partial correlation coefficient	0.81	0.86	0.61	0.62	0.90	0.90	0.93	0.92
Coefficient of determination	0.74	0.77	0.49	0.45	0.85	0.87	0.89	0.88
Multiple correlation coefficient	0.86	0.88	0.70	0.67	0.92	0.94	0.94	0.94
F value	106.36	144.16	39.15	29.67	303.04	338.40	390.61	352.49
Degree of freedom	2, 76	2, 85	2, 81	2, 73	2, 103	2, 97	2, 99	2, 93
AIC	2441.18	2706.92	2678.46	2466.46	3182.65	3007.13	3078.19	2929.59
DW ratio	1.93	1.65	2.57	2.47	1.56	1.51	1.44	1.38
Data number	79	88	84	76	106	100	102	96

Table 4 Results of Fragility-Sales Revenue Regression Model.

Sales	Models							
	Yokokai				Kyohokai			
	2004	2005	2006	2007	2004	2005	2006	2007
Fragility regression coefficient	13520895	1855419	87330.97	4931913	-19942684.1	-22446825.7	-26007968.4	-29733934.04
Standard coefficient	0.1537	0.031	0.0025	0.1061	-0.7684	-0.7656	-0.7752	-0.7798
t value	1.4505	0.2992	0.0236	0.9481	12.2438	-11.7819	-12.2705	-12.0763
Probability	0.1505	0.7655	0.9812	0.346	0	0	0	0
Correlation coefficient	0.1537	0.031	0.0025	0.1061	-0.7684	-0.7656	-0.7752	-0.7798
Partial correlation coefficient	0.1537	0.031	0.0025	0.1061	-0.7684	-0.7656	-0.7752	-0.7798
Coefficient of determination (R <sup>2</sup> )	0.02361	0.00096	0.00001	0.01125	0.59041	0.58617	0.6009	0.60807
Multiple correlation coefficient	0.15367	0.03101	0.00252	0.10606	0.76838	0.76562	0.77518	0.77979
F value	2.10402	0.08951	0.00056	0.8984	149.9108	138.81668	150.56441	145.83724
Degree of freedom	1, 87	1, 93	1, 88	1, 79	1, 104	1, 98	1, 100	1, 94
AIC	2854.8	3055.21	2803.2	2542.74	3290.54	3124.56	3205.68	3044.02
DW ratio	0.9059	0.9059	1.201	1.2807	0.9158	0.9119	0.8992	0.9052
Data number	89	95	90	81	106	100	102	96

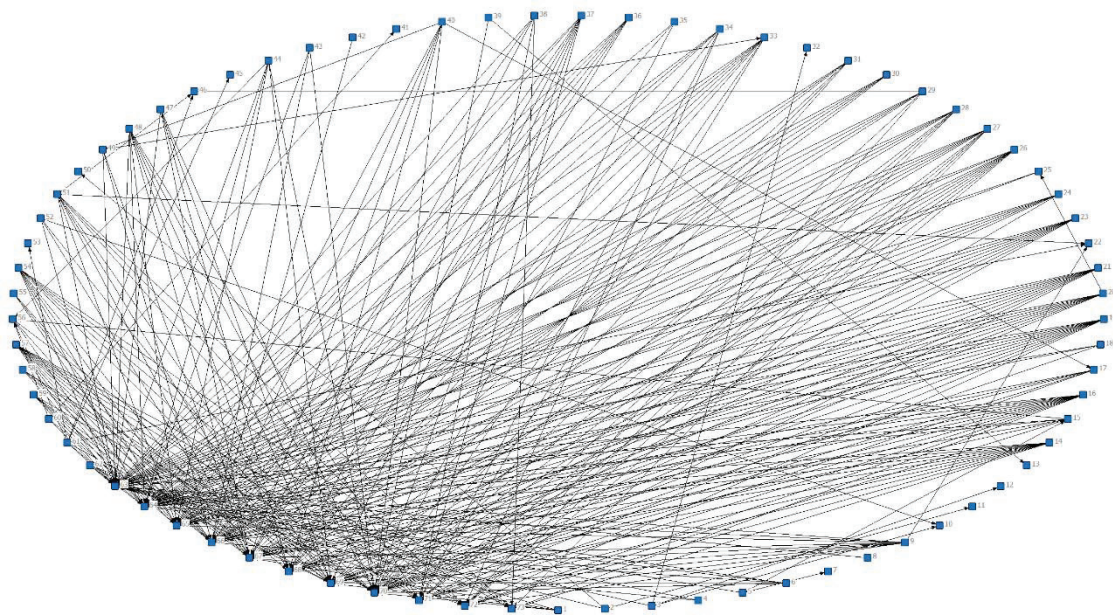
Table 4 shows that compared with Yokokai, all the partial regression coefficients of fragility in Kyohokai from 2004 to 2007 are statistically significant, and coefficients of determination are higher. Thus, the model assumptions of Kyohokai hold, which confirms H3. However, the findings with regard to Yokokai are opposite. Specifically, the linkage between fragility and sales revenues is not verified in the four years. This is because, all correlation coefficients are negative. Thus, the assumption of higher fragility having an inverse association with sales revenue is partly confirmed. Because the meaning of fragility denotes the value of entire degree of a given network after removing a specific node, it is evident that firms in Kyohokai have a higher possibility to improve sales revenue. Conversely, all correlation coefficients in Mazda are positive means that lower fragility is associated with lower sales revenue—opposite results compared with that of Yokokai. However, as the probabilities of each year are larger than 0.05, additional longitudinal data should be collected.

I collected the data of Mazda's Yokokai from 2008 to 2012 in order to ascertain the relationship between fragility and sales revenue. The inter-firm transactional relationships of Mazda's Yokokai from 2008 to 2012 is illustrated in Figure 3.

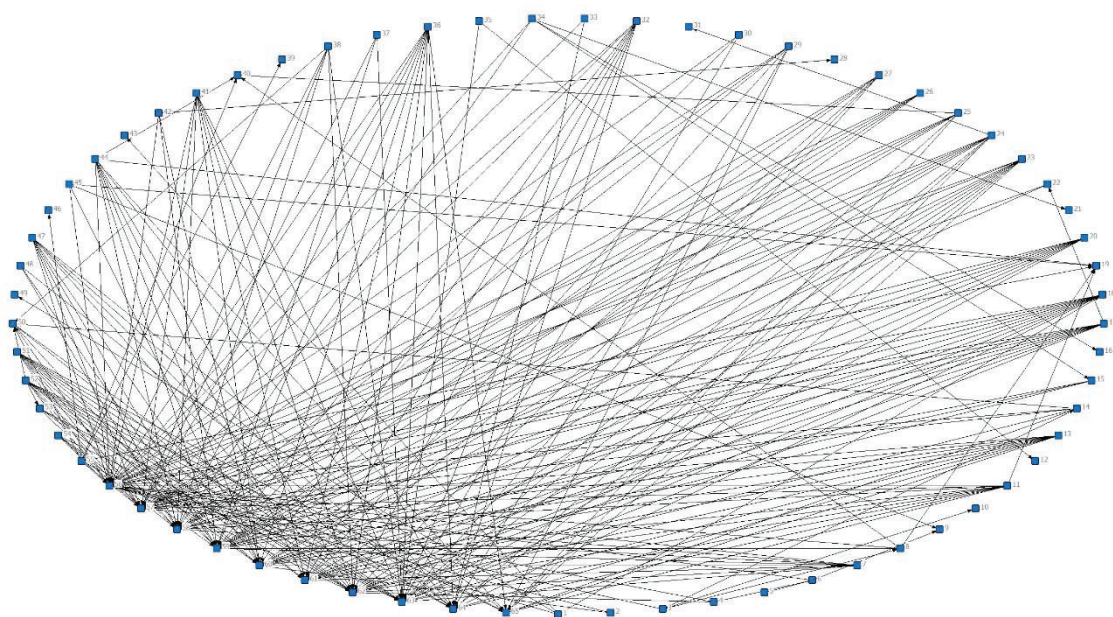


2008





2010



2011

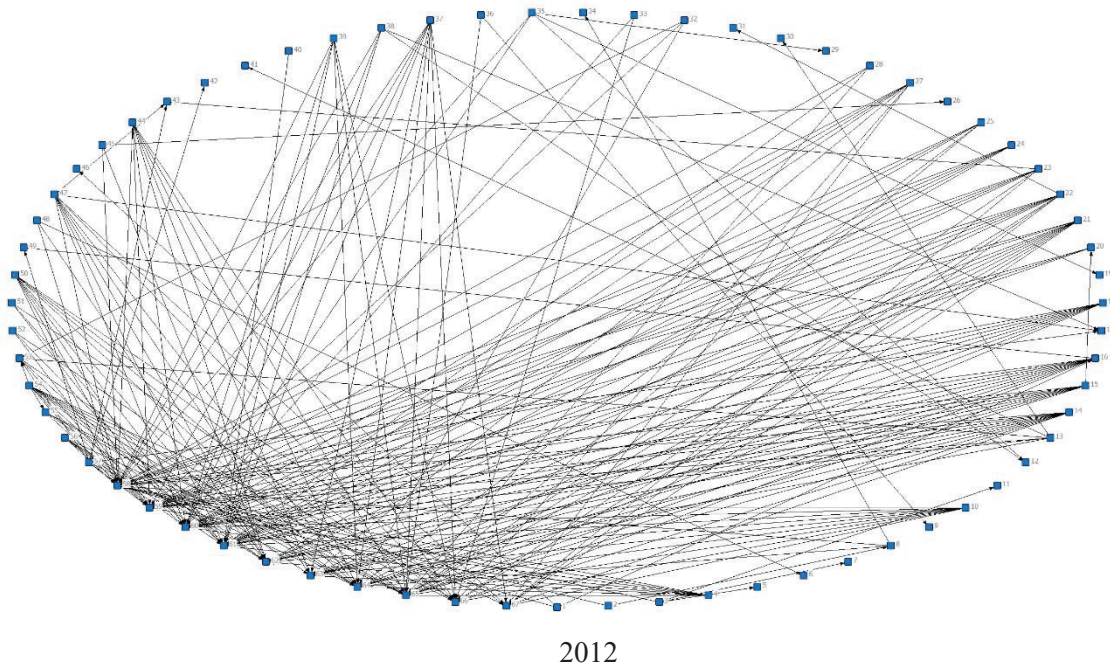


Figure 3 Transaction Networks of Yokokai from 2008 to 2012.

The results of fragility of Kyohokai and Yokokai in 2007 are illustrated in Figure 4 and Figure 5 respectively.

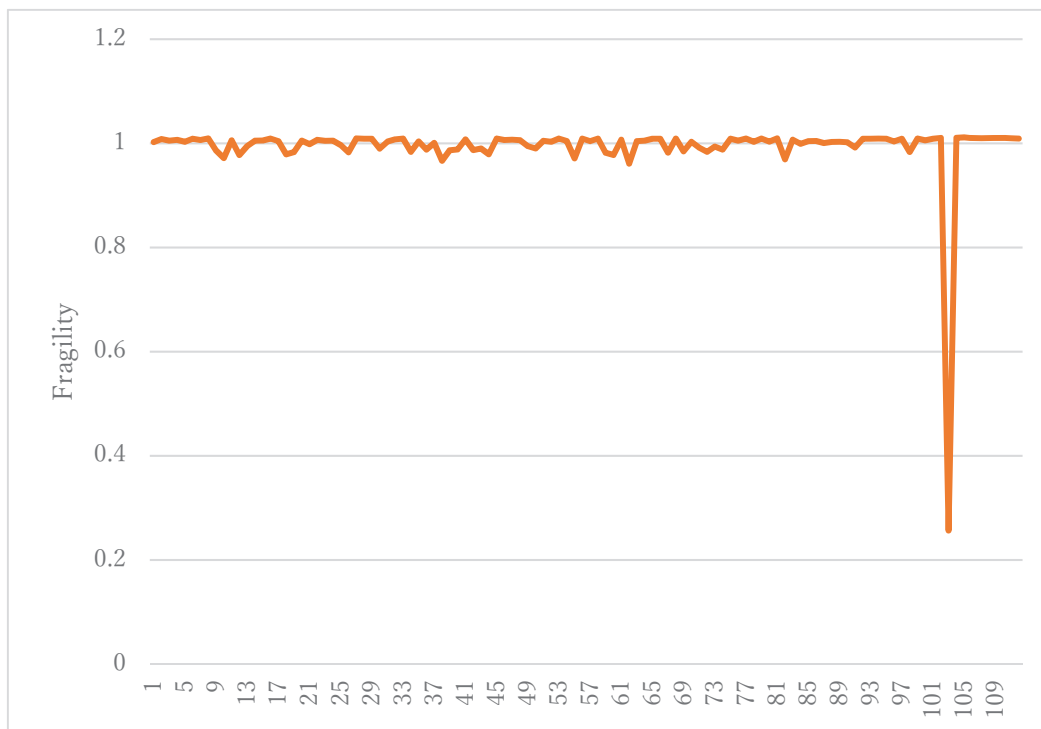


Figure 4 Fragility of Each Firm in Kyohokai in 2007<sup>iii</sup>.



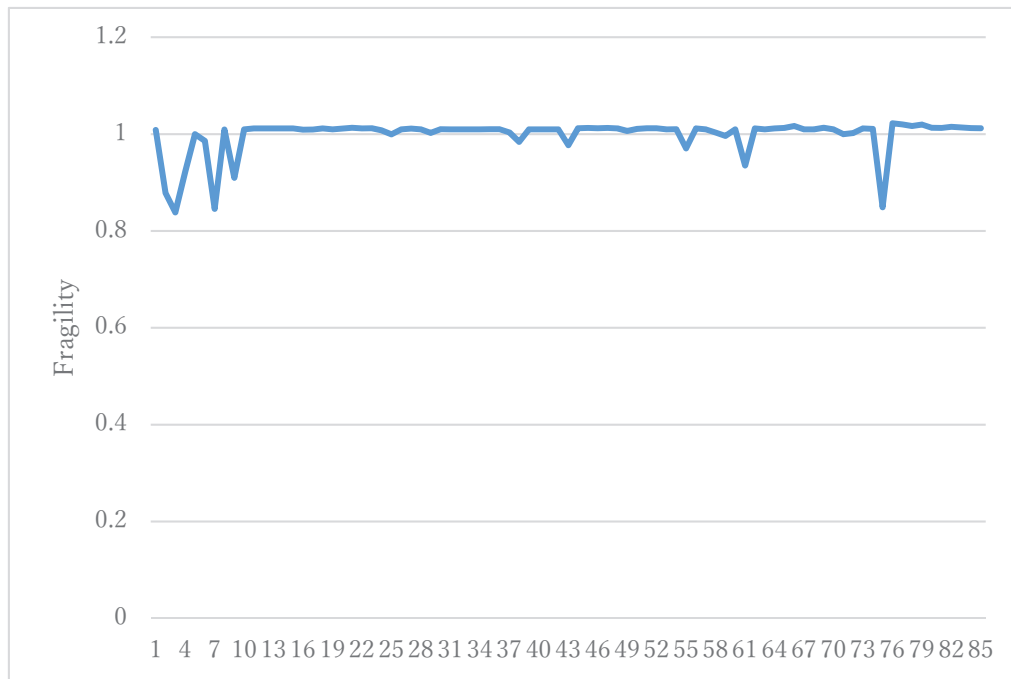


Figure 5 Fragility of Each Firm in Yokokai in 2007<sup>iv</sup>.

The results of fragility-sales revenue regression model is shown in Table 5.

Table 5 Results of Fragility-Sales Revenue Regression Model.

Sales	Yokokai			
	2008	2010	2011	2012
Fragility				
Partial regression coefficient	36725652	-30370337.71	10712384	33495932
Standard coefficient	0.2243	-0.3476	0.158	0.2894
t value	2.0195	-2.9426	1.2292	2.3417
Probability	0.0469	0.0046	0.2239	0.0225
Correlation coefficient	0.2243	-0.3476	0.158	0.2894
Partial correlation coefficient	0.2243	-0.3476	0.158	0.2894
Coefficient of determination	0.0503	0.12084	0.02497	0.08374
Multiple correlation coefficient	0.22428	0.34761	0.15801	0.28938
F value	4.07822	8.65899	1.51084	5.48348
Degree of freedom	1, 77	1, 63	1, 59	1, 60
AIC	2603.01	2104.51	1988.82	2013.82
DW ratio	0.9757	0.8766	0.8716	0.9026
Data number	79	65	61	62

All partial regression coefficients of the models from 2008 to 2012 are positive except 2010. It means that “higher fragility, higher sales revenue” holds, which show different behavior compared that in Toyota’s Kyohokai. This is consistent with the results of fragility from 2004 to 2007. Accordingly, different behaviors in different keiretsus holds. Fragility is a different approach compared with degree, because degree stresses the strength of connections, but fragility emphasizes the brittleness of connections. In addition, it will be impossible to get such conclusion between Mazda and Toyota if degree index are used. This will be considered as new contribution of this chapter.

## 2.5 Management Implications

Degree is an index to express the number of deals in transactional network, while fragility is an index reflecting the impact on the whole network. Accordingly, one important thing should not be ignored is that degree and fragility have different impact on corporate performance respectively. In other word, corporate performance could be improved based on “higher fragility, lower sales revenue”.

The results of fragility of Mazda and Toyota in Kyohokai and Yokokai are shown in Figure 6 and Figure 7.

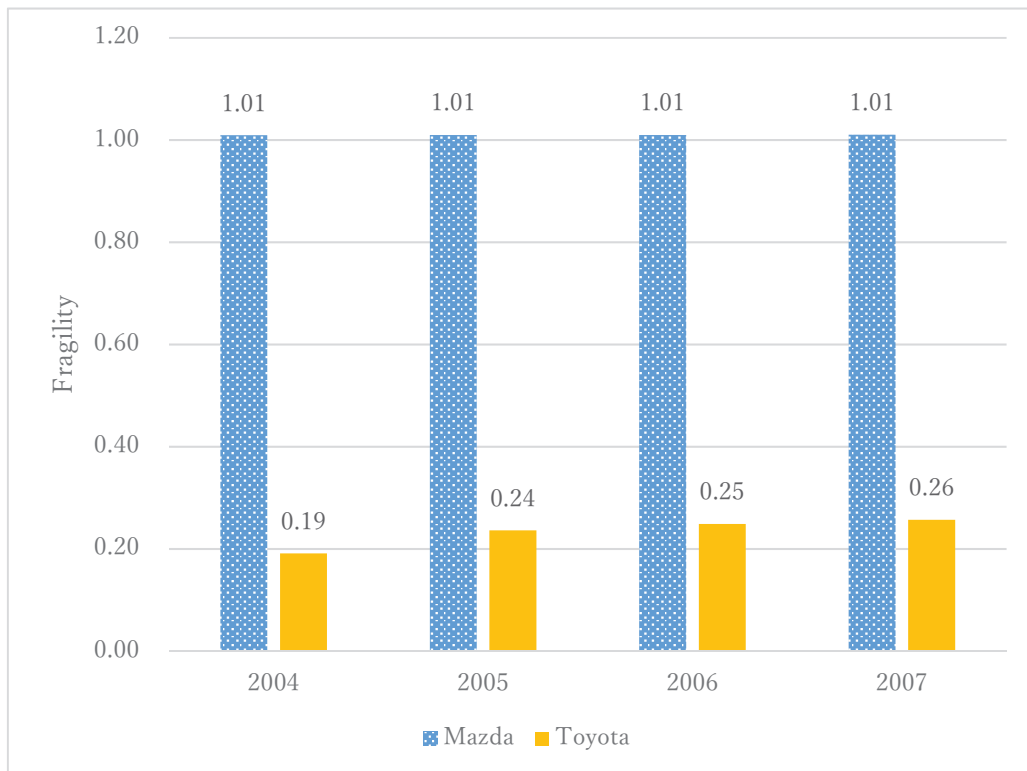


Figure 6 Fragility of Mazda and Toyota in Kyohokai from 2004 to 2007.

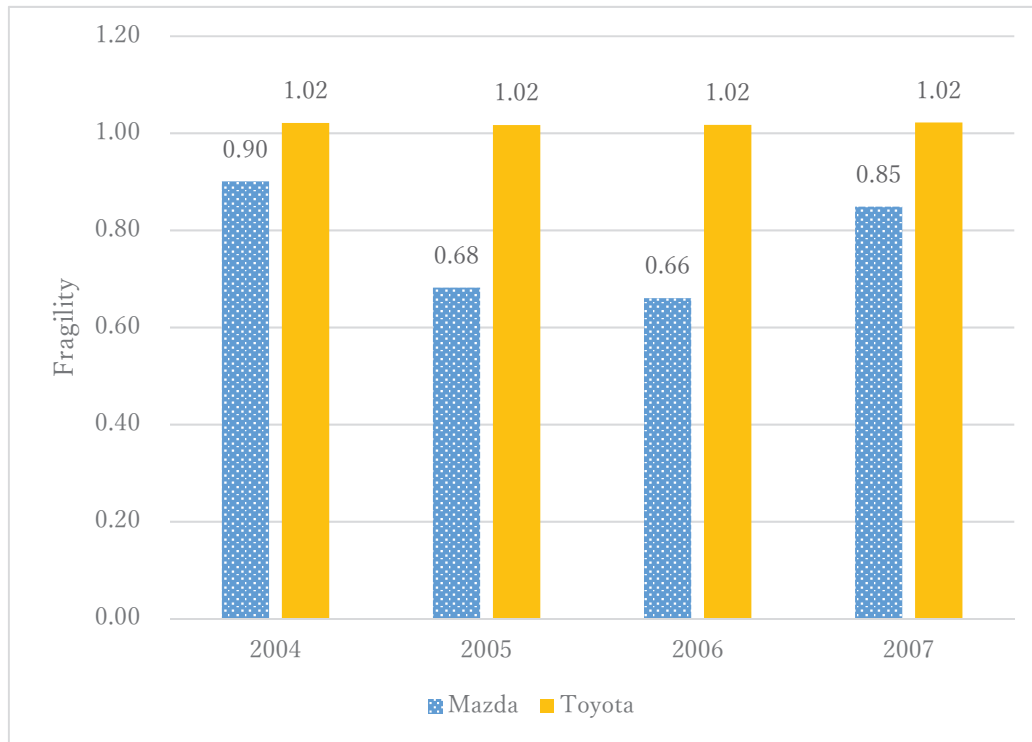


Figure 7 Fragility of Mazda and Toyota in Yokokai from 2004 to 2007.

Obviously the fragility of Toyota is low in Kyohokai and high in Yokokai. It means that the position of Toyota is strong in Kyohokai but weak in Yokokai. Compared with Toyota, the fragility of Mazda is not very low even in Yokokai. This could be considered as the result of keiretsu loosening, consistent with the analysis of degree and fragility.

The partial regression coefficients in 2010 model is statistically significant. Based on “higher fragility, lower sales revenue”, Kokusan Buhin Kogyo and Toyoda Gosei can be compared. Those two companies are selected randomly because they are two typical companies. Table 6 shows the results of Kokusan Buhin Kogyo and Toyoda Gosei.

Table 6 Fragility and Degree of Kokusan Buhin Kogyo and Toyoda Gosei.

	Sales Revenue	Fragility
Kokusan Buhin Kogyo	5270	1.01535
Toyoda Gosei	495002	0.903538

Table 6 shows that “higher fragility, lower sales revenue” holds. Kokusan Buhin Kogyo has higher value of fragility, but lower sales revenue compared with Toyoda Gosei. Therefore, it will be an important thing to lower its fragility to improve its performance. Thus the managerial

meaning of fragility is to find the way to decrease its value for each firm. Lower value of fragility means to decrease the numerator in equation 2.

The basic implication of fragility is the structure importance. The node is called strength node if the centrality after removing the node is smaller than before, while the node is called weak node if the centrality after moving the node is bigger than before. The node with lower fragility means it is a strength node<sup>v</sup>.

However, different keiretsu will have different behavior based on the finding of our analysis. Accordingly, one important thing is that different behaviors in different keiretsus holds. In other word, even the strength node will be difficult to improve its performance if the group it belonging to is weak one.

## **2.6 Concluding Remarks**

Grounded in the review of the relevant literature, this chapter proposed a new approach called fragility to shed light on interfirm behaviors within network organizations known as keiretsu. Data were drawn from Yokokai in Mazda and Kyohokai in Toyota to ascertain the relationship between degree and fragility. The results look similar between both the keiretsu when investigate the relationships between degree and sales revenue. However, different behaviors are manifest when fragility is viewed as a determinant of sales revenue.

## **2.7 Directions for Future Research**

Based on the results obtained, four fiscal years of data is not sufficient to support contentions of internal validity. Because there is lack of support for H1, which posits a positive relationship between out-degree and sales revenue, additional research should be conducted to replicate the findings, thus shedding greater light on the real association between these constructs. In addition to degree, other centrality indexes, such as closeness and betweenness, should be tested as determinants of corporate performance. Furthermore, the original definition of fragility in Physics is a derivative of a mathematical function. Thus, in the future the models tested in this study should be investigated using data drawn from other settings, such as, information technology, and the ship-building industry for comparative research as well as replicating the findings of this study.

## **Chapter 3 Measuring Efficiencies using Dynamic Network-based DEA in Network Systems**

### **3.1 Introduction**

Finding newer methods of improving efficiency is a continuing endeavor of corporate management. Although numerous tools to measure efficiency have been developed, this chapter proposes a newer approach known as dynamic network-based Data Envelopment Analysis (DEA) as an even more effective tool for examining inter-firm relationships. This is because dynamic network-based DEA makes it possible to detect system-wide effects when marginal changes in related inter-firm phenomena occur. Thus, to advance knowledge in the area, this new approach has been tested using data drawn from Mazda's Yokokai keiretsu to reveal the impact that transactions among member firms in the network have on sales revenues. More specifically, this chapter makes a unique contribution by: (1) Developing a new DEA model based on network analysis, and (2) Finding its function in corporate strategy.

This chapter is structured as follows: Section 2 reviews the background and literature focusing on network analysis. In Section 3, the chapter utilizes a five-node network to illustrate the problem solving using conventional DEA model, and details the steps to resolve this issue. Section 4 explicates data collection procedures as well as calculates the efficiency of Yokokai, a typical network organization comprising the suppliers of Mazda, a globally known automotive manufacturer. In Section 5, the results are reported and discussed. Section 6 discusses management implications. The directions for further research are proffered in Section 7. In the final section, the conclusions are presented.

### **3.2 Background and Literature Review**

DEA refers to a linear programming methodology that measures the efficiency of multiple decision-making units (DMUs) when the production process shows a structure of multiple inputs and outputs [38]. Farrell proposed the original concept in 1957 [39] which became a popular approach after Charnes, Cooper and Rhodes applied linear programming to estimate an empirical production technology frontier in 1978 [40]. In noticing that DEA models treat DMUs as a "black box", Lewis and Sexton developed a novel approach that illustrated DMUs that consist of a network of Sub-DMUs some of which consume resources produced by other Sub-DMUs whereas others produce resources consumed by other Sub-DMUs [41]. Extending the work of previous

scholars [42-45], Chang, Tone, and Wu proposed a new system of DEA models that incorporate a DMU's uncertain future performance because past results are not sufficient for practically evaluating a DMU's performance in highly volatile operating environments [46]. Concurrently, many statistical packages that can be used to measure efficiency are available. Of these, the DEA provides a practical way to assess performance and relative efficiency issues using a linear programming-based method. For instance, DEA was applied to investigate the efficiency of banks in transition by Boris and Igor [47], and a simultaneous analysis of the interrelationships among economic growth, environmental pollution and energy consumption was reported by Christina and George [48]. These approaches obviously are effective and significant. However, an implicit understanding is that all multiple DMUs are independent of each other. However, in reality, many firms are connected to each other as affiliates. Because a keiretsu is a manifestation of a typical affiliated organization, it necessitates viewing it as a network. This perspective to develop DEA from network viewpoint is not new; in fact, several studies on DEA have been published. For example, Liu and Lu developed network-based approach in applying one measure of the centrality—known as eigenvalue—to discriminate efficient decision-making organizations as determined by standard DEA [49]. Chen indicated the importance of the intermediate outputs consumed by one sub DMU and suggested a network-DEA model with new efficiency measures to systematically cope with the dynamic effect within a production network [50]. Tone and Tsutsui advocated a slacks-based network DEA model because intermediate products or linking activities in traditional DEA models were neglected [51]. All these approaches try to solve network issues applying standard DEA. However, this research focuses on systemic changes in network systems to propose a new approach for calculating efficiency within a constellation of firms because systemic changes have strong impact on efficiencies calculation.

### **3.3 Dynamic network-based DEA**

The level of transactions as well as cross shareholdings reflect facets of key connections and extent of how close inter-firm relationships are among members of any typical keiretsu. Another manifestation of the degree of close ties among partner-members of a network is interactive influence, which refers to successive powers of networks since they enumerate the number of possible connections of given length between all pairs of firms. Although input and output data can be considered independently and separately, DEA also allows the data to be interchanged freely. Thus, this characteristic makes DEA especially appealing and appropriate for studying the interrelationships among members of a keiretsu. This is because it is widely recognized that the interrelationships among real world phenomena are interconnected such that it is possible to determine how even a marginal change in one variable can dramatically alter the nature of the entire network system. In short, with DEA it is feasible to detect systemic effects due to

interrelated factorial changes, which can be illustrated using an example.

A diagrammatic representation among members of a small network—as shown in Figure 8—reveals an asymmetric group of interconnected firms composed of five nodes.

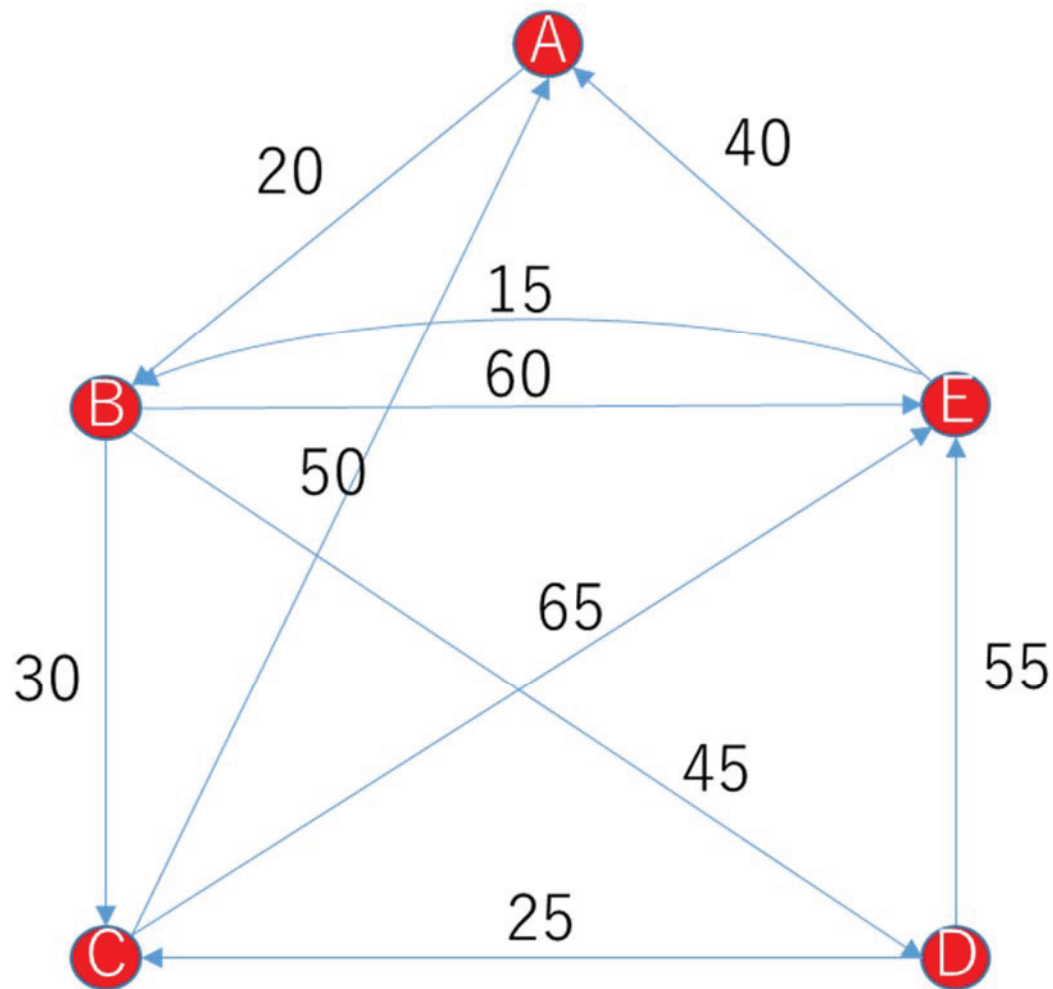


Figure 8 An Example of Five-node Network.

A node may be represented by a human, computer or firm, whereas the arc reflects friendship, internet connections, or transactions. The input and output data shown in Table 7 is based on the supposition that the node represents a company, while inputs and outputs reflect selling and purchasing transactions among keiretsu members.

For this network, it is possible to calculate the degree index. Degree can be divided into out-degree and in-degree in an asymmetric network. The results of out-degree and in-degree are shown in Table 8.

Table 7 Input and Output Data in Figure 8.

	A	B	C	D	E
A	0	20	0	0	0
B	0	0	30	45	60
C	50	0	0	0	65
D	0	0	25	0	55
E	40	15	0	0	0

Table 8 Results of Out-degree and In-degree in Figure 8.

	Out-degree	In-degree
A	20	90
B	135	35
C	115	55
D	80	45
E	55	180

Many types of the DEA have been developed; the most typical one is known as the Charnes-Cooper-Rhodes (CCR) model [40]. The generalized model of the CCR model is formulated as follows:

$$\max \quad \theta = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} = \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \quad (1)$$

Subject to

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad (j = 1, 2, \dots, n) \quad (2)$$

$$u_r \geq 0, \quad (r = 1, 2, \dots, s) \quad (3)$$

$$v_i \geq 0, \quad (i = 1, 2, \dots, m) \quad (4)$$

Suppose the sales revenue of the five firms are 100, 900, 250, 300, and 400 respectively. Thus, a model of two inputs including out-degree and in-degree and one output of sales revenue is formulated. Based on the calculation of the DEA model mentioned above, the following results



are obtained, which are reported in Table 9.

Table 9 Results of Efficiencies of Figure 8.

	Efficiency	Reference Set ( $\lambda$ )	Sx1	Sx2	Sy1	v1	v2	u1
A	0.688	E(0.250)	0	16.875	0.00	0.050	0	0.007
B	1	B(1.000)	0	00	0.00	0.007	0.000	0.001
C	0.324	B(0.256), E(0.049)	0	0	0.00	0.009	0.000	0.001
D	0.557	B(0.297), E(0.082)	0	0	0.00	0.012	0.000	0.002
E	1	E(1.000)	0	0	0.00	0.018	0	0.003
DMU:A(0.6875) Make input 0.6875 times. Remove in-degree (16.875). DMU:B(1.0000) Efficient. DMU:C(0.3239) Make input 0.3239 times. DMU:D(0.5574) Make input 0.5574 times. DMU:E(1.0000) Efficient.								

In Table 9, v1 and v2 represent out-degree and in-degree, respectively. Efficiency refers to efficiencies of each node. Thus, the efficiency of node A is 0.688, but it will be improved if the out-degree and in-degree of the input data are to change 0.6875 times, respectively.

After changing the out-degree and in-degree of node A from 20 and 90 to 13.75 and 61.875 respectively, the new results are revealed in Table 10, which shows that the efficiency of node A has been improved to 1.0.

However, an important aspect which should not be overlooked is that the other data still remain same even though out-degree and in-degree of node A have been changed. This result is seemingly inconsistent with the fact that whole system will change even if a small adjustment has transpired. Thus, the input data should be recalculated. Following this process, the altered results are shown in Table 11.

Table 10 New Results after changing the out-degree and in-degree  
of node A from 20 and 90 to 13.75 and 61.875.

	Efficiency	Reference Set ( $\lambda$ )	Sx1	Sx2	Sy1	v1	v2	u1
A	1	E(0.250)	0	16.875	0	0.073	0	0.010
B	1	B(1.000)	0	0	0	0.007	0.000	0.001
C	0.324	B(0.256), E(0.049)	0	0	0	0.009	0.000	0.001
D	0.557	B(0.297), E(0.082)	0	0	0	0.012	0.000	0.002
E	1	E(1.000)	0	0	0	0.018	0	0.003
DMU:A(1.0000) Make input 1.0000 times. Remove in-degree(16.875). DMU:B(1.0000) Efficient. DMU:C(0.3239) Make input 0.3239 times. DMU:D(0.5574) Make input 0.5574 times. DMU:E(1.0000) Efficient.								

Table 11 New Input and Output Data in Figure 8.

	A	B	C	D	E
A	0	<i>13.75</i>	0	0	0
B	0	0	30	45	60
C	<i>34.375</i>	0	0	0	65
D	0	0	25	0	55
E	<i>27.5</i>	15	0	0	0

Note: Italics are the modified data compared with Table 7.

Then the new altered out-degree and in-degree are shown in Table 12.

Table 12 New Results of Out-degree and In-degree in Figure 8.

	Out-degree	In-degree
A	<i>13.75</i>	<i>61.87590</i>
B	135	28.75
C	<i>99.375</i>	55
D	80	45
E	<i>42.5</i>	180

Note: Italics are the data changed compared with Table 8.

The results using the altered input data are depicted in Table 13.

Table 13 New Results of Efficiencies in Figure 8.

	Efficiency	Reference Set ( $\lambda$ )	Sx1	Sx2	Sy1	v1	v2	u1
A	0.773	E(0.250)	0	2.813	0	0.072	0	0.007
B	1	B(1.000)	0	0	0	0.007	0.000	0.001
C	0.365	B(0.246), E(0.072)	0	0	0	0.010	0.000	0.001
D	0.543	B(0.294), E(0.089)	0	0	0	0.011	0.001	0.002
E	1	E(1.000)	0	0	0	0.024	0	0.003
DMU:A(0.7727) Make input 0.7727 times. Remove in-degree (2.813). DMU:B(1.0000) Efficient. DMU:C(0.3646) Make input 0.3646 times. DMU:D(0.5431) Make input 0.5431 times. DMU:E(1.0000) Efficient.								

Basically the efficiency of the specific node should be 1.0, the most highest value of the efficiency. The efficiency of node A is 0.773, which is smaller than 1.0. This indicates that the DEA is not sufficiently suitable for detecting real systemic changes. Consequently, the DEA should be modified when it is used to measure efficiency. Thus, it is necessary to find the answer that makes the result of node A equals to 1.0. The best method is to employ a heuristic approach and calculate the input data at different levels because it is required to find the best solution. In our case, the efficiency of node A will be 1.0 if the input data are fixed at 45 percent (0.45). The results of the input data analysis are shown in Figure 9.

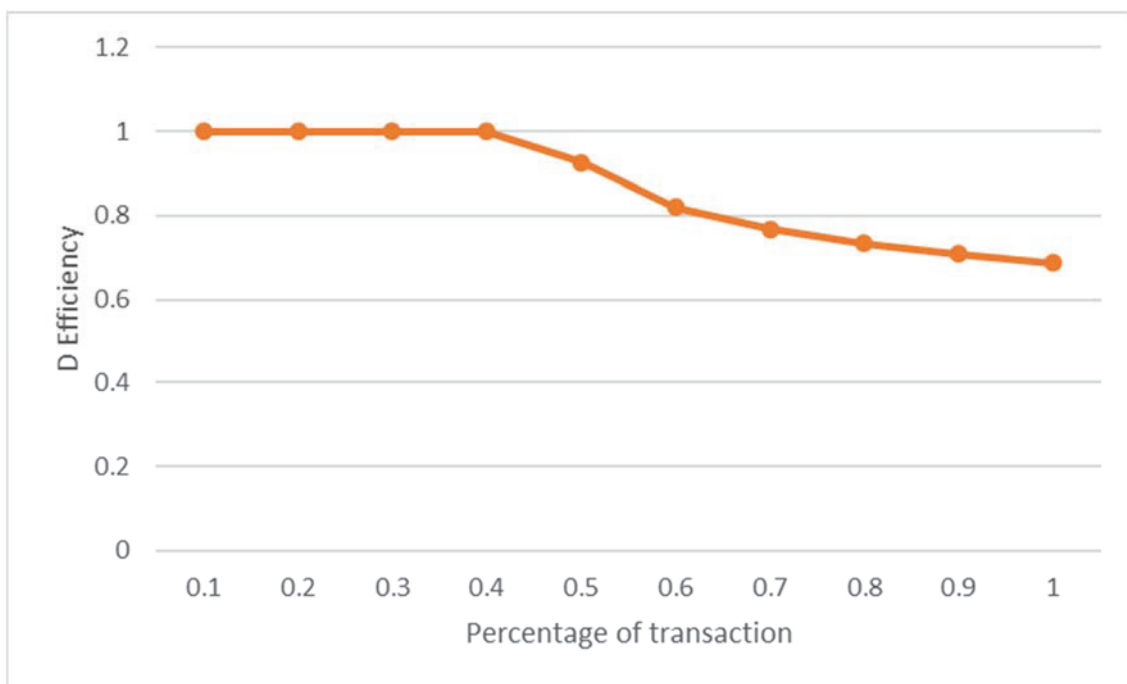


Figure 9 Heuristic Results of the Input Data at Different Levels.

The results are predicated on inputs that are difficult to adjust. Moreover, all firms are not necessarily completely efficient. Thus, setting the efficiency to 1.0 is an ideal objective. The DEA shows the reference set for improving efficiency, but does not provide any detailed directions for providing the optimal solution. Indeed, one of its drawbacks is that it treats the detailed information as a “black box.” However, a crucial issue is to identify the importance of each company that it has ties with for the purposes of strategy formulation.

Accordingly, this chapter proposes a new index, called efficiency criterion that is rooted in the relevant literature on dynamic network-based DEA. Therefore, the dynamic network-based DEA is a useful tool not only to calculate the efficiency, but also to identify the importance of the relationship in a given network system. Many approaches, such as incremental approach and

decremental approach, can be considered as useful tools.

Next, this chapter tests the new index known as the efficiency criterion to illustrate a detailed approach for Mazda's Yokokai using decremental approach. For illustration, I calculate the efficiency criterion using the data in Figure 8 before discussing its implications for Mazda's Yokokai.

A new approach for using the DEA called dynamic network-based DEA is suggested that it is specific applied to network systems in this chapter. The procedure of the dynamic network-based DEA is described next.

#### **Step 1: Building problem formulation.**

To determine the output and input data in a given network system. Figure 8 could be considered as one of the typical examples. The output data could be sales revenue, profit, and/or productivity, and the input data could be degree, closeeness, and/or any other network indices. The output data are out-degree and in-degree as shown in Table 8, and the input data is sales revenue in Figure 8.

#### **Step 2: Calculating Efficiencies.**

The efficiencies are calculated using conventional DEA model which was shown in Equations (1) - (4) in this Chapter. The solution, or reference set, for a selected node with lower efficiency can, thus, be found. Table 9 shows the example of the results of efficiencies calculaiton of Figure 8.

#### **Step 3: Recalculating Data Set.**

The input and/or output data should be recalculated based on the reference set using the network model as shown in Table 9 if the efficiency is not equal to 1.0. Table 11 and Table 12 show the new input and output data in Figure 8.

#### **Step 4: Recalculating Efficiencies.**

The efficiencies should be recalculated using the new data set calculated in Step 3. New results will be ascertained. Table 13 shows new results after changing the out-degree and in-degree of node A from 20 and 90 to 13.75 and 61.875 based on the fidnings of referense set.

#### **Step 5: Finding new results.**

The calculation will be completed if the answer of the efficiency of the selected node is 1.0; otherwise the answer should be ascertained by employing heuristic appraoch. Figure 9 illustrated the heuristic results using the input data including outdegree and indegree, and shows that the efficiency of node A will be 1.0 if the input data are fixed at 45 percent (0.45).

#### **Step 6: Determining the priority.**

Finally, it is necessary to calculate the difference scores and difference criterion to determine the priority of each node dealing with the selected node. The difference score is defined as the gap between the efficiencies of all nodes of its original system and the efficiencies of all nodes of the new system after changing certain amount when the solution is fixed at one selected transaction

between any two nodes. If the difference score is high, it means that the impact by changing the transaction amount is strong. Thus the difference score will be considered as an index that identifies the priority of efficiency improvement for each individual node.

Evidently, node A has three connections, node B, node C, and node E in Figure 8. The amount between node A and node B is 20. It means node A sells its 20 percent parts to node B. The efficiency of all nodes are calculated as shown in Table 14 after removing a certain amount, for instance, fifty percent from the total amount between node A and node B.

Table 14 Difference Score of the Transaction of Node A with Node B in Figure 8.

	Efficiency	Efficiency after Removing Certain Amount	Difference Score
A	0.688	1	0.312
B	1	1	0
C	0.324	0.321	-0.003
D	0.557	0.551	-0.006
E	1	0.928	-0.072

In Table 14, the value of efficiency of all nodes is computed using standard DEA modelling. The value of efficiency after removing 50% is the efficiency of all nodes calculated by removing a certain amount, say 50%--as it is in this example between node A and node B. Difference score is defined as the gap between “Efficiency” and “Efficiency after removing certain amount”. The efficiency has been improved if the value of the difference score is positive. The difference score of node A is 0.312. That indicates the efficiency will be improved if the transaction amount between node A and node B is decreased by 50%. The difference score of node B is zero. Accordingly, there is no impact on node B if the amount between node A and node B is reduced. Conversely, the efficiency will be decreased if the amount between node A and node B was decreased. Accordingly, the efficiency of node A will be improved if node A changes the transaction amount with node B.

The difference score of node A with node B, node C, and node E is shown in Figure 10.

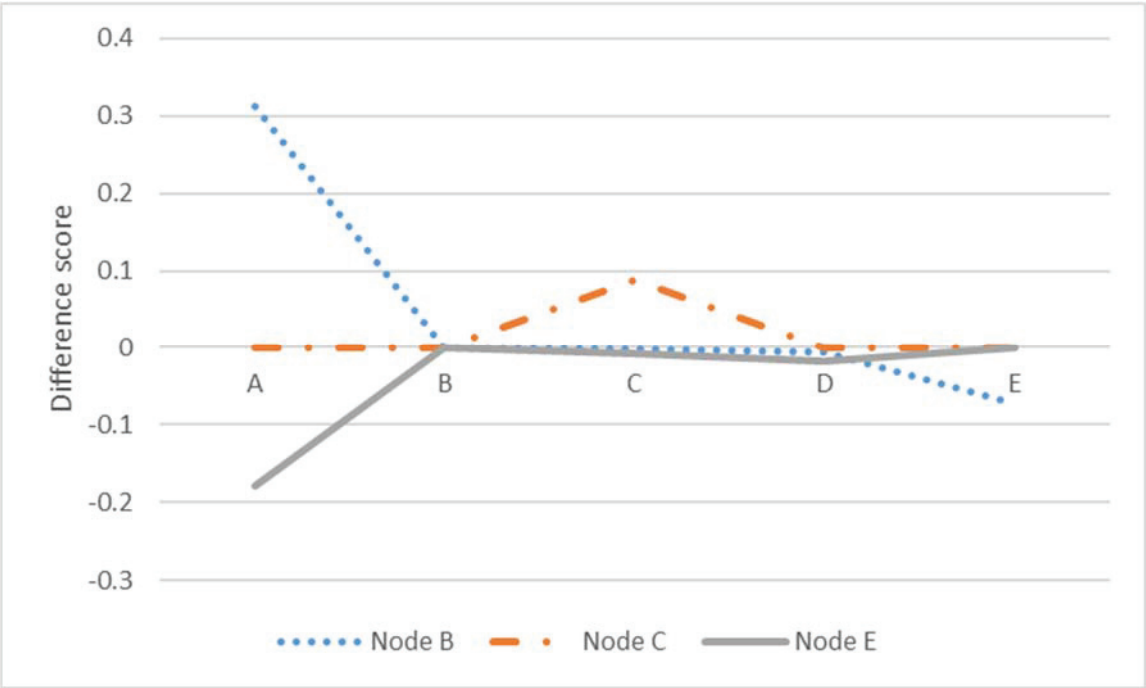


Figure 10 Difference Scores of Node A with Node B, Node C, and Node E.

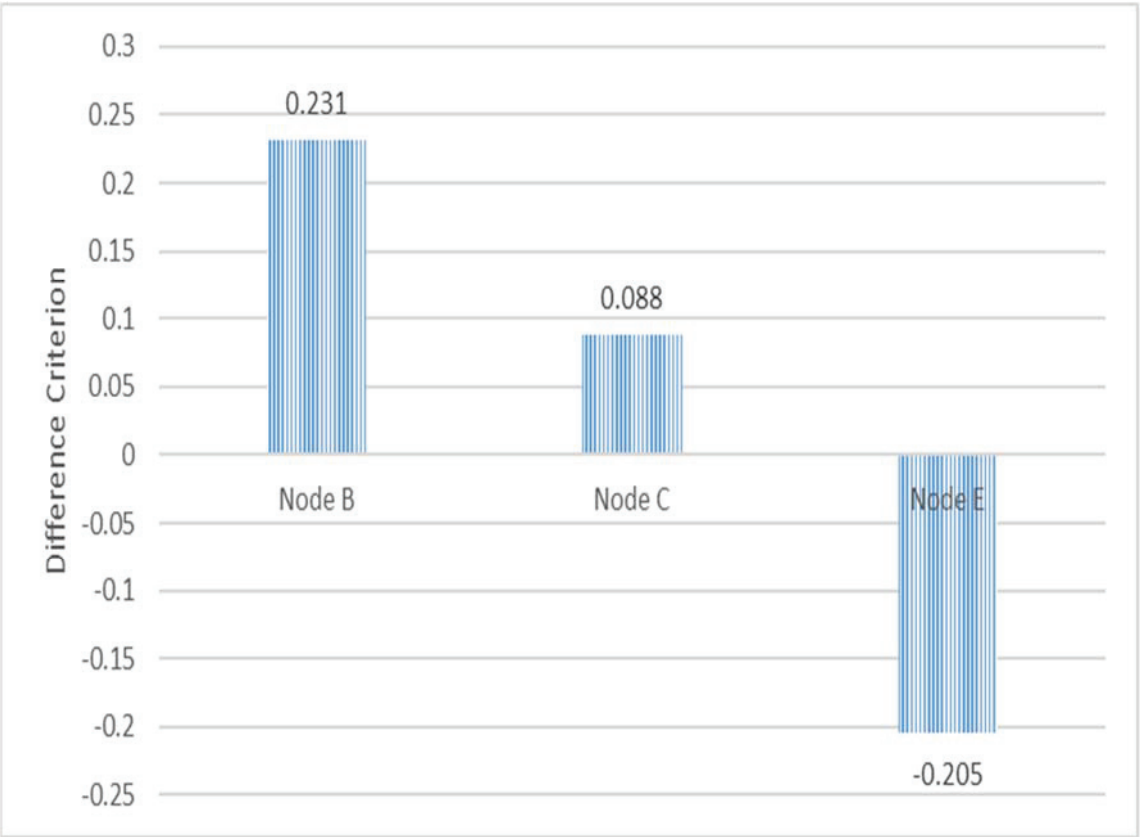


Figure 11 Difference Criteria of Node A with Node B, Node C, and Node E.



Essentially, the difference score indicates the impact of each transactional relationship between any two nodes. Accordingly, Figure 10 shows that the priority of node A for improving its efficiency is node B, node C and node E. In other words, the efficiency of node A will be improved (+0.312) if node A adjust its transactional amount with node B. One interesting thing is that the efficiency of node C, but not node A will be improved (+0.03) if node A change its transactional amount with node C. The reason could be considered as the structure position of node C is much stronger than that of node A. As such, the efficiency score can be considered as an index of the impact of the selected company. It reveals that as the efficiency score gets larger, its impact gets stronger<sup>vi</sup>.

The summation of the difference score, —called difference criterion— will be considered as an index that identifies the priority of efficiency improvement in whole network. The difference criterions of node A with node B, node C and node E are shown as in Figure 11.

Accordingly, the priority of node A for improving its efficiency is node B, and node C. Node E will be excluded because its value is negative.

### 3.4 Data Collection and Results

In order to study inter-firm relationships among keiretsu members, transaction data were obtained from Mazda's Yokokai, which represents a typical auto maker and parts-suppliers keiretsu to calculate the efficiency of each company [30-37]. It is noteworthy that the number of the firms dealing with Mazda is different year by year. The total number of the firms in Yokokai in 2004 was 188, but the total number of firms in Yokokai dealing with each other was 91. The transaction network of Yokokai in 2004 is illustrated as Figure 12.

The linkage between two firms is expressed as degree. Degree, including out-degree and in-degree, are calculated. Out-degree means that one company sells parts to other company, and in-degree means that one company purchases the parts from that same supplier firm. Degree is considered as the input data, and sales revenues are considered as the output data. The efficiency of all companies is shown in Figure 13. The detailed information is shown in Appendix 1.

Mazda's Yokokai is divided into two groups comprising suppliers and automotive manufacturers. In the group of suppliers, the top three companies are No.39, Pioneer Corporation, No.76, Matsushita Electric Industrial Co., Ltd., and No.45, Bosch Corporation. The efficiency of Pioneer Corporation and Matsushita Electric Industrial Co., Ltd. is 1.0. Moreover, the efficiency of Bosch Corporation is 0.954. Conversely, the efficiency of No.55 of Aisin AI Co., Ltd. and No. 21 of Jatco Ltd. are the lowest as they are 0.002 and 0.003, respectively. They are subsidiaries of Toyota, and the distance to Mazda is considered as long than other suppliers. In the group of auto makers, the highest value of efficiency is Toyota (0.01), and the lowest is Mazda (0.001). A possible reason of low rank of Mazda is that its performance was low in 2004.

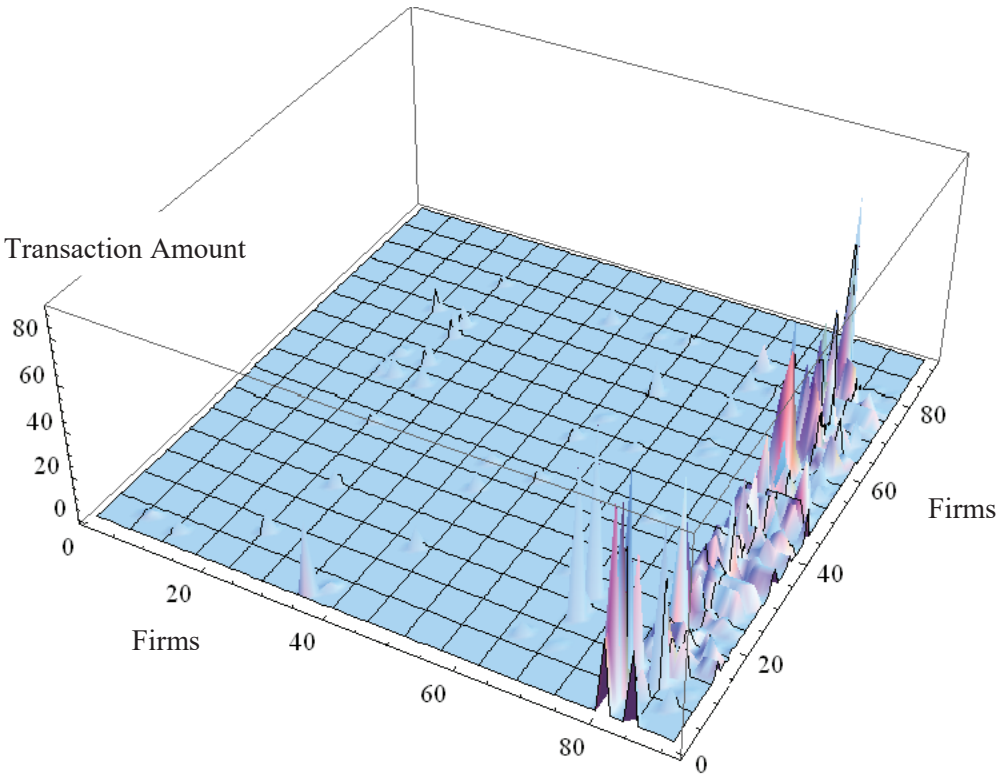


Figure 12 Transaction Network of Yokokai in 2004.

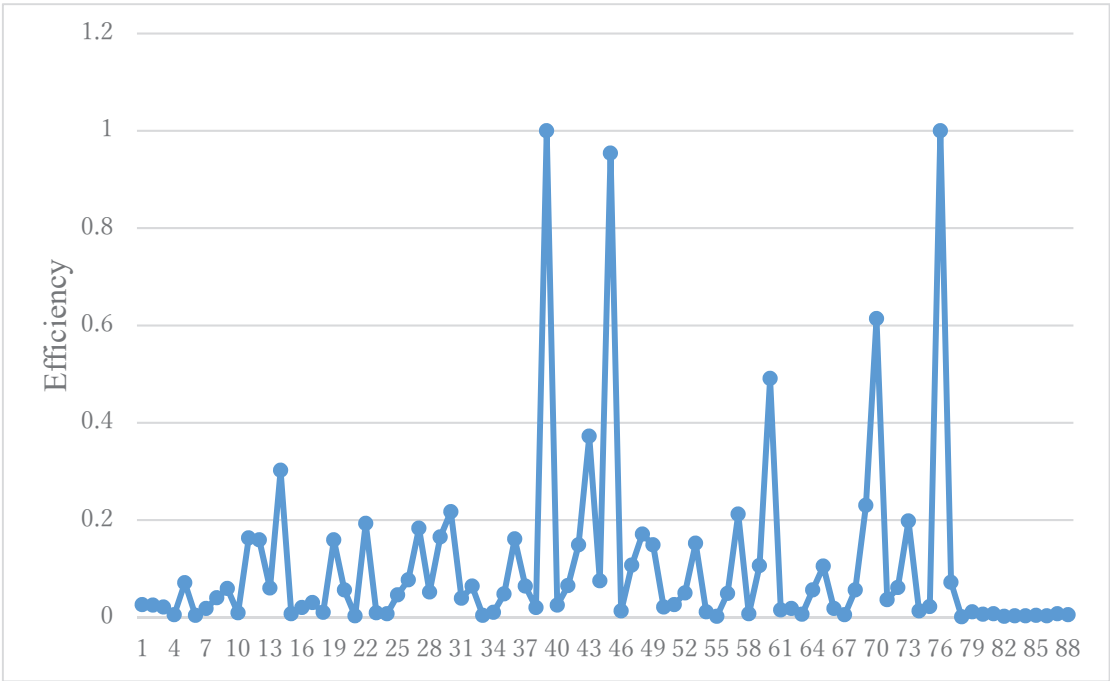


Figure 13 Efficiency of the Firms in Yokokai in 2004.

### 3.5 Analysis and Discussion

In order to find the detailed approach to improve a firm's efficiency, the efficiency of all firms in Yokokai need to be calculated. For example, to find the best solution for suppliers, Unipres is selected for illustrative purposes randomly. Unipres has strong relationship with Nissan. The primary business of Unipres, one of several Yokokai members, which was established in 1945, is manufacturing automotive and allied electronic parts that are sold not only to Mazda, but also non-keiretsu members, such as Nissan, Isuzu, Toyota and Jatco. Unipres even purchases parts from Yorozu Corporation, which manufactures automobile suspension systems. Both of Unipres and Yorozu are members of independent group of parts suppliers.

The efficiency of Unipres is 0.0261. From Figure 8 and Appendix 1, I can ascertain that the objective of Unipres is to improve its efficiency, which can be accomplished by changing its input data of out-degree and in-degree 0.0261 times, respectively. The efficiency of Unipres will be 0.996 when the input data are changed 0.0261 times.

Based upon Figure 8, Appendix 1, and the procedure of dynamic network-based DEA, the efficiency of Unipres is calculated. The value is 0.0258 if the efficiency of Unipres want to be 1.0. It means that the input data should be changed 0.0258 times.

To find the best solution of Unipres, the detailed transaction information in Yokokai in 2004 should be analyzed. It can be shown as Table 15 [30].

Table 15 Transaction of Unipres in Yokokai in 2004.

	To Unipres	From Unipres
Mazda	0	1.1
Calsonic Kansei	0	3.5
Jatco	0	10.8
Nissan	0	58.9
Isuzu	0	0.7
Yorozu	1.6	0

In Table 15, Unipres purchases the parts from Yorozu and sells its products to Mazda, Calsonic Kansai, Jatco, Nissan and Isuzu. Difference score of Unipres with other firms are revealed in Figure 14.

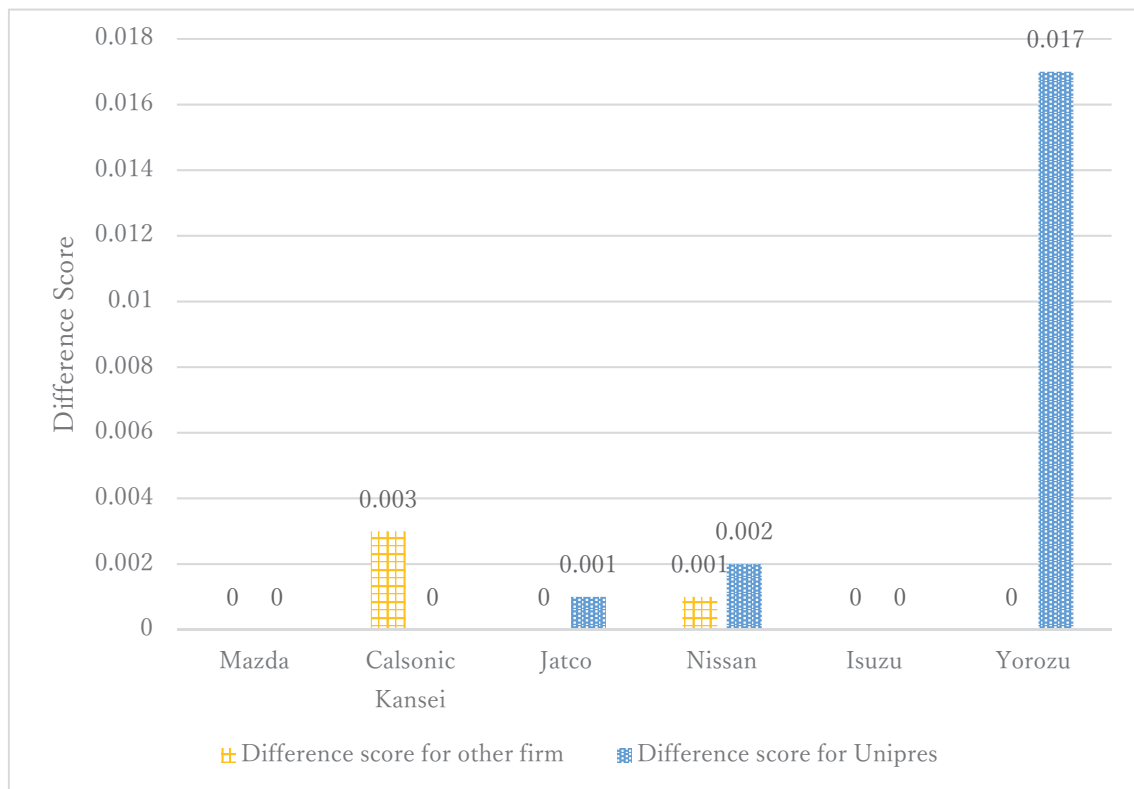


Figure 14 Difference Score of Unipres.

In Figure 14, the difference score for Unipres means the result of Unipres, and the difference score for other firm refers to the result of other firm such as Calsonic Kansei and Nissan when the transactional volume has been changed. Accordingly, the difference score of Unipres with Yorozu, Nissan, and Jatco is 0.017, 0.002, and 0.001, respectively. The efficiencies of Unipres will be improved if the transactional volume with Yorozu, Nissan and Jatco is changed. Thus, the transactional priority of Unipres is considered as Yorozu, Nissan and Jatco.

The difference score for Calsonic Kansei and Nissan is 0.003 and 0.001, respectively. Therefore, not only Unipres, but also Calsonic kansei and Nissan will have the opportunity to improve their efficiencies if the transaction volume between Unipres and Calsonic and Nissan are altered.

According to the definition of difference criterion, difference criteria between Unipres and other related firms are illustrated in Figure 15.

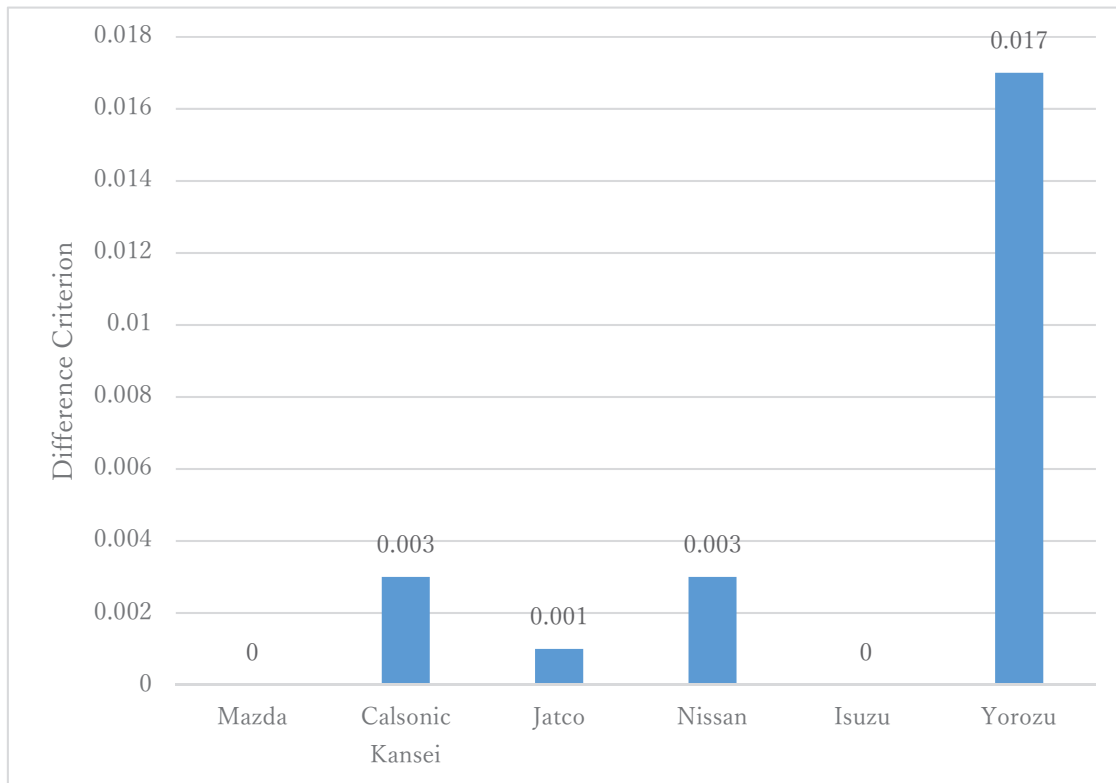


Figure 15 Difference Criterion of Unipres.

Figure 15 shows that the highest value of difference criterion of Unipres is 0.017 with Yorozu. It means that it will be effective if the transactional volume with Yorozu is changed. In fact, the transactional volume in 2005 has been deleted, and the sales revenue was increased to 163,505 million Japanes Yen, almost 4.2 percent growth rate compared with that in 2004. The difference criterion of Unipres with Calsonic Kansei and Nissan is 0.003 both, and with Jatco is 0.001. Thus, the transactional priority in Yokokai is Yorozu, Calsonic Kansei, Nissan and Jatco.

Other two examples are Sumino and Japan Climate Systems Corporation. Both of those two companies are members of Yokokai. Established in 1906, Sumino is a parts maker producing precision press welding components for automobiles, mold design and manufacturing, and robot welding. It is a renowned key partner in Yokokai. Established in 1987, Japan Climate Systems is a company that manufactures air-conditioning systems, condencers, and engine cooling systems. In 2004, Sumino sold its parts to Japan Climate Systems, NSK, and Mazda. Japan Climate Systems sold its parts to Mazda while it purchased from Sumino. The detailed transaction information of Sumino and Japan Climate Systems in Yokokai are shown as Table 16 and Table 17 respectively [30].

Table 16 Transaction of Sumino in Yokokai (%)

	To Sumino	From Sumino
Japan Climate Systems	0	2
NSK	0	2
Mazda	0	83

Table 17 Transaction of Japan Climate Systems in Yokokai (%)

	To Japan Climate Systems	From Japan Climate Systems
Mazda	0	92
Sumino	2	0

Difference scores of all firms with Sumino and Japan Climate Systems are illustrated as in Figure 16 and Figure 17.

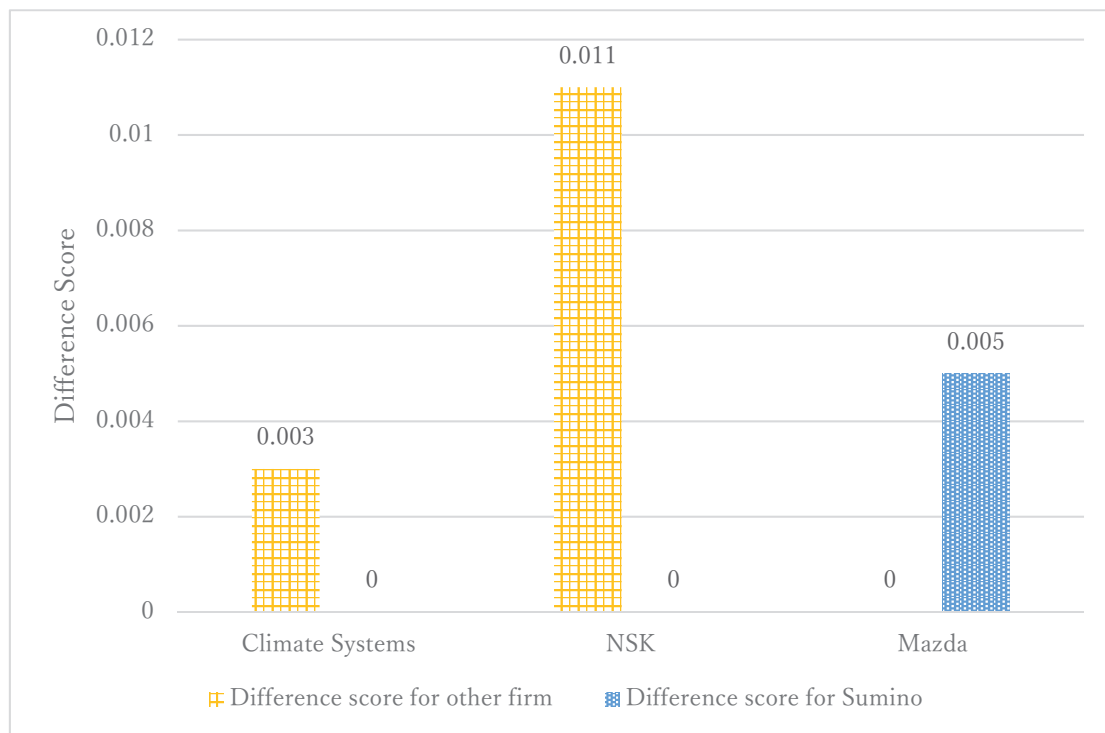


Figure 16 Difference Score of Sumino.

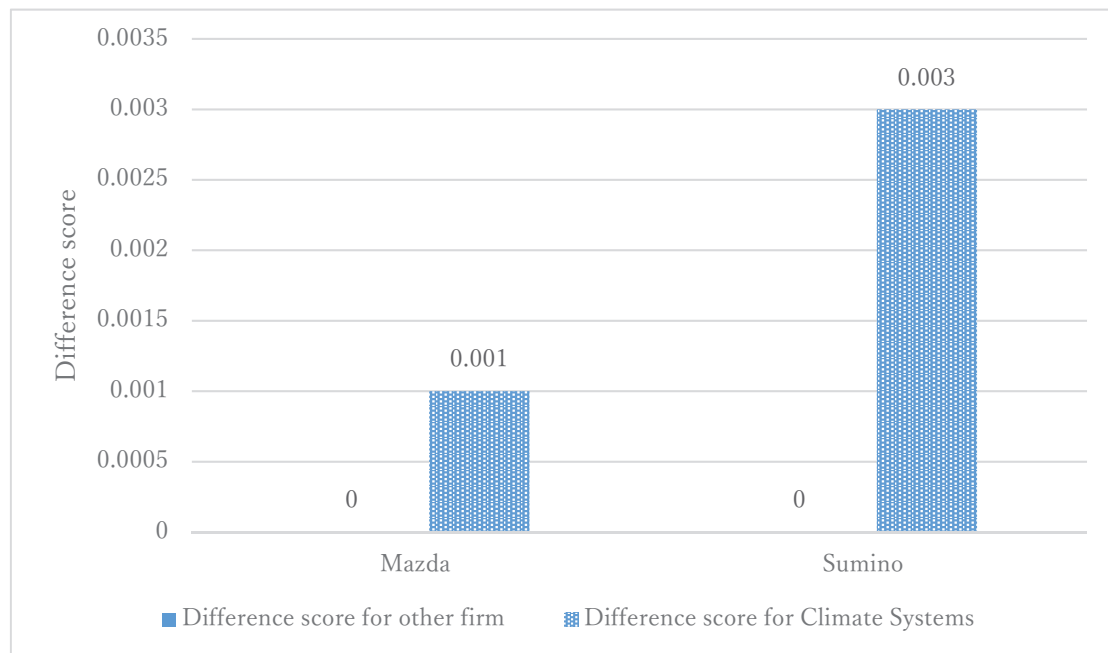


Figure 17 Difference Score of Japan Climate Systems.

Figure 16 shows that the highest value of difference score of Sumino is Mazda. The transactional volume in 2004 and 2005 with Mazda is 83 percent and 79.7 percent respectively<sup>vii</sup>. This could be considered as the reason why sales revenue of Sumino has been improved from 5,433 million Japanese Yen in 2004 to 6,099 million Japanese Yen in 2005 [30, 31].

In Figure 17, the difference score is the same as the difference criterion. Figure 17 indicates that Japan Climate Systems should prioritize the number of transactions with Sumino and Mazda. In fact, Japan Climate Systems changed its transaction volume with Sumino from 2 percent in 2004 to 2.4 percent in 2005, and with Mazda from 92 percent in 2004 to 85 percent in 2005. This could be considered as the reason why Japan Climate Systems' sales revenue was increased from 22,450 million Japanese Yen to 22,985 million Japanese Yen [30, 31]. This is consistent with the result of Unipres and Sumino. Thus, the validity of our analysis has been verified.

### 3.6 Management Implications

The results of this study provide several managerial implications. Accordingly, to augment corporate efficiency, I offer the following suggestions for managing the interrelationships among keiretsu members:

First, this study proposed a new approach to identify systemic changes in a given network system. It clarified the internal solutions to link with the DEA model and network approach. In this chapter, not only the efficiency of all firms can be measured, but also the priority of the different firms can be determined. Efficiency and effectiveness are two basic issues in corporate



management. DEA and dynamic network-based DEA are the effect tools to improve efficiency.

Second, the DEA model calculated the efficiency of the multiple DMUs and shows the results how to make the efficiency of the DMU to be 1.0. This chapter proposed a dynamic heuristic approach and showed that it is not always best to set the efficiency to be 1.0 by adjusting the input and/or output data to improve efficiency in real manufacturing settings. For instance, Bridgestone produces tires, and sells them to Toyota. The sales revenue output will be decreased if Bridgestone tries to reduce the number of transactions because output and input are related with each other sometimes.

Third, new indexes, such as difference scores and difference criterion were proposed. These new indexes express the impact of the transaction between any two firms on efficiency.

Fourth, calculating the efficiency in a given network a useful tool as the relationship between a member vis-à-vis the whole network system can be developed. Thus, dynamic network-based DEA also could be considered as the new tool for improving external inter-firm relationship.

Fifth, predicting systemic changes for a certain amount should be considered. Simulating changes and their results will be helpful for formulating strategic plans.

### **3.7 Concluding Remarks**

In this chapter, dynamic network-based DEA was proposed as a new approach for analyzing interrelationships among members of a keiretsu. Using transaction data drawn from Mazda's Yokokai, the efficiency of all member firms were calculated. This chapter also suggested a new index—the efficiency score and efficiency criterion—to determine the importance of the transaction between any two firms in a given network.

### **3.8 Limitations and Directions for Future Research**

This study has some limitations that may temper its findings. First, some transactional data among network members is missing even though the data have been collected from several sources that include published books, financial reports and from the webpages of the related companies, as well as telephone interviews and questionnaire surveys. The data of some companies, such as Asteer Co., Ltd. and Y-Tec Co., Ltd. could not be gathered due to confidential information disclosure clauses. Thus, in this study the data of these companies were treated as missing data.

Second, the sales revenues have not been changed when the data was re-estimated. Sales revenue should be re-evaluated because the volume of transactions are known to change.

Third, the data is drawn from the fiscal year 2004. Thus, additional time series data are required for help formulating corporate strategy that has longer-term objectives. Consequently, owed to these limitations, the findings of the study should be treated with caution.

The findings of this investigation should be viewed in light of the above-noted limitations that

are suggestive of future research efforts. First, the interrelationships among the focal constructs should be tested using data gathered from a sample of keiretsus comprised in different industries, such as consumer electronics industry of Panasonic and Hitachi, and the aviation industry. Second, all the data used in this study are historical in nature. Thus, for predictive purposes longitudinal data should be gathered to test the validity of the DEA model using probability approaches. And third, not only degree, but also the impact of betweenness, closeness and information centrality index on corporate performance should be investigated in future studies.

## Chapter 4 Measuring Momentum using Limited Cycle

### Theory in Network Systems

#### 4.1 Introduction

Many theories and models of corporate strategy have been published in the past century. Porter's theory of competitive advantage, Barney's Resource-based view, and Mintzberg's 5Ps concepts have been considered to be among the most representative contributions in this field [1, 52, 53]. Recently, red ocean and blue ocean strategy associated with market competition has been proposed by Kim and Mauborgne [54]. In this literature, managerial resources, cost competition, organizational structure and bargaining power of suppliers, among others, are identified and described as useful basic concepts. The foundations of the original thought proposed in this Chapter can be traced to two seminal books: *The Art of War*, and *On War* written by Chinese military strategist, and philosopher Sun Tzu in the late sixth century BC and Prussian military thinker Carl von Clausewitz in 1827, respectively [55, 56]. In comparing these two books, especially the Art of War, with extant strategic theories, discussions on momentum, an important concept, have been sparse, although in the context of current management strategies the pivotal nature of momentum recently has been operationalized and discussed in research on marketing, and finance. This chapter reviews the literature associated with corporate strategy to propose a new approach of acceleration for measuring momentum based on limited cycle theory. This chapter also attempts to shed light on the relationship between sales revenues and momentum and offers an explanation why the business cycle in Japan changed to a four-year period. Furthermore, the chapter also proposes using a four cell matrix model of momentum and firm scale as an effective approach for improving corporate performance.

This chapter is structured as follows. Section 2 reviews the literature focusing on the momentum and corporate management. Section 3 explicates the calculation process of momentum. Section 4 discusses the findings based on which the study limitations are identified and directions for further research are proffered.

#### 4.2 Background and Literature Review

Momentum is a term to express power, force and speed of organizational movement. The original description of momentum appears in *Art of War* written by famous strategist Sun Tzu. In indicating the importance of momentum at the beginning of his book, Sun Tzu famously asserts: It is important to "look for advantages when applying my principles and you will gather sufficient

force to take on unforeseen situations. Force is tilting the balance of power to your side by gathering advantages” to win any battle. He continued to explain the meaning of momentum in chapter five as force. In this context, he asserts “the rush of torrential waters tossing boulders illustrates force. The strike of a bird of prey breaking the body of its target illustrates timing. Therefore, the force of those skilled in warfare is overwhelming and their timing precise. Their force is like a drawn crossbow and their timing is like the release of the trigger”. Furthermore, in analyzing the relationship between the momentum and war, Sun Tzu, posits “Those skilled in warfare seek victory through force and do not require too much from individuals. Therefore, they are able to select the right men and exploit force. One who exploits force commands men into battle like rolling logs and boulders. Logs and boulders are still when on flat ground, but roll when on steep ground. Square shapes are still, but round shapes roll. Therefore, those skilled in warfare use force by making the troops in battle like boulders rolling down a steep mountain. This is force”.

It is widely acknowledged that military strategy forms the basis of corporate strategy. But in the literature on strategic management, surprisingly there is no theoretical description nor application of momentum, which plays an important role in the performance of business activities. An on-line browse of the term “strategy momentum” (in Japanese) yielded approximately 932,000 hits<sup>viii</sup>, which suggests that it obviously is an important concept in corporate strategy.

Momentum expresses a force or speed of movement. In this paper, momentum is defined as a force or impetus of firms to maintain firm’s development durability in certain period. Why is momentum is becoming more and more important? A possible explanation is that inherent uncertainty is in-built within the dynamic, high-speed global economy. With the high rate of innovation, the speed of decision-making has become a condition for successful performance.

In 1995, as a new method applying business to U.S. army logistics, velocity management focused on improving the speed and accuracy with which materials and information flow from providers to users [57]. Mourier observes that velocity management is decision making at speeds consistent with today’s competitive environment and technology. Meanwhile, velocity management is an emergent scientific field that conflates army operations and business together to reflect the new realities of the global environment [58].

It is noteworthy that momentum has been the subject of study in finance and marketing. Many different tools such as moving average and pattern recognition have been developed for momentum calculation [59-67]. Momentum in stock and securities is used to illustrate that their price is more likely to keep moving in the same direction than to change directions. In technical analysis, momentum is considered as an oscillator and is used to help identify trend lines. It is the empirically observed tendency for rising asset prices to rise further, and falling prices to keep falling. Stocks with strong past performance continue to outperform stocks with poor past

performance in the next period with an average excess return of about 1% per month.

However, to our best knowledge, no known studies exist that have investigated the linkage between momentum and corporate performance. Given that the global economy is becoming increasingly uncertain, assessing the impact of momentum on corporate performance is vital. This body of thought is important as it will help increase our understanding and provide guidance that strategic management practitioners can use to increase organizational performance. Thus, this study addresses the paucity in the strategic management literature and makes a contribution to the field by being the first, initial, investigation that illustrates how to measure momentum using velocity, and its observed importance for corporate strategy.

### **4.3 Model and Data Collection**

Previous studies have showed that chaos, which is generally described as a disorder state, is driven by deterministic nonlinear processes, such as hydraulic flow and astronomical phenomena. Findings in physics and biology have discovered some examples of chaos [68]. For example, Tsuda et al, [69] found a chaotic pulsation in a finger's capillary vessels in normal subjects and psychiatric patients, as well as cardiac chaos.

Additional research illustrates that chaotic movement is not only applicable in physics and biology, but also in sociology and management science. For instance, Priesmeyer and Baik proposed a new method to discover the pattern of chaos in 1989 [70]. They noticed that organization have characteristics limit cycle like the human heart. They indicated "Company data tend to adhere to an attractor as they collect their quarterly sales revenue and drive their quarterly profits. One can almost hear the organizational heartbeat pounding out 'Quarter 1, Quarter 2, Quarter 3, Quarter 4'" [70]. Furthermore, Ito and Sakamoto [71] shed light on the nature of the relationship between economic development and the velocity history of the typical companies in Japan.

Because most of the behaviours of the firms are nonlinear, momentum should be calculated based on complex systems theory. In this chapter, momentum is conceptualized as a force that impacts sales revenue and profit movement, and is calculated based upon limit cycle theory because of its non-linear movement.

#### **4.3.1 Model**

Based on the proposal by Priesmeyer and Baik [70] and the formula of acceleration, a brief overview of the procedure to measure the momentum is described as follows.

##### **Step 1: Select variables for analysis.**

Data on two related variables are required. Examples include net income and total assets. However, this chapter uses total assets and total liabilities. Total assets refers to the total amount

of assets owned by a person or entity. Total liabilities refer to the aggregate of all debts an individual or company is liable for and can be easily calculated by summing all short-term and long-term liabilities, along with any off balance sheet liabilities that corporations may incur.

**Step 2: Compute the marginal values of each variable.**

Compute the difference between the observed value and its preceding value. The difference is called marginal value, which can be calculated as follows:

$$d_{i-1,j} = x_{i,j} - x_{i-1,j} \quad (1)$$

where

$i$  ( $= 2, 3, 4, \dots, n$ ): the number of observations;

$n$ : the total number of periods;

$j$  ( $= 1, 2$ ): the kind of variables.

**Step 3: Measure the means of the marginal values.**

The means of the marginal value can be measured as follows.

$$\bar{m}_j = \frac{\sum_{k=1}^m d_{k,j}}{m} \quad (2)$$

where

$j = 1, 2$ ;

$k = 1, 2, 3, \dots, m$ ;

$m = n - 1$ .

**Step 4: Calculate the difference score.**

Difference between each marginal value and the marginal mean is called difference score. It can be calculated as:

$$d_{i,j}^* = d_{k,j} - \bar{m}_j \quad (3)$$

where

$i = 2, 3, \dots, n$ ;

$j = 1, 2$ .

$k = 1, 2, 3, \dots, n - 1$ .

**Step 5: Compute the velocity at each observation.**

Velocity of each observation can be obtained through multiplying the different scores of the two variables as follows:

$$v_k = d_{k,j}^* \times d_{k,j+1}^* \quad (4)$$

where

$$j = 1;$$

$$k = 1, 2, 3, \dots, n-1.$$

**Step 6: calculate the momentum.**

Acceleration, as one pattern of momentums will be calculated as below:

$$a = \frac{v_t - v_0}{t} \quad (5)$$

where

$a$  : acceleration;

$v_t$  : velocity in term  $t$ ;

$v_0$  : velocity in term  $t=0$ ;

$t$  : the interval years between  $v_t$  and  $v_0$ .

### 4.3.2 Data Collection

In order to calculate and assess the impact of momentum on corporate performance, data were collected from 35 selected companies, including 10 auto makers and 25 parts suppliers as shown in Table 18. For the selected companies, the data, total assets and total liabilities, from 2003 to 2013 for the firms were obtained from the publications of corporate financial data [72-86].

Table 18 Company List.

No.	Companies	No.	Companies
1	Toyota Motor Corp.	19	Keihin Corporation
2	Nissan Motor Co., Ltd.	20	Kasai Kogyo Co., Ltd.
3	Mitsubishi Motors	21	Aishin Seiki Co., Ltd.
4	Honda Motor	22	Ikuyo Co., Ltd.
5	Mazda Motor Corp.	23	Showa Corporation
6	Suzuki Motor Corp.	24	Koito Manufacturing Co., Ltd.
7	Daihatsu Motor Co., Ltd.	25	Mitsuba Corporation
8	Isuzu Motors Limited	26	Toyoda Gosei Co., Ltd.
9	Hino Motors, Ltd.	27	Aisan Industry Co., Ltd.
10	Fuji Heavy Industries Ltd.	28	Meiwa Corporation
11	Kawasaki Heavy Industries, Ltd.	29	Nihon Plast Co., Ltd.
12	F-Tech Inc.	30	Murakami Corporation
13	Musashi Seimitsu Industry Co., Ltd.	31	Yorozu Corporation



14	Nissan Shatai Co., Ltd.	32	Yachiyo Industry Co., Ltd.
15	Jidosha Buhin Kogyo Co., Ltd.	33	TS Tech Co., Ltd.
16	Tachi-S Co., Ltd.	34	Akebono Brake Industry Co., Ltd.
17	NOK	35	TBK
18	Shiroki Corporation		

#### 4.4 Discussion and Analysis

The  $t$  in momentum equation (5) may vary depending on different analysis proposed. For instance, one-year momentum is calculated when  $t$  is equal to 1, and two-year momentum is calculated when  $t$  is equal to 2. The results are listed in Appendix 2.

To understand the movement of the momentum within a short period, one-year momentum is calculated as below.

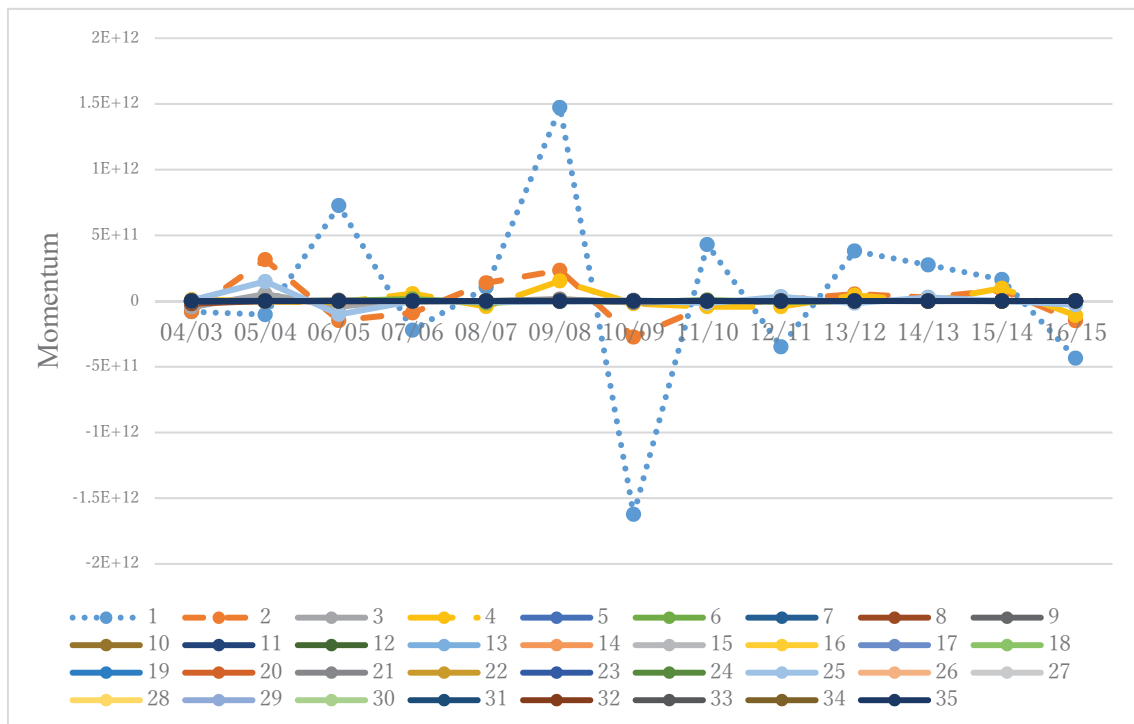


Figure 18 One-year Momentum of Each Firm (2003-2016)<sup>ix</sup>.

All momentums look very stable except the period from 2007 to 2010 in Figure 18. As a well-known fact, 2007-2008 financial crisis resulted from subprime lending practices. The prospects of Japan's economy are unpredictable and the sales revenue of new decreased. The unstable momentum could be considered as a reaction of the financial crisis. Therefore, first conclusion is made based on observing Figure 19 is that momentum is very sensitive to external changes<sup>x</sup>.

Another important fact is that momentum of Toyota increased in '09/'08, decreased in '10/'09, and recovered in '11/'10. Other auto makers, such as Nissan and Mitsubishi, reacted similarly. Second, the financial crisis had an impact over three years on the Japanese car market. In other words, momentum could be considered as an effective index to calculate the environmental changes.

Next, the multiple year momentum was calculated. For instance, 14 results are calculated for two-year momentum because the data are collected from 2002 to 2016. As representative value of the different year, the median of the momentum results with different term  $t$  are calculated to express the trend of multiple year momentum. The multiple year momentum is illustrated in Figure 19. The numbers are firms as shown in Figure 18.

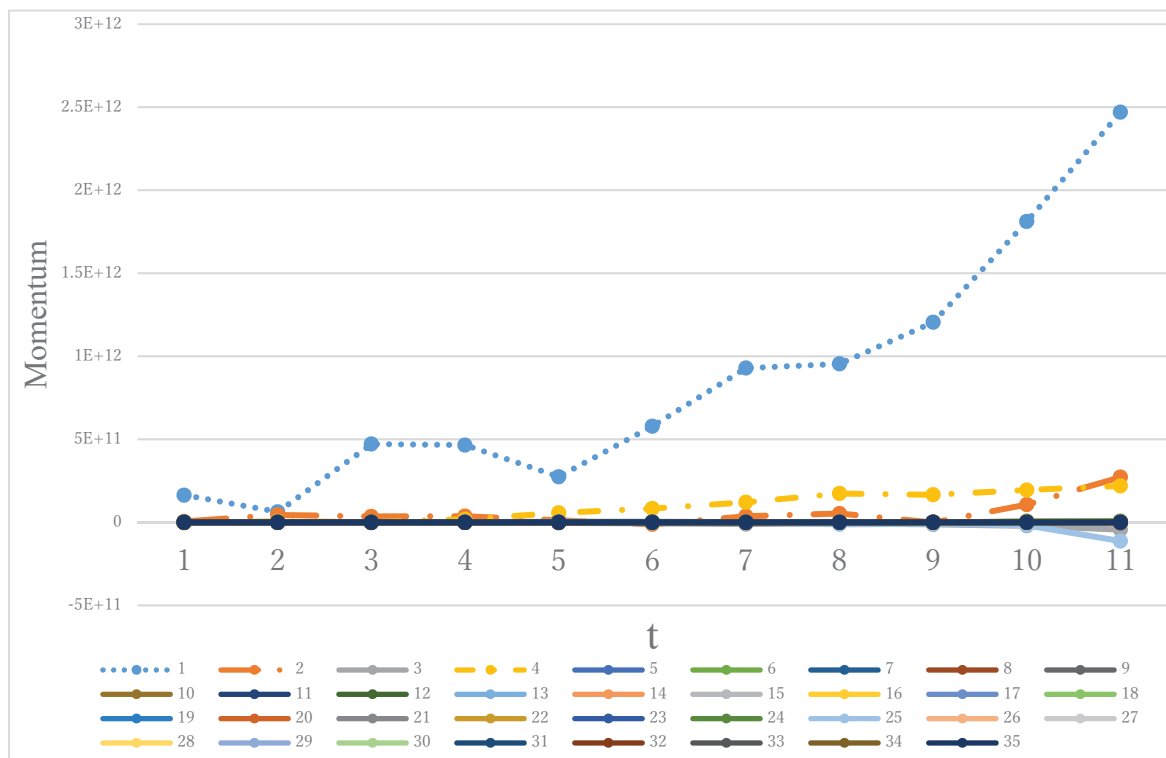


Figure 19 1-11 Year Momentum of Each Firm.

In Figure 19, Toyota is seen to have the biggest value for momentum over 11-years. The second is Honda, and the third is Nissan. As period  $t$  becomes longer, momentum of a big scale company become larger. The second conclusion is that the reaction of the external environment changes is apparently pronounced if the scale of the company is large.

Understandably, the momentum of big scale companies shows a large change, but all the others show stable change or marginal change.

Table 19 The Matrix of Correlation Coefficient between One-year Momentums.

	'02/ '01	'03/ '02	'04/ '03	'05/ '04	'06/ '05	'07/ '06	'08/ '07	'09/ '08	'10/ '09	'11/ '10	'12/ '11	'13/ '12	'14/ '13	'15/ '14	'16/ '15
'02/ '01 Pearson Correlation Coefficient Probability (two-side) Number	1 35	-1.000** .000 35	.105 .550 35	.386* .022 35	-.155 .374 35	.031 .859 35	-.057 .744 35	-.041 .815 35	.039 .822 35	-.061 .726 35	.127 .465 35	-.079 .650 35	.071 .687 35	-.047 .788 35	-.018 .918 35
'03/ '02 Pearson Correlation Coefficient Probability (two-side) Number		1 35	-.105 .550 35	-.386* .022 35	.155 .373 35	-.031 .858 35	.057 .744 35	.041 .814 35	-.040 .821 35	.061 .726 35	-.128 .465 35	.080 .650 35	-.070 .688 35	.047 .787 35	.018 .919 35
'04/ '03 Pearson Correlation Coefficient Probability (two-side) Number			1 35	-.364* .031 35	-.482** .003 35	.814** .000 35	-.871** .000 35	-.715** .000 35	.732** .000 35	-.590** .000 35	.607** .000 35	-.703** .000 35	-.679** .000 35	-.697** .000 35	.754** .000 35
'05/ '04 Pearson Correlation Coefficient Probability (two-side) Number				1 35	-.537** .001 35	-.021 .905 35	.460** .005 35	-.194 .265 35	.182 .296 35	-.400* .017 35	.377* .025 35	-.223 .197 35	-.203 .243 35	.070 .691 35	.014 .935 35
'06/ '05 Pearson Correlation Coefficient Probability (two-side) Number					1 35	-.804** .000 35	.416* .013 35	.925** .000 35	-.926** .000 35	.983** .000 35	-.974** .000 35	.933** .000 35	.931** .000 35	.679** .000 35	-.822** .000 35

Table 19 The Matrix of Correlation Coefficient between One-year Momentums (Continued).

	'02/ '01	'03/ '02	'04/ '03	'05/ '04	'06/ '05	'07/ '06	'08/ '07	'09/ '08	'10/ '09	'11/ '10	'12/ '11	'13/ '12	'14/ '13	'15/ '14	'16/ '15
'07/ '06 Pearson Correlation Coefficient Probability (two-side) Number						1 35	-.864** .000 35	-.915** .000 35	.943** .000 35	-.881** .000 35	.850** .000 35	-.906** .000 35	-.926** .000 35	-.740** .000 35	.888** .000 35
'08/ '07 Pearson Correlation Coefficient Probability (two-side) Number							1 35	.658** .000 35	-.691** .000 35	.530** .001 35	-.524** .001 35	.644** .000 35	.641** .000 35	.648** .000 35	-.717** .000 35
'09/ '08 Pearson Correlation Coefficient Probability (two-side) Number  '10/ '09 Pearson Correlation Coefficient Probability (two-side) Number								1 35	-.996** .000 35	.953** .000 35	-.981** .000 35	.999** .000 35	.985** .000 35	.878** .000 35	-.974** .000 35
										1 35	-.964** .000 35	-.993** .000 35	-.991** .000 35	-.842** .000 35	.960** .000 35

Table 19 The Matrix of Correlation Coefficient between One-year Momentums (Continued).

	'02/ '01	'03/ '02	'04/ '03	'05/ '04	'06/ '05	'07/ '06	'08/ '07	'09/ '08	'10/ '09	'11/ '10	'12/ '11	'13/ '12	'14/ '13	'15/ '14	'16/ '15
'11/ '10 Pearson Correlation Coefficient Probability (two-side) Number										1	-.972**	.954**	.972**	.697**	-.861**
'12/ '11 Pearson Correlation Coefficient Probability (two-side) Number											1	-.986**	-.965**	-.823**	.924**
'13/ '12 Pearson Correlation Coefficient Probability (two-side) Number												1	.980**	.878**	-.970**
'14/ '13 Pearson Correlation Coefficient Probability (two-side) Number														.000	-.941**

Table 19 The Matrix of Correlation Coefficient between One-year Momentums (Continued).

	'02/ '01	'03/ '02	'04/ '03	'05/ '04	'06/ '05	'07/ '06	'08/ '07	'09/ '08	'10/ '09	'11/ '10	'12/ '11	'13/ '12	'14/ '13	'15/ '14	'16/ '15
'15/ '14 Pearson Correlation Coefficient Probability (two-side) Number														1	-.955**
														35	.000
															35
'16/ '15 Pearson Correlation Coefficient Probability (two-side) Number															1
															35
** . 1% statistically significant (two-side).															
* . 5% statistically significant (two-side).															



The inertia varies according to mass in physics. Then the question of how long the momentum will keep going forward should be ascertained. In order to discern the result, the correlation coefficients were calculated for momentum over one year spread for the period 2001 to 2013. The result is shown in Table 19.

From Table 19, all the correlation coefficients except the coefficient of '02/'01, '03/'02, and '05/'04 are statistically significant. Accordingly, the third conclusion holds that all momentum of each year are correlated with each other within certain period of about 10 years.

Furthermore, the relationship between one-year momentum and corporate performance such as sales revenue and operating income are calculated in order to confirm the period of the momentum keeping going. The correlation coefficient between sales revenue and operating income and one-year momentum is illustrated in Figure 20.



Figure 20 Correlation Coefficient between One-year Momentum and Sales Revenue and Operating Income.

All correlation coefficients are statistically significant except '02/'01, '03/'02, and part in '05/'04. The direction of momentum '04/'03 is changed compared with the last year '03/'02.

The average interval between negative momentums is almost 4 years. The result of '12/'11 looks irregular, the term between '10/'09 is only two years. The possible reason is that the external environment has been changed dramatically after the finance crisis in 2008. Therefore, the fourth conclusion is that the validate period of momentum in automobile is considered as about 4 years. This may be considered as one of the reasons why all the models changed over a four-year cycle in Japan.

The relationship between multiple-year momentum and corporate performance such as sales revenue and operating income is depicted in Figure 21.



Figure 21 Correlation Coefficient between Multiple-year Momentum and Sales Revenue and Operating Income.

Table 20 Relationship between Momentum and Sales Revenue and Profit.

	Sales '05	Profit '05	Sales '06	Profit '06	Sales '07	Profit '07	Sales '08	Profit '08	Sales '09	Profit '09	Sales '10	Profit '10	Sales '11	Profit '11	Sales '12	Profit '12	Sales '13	Profit '13
Momentum (05/04)	-.733** .000 35	-.513** .002 35	-.731** .000 35	-.698** .000 35	-.733** .000 35	-.775** .000 35	-.745** .000 35	-.784** .000 35	-.733** .000 35	.750** .000 35	-.740** .000 35	-.488** .003 35	-.724** .000 35	-.416** .013 35	-.723** .000 35	-.430** .010 35	-.734** .000 35	-.756** .000 35
Momentum (06/05)	.894** .000 35	.824** .000 35	.899** .000 35	.919** .000 35	.903** .000 35	.954** .000 35	.911** .000 35	.955** .000 35	.909** .000 35	-.668** .000 35	.915** .000 35	.808** .000 35	.893** .000 35	.710** .000 35	.878** .000 35	.596** .000 35	.903** .000 35	.924** .000 35
Momentum (07/06)	.489** .003 35	.560** .000 35	.493** .003 35	.554** .001 35	.502** .002 35	.617** .000 35	.511** .002 35	.622** .000 35	.495** .002 35	-.753** .000 35	.522** .001 35	.154 .377 35	.491** .003 35	.078 .657 35	.501** .002 35	.184 .290 35	.513** .002 35	.578** .000 35
Momentum (08/07)	-.791** .000 35	-.758** .000 35	-.795** .000 35	-.828** .000 35	-.801** .000 35	-.883** .000 35	-.810** .000 35	-.887** .000 35	-.801** .000 35	.787** .000 35	-.816** .000 35	-.564** .000 35	-.790** .000 35	-.475** .004 35	-.786** .000 35	-.469** .004 35	-.806** .000 35	-.850** .000 35
Momentum (09/08)	.892** .000 35	.861** .000 35	.895** .000 35	.922** .000 35	.899** .000 35	.955** .000 35	.904** .000 35	.958** .000 35	.896** .000 35	-.84** .000 35	.909** .000 35	.649** .000 35	.892** .000 35	.618** .000 35	.893** .000 35	.630** .000 35	.904** .000 35	.932** .000 35
Momentum (10/09)	-.897** .000 35	-.865** .000 35	-.900** .000 35	-.926** .000 35	-.904** .000 35	-.958** .000 35	-.909** .000 35	-.961** .000 35	-.901** .000 35	.845** .000 35	-.913** .000 35	-.655** .000 35	-.897** .000 35	-.626** .000 35	-.898** .000 35	-.638** .000 35	-.909** .000 35	-.936** .000 35
Momentum (11/10)	.959** .000 35	.915** .000 35	.958** .000 35	.968** .000 35	.960** .000 35	.968** .000 35	.958** .000 35	.969** .000 35	.951** .000 35	-.860** .000 35	.958** .000 35	.705** .000 35	.959** .000 35	.771** .000 35	.967** .000 35	.823** .000 35	.963** .000 35	.966** .000 35
Momentum (12/11)	.473** .004 35	.445** .007 35	.485** .003 35	.519** .001 35	.489** .003 35	.549** .001 35	.502** .002 35	.545** .001 35	.515** .002 35	-.001 .993 35	.511** .002 35	.763** .000 35	.475** .004 35	.508** .002 35	.427** .010 35	.153 .380 35	.482** .003 35	.503** .002 35
Momentum (13/12)	.802** .000 35	.778** .000 35	.805** .000 35	.839** .000 35	.811** .000 35	.889** .000 35	.819** .000 35	.893** .000 35	.809** .000 35	-.827** .000 35	.826** .000 35	.542** .001 35	.801** .000 35	.476** .004 35	.802** .000 35	.493** .003 35	.817** .000 35	.859** .000 35

Note: The first layer is Pearson Correlation Coefficient. The second layer is significant probability (two-side). The third layer is number of dataset. The asterisks \*\* and \* indicate that the coefficients are statistically significant at 1 and 5 percent level respectively.

The correlation coefficients of '01/'16, '02/'16, and '11/'16 are statistically insignificants in Figure 21. Figure 21 shows that the long term momentums such as '03/'16, '04/'16 have strong correlations with sales '16 and operating income '16. This is consistent with our third conclusion. Compared with Figure 20, the period between negative momentum and positive momentum is longer. Therefore, long term momentums have tendency to give strong impact on corporate performance. Moreover, as a result, the interval between '09/'16 and '13/'16 is also 4 years, consistent with the our fourth conclusion coincidently.

To identify the relationship between momentum and performance more, the correlation coefficients between momentum and corporate performance (as measured by sales revenue and profits) are reported in Table 20.

All correlation coefficients for momentum are significant except for momentum '07/'06 and Profit '10, Profit '11, and Profit '12, and momentum '12/'11 and Profit '09. Thus, evidently momentum has close association with sales revenue and profit<sup>xi</sup>. Another important point is that Table 20 is separated into two parts by the column of Profit '09. As noted before, this change could be considered as the result caused by the impact of the financial crisis. Furthermore, the raw data for momentum '05/'04, '08/'07, and '10/'09 are negative, and all the rest are positive. This should be inferred as the influence resulting from external environmental changes such as “keiretsu loosening” and deflationary spiral of domestic economy and the financial crisis in 2008. Therefore, the higher momentum, the more sales revenue and profit is our fifth conclusion.

To verify the relationship between momentum and performance, regression analysis was used. Sales revenue and profit in 2013 were used as the dependent variables, and momentums of each year as the explanatory variable. For instance, model 1 in Table 21 means only one momentum '13/'12 exists. And in model 8, eight momentums are included, they are Momentum '13/'12, Momentum '12/'11, Momentum '11/'10, Momentum '10/'09, Momentum '09/'08, Momentum '08/'07, Momentum '07/'06, and Momentum '06/'05. The results of the regression analyses depicted in Table 21 below reveal the interrelationships between momentum and sales revenue and profits, respectively.

Table 21 Relationship between Momentum and Sales Revenue and Profit.

model		Partial correlation coefficient	Standardizing coefficient	t value	Prob.	Correlation Coefficient	D. F.	Intercept	Adjusted R-square	DW Ratio
model 1	Momentum '13/'05	Sales revenue	1.1316	0.86996	10.116	0	33	-0.1375	0.86532	0.788
		Profit	1.1351	0.9048	12.208	0		-0.1459	0.9018	0.839
model 2	Momentum '13/'06	Sales revenue	1.0855	0.9491	10.976	0	32	-0.0781	0.88678	1.060
	Momentum '12/'05	Profit	0.232	0.1743	2.016	0.0523		-0.0686	0.91843	1.200
model 3	Momentum '13/'07	Sales revenue	1.0732	0.9733	13.152	0.0523	31	-0.291	0.91241	0.804
	Momentum '12/'06	Profit	0.1936	0.1509	2.039	0.0498		-0.267	0.937	0.840
model 4	Momentum '13/'08	Sales revenue	1.1446	0.9749	7.484	0	30	0.7355	0.98377	0.954
	Momentum '12/'07	Profit	0.2667	0.2299	2.737	0.0102		-0.219	0.98618	0.912
	Momentum '11/'05	Sales revenue	0.3803	0.2801	2.400	0.0226				
	Momentum '10/'05	Profit	1.1524	1.0181	9.158	0				
	Momentum '13/'06	Sales revenue	0.2091	0.187	2.608	0.0139				
	Momentum '12/'05	Profit	0.3437	0.2626	2.636	0.013				
	Momentum '13/'07	Sales revenue	0.266	0.2356	1.349	0.1873				
	Momentum '12/'06	Profit	0.3733	0.2497	5.063	0				
	Momentum '11/'05	Sales revenue	0.3013	0.2137	4.817	0				
	Momentum '10/'05	Profit	-0.952	-0.8642	-4.753	0				
	Momentum '13/'08	Sales revenue	0.5792	0.5323	3.096	0.0042				
	Momentum '12/'07	Profit	0.2297	0.1594	3.285	0.0026				
	Momentum '11/'06	Sales revenue	0.289	0.2127	4.872	0				
	Momentum '10/'05	Profit	-0.5846	-0.5505	-3.077	0.0044				

Table 21 Relationship between Momentum and Sales Revenue and Profit (Continued) .

			Partial correlation coefficient	Standardizing coefficient	t value	Prob.	Correlation Coefficient	D. F.	Intercept	Adjusted R-square	DW Ratio
model 5	Momentum '13/'09	Sales revenue	0.1751	0.1555	0.083	0.9342	0.8851	29	1.1974	0.98294	0.919
	Momentum '12/'08		0.4076	0.2617	1.1908	0.2434	-0.3635				
	Momentum '11/'07		0.1266	0.0843	0.213	0.8326	-0.5754				
	Momentum '10/'06	Profit	-1.4599	-1.3372	-2.488	0.0188	-0.9515		1.2051	0.98539	0.930
	Momentum '09/'05		-0.3714	-0.3262	-0.152	0.8801	0.9049				
model 6	Momentum '13/'10	Sales revenue	-0.3109	-0.3356	-1.165	0.2537	-0.6689	28	-13.307	0.983	1.149
	Momentum '12/'09		14.2385	12.7132	0.799	0.4309	0.9035				
	Momentum '11/'08		1.5439	1.4068	0.596	0.5558	-0.9505				
	Momentum '10/'07		1.655	1.1222	1.423	0.1655	-0.5947				
	Momentum '09/'06	Profit	0.3202	0.276	0.814	0.4221	0.4916		-41.2187	0.9884	1.331
	Momentum '08/'05		10.9585	9.801	0.662	0.5131	-0.905				
			-0.7779	-0.8712	-3.657	0.001	-0.6833				
			42.1239	39.0142	2.965	0.0061	0.9314				



Table 21 Relationship between Momentum and Sales Revenue and Profit (Continued) .

		Partial correlation coefficient	Standardizing coefficient	t value	Prob.	Correlation Coefficient	D. F.	Intercept	Adjusted R-square	DW Ratio
model 7	Momentum '13/'11	-3.502	-2.3893	-8.351	0	0.305	27	-126.609	0.9947	2.151
	Momentum '12/'10	2.7674	2.0177	6.658	0	0.7237				
	Momentum '11/'09	119.3885	106.3982	7.059	0	0.9022				
	Momentum '10/'08	44.4399	39.845	7.690	0	-0.9224				
	Momentum '09/'07	2.6417	1.7224	7.439	0	-0.1796				
	Momentum '08/'06	82.5702	73.7107	6.4895	0	-0.896	27	-85.0866	0.99431	1.982
	Momentum '07/'05	8.9549	8.021	3.4292	0.002	0.9195				
	Sales revenue	-2.3843	-1.6873	-5.692	0	0.3539				
	Profit	1.3884	1.05	3.3445	0.0024	0.7695				
		74.0219	68.428	4.3824	0.0002	0.9303				
		39.3471	36.5945	6.8172	0	-0.9461				
		2.3381	1.5813	6.592	0	-0.2441				
		45.9385	42.539	3.6149	0.0012	-0.9249				
		13.0606	12.1348	5.0075	0	0.9452				

Table 21 Relationship between Momentum and Sales Revenue and Profit (Continued).

		Partial correlation coefficient	Standardizing coefficient	t value	Prob.	Correlation Coefficient	D. F.	Intercept	Adjusted R-square	DW Ratio
model 8	Momentum '13/'12	0.1683	0.1214	0.22	0.8276	-0.1921	26	110.534	0.994	2.383
	Momentum '12/'11	-27.8774	-22.9073	-5.196	0	0.7995				
	Momentum '11/'10	2.2158	2.1705	1.7768	0.0873	-0.9099				
	Sales revenue	-88.628	-79.2406	-2.804	0.0094	0.9068				
		19.023	17.2948	4.592	0.0001	-0.9456				
		-129.7925	-115.6964	-3.449	0.0019	-0.8978				
		4.1565	3.9643	1.080	0.2897	0.9717				
	Momentum '10/'09	2.7644	2.1863	1.505	0.1443	0.8185				
	Momentum '09/'08	0.9011	0.6745	1.535	0.1368	-0.2056				
	Profit	-26.4423	-22.5384	-6.424	0	0.8439				
		-0.0089	-0.009	-0.009	0.9927	-0.9198				
		-38.1124	-35.3465	-1.571	0.1281	0.934				
		14.9174	14.068	4.6933	0.0001	-0.9627		60.8242	0.9962	2.309
		-74.8612	-69.2196	-2.593	0.0154	-0.9269				
	Momentum '07/'06	-2.2784	-2.2541	-0.772	0.447	0.9799				
	Momentum '06/'05	6.743	5.5317	4.785	0.0001	0.8589				

Table 21 reveals that adjusted R-square are high, and the partial correlation coefficient of momentum in Models 1 to 4 are significant, but rest part of the other remain in models 5 to 8 are insignificant. The most recent four years have strong impact on sales revenue and profits. This result is consistent with our fourth conclusion.

Based on the results, it is also possible to identify successful companies as well as firms with impaired performance using momentum measurements. Momentum is influenced by the external environment changes, corporate performance such as sales revenue and profit. Based on the findings shown in Table 21, sales revenue is strongly associated with momentum. Thus, a four-cell model is proposed in this chapter comprising of momentum and scale should be effective. The four-cell matrix model of momentum '13/'05 and sales revenue '13 is illustrated in Figure 22.

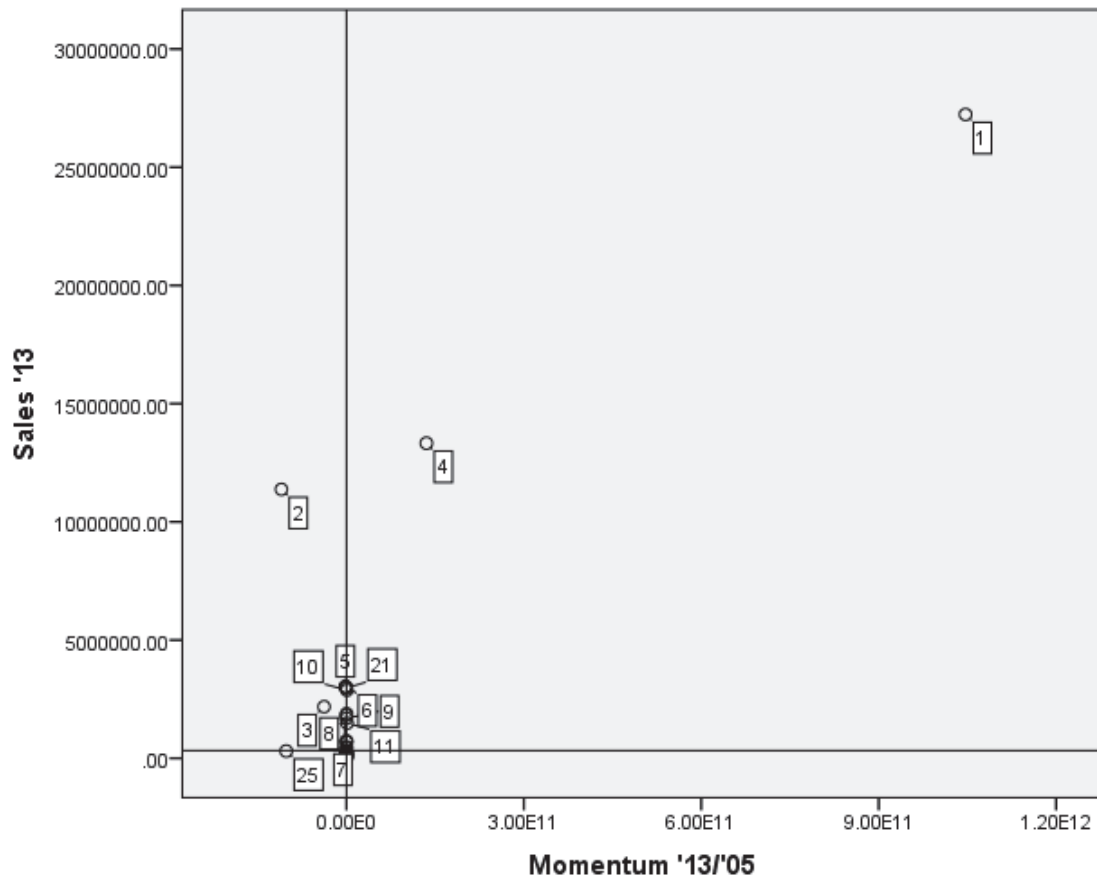


Figure 22 A Four-cell Matrix Model of Momentum '13/'05 and Sales Revenue '13.

The reference line of x axis and y axis are the median of momentum '13/'05 and sales revenue '13 respectively in Figure 22. The firms located in the 1<sup>st</sup> quadrant and the 3<sup>rd</sup> quadrant are good firms and poorly performing firms, respectively, because they have appropriate relationship between momentum and sales revenue '13. The firm is called developing company with high development potential if it is located in 4<sup>th</sup> quadrant, while the firm is called problem child if it is located in 2<sup>nd</sup> quadrant. A firm moving from 3<sup>rd</sup> quadrant to 2<sup>nd</sup> or 4<sup>th</sup> quadrant, or further from 2<sup>nd</sup> and 4<sup>th</sup> to 1<sup>st</sup> quadrant would be considered positive signs.

No.1 is Toyota and No. 4 is Honda in Figure 21. The good firms in the 1<sup>st</sup> quadrant are Toyota Motor Corp., Honda Motor Co., Ltd., Isuzu Motors Limited, Fuji Heavy Industries Ltd., Kawasaki Heavy Industries, Ltd., NOK, Koito Manufacturing Co., Ltd., and Keihin Corporation, which are main auto makers and important suppliers. NOK and Koito manufacturing are suppliers in the Toyota group, and Keihin is main supplier of Honda group.

The problem children of the 2<sup>nd</sup> quadrant are Nissan Moto Co., Ltd., Mitsubishi Motors, Mazda Motor Corp., Suzuki Motor Corp., Daihatsu Motor Co., Ltd., Hino Motors, Ltd., Nissan Shatai Co., Ltd., Aishin Seiki Co., Ltd., Toyoda Gosei Co., Ltd., and TS Tech Co., Ltd. which are well known to be auto makers and main suppliers. Aishin Seiki and Toyoda are main subsidiaries of the Toyota group, and TS Tech is main subsidiary of Honda group.

The poorly performing firms in the 3<sup>rd</sup> quadrant are F-Tech Inc., Tachi-S Co., Ltd., Kasai Kogyo Co., Ltd., Mitsuba Corporation, Meiwa Corporation, Murakami Corporation, Akebono Brake Industry Co., Ltd., and Ikuyo Co., Ltd., F-Tech, Tachi-S, Kasai and Mitsuba are the main suppliers of Honda group, and Meiwa, Murakami and Akebono are the main suppliers of Toyota group. The reason those companies are located in the group of problem children is that their momentum values are small.

All the rest are developing companies in the 4<sup>th</sup> quadrant, including Musashi Seimitsu Industry Co., Ltd., Jidosha Buhin Kogyo Co., Ltd., Shiroki Corporation, Showa Corporation, Aisan Industry Co., Ltd., Nihon Plast Co., Ltd., Yorozu Corporation, Yachiyo Industry Co., Ltd. and TBK. Musashi Seimitsu Industry, Showa, Nihon Plast and Yachiyo Industry are main suppliers of Honda group, Jidosha Buhin Kogyo and TBK are suppliers of Isuzu group, Shiroki and Aisan Industry belong to the Toyota group, and Yorozu is one of the suppliers of Nissan group.

In order to compare with the corporate performance, four perspectives of growth, profitability, efficiency, and finance solvency of those companies are investigated. The results are reported in Table 22.

Table 22 Financial Information of the 35 Firms.

	Growth	Profitability	Efficiency	Solvency
1	A	C	B	CC
2	B	A	C	C
3	B	B	A	CC
4	B	A	B	C
5	C	CC	A	CC
6	C	B	A	B
7	A	AA	AA	C
8	AA	AA	AA	C
9	AA	B	AA	CC
10	AA	A	A	C
11	C	B	C	CC
12	B	B	AA	CC
13	CC	AA	A	C
14	C	B	AA	A
15	AA	A	AA	B
16	A	A	AA	A
17	A	B	C	B
18	C	A	AA	B
19	C	A	A	AA
20	A	A	AA	CC
21	B	A	A	B
22	CC	CC	A	CC
23	CC	C	A	B
24	AA	A	B	B
25	CC	CC	A	CC
26	B	A	A	B
27	A	C	A	B
28	A	CC	C	B
29	A	C	A	C

Table 22 Financial Information of the 35 Firms (Continued).

	Growth	Profitability	Efficiency	Solvency
30	A	AA	AA	A
31	C	AA	A	A
32	C	CC	AA	CC
33	C	A	AA	A
34	A	C	A	C
35	AA	A	A	B

(Data source: Data bank series 2014, Toyo Keizai)

As I indicated above that all these companies can be divided into four groups: the good firms in the 1<sup>st</sup> quadrant, the problem children in the 2<sup>nd</sup> quadrant, the poorly performing firms in the 3<sup>rd</sup> quadrant, and the developing companies in the 4<sup>th</sup> quadrant in Figure 22. And the corporate performance is evaluated as five group: top 20 is the AA group, from top 20 to 40 is the A group, from 40 to 60 is the B group, from 60 to 80 is the C group, and the rest is the CC group. Based on the corporate performance, the mode of the four different quadrant is shown in Table 23.

Table 23 Mode of the Financial Information of the Four Groups.

Quadrant	Growth	Profitability	Efficiency	Solvency
1 (8 firms)	AA	A	B	C
2 (10 firms)	B, C	A, B	A	B, CC
3 (8 firms)	A	CC	AA	CC
4 (9 firms)	C	A, C	A	B

The characteristics of the good firms group is excellent growth rate, and high profitability. The problem children and the poorly performing firms have the worst rate of solvency both. Compared with problem children, the poorly performing firms has excellent evaluation of efficiency, but worst results of the profitability and solvency rate both. Thus, part of the problem children have the problems of solvency and growth, and the poorly performing firms are poor at improving profitability and solvency. Characteristics of the developing companies is higher rate of solvency and low evaluation of growth.



Table 24 Position Changes of Momentum and Sales Revenue.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mode
Toyota Motor Corp.	2	1	1	2	4	2	1	1	1	1
Nissan Motor Co., Ltd.	1	2	2	1	4	2	1	2	2	2
Mitsubishi Motors	3	4	3	2	4	2	1	2	1	2
Honda Motor	1	1	2	1	1	2	1	1	2	1
Mazda Motor Corp.	2	1	2	1	4	3	4	4	1	1
Suzuki Motor Corp.	2	2	1	2	1	2	2	2	1	2
Daihatsu Motor Co., Ltd.	2	2	2	1	1	2	2	1	1	2
Isuzu Motors Limited	2	2	1	2	4	2	1	2	2	2
Hino Motors, Ltd.	2	1	2	1	4	3	4	1	1	1
Fuji Heavy Industries Ltd.	1	2	2	2	4	3	1	2	1	2
Kawasaki Heavy Industries, Ltd.	2	2	1	2	1	4	2	2	1	2
F-Tech Inc.	4	4	4	3	3	1	3	4	3	4
Musashi Seimitsu Industry Co., Ltd.	4	3	4	4	3	1	1	3	3	3
Nissan Shatai Co., Ltd.	2	2	1	1	1	2	2	1	3	2
Jidosha Buhin Kogyo Co., Ltd.	4	3	4	4	2	4	3	3	4	4
Tachi-S Co., Ltd.	4	3	4	4	3	1	1	1	3	4
NOK	2	2	1	1	1	3	1	2	1	1
Shiroki Corporation	3	4	4	4	2	1	3	4	3	4
Keihin Corporation	1	1	2	4	4	2	1	4	3	1

Table 24 Position Changes of Momentum and Sales Revenue (Continued).

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mode
Kasai Kogyo Co., Ltd.	4	3	3	3	2	4	3	4	3	3
Aishin Seiki Co., Ltd.	1	1	2	1	4	2	1	2	1	1
Ikuyo Co., Ltd.	4	4	3	3	2	4	3	4	4	4
Showa Corporation	1	1	3	3	3	4	4	3	1	3
Koito Manufacturing Co., Ltd.	1	1	2	1	1	1	2	2	1	1
Mitsuba Corporation	3	4	3	3	3	4	4	3	1	3
Toyoda Gosei Co., Ltd.	1	1	1	1	1	2	1	1	1	1
Aisan Industry Co., Ltd.	4	3	3	4	3	4	4	4	3	4
Meiwa Corporation	4	4	4	3	2	4	3	4	4	4
Nihon Plast Co., Ltd.	3	4	3	3	3	4	3	3	3	3
Murakami Corporation	4	3	4	3	2	1	3	4	3	3
Yorozu Corporation	3	4	3	3	2	4	3	2	3	3
Yachiyo Industry Co., Ltd.	4	3	4	3	2	4	3	3	3	3
TS Tech Co., Ltd.	3	3	1	1	2	2	2	1	2	2
Akebono Brake Industry Co., Ltd.	2	1	1	2	4	3	4	3	3	3
TBK	3	3	4	4	2	4	3	4	4	4

Basically momentum could be considered as an index of stability, the stability is high if the momentum is weak, and the stability is low if the momentum is strong. Accordingly, the firms with strong momentum and high sales revenue have high growth rate, and the firms with weak momentum have low rate of solvency. Furthermore, the firms with strong momentum but low sales revenue have low rate of growth.

Therefore, the four-cell matrix model is appropriate to judge a firm's position. In order to clarify the time series change, the position changes of momentum and sales revenue are calculated in Table 24.

From Table 24, the mode of the firm such as Toyota and Honda are 1 and the mode of the firm such as Yorozu and Yachiyo are 3 respectively. The mode of the firm such as Jidosha Buhin and Ikuyo are 4, while the mode of the firm such as Nissan and Mitsubishi are 2. These findings are consistent with our analytical results.

#### 4.5 Management Implications

Not only the momentum of selected 35 companies have been calculated, but also close correlation coefficients between sales revenue and momentum have been proved.

Based upon the hypothesis “higher momentum higher sales revenue”, the four cell matrix model provides a useful tool to determine the state of the companies.

Because of the predictable of the momentum, momentum will be under control of the companies for improving their performance.

In order to explain the forecasting of sales revenue using momentum, the result of Toyota's sales revenue from 2009 to 2015 using momentum will be illustrated in Figure 23. The regression model between sales revenue and momentum is shown as below.

$$Y=aX+b+\varepsilon_0 \quad (6)$$

where

Y: Sales Revenue

X: Momentum

b: Parameter

$\varepsilon_0$ : error

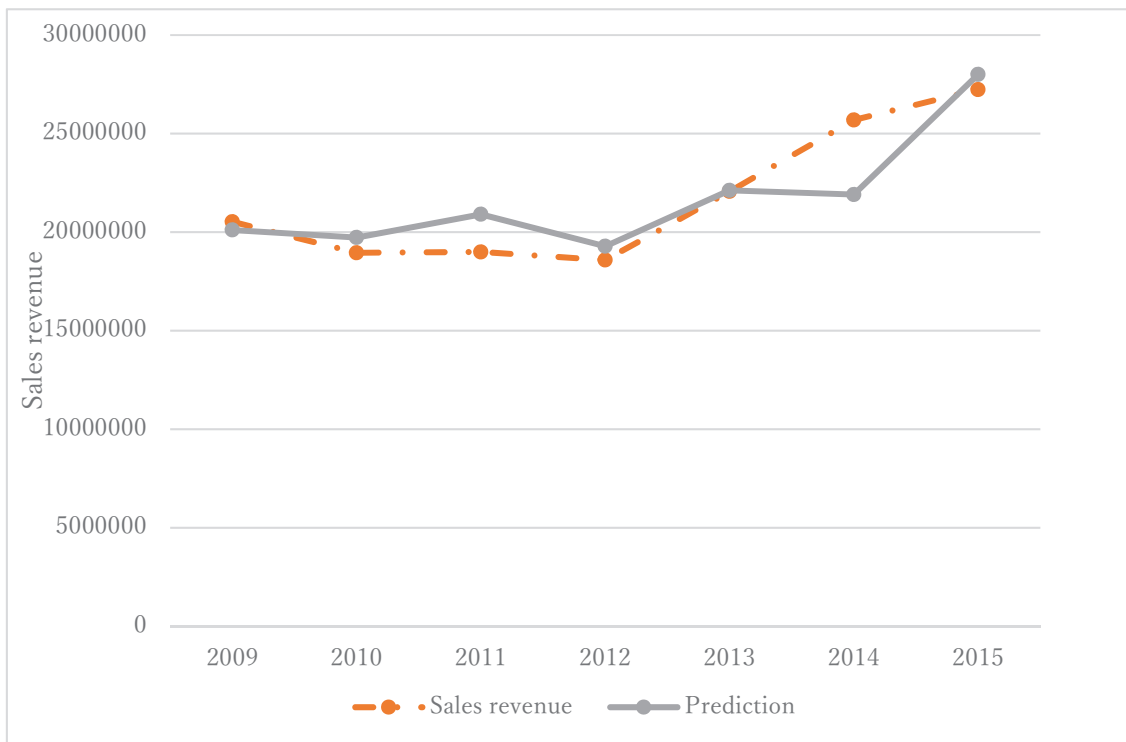


Figure 23 Prediction of Toyota's Sales Revenue using Momentum from 2009 to 2015.  
Another example of Akebono brake Industries also can be depicted as Figure 24.

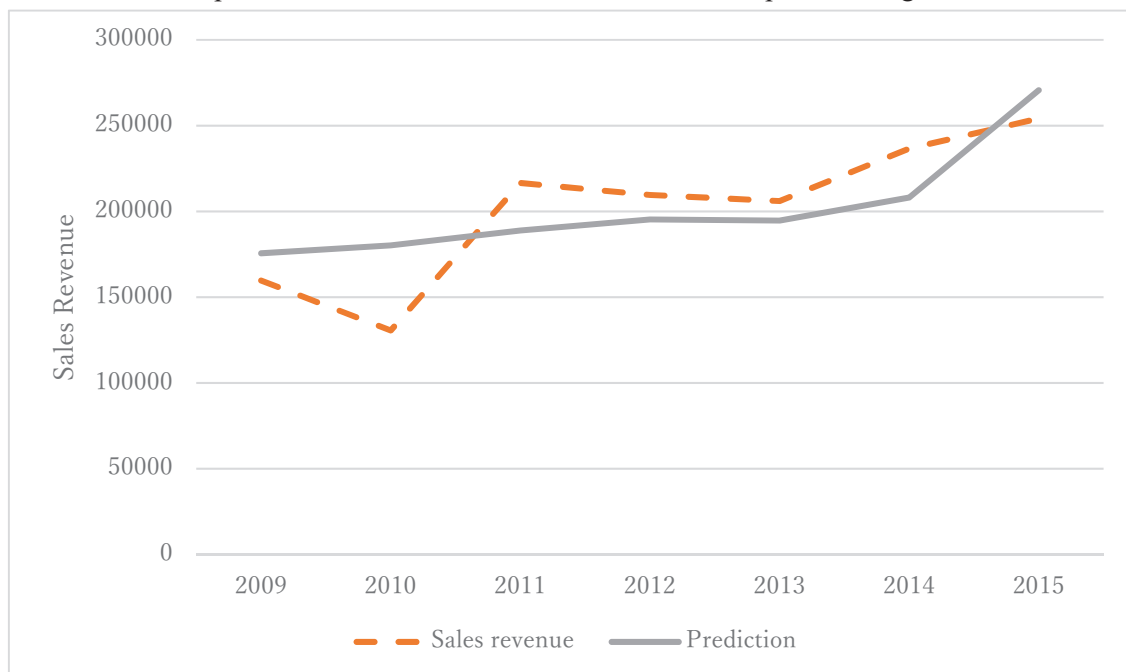


Figure 24 Prediction of Akebono Brake Industries using Momentum from 2009 to 2015.

The results of prediction in 2016 after calculating momentum using Prediction Sheet is as shown in Figure 25.

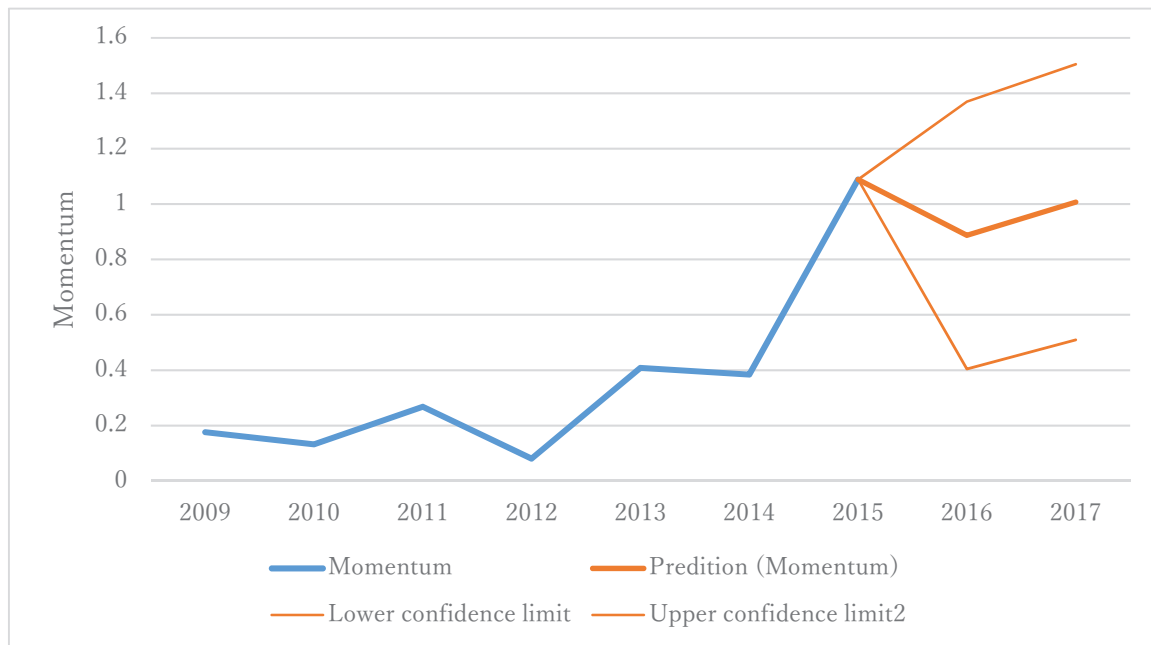


Figure 25 Prediction of Toyota's Momentum in 2016.

The prediction value of the momentum in 2016 is 0.887, the lower confidence limit and upper confidence limit is 0.40 and 1.037 respectively. The prediction value of sales revenue is 26,257,321.92 million Japanes Yen, and the confidence interval is {22,082,181.14, 30,432,462.69} using regression model. The sales revenue and its prediction is shown as Figure 26.

Other companies such as Akebono brake industries and Meiwa have been tested. Thus, the momentum proposed in this Chapter is not only effective for identifying the external exchanges and determining the trend and the development direction of the firm, but also useful to forecast sales revenue.

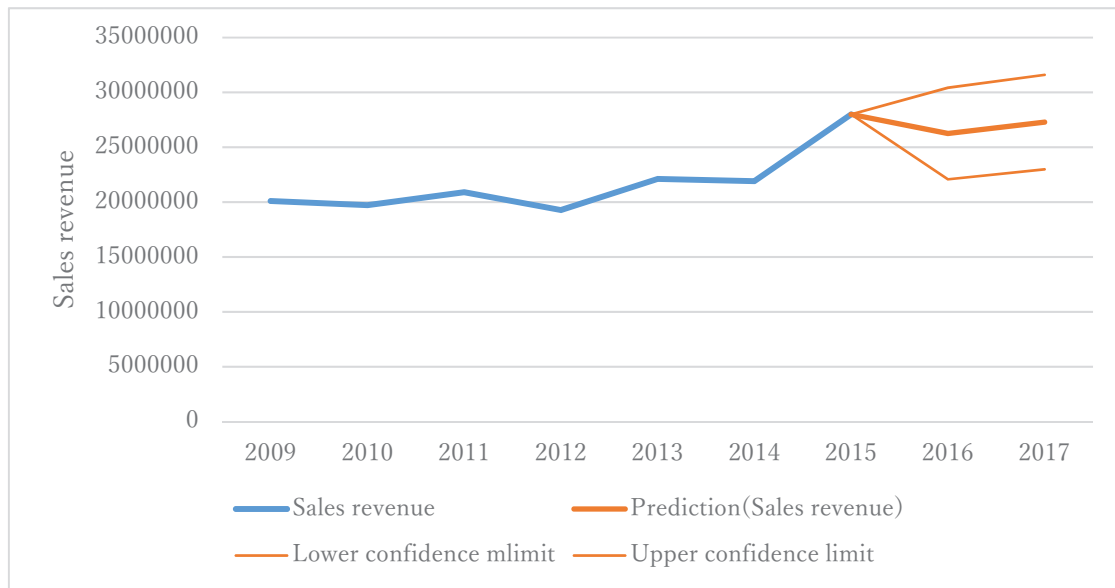


Figure 26 Prediction Results of Toyota's Sales Revenue in 2016 using Momentum.

#### 4.6 Concluding Remarks

This chapter proposed a new approach for using momentum based on the limit cycle after reviewing the relevant literature. The relationship between momentum and its external changes, momentum and company scale were analyzed over various momentum periods. Furthermore, the four-cell matrix model composed of momentum and company sales revenue confirmed that it is effective for judging firm's position. Additionally, the impact of the financial crisis on momentum was also tested.

Sales revenue and profit, as indices of corporate performance, is insufficient. Additional indices, such as aggregate market value and ROI (return on investment), should be investigated. What's more, in the future these models should be tested using data drawn from other settings, such as information technology, and the ship-building industry for comparative research as well as replicating the current findings.

#### 4.7 Directions for Future Research

The 35 companies, as the typical and important firms in automobile industry, have been selected and tested using momentum model in this Chapter. Although our findings proved that all data of those 35 firms is sufficient to confirm our new model because automobile industry is one of the



most developed industries and these companies are playing important role in automobile industry, the study possesses certain limitations that are redolent of future research efforts, which are suggested as follows. First, the linkages among the focal constructs should be tested using data drawn from keiretsu in different industries, such as steel, electronics, and shipbuilding. Second, in a similar vein, the linkages among the focal constructs should be replicated using data gathered from additional automotive keiretsu that include Nissan and Honda to test the external validity of the findings. Third, additional network indices, such as influence, density, and balance, should be used to calculate the relationship with momentum in a given spatial space. Finally, the present research only used data from only 10 fiscal year. Additional data set should be gathered to ascertain the rational interrelationship between momentum and corporate performance. Furthermore, the original definition of momentum in the art of war is a theoretical concept. Thus, in the future the models tested in this study should be investigated using data drawn from other settings, such as, information technology, and the shipbuilding industry for comparative research as well as replicating the findings of this study.

## Chapter 5 Conclusion

It is widely acknowledged that the resurgence of Japan into a global economic powerhouse has largely been attributed to institutions known as keiretsus. Having morphed from Zaibatsus that existed prior to the 1950s, keiretsus are a family-owned array of businesses, which are organized as an inter-firm network, wherein all member counterparts forge strong relationships. In essence, member firms within the network cement bonds to operate as strategic alliance partners that cooperate with one another to achieve super-ordinate goals with a concerted focus on the survival of the entire system. Instead of individual firms, such as Toyota Motors and Mazda Motors competing and cooperating with one another, these organizations cement alliances with their partnering manufacturer- suppliers and distributors, respectively, encompassing the entire value chain to form formidable networks that compete with one another to vie for market share and corporate profits.

More recently, global competitive pressures that have intensified over the last two decades, and the geographic dispersion of the world's supply chains have had a significant impact on the operation and interrelationships among member firms in Japanese keiretsus. In specific, keiretsus have more recently started to experience a “loosening” of ties among their family-related counterparts with many firms breaking generational familial norms by simultaneously conducting exchange relationships with firms that lie outside their family network boundaries—behavior that traditionally is considered incongruent and inconsistent within the nature of keiretsu norms and policies.

Much about the existence of keiretsu networks that have been prominent in the Japanese economy over the last 70 years have only been the subject of news and anecdotal discussions in the popular press. In contrast, academic research in scholarly journals that seeks to advance our understanding of these networks by expounding on the theory, nature and interrelationships among member keiretsu partners has only started to emerge within the last decade. From the albeit scant academic research, it is readily evident that the systematic body of knowledge on Japanese keiretsus is considered to be fragmentary. Additionally, reflective of disjointed disparate research, there is a paucity of knowledge in theory development and empirical investigations.

As academic research on keiretsus is still considered nascent, it is necessary to augment

knowledge on these important business networks. For example, identifying strategies that cement stronger bonds among keiretsu member-partners that enable family-centered networks to remain viable has taken on greater importance as this can ultimately culminate in augmenting the performance and efficiency of these “super-organizations.” Moreover, it is readily discernible that there is no systematic agenda to identify and empirically test the extent to which keiretsu-related inter-firm relationships and ties, such as: (a) Centrality, (b) Betweenness, (c) Closeness, (d) Capacity, (e) Degree, (f) Influence, (g) Balance, (h) Radius, (i) Diameter, (j) Stability, (k) Density, (l) Fragility, (m) Momentum, (n) Periphery, (o) Eigenvalue, (p) Structure hole, (q) Block, and (r) Cluster, among a plethora of others, are statistically significant determinants of corporate performance—as measured by sales revenues and profits.

To partially rectify this imbalance of academic research as well as develop a streamlined agenda that makes a concerted effort in augmenting our understanding of Japanese keiretsus, the purpose of this dissertation is to document a series of empirical investigations on inter-firm business networks. More specifically, this thesis describes three empirical investigations that were executed to investigate the extent to which (a) Fragility, (b) Degree, and (c) Momentum are statistically significant predictors of sales revenues and corporate profits.

In Chapters 2, 3 and 4, the relevant literature, conceptual model, research methods, results, implications, drawbacks and directions for future research for each of the three studies were discussed. However, this concluding chapter reiterates the salient highlights of the three studies—as summarized below.

### **Study 1: Measuring Fragility using the Entire Degree in Network Systems**

In Chapter 2 the study entitled “Measuring Fragility using the Entire Degree in Network Systems” develops and empirically tests a mathematical conceptual framework of fragility from the standpoint of how ties among network members significantly influence corporate performance. To shed light on the relationship between degree and fragility, data was drawn from a sample of two well-known network organizations—Mazda and Toyota. The empirical investigation confirmed the validity of the new concept as well as enabling a contrast of Mazda and Toyota’s network structures. More specifically, for Toyota’s Kyohokai data set (2004 to 2007), the study found that higher levels of fragility were associated with lower sales revenues, whereas for Mazda’s Yokokai dataset (2004 to 2012) the higher levels of fragility were associated with higher sales revenues. Although the relationships are statistically significant for the Toyota and Mazda samples, the findings display an inverse effect. Thus, Toyota and Mazda’s keiretsu manifests

contrasting behaviors. A possible explanation is that fragility is conceptualized differently when compared to degree because the latter stresses the “strength of connections,” while the former emphasizes the “brittleness of connections.” These contrasting findings will not be possible to attain between Mazda and Toyota if degree was used as an index. Additionally, these divergent results are also suggestive of the possibility that the keiretsu is “loosening” for Mazda’s keiretsu, whereas it is strengthening for the Toyota’s keiretsu. Thus, these findings can be considered as a fresh contribution of this study.

## **Study 2: Measuring Efficiencies using Dynamic Network-based DEA in Network Systems**

Described in Chapter 3, the study entitled “Measuring Efficiencies using Dynamic Network-based DEA in Network Systems” suggests a novel procedure for improving the efficiency of organizations, which is a continuing objective of strategic corporate management. Although numerous tools to assess efficiency have been devised, this investigation sought to propose a newer approach known as dynamic network-based Data Envelopment Analysis (DEA) is an even more effective procedure for identifying which transaction should be given priorities in any network-based organization. This is because the use of dynamic network-based DEA makes it possible to detect systemic impacts when marginal changes in related inter-firm phenomena are observed. Put another way, traditional DEA is a tool that focuses on measuring the efficiency, which is inappropriate to apply to a network-based system because they are subject to dynamic changes. Given this condition, this study instead proposed the use of a newer, more novel approach known as dynamic network-based DEA, which not only can measure efficiency and find the alternatives to improving efficiency, but can also will help decision-makers to determine the priorities of transactions.

This new approach for determining the priority of transactions or deals in networks was tested using data drawn from a random sample of firms comprising Mazda’s Yokokai keiretsu to shed light on the impact the number of transactions among members have on sales revenues. This fresh approach helps determine which types of transactions should be prioritized based on systemic changes instead of placing importance on the total number of transactional events. In other words, the total number of transactions can be used to determine effectiveness, whereas the newer dynamic network-based Data Envelopment Analysis approach for detecting systemic change is more useful for improving efficiency.

Given the paucity of research in this domain, this study made a unique contribution to the extant literature by proposing and empirically testing a novel DEA conceptual model based on

network analysis, which focuses on discerning systemic changes in networks for calculating efficiency within keiretsus and identifying its implications for formulating in corporate strategy for network-based organizations.

### **Study 3: Measuring Momentum Using Limited Cycle Theory in Network Systems**

Chapter 4 describes the rationale, procedure and results obtained from an empirical investigation on keiretsus, which is entitled “Measuring Momentum Using Limited Cycle Theory in Network Systems”. While the importance of momentum has been widely recognized in the literature, only scholars within the domain of finance have calculated stock market momentum by using the moving average and pattern recognition model. Thus, no extant studies are known to exist that have attempted to develop quantitative approaches for measuring it as well as finding additional functions for applying momentum, such as within the domain of keiretsus. This first known study to extend the concept of momentum to the context of keiretsus was based on a review of the literature wherein a new approach of acceleration that measures and applies momentum was proposed. Specifically, because corporate behavior is non-linear, it is appropriate to calculate momentum by integrating complex systems theory and limited cycle theory. Based on this justification, momentum, which is conceptualized as a force that impacts sales revenues and profits, was calculated using data on total assets and liabilities for the period 2003 to 2013 drawn from a sample of firms in the Japanese automobile industry that included 10 auto manufacturers and 25 parts suppliers.

The results of study found support for the notion that “larger scale was associated with higher momentum.” Additionally, momentum was observed to be a statistically significant predictor of sales revenues and operating income. The interval of the impact of momentum on sales revenues and operating income was almost four years, which is consistent with the change cycle model. Moreover, a four-cell matrix of momentum vis-à-vis sales was proposed for judging a firm’s position classified as: (a) a problem child, (b) a good performer, (c) a poor performer, and (d) has potential for development, which can be used as a useful framework for suggesting future courses of action relative to investment/divestment.

Collectively, because of these original thoughts and novel procedures, this study made a contribution to the literature by increasing our extant knowledge on keiretsu networks.

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## Appendices

### Appendix 1

Efficiency of Each Firm in Yokokai

No.	Firm	Efficiency	Reference Set ( $\lambda$ )
1	Ishizaki Honten Company, Limited	0.026	Pioneer Corporation (0.032)
2	Keylex Corporation	0.025	Pioneer Corporation (0.039)
3	Kurashiki Kako Co., Ltd.	0.021	Pioneer Corporation (0.025)
4	Sumino Kogyo Co., Ltd.	0.005	Pioneer Corporation (0.008)
5	Nishikawa Rubber Co., Ltd.	0.071	Pioneer Corporation(0.061)
6	Japan Climate Systems Corporation	0.004	Pioneer Corporation (0.007), Matsushita Electric Industrial Co., Ltd. (0.004)
7	Hiruta Kogyo Co., Ltd.	0.018	Pioneer Corporation (0.027)
8	Hiroshima Aluminum Co., Ltd.	0.04	Pioneer Corporation (0.053)
9	Molten Corporation	0.059	Pioneer Corporation (0.042)
10	Ring Techs Hiroshima Co., Ltd.	0.009	Pioneer Corporation (0.013)
11	Akebono Brake Industry Co., Ltd.	0.163	Pioneer Corporation (0.190)
12	Asmo Co., Ltd.	0.159	Pioneer Corporation (0.233)
13	Usui Kokusai Sangyo Kaisha, Ltd.	0.06	Pioneer Corporation (0.066)
14	NOK Corporation	0.302	Pioneer Corporation (0.370)
15	KYB Co., Ltd.	0.007	Pioneer Corporation (0.004), Matsushita Electric Industrial Co., Ltd. (0.040)
16	Calsonic Kansei Corporation	0.02	Pioneer Corporation (0.027), Matsushita Electric Industrial Co., Ltd. (0.124)

Efficiency of Each Firm in Yokokai (Continued).

No.	Firm	Efficiency	Reference Set ( $\lambda$ )
17	Kyosan Denki Co., Ltd.	0.03	Pioneer Corporation (0.047)
18	Clarion Co., Ltd.	0.01	Matsushita Electric Industrial Co., Ltd. (0.044)
19	Koito Manufacturing Co., Ltd.	0.159	Pioneer Corporation (0.236)
20	Sanoh Industrial Co., Ltd.	0.056	Pioneer Corporation (0.061)
21	Jatco Ltd.	0.003	Matsushita Electric Industrial Co., Ltd. (0.073)
22	Showa Corporation	0.193	Pioneer Corporation (0.296)
23	Stanley Electric Co., Ltd.	0.009	Pioneer Corporation (0.006), Matsushita Electric Industrial Co., Ltd. (0.041)
24	Takata Co., Ltd.	0.007	Pioneer Corporation (0.012), Matsushita Electric Industrial Co., Ltd. (0.027)
25	Tokyo Roki Co., Ltd.	0.046	Pioneer Corporation (0.077)
26	Toyo Radiator Co., Ltd.	0.077	Pioneer Corporation (0.068)
27	Tokico Ltd.	0.183	Pioneer Corporation (0.107)
28	GKN Driveline Torque Technology K. K.	0.052	Pioneer Corporation (0.073)
29	Topy Industries Ltd.	0.165	Pioneer Corporation (0.206)
30	Nisshinbo Industries, Inc.	0.217	Pioneer Corporation (0.348)
31	Nittan Valve Co., Ltd.	0.039	Pioneer Corporation (0.029)
32	Nifco Inc.	0.064	Pioneer Corporation (0.082)
33	Nippon Sheet Glass Co., Ltd.	0.004	Matsushita Electric Industrial Co., Ltd. (0.066)
34	Nippon Thermostat Co., Ltd.	0.01	Pioneer Corporation (0.013)
35	NSK Ltd.	0.048	Pioneer Corporation (0.057), Matsushita Electric Industrial Co., Ltd. (0.114)
36	NHK Spring Co., Ltd.	0.161	Pioneer Corporation (0.226)

Efficiency of Each Firm in Yokokai (Continued).

No.	Firm	Efficiency	Reference Set ( $\lambda$ )
37	Nippon Piston Ring Co., Ltd.	0.064	Pioneer Corporation (0.061)
38	Japan Brake Industrial Co., Ltd.	0.02	Pioneer Corporation (0.018)
39	Pioneer Corporation	1	Pioneer Corporation (1.000)
40	Piolax, Inc.	0.025	Pioneer Corporation (0.044)
41	Hitachi, Ltd.	0.065	Pioneer Corporation (0.113), Matsushita Electric Industrial Co., Ltd. (0.717)
42	Bridgestone Corporation	0.149	Matsushita Electric Industrial Co., Ltd. (0.530)
43	The Furukawa Electric Co., Ltd.	0.372	Pioneer Corporation (0.652)
44	Press Kogyo Co., Ltd.	0.075	Pioneer Corporation (0.106)
45	Bosch Corporation	0.954	Pioneer Corporation (0.451)
46	Marui Industrial Co., Ltd.	0.013	Pioneer Corporation (0.016)
47	Mikuni Corporation	0.107	Pioneer Corporation (0.084)
48	Mitsuba Corporation	0.171	Pioneer Corporation (0.141)
49	Mitsubishi Electric Corporation	0.149	Matsushita Electric Industrial Co., Ltd. (0.859)
50	Meiwa Industry Co., Ltd.	0.021	Pioneer Corporation (0.026)
51	Unipres Corporation	0.026	Pioneer Corporation (0.034), Matsushita Electric Industrial Co., Ltd. (0.021)
52	Yorozu Corporation	0.05	Pioneer Corporation (0.062)
53	Riken Corporation	0.152	Pioneer Corporation (0.095)
54	Aisan Industry Co., Ltd. Hiroshima Sales	0.011	Pioneer Corporation(0.016), Matsushita Electric Industrial Co., Ltd. (0.025)
55	Aisin AI Co., Ltd.	0.002	Matsushita Electric Industrial Co., Ltd. (0.016)
56	Ashimori Industry, Co., Ltd.	0.049	Pioneer Corporation (0.040)



Efficiency of Each Firm in Yokokai (Continued).

No.	Firm	Efficiency	Reference Set ( $\lambda$ )
57	Inoac Corporation	0.212	Pioneer Corporation (0.248)
58	Imasen Electric Industrial Co., Ltd.	0.007	Pioneer Corporation (0.009), Matsushita Electric Industrial Co., Ltd. (0.008)
59	Exedy Corporation	0.106	Pioneer Corporation (0.110)
60	NTN Corp.	0.491	Pioneer Corporation (0.516)
61	Owari Precise Products Co., Ltd.	0.015	Pioneer Corporation (0.018)
62	Koyo Seiko Co., Ltd.	0.018	Pioneer Corporation (0.028), Matsushita Electric Industrial Co., Ltd. (0.067)
63	Kokusan Parts Industry Co., Ltd.	0.006	Pioneer Corporation (0.008)
64	Daido Metal Corporation	0.056	Pioneer Corporation (0.065)
65	Chuo Spring Co., Ltd.	0.105	Pioneer Corporation (0.103)
66	TRW Automotive Japan	0.018	Pioneer Corporation (0.026)
67	Denso Corporation	0.005	Pioneer Corporation (0.006), Matsushita Electric Industrial Co., Ltd. (0.549)
68	Tokai Rubber Industries, Ltd.	0.056	Matsushita Electric Industrial Co., Ltd. (0.034)
69	Tokai Rika Co., Ltd.	0.23	Pioneer Corporation (0.367)
70	Toyo Tire & Rubber Co., Ltd.	0.614	Pioneer Corporation (0.215)
71	Toyota Gosei Co., Ltd.	0.036	Pioneer Corporation (0.038), Matsushita Electric Industrial Co., Ltd. (0.057)
72	Nihon Cable System Co., Ltd.	0.061	Pioneer Corporation (0.076)
73	NGK Spark Plug Co., Ltd.	0.198	Pioneer Corporation (0.289)
74	Hanshin Electric Co., Ltd.	0.013	Pioneer Corporation (0.021)
75	Hikari Seiko Co., Ltd.	0.022	Pioneer Corporation (0.021)
76	Matsushita Electric Industrial Co., Ltd.	1	Matsushita Electric Industrial Co., Ltd. (1.000)

Efficiency of Each Firm in Yokokai (Continued).

No.	Firm	Efficiency	Reference Set ( $\lambda$ )
77	Maruyasu Industries Co., Ltd.	0.072	Pioneer Corporation (0.112)
78	Mazda Motor Corporation	0.001	Matsushita Electric Industrial Co., Ltd. (0.558)
79	Toyota Motor Corporation	0.011	Matsushita Electric Industrial Co., Ltd. (4.081)
80	Nissan Motor Co., Ltd.	0.006	Matsushita Electric Industrial Co., Ltd. (1.753)
81	Honda Motor Co., Ltd.	0.007	Matsushita Electric Industrial Co., Ltd. (1.926)
82	Mitsubishi Motors Corporation	0.002	Matsushita Electric Industrial Co., Ltd. (0.595)
83	Fuji Industries Ltd.	0.003	Matsushita Electric Industrial Co., Ltd. (0.340)
84	Daihatsu Motor Co., Ltd.	0.003	Matsushita Electric Industrial Co., Ltd. (0.234)
85	Suzuki Motor Corporation	0.004	Matsushita Electric Industrial Co., Ltd. (0.519)
86	Isuzu Motors Limited	0.003	Matsushita Electric Industrial Co., Ltd. (0.338)
87	Hino Motors Ltd.	0.007	Matsushita Electric Industrial Co., Ltd. (0.248)
88	Nissan Diesel Motor Co., Ltd.	0.005	Matsushita Electric Industrial Co., Ltd. (0.109)

Appendix 2

Results of Momentum.

Firms	t	Momentum													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Toyota Motor Corp.	1	6.77E+11	1.81E+11	-8.1E+10	-1E+11	7.26E+11	-2.2E+11	1.05E+11	1.47E+12	-1.6E+12	4.29E+11	-3.5E+11	2.75E+11	1.64E+11	-4.3E+11
	2	1.04E+12	5.99E+10	-2.2E+11	8.05E+11	4.6E+11	-9.9E+10	1.79E+12	-3.5E+11	-1.1E+12	4.6E+10	6.67E+10	4.51E+11	-3E+11	
	3	7.97E+11	-1.5E+11	9.92E+11	4.72E+11	6.07E+11	1.86E+12	-3E+11	1.83E+11	-1.6E+12	5.02E+11	3.91E+11	8.69E+11	-5E+10	
	4	3.82E+11	1.67E+12	5.48E+11	6.56E+11	2.96E+12	-5.7E+11	3.14E+11	-3E+11	-1.1E+12	8.59E+11	6E+11	3.26E+11		
	5	4.01E+12	1E+12	7.94E+11	3.6E+12	4.18E+10	1.45E+11	-2.3E+11	2.75E+11	-6.7E+11	1.09E+12	7.08E+09			
	6	2.68E+12	1.37E+12	4.72E+12	-5.1E+10	9E+11	-4.9E+11	4.19E+11	7.21E+11	-4.1E+11	4.37E+11				
	7	3.42E+12	7.26E+12	-1.5E+11	1.02E+12	1.34E+11	2.67E+11	9.29E+11	1.01E+12	-1.1E+12					
	8	1.52E+13	-4.3E+10	1.28E+12	6.37E+10	1.05E+12	8.62E+11	1.26E+12	1.93E+11						
	9	5.92E+11	2.1E+12	4.28E+09	1.2E+12	1.76E+12	1.24E+12	3.25E+11							
	10	4.88E+12	1.87E+11	1.53E+12	2.1E+12	2.22E+12	1.58E+11								
	11	1.05E+12	2.47E+12	2.72E+12	2.67E+12	9.16E+11									
	12	5.62E+12	4.25E+12	3.48E+12	1.04E+12										
	13	9.19E+12	5.4E+12	1.31E+12											
	14	1.15E+13	2.14E+12												
	15	4.96E+12													

Results of Momentum (Continued).

Firms	t	Momentum														
		-4.5E+11	1.44E+11	-8E+10	3.14E+11	-1.5E+11	-9E+10	1.39E+11	2.33E+11	-2.7E+11	-3.5E+10	5.85E+09	5.35E+10	2.68E+10	8.34E+10	-1.5E+11
Nissan Moto Co., Ltd.	1	-4.5E+11	1.44E+11	-8E+10	3.14E+11	-1.5E+11	-9E+10	1.39E+11	2.33E+11	-2.7E+11	-3.5E+10	5.85E+09	5.35E+10	2.68E+10	8.34E+10	-1.5E+11
	2	-1.6E+11	2.51E+10	3.4E+11	1.29E+11	-2.6E+11	7.21E+10	4.05E+11	-7.5E+10	-3.1E+11	-2.8E+10	6.42E+10	8.25E+10	1.17E+11	-7.7E+10	
	3	-4E+11	6.54E+11	9.25E+10	-5.7E+09	-6.2E+10	3.83E+11	5.33E+10	-1.2E+11	-3.1E+11	3.57E+10	9.59E+10	1.8E+11	-5.7E+10		
	4	8.55E+11	2.83E+11	-8.7E+10	2.37E+11	3.12E+11	-2.8E+10	3.42E+09	-1.1E+11	-2.3E+11	7.06E+10	2.02E+11	-7.9E+09			
	5	1.13E+11	1.37E+10	2.37E+11	7.04E+11	-1.8E+11	-8.6E+10	1.26E+10	-3E+10	-2E+11	1.87E+11	-2.7E+09				
	6	-4.3E+11	5E+11	8.59E+11	8.75E+10	-2.5E+11	-7.5E+10	1.04E+11	1.33E+10	-6.6E+10	-3.8E+10					
	7	5.46E+11	1.43E+12	3.71E+10	2.52E+08	-2.4E+11	3.19E+10	1.54E+11	1.59E+11	-3.2E+11						
	8	2.41E+12	2E+11	-7.9E+10	1.63E+10	-1.1E+11	8.99E+10	3.21E+11	-1.2E+11							
	9	-5.3E+10	2.56E+10	-5.8E+10	1.77E+11	-4E+10	2.85E+11	-8.5E+08								
	10	-4E+11	5.78E+10	1.56E+11	2.64E+11	1.93E+11	-9.1E+10									
	11	-3.4E+11	3.79E+11	2.72E+11	5.56E+11	-2.6E+11										
	12	3.04E+11	5.53E+11	6.62E+11	-7.2E+09											
	13	6.53E+11	1.14E+12	-8.9E+10												
	14	1.82E+12	1.07E+10													
	15	-4.3E+11														

Results of Momentum (Continued).

Firms	t	Momentum														
		-1.2E+11	7.41E+10	-4.5E+10	5.25E+10	-4.3E+10	1.41E+10	-1.2E+10	1.18E+10	-6.4E+09	-2.4E+09	-1E+09	1.96E+09	-2.5E+09	2.4E+08	70552600
Mitsubishi Motors	1	-1.2E+11	7.41E+10	-4.5E+10	5.25E+10	-4.3E+10	1.41E+10	-1.2E+10	1.18E+10	-6.4E+09	-2.4E+09	-1E+09	1.96E+09	-2.5E+09	2.4E+08	70552600
	2	3.03E+10	6.02E+09	2.45E+10	-1.4E+09	-2.6E+10	89227700	1.46E+09	4.57E+09	-9E+09	-3.5E+09	1.13E+09	-7.9E+08	-2.3E+09	3.16E+08	
	3	-1.1E+11	1.11E+11	-4.7E+10	1.98E+10	-4.3E+10	1.58E+10	-6.8E+09	1.6E+09	-1E+10	-1.1E+09	-1.9E+09	-5.1E+08	-2.2E+09		
	4	1.04E+11	3.3E+09	-1.9E+10	-1.2E+09	-2.4E+10	6.19E+09	-1E+10	2.15E+08	-7.7E+09	-4.4E+09	-1.6E+09	-4.2E+08			
	5	-1.1E+11	4.56E+10	-4.7E+10	2.23E+10	-3.6E+10	2.22E+09	-1.2E+10	3.16E+09	-1.1E+10	-4.1E+09	-1.5E+09				
	6	-2.7E+10	3.57E+09	-1.6E+10	7.93E+09	-4E+10	3.75E+08	-8.4E+09	-9.7E+08	-1.1E+10	-4E+09					
	7	-1.1E+11	5.07E+10	-3.5E+10	1.98E+09	-4.3E+10	4.3E+09	-1.3E+10	-5.5E+08	-1.1E+10						
	8	-1.7E+10	2.19E+10	-4.3E+10	-7.9E+08	-3.8E+10	-1.2E+09	-1.3E+10	-4.2E+08							
	9	-7.4E+10	9.97E+09	-4.6E+10	5.09E+09	-4.5E+10	-6.5E+08	-1.2E+10								
	10	-9.8E+10	4.43E+09	-3.9E+10	-3.2E+09	-4.4E+10	-4.7E+08									
	11	-1.1E+11	1.62E+10	-5E+10	-2.3E+09	-4.4E+10										
	12	-8.6E+10	-3.2E+08	-4.9E+10	-2.1E+09											
	13	-1.2E+11	1.36E+09	-4.8E+10												
	14	-1.2E+11	1.89E+09													
	15	-1.1E+11														

Results of Momentum (Continued).															
Firms	t	Momentum													
Honda Motor Co., Ltd.	1	1.8E+11	-9.9E+10	1.22E+10	-2.9E+09	-9.9E+09	5.63E+10	-4.2E+10	1.53E+11	-2E+10	-4.3E+10	-4.2E+10	4.41E+10	-3.3E+09	9.77E+10
	2	-1.9E+10	-8.1E+10	8.31E+09	-1.5E+10	5.76E+10	7.42E+09	1.33E+11	1.31E+11	-6.8E+10	-9E+10	5.64E+09	4.05E+10	1.02E+11	-1.9E+10
	3	1.78E+10	-8.7E+10	-8.2E+09	6.92E+10	-1E+09	2.12E+11	1.08E+11	7.74E+10	-1.2E+11	-3.7E+10	1.72E+09	1.55E+11	-2.4E+10	
	4	6.23E+09	-1.1E+11	1.04E+11	-4.2E+09	2.44E+11	1.82E+11	4.65E+10	1.9E+10	-6.1E+10	-4.1E+10	1.26E+11	1.79E+10		
	5	-4.3E+10	5.72E+10	6.61E+09	3.03E+11	2.09E+11	1.11E+11	-2E+10	8.51E+10	-6.5E+10	9.56E+10	-2.3E+10			
	6	2.94E+11	-8.9E+10	4.16E+11	2.58E+11	1.23E+11	3.27E+10	5.54E+10	7.98E+10	8.66E+10	-6.8E+10				
	7	1.12E+09	5.24E+11	3.57E+11	1.51E+11	2.93E+10	1.21E+11	4.93E+10	2.51E+11	-9.6E+10					
	8	1.23E+12	4.36E+11	2.13E+11	3.38E+10	1.35E+11	1.14E+11	2.45E+11	4.58E+10						
	9	1.05E+12	2.2E+11	5.72E+10	1.66E+11	1.27E+11	3.42E+11	1.05E+10							
	10	6.2E+11	-1.4E+10	2.34E+11	1.55E+11	4E+11	6.85E+10								
	11	1.53E+11	2.51E+11	2.19E+11	4.97E+11	7.23E+10									
	12	6.82E+11	2.3E+11	6.75E+11	8.75E+10										
	13	6.39E+11	9.14E+11	1.29E+11											
	14	2.01E+12	9.38E+10												
	15	3.68E+11													

Results of Momentum (Continued).

Firms	t	Momentum														
		-6.7E+10	-1.2E+09	-2.7E+08	2.19E+09	-5.7E+08	-8.3E+08	-2E+08	2.16E+09	-1.6E+09	2.67E+09	-2.1E+09	-5E+08	1.25E+09	-1.3E+09	86654200
Mazda Motor Corp.	1	-6.7E+10	-1.2E+09	-2.7E+08	2.19E+09	-5.7E+08	-8.3E+08	-2E+08	2.16E+09	-1.6E+09	2.67E+09	-2.1E+09	-5E+08	1.25E+09	-1.3E+09	86654200
	2	-7E+10	-1.6E+09	2.65E+09	1.48E+09	-1.6E+09	-1.1E+09	2.26E+09	3.15E+08	1.33E+09	3.65E+08	-2.6E+09	8.59E+08	-1.2E+08	-1.2E+09	
	3	-7.1E+10	2.77E+09	1.7E+09	2.36E+08	-1.8E+09	1.81E+09	1.55E+08	3.65E+09	-1.2E+09	-2.3E+08	-1.2E+09	-6.3E+08	-1.9E+07		
	4	-6.2E+10	1.35E+09	42052300	-1.2E+08	1.6E+09	-6.5E+08	3.97E+09	7.71E+08	-1.9E+09	1.4E+09	-2.8E+09	-5.2E+08			
	5	-6.5E+10	-1.1E+09	-4.4E+08	4.19E+09	-1.3E+09	3.8E+09	6.77E+08	23754800	-8.5E+07	-3.9E+08	-2.7E+09				
	6	-7E+10	-1.8E+09	5.31E+09	5.07E+08	3.99E+09	-3.8E+07	-1.8E+08	2.06E+09	-2.1E+09	-2.6E+08					
	7	-7.1E+10	6.77E+09	4.03E+08	7.18E+09	-6.2E+08	-1E+09	2.15E+09	-1.7E+08	-1.9E+09						
	8	-5.4E+10	-5.9E+08	9.3E+09	1.42E+09	-1.8E+09	1.68E+09	-4E+08	-6892090							
	9	-6.9E+10	1.28E+10	1.62E+09	-7.5E+07	1.45E+09	-1.3E+09	-2.1E+08								
	10	-4.2E+10	1.24E+09	-3.7E+08	4E+09	-2.1E+09	-1.1E+09									
	11	-6.5E+10	-1.8E+09	5.06E+09	-4.6E+08	-1.9E+09										
	12	-7.1E+10	6.39E+09	-8.9E+08	-1.4E+08											
	13	-5.5E+10	-2.5E+09	-4.5E+08												
	14	-7.2E+10	-1.9E+09													
	15	-7.1E+10														



Results of Momentum (Continued).

Firms	t	Momentum														
		2.23E+09	2.23E+09	-8.2E+08	-9E+08	2.54E+09	1.5E+10	-1.5E+10	6.27E+09	-8.1E+09	8.01E+09	-5.3E+09	-3.8E+08	3.45E+09	-4.6E+08	1.67E+09
Suzuki Motor Corp.	1	2.23E+09	2.23E+09	-8.2E+08	-9E+08	2.54E+09	1.5E+10	-1.5E+10	6.27E+09	-8.1E+09	8.01E+09	-5.3E+09	-3.8E+08	3.45E+09	-4.6E+08	1.67E+09
	2	6.69E+09	9.95E+08	-2E+09	2.28E+09	2.05E+10	-2.1E+09	-7.5E+09	-2.8E+09	8.12E+08	2.22E+09	-5.7E+09	3.35E+09	2.95E+09	1.33E+09	
	3	4.22E+09	-8.1E+08	2.21E+09	2.47E+10	25977400	6.26E+09	-1.8E+10	7.18E+09	-5.6E+09	1.76E+09	-1.6E+09	2.82E+09	4.88E+09		
	4	6.08E+08	5.55E+09	3.22E+10	-8.7E+08	1.01E+10	-5.9E+09	-6.4E+09	-5.7E+07	-6.1E+09	6.24E+09	-2.2E+09	4.9E+09			
	5	1.33E+10	5.05E+10	-2E+09	1.17E+10	-4.5E+09	7.47E+09	-1.5E+10	-6.3E+08	-1.1E+09	5.6E+09	84936600				
	6	1.03E+11	-7.5E+08	1.47E+10	-6.5E+09	1.15E+10	-2.2E+09	-1.5E+10	4.97E+09	-1.9E+09	8.1E+09					
	7	7.38E+08	2.43E+10	-9.5E+09	1.35E+10	-6.6E+07	-2.9E+09	-8.9E+09	4.17E+09	9.16E+08						
	8	5.09E+10	-1.2E+10	1.72E+10	-9.9E+08	-9.7E+08	4.53E+09	-9.9E+09	7.3E+09							
	9	-2.2E+10	2.8E+10	-2.1E+09	-2.1E+09	7.98E+09	3.46E+09	-6.3E+09								
	10	5.82E+10	-9.8E+08	-3.7E+09	9.08E+09	6.7E+09	7.63E+09									
	11	2.79E+08	-3.3E+09	1.13E+10	7.47E+09	1.17E+10										
	12	-4.3E+09	1.91E+10	9.14E+09	1.37E+10											
	13	4.05E+10	1.59E+10	1.75E+10												
	14	3.41E+10	2.84E+10													
	15	5.91E+10														

Results of Momentum (Continued).

Firms	t	Momentum														
		6.25E+08	-2.2E+08	-4.3E+08	6.06E+08	6.64E+08	-4.5E+08	-4.4E+08	5.59E+08	-4.9E+08	7.26E+08	5.81E+08	-1.2E+09	1.39E+08	-1.3E+08	7.03E+08
Daihatsu Motor Co., Ltd.	1	6.25E+08	-2.2E+08	-4.3E+08	6.06E+08	6.64E+08	-4.5E+08	-4.4E+08	5.59E+08	-4.9E+08	7.26E+08	5.81E+08	-1.2E+09	1.39E+08	-1.3E+08	7.03E+08
	2	1.78E+08	-8.7E+08	3.79E+08	1.44E+09	1.3E+08	-9.6E+08	1.94E+08	10545400	3.2E+08	1.37E+09	-7.2E+08	-1E+09	1829870	6.26E+08	
	3	-1.1E+09	3.45E+08	1.49E+09	7.68E+08	-4.9E+08	-2.2E+08	-4.3E+08	9.18E+08	1.03E+09	-6.9E+07	-5.6E+08	-1.2E+09	8.13E+08		
	4	1.32E+09	2E+09	5.95E+08	-1E+07	4.01E+08	-9.5E+08	6.05E+08	1.72E+09	-5.6E+08	1.12E+08	-7.2E+08	-3.2E+08			
	5	4.63E+09	6.69E+08	-4.4E+08	1.11E+09	-4.8E+08	2.6E+08	1.52E+09	-7.6E+07	-3.6E+08	-6.7E+07	2.38E+08				
	6	1.96E+09	-8.9E+08	1.05E+09	11048900	9.76E+08	1.33E+09	-5.3E+08	1.5E+08	-5.6E+08	9.88E+08					
	7	-1.2E+09	1.35E+09	-4.1E+08	1.83E+09	2.26E+09	-1.1E+09	-2.7E+08	-7.3E+07	6.1E+08						
	8	3.32E+09	-8.5E+08	2.01E+09	3.43E+09	-6.1E+08	-7.6E+08	-5.3E+08	1.25E+09							
	9	-1.1E+09	2.79E+09	4.14E+09	-1.6E+08	-2.5E+08	-1.1E+09	9.78E+08								
	10	6.2E+09	5.98E+09	-6.5E+08	2.9E+08	-6.1E+08	6.96E+08									
	11	1.26E+10	-1.2E+09	-4.3E+07	-1.6E+08	1.5E+09										
	12	-1.8E+09	-2.9E+08	-6.4E+08	2.48E+09											
	13	50196100	-1.2E+09	2.88E+09												
	14	-1.7E+09	4.09E+09													
	15	8.81E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
		2.66E+11	-1.1E+11	-2.1E+10	7.13E+08	-8.4E+08	39064900	1.47E+08	2.33E+09	-1.1E+09	-9.2E+08	5.13E+08	-1.2E+08	7.96E+08	2.62E+09	-3.4E+09
Isuzu Motors Limited	1	2.66E+11	-1.1E+11	-2.1E+10	7.13E+08	-8.4E+08	39064900	1.47E+08	2.33E+09	-1.1E+09	-9.2E+08	5.13E+08	-1.2E+08	7.96E+08	2.62E+09	-3.4E+09
	2	5.35E+10	-1.4E+11	-2E+10	-3.4E+08	-7.9E+08	2.11E+08	2.81E+09	1.09E+09	-2.1E+09	-3.5E+08	3.85E+08	7.45E+08	3.62E+09	-1E+09	
	3	-8.2E+09	-1.4E+11	-2.1E+10	-2.8E+08	-5.9E+08	3.32E+09	1.39E+09	-6E+07	-1.5E+09	-5E+08	1.33E+09	3.8E+09	-2.8E+08		
	4	-5.4E+09	-1.4E+11	-2.1E+10	-2.1E+07	3.15E+09	1.66E+09	78522000	6.46E+08	-1.7E+09	5.4E+08	4.66E+09	-4.2E+08			
	5	-9.6E+09	-1.4E+11	-2.1E+10	4.65E+09	1.15E+09	1.31E+08	8.85E+08	4.69E+08	-5.1E+08	4.21E+09	54957900				
	6	-9.3E+09	-1.4E+11	-1.4E+10	2.15E+09	-6.8E+08	1.07E+09	6.83E+08	1.76E+09	3.56E+09	-8.6E+08					
	7	-8.3E+09	-1.3E+11	-1.8E+10	-1.4E+08	4.46E+08	8.36E+08	2.16E+09	6.34E+09	-2.1E+09						
	8	1.04E+10	-1.3E+11	-2.1E+10	1.27E+09	1.63E+08	2.56E+09	7.4E+09	15525700							
	9	4.14E+08	-1.4E+11	-1.9E+10	9.17E+08	2.23E+09	8.67E+09	1.65E+08								
	10	-8.8E+09	-1.3E+11	-1.9E+10	3.5E+09	9.56E+09	2.31E+08									
	11	-3.1E+09	-1.4E+11	-1.6E+10	1.27E+10	-5.6E+08										
	12	-4.5E+09	-1.3E+11	-3.7E+09	10326400											
	13	5.81E+09	-1.1E+11	-2.1E+10												
	14	4.25E+10	-1.4E+11													
	15	-8.2E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
		-1.5E+09	1.69E+08	-3.9E+08	-2E+08	8.92E+08	-7.4E+08	1.99E+08	2.15E+08	-3.7E+08	2.86E+08	7.7E+08	-9.5E+08	2.05E+08	44057300	-2E+08
Hino Motors, Ltd.	1	-1.5E+09	1.69E+08	-3.9E+08	-2E+08	8.92E+08	-7.4E+08	1.99E+08	2.15E+08	-3.7E+08	2.86E+08	7.7E+08	-9.5E+08	2.05E+08	44057300	-2E+08
	2	-1.2E+09	-4.1E+08	-6.6E+08	9.14E+08	7900190	-5E+08	4.45E+08	-2E+08	-5.3E+07	1.13E+09	-2.7E+08	-7.3E+08	2.53E+08	-1.7E+08	
	3	-2.3E+09	-8.1E+08	8.31E+08	-1.9E+08	2.87E+08	-2.2E+08	-3.1E+07	1.55E+08	8.88E+08	-1.3E+07	-2.9E+07	-6.8E+08	18005700		
	4	-3.1E+09	1.42E+09	-6.4E+08	1.58E+08	6.31E+08	-7.7E+08	3.77E+08	1.21E+09	-3.9E+08	2.53E+08	26711200	-9.4E+08			
	5	1.33E+09	-7.9E+08	-1.8E+08	5.88E+08	-3.6E+07	-3E+08	1.59E+09	-2.2E+08	-8.9E+07	3.15E+08	-2.5E+08				
	6	-3.1E+09	-9.6E+07	3.96E+08	-2.5E+08	5.35E+08	1.11E+09	-5E+07	1.15E+08	-2E+07	10211500					
	7	-1.7E+09	7.64E+08	-7.2E+08	4.69E+08	2.23E+09	-7.9E+08	3.31E+08	1.92E+08	-3.6E+08						
	8	29053900	-9E+08	2.37E+08	2.59E+09	-6.2E+07	-3.5E+08	4.19E+08	-1.9E+08							
	9	-3.3E+09	5.25E+08	3.06E+09	-2.8E+08	4.71E+08	-2.5E+08	-1.7E+07								
	10	-4.5E+08	4.76E+09	-7.6E+08	3.88E+08	5.94E+08	-7.6E+08									
	11	8.02E+09	-9.7E+08	1.3E+08	5.42E+08	-1.6E+07										
	12	-3.4E+09	3.63E+08	3.35E+08	-2.2E+08											
	13	-7.7E+08	6.72E+08	-6.8E+08												
	14	-1.5E+08	-8.5E+08													
	15	-3.2E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
		1.65E+09	-4.5E+08	2.17E+09	-6.3E+08	-4.1E+07	1.36E+09	-8.6E+08	9.87E+08	-1.6E+09	1.58E+09	-6.8E+08	9137100	1.31E+09	-1.3E+09	5.92E+08
Fuji Heavy Industries Ltd.	1	7.43E+08	2.8E+09	1.32E+09	-6.9E+08	1.59E+09	3.64E+08	2.72E+08	-8.5E+08	1.22E+08	8.38E+08	-6.7E+08	1.43E+09	-1.2E+08	-6.9E+08	
	2	7.25E+09	1.53E+09	1.26E+09	1.36E+09	3.96E+08	1.68E+09	-1.8E+09	1.12E+09	-7.1E+08	8.49E+08	8.77E+08	-1.2E+08	5.62E+08		
	3	4.71E+09	1.43E+09	3.98E+09	-1.4E+08	1.97E+09	-7.8E+08	4.29E+08	1.92E+08	-6.9E+08	2.55E+09	-8.1E+08	6.17E+08			
	4	4.51E+09	5.52E+09	1.98E+09	1.83E+09	-9.7E+08	1.86E+09	-6.4E+08	2.06E+08	1.19E+09	6.9E+08	-4005340				
	5	1.27E+10	2.52E+09	4.61E+09	-1.8E+09	2.19E+09	6.21E+08	-6.2E+08	2.33E+09	-8.7E+08	1.58E+09					
	6	6.69E+09	6.47E+09	-3E+08	2.11E+09	7.04E+08	6.39E+08	1.81E+09	8045950	1.18E+08						
	7	1.46E+10	-9E+08	4.98E+09	2.46E+08	7.26E+08	3.47E+09	-8.5E+08	1.12E+09							
	8	-1.4E+08	7.02E+09	2.5E+09	2.74E+08	4.12E+09	3.75E+08	4.23E+08								
	9	1.57E+10	3.29E+09	2.53E+09	4.52E+09	4.09E+08	1.86E+09									
	10	8.23E+09	3.35E+09	8.2E+09	-1.2E+08	2.19E+09										
	11	8.34E+09	1.18E+10	2.01E+09	2.1E+09											
	12	2.53E+10	2.56E+09	4.97E+09												
	13	6.76E+09	7E+09													
	14	1.56E+10														
	15															

Results of Momentum (Continued).

Firms	t	Momentum														
		-5.4E+08	8.02E+09	-5.3E+09	-2.3E+07	5.15E+08	-3.6E+08	-7.5E+07	-2.9E+07	3.81E+08	-2.7E+08	-1.5E+07	3.67E+08	-1.2E+08	-7.2E+07	71385300
Kawasaki Heavy Industries, Ltd.	1	-5.4E+08	8.02E+09	-5.3E+09	-2.3E+07	5.15E+08	-3.6E+08	-7.5E+07	-2.9E+07	3.81E+08	-2.7E+08	-1.5E+07	3.67E+08	-1.2E+08	-7.2E+07	71385300
	2	1.55E+10	86055800	-5.3E+09	6.21E+08	80210900	-4.5E+08	-1.1E+08	3.99E+08	77495300	-2.9E+08	3.85E+08	2.4E+08	-1.9E+08	4719080	
	3	-3.7E+08	40512300	-4.5E+09	77491900	-2.5E+07	-4.9E+08	3.81E+08	57951100	59029200	1.51E+08	2.47E+08	1.56E+08	-1.1E+08		
	4	-4.6E+08	1.33E+09	-5.2E+09	-5.4E+07	-7.2E+07	81995600	-9186990	37176700	5.49E+08	-1621550	1.55E+08	2.45E+08			
	5	2.11E+09	2.41E+08	-5.4E+09	-1.1E+08	6.13E+08	-3.7E+08	-3.3E+07	5.88E+08	3.79E+08	-1E+08	2.53E+08				
	6	-6.1E+07	-2.3E+07	-5.4E+09	7.44E+08	67349100	-4E+08	5.96E+08	3.97E+08	2.67E+08	4985150					
	7	-5.9E+08	-1.4E+08	-4.3E+09	61414700	34110100	3.34E+08	3.78E+08	2.72E+08	3.86E+08						
	8	-8.2E+08	1.57E+09	-5.2E+09	19865900	9.15E+08	79293100	2.35E+08	4.05E+08							
	9	2.6E+09	2.09E+08	-5.3E+09	1.12E+09	6.1E+08	-8.8E+07	3.88E+08								
	10	-1.3E+08	1.26E+08	-3.8E+09	7.4E+08	4.09E+08	90304200									
	11	-2.9E+08	2.33E+09	-4.3E+09	4.89E+08	6.23E+08										
	12	4.11E+09	1.57E+09	-4.6E+09	7.56E+08											
	13	2.59E+09	1.06E+09	-4.3E+09												
	14	1.58E+09	1.6E+09													
	15	2.65E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
		18902400	-1.7E+07	18902400	-1.4E+07	-816518	2563950	1230170	20870500	-2E+07	7878000	-7527230	95610.4	4041310	9779580	-1.3E+07
F-Tech Inc.	1	28158200	-1.7E+07	18902400	-1.4E+07	-816518	2563950	1230170	20870500	-2E+07	7878000	-7527230	95610.4	4041310	9779580	-1.3E+07
	2	-6075320	11236900	-138071	-1.5E+07	2260220	3999150	25082100	-2177580	-1.2E+07	-401956	-7422930	4473700	14573200	-3857370	
	3	50631900	-1.7E+07	-1498930	-1.1E+07	3982460	31826400	-1258490	7669920	-2.1E+07	-287223	-2646840	15883200	-112783		
	4	-6489540	-1.9E+07	3628960	-9302280	37375200	1095710	9995800	-2680020	-2.1E+07	4966480	9799900	-26571.1			
	5	-1.1E+07	-1.2E+07	6499360	32438600	498333	14225700	-1832710	-2536610	-1.5E+07	18657900	-7556220				
	6	4811570	-7367700	62153900	-1.4E+07	16254300	425783	-1668810	4030520	243849	-433841					
	7	13422800	76114100	692484	6037560	-305579	617004	5836480	21144800	-2.1E+07						
	8	1.8E+08	-1.6E+07	26952500	-1.5E+07	-76113.6	9373180	25395600	-2719880							
	9	-3997870	23312000	-647369	-1.4E+07	10431300	32192200	-1878260								
	10	74782100	-1.8E+07	-264927	-1241240	37814100	372641									
	11	-8017430	-1.8E+07	17247400	32987300	-369349										
	12	-6870110	8754390	62885500	-1.5E+07											
	13	45666900	77211400	-753653												
	14	1.83E+08	-1.8E+07													
	15	-8336280														



Results of Momentum (Continued).

Firms	t	Momentum														
Musashi Seimitsu Industry Co., Ltd.	1	14686500	6936510	-1898010	1641370	42797400	-4E+07	8459030	57629100	-5.1E+07	-3152910	5650750	10577300	-9182890	-8271630	17167100
	2	28559500	4089500	290483	55138100	-5552470	-3E+07	74320900	333650	-5.4E+07	3062910	17189600	629141	-1.8E+07	10121700	
	3	22865500	7372230	71619400	-5299230	6290170	46416200	8840340	-3607480	-4.8E+07	15755600	6337080	-9021100	1717390		
	4	29431000	1.14E+08	-8963640	9504070	98496700	-3E+07	4336190	4162290	-3.3E+07	3817880	-4190450	12437800			
	5	2.43E+08	-6508950	10774100	1.25E+08	6824010	-3.5E+07	13215900	20028200	-4.7E+07	-7762400	19219200				
	6	1668610	23097600	1.64E+08	10171400	518194	-2.5E+07	31348400	5106010	-6E+07	17988200					
	7	60881800	2.54E+08	11663800	2289110	12949800	-3718380	14294500	-9369350	-3.1E+07						
	8	5.22E+08	24432200	1154140	17828700	38335300	-2.4E+07	-2248800	22819000							
	9	63551000	8667720	21873500	49560500	14459800	-4.3E+07	34537800								
	10	32021900	39746800	64182600	19716100	-8700800	2621.75									
	11	94180200	1.03E+08	24390100	-9234630	42800500										
	12	2.21E+08	43521700	-1.4E+07	55142000											
	13	1.02E+08	-1.4E+07	71624700												
	14	-1.4E+07	1.14E+08													
	15	2.43E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		-5.3E+08	1.75E+08	-2.1E+07	-6.7E+07	61843700	-4.6E+07	37700100	1.23E+08	65806700	-1.3E+08	-5.5E+07	2436820	28881200	-2.9E+07	492664
Nissan Shatai Co., Ltd.	1	-5.3E+08	1.75E+08	-2.1E+07	-6.7E+07	61843700	-4.6E+07	37700100	1.23E+08	65806700	-1.3E+08	-5.5E+07	2436820	28881200	-2.9E+07	492664
	2	-1.8E+08	1.44E+08	-1.1E+08	10290900	6401610	-2218280	1.78E+08	1.97E+08	-7.9E+07	-1.9E+08	-5.3E+07	33724800	-2885820	-2.9E+07	
	3	-2.4E+08	9981240	-7203250	-5.9E+07	59181700	1.61E+08	2.62E+08	33257900	-1.5E+08	-1.9E+08	-1.9E+07	-689480	-2317360		
	4	-5.1E+08	1.65E+08	-1E+08	6963490	2.55E+08	2.6E+08	75709100	-4.3E+07	-1.4E+08	-1.5E+08	-5.6E+07	-73649.6			
	5	-2E+08	25985300	-1.2E+07	2.52E+08	3.74E+08	42125600	-1.1E+07	-3.9E+07	-1E+08	-1.9E+08	-5.5E+07				
	6	-4.8E+08	1.58E+08	3.15E+08	4E+08	1.12E+08	-5.9E+07	-7191990	7651400	-1.5E+08	-1.9E+08					
	7	-2.1E+08	6.48E+08	5.13E+08	73479300	-9515550	-5.5E+07	46444500	-4.4E+07	-1.5E+08						
	8	7.67E+08	9.44E+08	77047900	-7.9E+07	-3667170	7983590	-1.3E+07	-4.3E+07							
	9	1.36E+09	2.91E+08	-1.3E+08	-7.2E+07	71424000	-6.1E+07	-1.1E+07								
	10	52116100	-1.4E+07	-1.2E+08	22266300	-1.1E+07	-6E+07									
	11	-5.6E+08	813307	8763930	-8.1E+07	-9692310										
	12	-5.3E+08	1.89E+08	-1.3E+08	-7.9E+07											
	13	-1.5E+08	-1.8E+07	-1.3E+08												
	14	-5.7E+08	-1.4E+07													
	15	-5.6E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		-1.4E+07	16058900	-5552740	-4144560	-1974790	344345	-44829.6	8645400	-7891140	-315449	931636	1691100	-2193690	923321	1.37E+08
Jidosha Buhin Kogyo Co., Ltd.	1	-1.4E+07	16058900	-5552740	-4144560	-1974790	344345	-44829.6	8645400	-7891140	-315449	931636	1691100	-2193690	923321	1.37E+08
	2	17729800	7729810	-1.1E+07	-6613040	-1561570	292044	9835630	-232131	-8241640	709350	2776480	-685393	-1199340	1.47E+08	
	3	1071560	-559309	-1.4E+07	-6096530	-1624330	11819200	-310122	-626442	-7102970	2738670	183935	391815	1.57E+08		
	4	-1.6E+07	-5496270	-1.4E+07	-6174980	12208300	-17463.8	-760764	654557	-4848170	-113121	1359070	1.71E+08			
	5	-2.5E+07	-4463240	-1.4E+07	11115800	-1995740	-543213	703236	3191210	-8016830	1179530	1.88E+08				
	6	-2.3E+07	-4620140	9268350	-6639240	-2626640	1164790	3602270	-373532	-6580550	2.06E+08					
	7	-2.4E+07	29961500	-1.4E+07	-7427860	-577042	4546990	-471724	1242280	2.21E+08						
	8	45534900	-5548670	-1.5E+07	-4865860	3481610	-205999	1374920	2.58E+08							
	9	-2.5E+07	-7125910	-1.2E+07	207446	-2221990	1948420	2.94E+08								
	10	-2.9E+07	-2001910	-5276150	-6922040	363314	3.44E+08									
	11	-1.8E+07	8144700	-1.5E+07	-3690420	4.11E+08										
	12	1901350	-6114270	-1E+07	5.09E+08											
	13	-2.7E+07	348976	6.73E+08												
	14	-1.4E+07	1.03E+09													
	15	2.04E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Tachi-S Co., Ltd.		4424990	-3854080	1916430	-3448220	6822950	-6224260	1702500	1.22E+08	-9.3E+07	-1.2E+07	4735270	-7336600	12373700	-3365610	-6578970
		-3283180	-979441	-2681190	5080470	-646161	-4238020	1.41E+08	17628900	-1.1E+08	-6817580	-3268290	6068200	8749160	-1E+07	
		2466110	-7875870	8690390	-4255920	1737330	1.59E+08	21849800	2595890	-1E+08	-1.6E+07	11355100	2141660	1158040		
		-1.1E+07	9181510	-3758130	-1276550	1.97E+08	19267100	4669220	9106880	-1.1E+08	464251	7071620	-6082060			
		22788000	-9491270	214361	2.43E+08	29943500	-776835	12110400	-1898020	-9.2E+07	-4247600	-1899700				
		-1.5E+07	-3532540	3.26E+08	33981200	5890750	7904500	-466666	18209200	-9.8E+07	-1.4E+07					
		-2640090	4.85E+08	47224700	3915220	16308300	-6768700	22513000	12319400	-1.1E+08						
		9.75E+08	66982900	7136720	16937200	-1299490	20040900	15781800	-16208							
		1.38E+08	6851000	24499400	-5072580	30872000	12187800	1683970								
		18127000	32895000	-4847020	35141800	21448300	-4259630									
		70215000	-1.1E+07	48772200	23362200	1711400										
		-1.8E+07	69304200	33066000	-1308970											
		1.43E+08	45744900	171140												
		95914800	-3597370													
		-2769760														

Results of Momentum (Continued).

Firms	t	Momentum														
		5.58E+08	-3.1E+08	2.35E+08	-1.3E+08	-5.1E+07	14005900	-103054	-1.5E+08	1.58E+08	1.39E+08	-1.2E+08	51286300	-3.6E+07	-8.3E+07	2.44E+08
NOK	1	-6.3E+07	42581500	64938700	-1.9E+08	-3.4E+07	13885700	-1.7E+08	28303200	3.12E+08	3343670	-6.7E+07	12341500	-1.3E+08	1.78E+08	
	2	6.43E+08	-2.1E+08	-2E+07	-1.7E+08	-3.4E+07	-1.9E+08	32243500	2.02E+08	1.62E+08	64887300	-1.1E+08	-8.5E+07	1.56E+08		
	3	1.32E+08	-3.4E+08	8393130	-1.7E+08	-2.7E+08	51623300	2.3E+08	32482800	2.31E+08	18153500	-2.2E+08	2.2E+08			
	4	-1.2E+08	-3E+08	8152670	-4.7E+08	11213500	2.83E+08	37020200	1.09E+08	1.79E+08	-9.8E+07	1.17E+08				
	5	-3.8E+07	-3E+08	-3.9E+08	-1.1E+08	2.88E+08	57196100	1.25E+08	50995100	49476600	2.67E+08					
	6	-3.8E+07	-9E+08	83628000	2.33E+08	17900900	1.6E+08	58177000	-9.4E+07	4.56E+08						
	7	-1.2E+09	-1.8E+08	5.46E+08	-1.1E+08	1.41E+08	81879100	-1.1E+08	3.62E+08							
	8	1.88E+08	5.08E+08	94773500	48441200	47520500	-1.1E+08	4.14E+08								
	9	1.57E+09	-1.7E+08	3E+08	-6.8E+07	-1.8E+08	4.97E+08									
	10	2.21E+08	1.39E+08	1.44E+08	-3.6E+08	5.46E+08										
	11	8.37E+08	-9.4E+07	-2.4E+08	5.55E+08											
	12	3.7E+08	-6.8E+08	9.75E+08												
	13	-7.9E+08	1.15E+09													
	14	2.86E+09														
	15															

Results of Momentum (Continued).															
Firms	t	Momentum													
Shiroki Corporation	1	-3135290	246411	-337689	43227	6235580	-4510910	-696727	6941550	-5629230	3704480	-2722380	-92205.5	2435570	-1810430
	2	-2642470	-260122	-280053	7837700	822488	-5323760	7236480	608672	-1513140	709866	-2822960	2546330	485876	-2708760
	3	-3655540	-173668	10112600	1071340	-152930	3931650	-1102.24	5239270	-4840490	599219	55440.9	434160	-481549	
	4	-3482630	15415300	1090760	-147935	10953600	-4512190	5291010	1496000	-4963430	3765460	-2248750	-613883		
	5	27695300	1882550	-534936	13735200	820945	1661940	1012990	1357700	-1445380	1230860	-3392070			
	6	629813	-555993	17975900	1069410	8229900	-3329080	854926	5315500	-4261610	-26793.7				
	7	-4247280	27210200	1088190	10330600	2240680	-3513500	5378130	2147240	-5659000					
	8	51285100	1878690	13436500	2844070	2019380	1763580	1757270	575180						
	9	622098	20401100	3454410	2567460	8351870	-2460760	-39379							
	10	37666900	5428020	3085590	10483100	3282660	-4556850								
	11	7720760	4874790	13639700	4146550	767358									
	12	6614290	20706000	5191050	1002420										
	13	38276700	8032980	998877											
	14	12930700	1744730												
	15	354160													

Results of Momentum (Continued).

Firms	t	Momentum														
		-1.7E+08	888193	16746300	865863	-1.2E+07	-2194860	6660390	48034800	-4.6E+07	6296600	-5529330	8919470	9034350	-1.9E+07	13556100
Keihin Corporati on	1	-1.7E+08	888193	16746300	865863	-1.2E+07	-2194860	6660390	48034800	-4.6E+07	6296600	-5529330	8919470	9034350	-1.9E+07	13556100
	2	-1.7E+08	26007600	17900800	-1.5E+07	-1.5E+07	5575590	61557300	-3371150	-3.9E+07	214338	4201000	18706700	-1.1E+07	-4509900	
	3	-1.2E+08	27739300	-2748490	-1.8E+07	-5698840	69622000	2807650	4499610	-4.5E+07	10917700	14878000	-3499940	4177530		
	4	-1.1E+08	-3234540	-7138220	-6257680	71156900	1080730	11802800	-3103230	-3.4E+07	22662400	-9347450	13445100			
	5	-1.7E+08	-9819130	8402690	89811900	-1.1E+07	11575100	3113850	10276000	-2.1E+07	-3985590	9138080				
	6	-1.9E+08	13492200	1.36E+08	-1.3E+07	1500530	1437960	18404400	24956800	-5E+07	16348500					
	7	-1.4E+08	2.06E+08	-587034	2741530	-1.1E+07	19276900	35182500	-8353140	-2.8E+07						
	8	2.43E+08	7642.19	20401600	-1.2E+07	10742700	38851300	-2886060	17064500							
	9	-1.7E+08	31490700	127425	14294300	34232000	-5561930	26162600								
	10	-1E+08	1079330	35805300	43655900	-1.9E+07	28328200									
	11	-1.7E+08	54596200	74954200	-2.3E+07	21604300										
	12	-5.9E+07	1.13E+08	-1.4E+07	27871300											
	13	58757100	-2E+07	53907900												
	14	-2.1E+08	81750100													
	15	-4381540														

Results of Momentum (Continued).

Firms	t	Momentum														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kasai Kogyo Co., Ltd.		-1652940	381131	401947	13105000	-8052690	-1948250	2233510	19104200	-1.9E+07	1825650	-1557040	1201350	5757410	3598300	-9612540
		-890676	984052	17875300	3039160	-1E+07	657509	24066900	-1985830	-1.7E+07	112908	-246475	7438540	9632500	-6700860	
		315166	27194100	4454170	116790	-7263680	26129800	-36010.3	296233	-1.9E+07	1554530	6557740	11636600	-1458900		
		52735300	7062380	557667	4025430	23303100	-1990260	2572060	-1844690	-1.7E+07	9039160	11137400	-379126			
		12471800	1217630	5769180	42233900	-1E+07	1052490	125286	-42669.8	-8703220	14076800	-1970630				
		782325	9034910	56713800	53771.8	-6789710	-1802080	2184740	9313120	-3105870	-342044					
		16416900	85451900	473643	4617890	-1E+07	600616	12877100	15610100	-1.9E+07						
		1.69E+08	1091600	6559140	336041	-7331950	13075000	20073700	-2413380							
		530253	10219800	850001	3940090	7637310	21471000	-524645								
		18786700	1656130	5655400	22651700	17712500	-2560330									
		1659330	8864230	30604200	35245700	-1.1E+07										
		16075500	46287400	47396200	-801338											
		90921800	71475500	-666504												
		1.41E+08	-618625													
		-2890190														



Results of Momentum (Continued).

Firms	t	Momentum														
		2.2E+08	-2E+09	2.81E+08	-1.4E+08	6.45E+09	-5.1E+09	1.06E+08	1.45E+10	-1.1E+10	-4.3E+08	-1.2E+09	-2.5E+08	1.72E+09	-1.2E+08	-3.6E+08
Aishin Seiki Co., Ltd.	1															
	2	-3.8E+09	-1.6E+09	99543500	7.92E+09	2.89E+08	-5E+09	1.67E+10	1.93E+09	-1.2E+10	-1.7E+09	-1.4E+09	1.62E+09	1.59E+09	-5.1E+08	
	3	-3E+09	-1.9E+09	1.08E+10	2.26E+08	4.38E+08	1.43E+10	2.31E+09	1.39E+09	-1.3E+10	-2E+09	5.9E+08	1.48E+09	1.17E+09		
	4	-3.5E+09	1.42E+10	5.82E+08	4.11E+08	2.37E+10	-2.4E+09	1.69E+09	-2.3E+08	-1.3E+10	2.18E+08	4.35E+08	1.02E+09			
	5	2.87E+10	-1.2E+09	8.3E+08	2.94E+10	3.52E+09	-3.2E+09	-1.6E+08	-6E+08	-1.1E+10	47317300	-6.3E+07				
	6	-2.1E+09	-7.8E+08	3.95E+10	4.26E+09	2.66E+09	-5.3E+09	-5.8E+08	2.2E+09	-1.1E+10	-5E+08					
	7	-1.3E+09	5.73E+10	5.96E+09	3.18E+09	65605000	-5.8E+09	2.62E+09	1.98E+09	-1.2E+10						
	8	1.15E+11	6.92E+09	4.53E+09	-5.4E+07	-5.3E+08	-2.1E+09	2.37E+09	1.3E+09							
	9	1.41E+10	4.77E+09	2.09E+08	-8E+08	3.96E+09	-2.4E+09	1.59E+09								
	10	9.75E+09	-1.7E+09	-7.8E+08	4.81E+09	3.61E+09	-3.3E+09									
	11	-3.2E+09	-3.2E+09	6.69E+09	4.38E+09	2.52E+09										
	12	-6.2E+09	8.01E+09	6.12E+09	3.01E+09											
	13	1.62E+10	7.16E+09	4.3E+09												
	14	1.45E+10	4.42E+09													
	15	9.06E+09														

Results of Momentum (Continued).

Firms	t	Momentum														
Ikuyo Co., Ltd.	1	1391110	-1548740	-121899	-43513.6	-20188.6	550125	-3182.1	19333.5	-335379	57586.6	-49113.9	-12146	11033.7	42543.4	83289.5
	2	-1706360	-1731580	-179917	-68749.3	639962	546413	18913.3	-357968	-271394	3561.32	-62364.1	-192.781	56849.7	131782	
	3	-2072050	-1818610	-213564	756439	635507	572191	-412289	-285985	-331422	-11013.9	-49324.2	49441.2	152953		
	4	-2246110	-1869080	886686	750870	666441	69121.9	-330022	-353517	-347617	3329.98	4821.96	153553			
	5	-2347050	-218706	879262	789537	62757.7	165100	-407201	-371736	-331679	62890.7	118398				
	6	953702	-229843	930818	34933.5	177931	75057.4	-428023	-353806	-265501	187825					
	7	931428	-152509	-75320.6	178900	69880.3	50765.4	-407532	-279355	-126685						
	8	1086100	-1661720	116635	43836.8	40729.9	74671.9	-322445	-123187							
	9	-1932320	-1373780	-63449.5	7398.83	69417.6	173940	-143967								
	10	-1356450	-1643910	-112034	43258.5	188539	382163									
	11	-1896710	-1716790	-64220.6	192160	438408										
	12	-2042460	-1645070	134315	504496											
	13	-1899020	-1347260	550763												
	14	-1303410	-722592													
	15	-54069.5														

Results of Momentum (Continued).

Firms	t	Momentum														
Showa Corporati on	1	-2.2E+07	5248400	519846	3159200	-3801790	9831490	9093180	-2.5E+07	9200510	12812700	-8965200	969021	8203170	-1E+07	-1165820
	2	-1.1E+07	6028170	4732120	-1593040	7995990	20440200	-2E+07	-1.5E+07	23436900	2951020	-7908080	9855790	-2649620	-1.1E+07	
	3	-9672660	12346600	-1604210	13154200	20726400	-1.3E+07	-7996030	1062860	12479400	4113840	1786570	-1901400	-3994790		
	4	2964150	2842090	18058800	29067300	-2E+07	502789	10307900	-1.1E+07	13771400	14778000	-1.1E+07	-3358670			
	5	-1.6E+07	32336600	39276200	-2.2E+07	-3198450	21857300	-3780290	-9810750	25620500	669343	-1.3E+07				
	6	42944100	64162700	-2.8E+07	-838857	22427000	5421150	-2119110	3519400	9944230	-1079390					
	7	1.07E+08	-3.7E+07	-598631	31193000	2703590	7359200	13115300	-1.4E+07	8001190						
	8	-9.6E+07	4350460	42110500	6538690	5029240	25132700	-7039830	-1.6E+07							
	9	-1.3E+07	68414100	9238100	9445750	26357500	1618360	-9538010								
	10	1.15E+08	19105600	13114200	36106100	-1859760	-1296190									
	11	16482100	24919700	48661200	834499	-5357220										
	12	28110400	78240300	1632510	-3537320											
	13	1.35E+08	7697170	-4196590												
	14	-6334670	-1046480													
	15	-2.4E+07														

Results of Momentum (Continued).

Firms	t	Momentum														
		3.45E+08	-1.1E+08	-7.1E+07	-2.1E+07	1.07E+08	-8.9E+07	16634400	2.2E+08	-2E+08	55938400	-5.4E+07	37199800	36400700	62649400	-1.2E+08
Koito Manufact uring Co., Ltd.	1	3.45E+08	-1.1E+08	-7.1E+07	-2.1E+07	1.07E+08	-8.9E+07	16634400	2.2E+08	-2E+08	55938400	-5.4E+07	37199800	36400700	62649400	-1.2E+08
	2	1.25E+08	-2.2E+08	-9.8E+07	1.13E+08	-118522	-7E+07	2.68E+08	-7605780	-1.4E+08	-3659300	-1.4E+07	76633900	1.04E+08	-6.4E+07	
	3	-8.8E+07	-2.6E+08	80259200	-2.1E+07	23169700	2.23E+08	7942100	62317200	-2.1E+08	40980500	29420800	1.5E+08	-3.3E+07		
	4	-1.7E+08	10300100	-9.9E+07	8272450	3.75E+08	-8E+07	87854100	-1.2E+07	-1.6E+08	88301300	1.09E+08	1548040			
	5	3.66E+08	-2.6E+08	-6E+07	4.48E+08	11000400	13088800	2714530	43619800	-1E+08	1.76E+08	-5.2E+07				
	6	-1.7E+08	-2E+08	5.27E+08	-6939110	1.23E+08	-8.6E+07	66485600	1.03E+08	-6657930	-1801650					
	7	-5.4E+07	6.8E+08	-8E+07	1.33E+08	3681820	-1.2E+07	1.34E+08	2.12E+08	-2E+08						
	8	1.7E+09	-2.3E+08	1.06E+08	-1.6E+07	92961400	67027000	2.59E+08	-9857850							
	9	-1.2E+08	49566400	-9.2E+07	95512100	1.88E+08	2.13E+08	5368310								
	10	4.44E+08	-2.5E+08	56576900	2.14E+08	3.63E+08	-8.3E+07									
	11	-1.5E+08	-2.5E+07	2.14E+08	4.33E+08	7397110										
	12	2.95E+08	2.11E+08	5.07E+08	-1.1E+07											
	13	7.68E+08	6.5E+08	-8.6E+07												
	14	1.64E+09	-2.4E+08													
	15	-1.3E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		6.62E+15	-3.4E+15	6.25E+09	1.49E+11	-1E+11	8.88E+08	-5.2E+09	-5.3E+09	7.38E+09	-1.6E+10	3.34E+10	-1.7E+10	2.84E+10	5.49E+08	-2.9E+10
Mitsuba Corporati on	1	-8.4E+13	-3.4E+15	2.05E+11	2.16E+10	-1E+11	-5.2E+09	-1.1E+10	2.95E+09	-1.1E+10	2.06E+10	1.53E+10	1.42E+10	2.9E+10	-3E+10	
	2	-8.4E+13	-3.4E+15	3.5E+10	2.29E+10	-1.1E+11	-1.2E+10	-1.8E+09	-1.7E+10	3.02E+10	7.07E+08	4.89E+10	1.48E+10	-4.2E+09		
	3	-8.4E+13	-3.4E+15	3.68E+10	1.38E+10	-1.2E+11	-1.2E+09	-2.5E+10	2.87E+10	8.16E+09	3.76E+10	4.96E+10	-2.1E+10			
	4	-8.4E+13	-3.4E+15	2.47E+10	3.11E+09	-1E+11	-2.8E+10	2.76E+10	3.84E+09	4.92E+10	3.84E+10	1.03E+10				
	5	-8.4E+13	-3.4E+15	1.04E+10	1.97E+10	-1.4E+11	3.31E+10	-8.1E+08	5E+10	5E+10	-4.8E+09					
	6	-8.4E+13	-3.4E+15	3.25E+10	-2.1E+10	-6.2E+10	-5.7E+07	5.19E+10	5.09E+10	2.06E+09						
	7	-8.4E+13	-3.4E+15	-2.1E+10	7.11E+10	-1E+11	6.14E+10	5.3E+10	-3E+09							
	8	-8.4E+13	-3.4E+15	1.01E+11	2.15E+10	-2.8E+10	6.27E+10	-8.6E+09								
	9	-8.4E+13	-3.4E+15	3.49E+10	1.14E+11	-2.7E+10	-9.2E+09									
	10	-8.4E+13	-3.4E+15	1.58E+11	1.16E+11	-1.1E+11										
	11	-8.4E+13	-3.4E+15	1.6E+11	7.75E+09											
	12	-8.4E+13	-3.4E+15	1.66E+10												
	13	-8.4E+13	-3.4E+15													
	14	-8.4E+13	-3.4E+15													
	15	-8.4E+13														

Results of Momentum (Continued).

Firms	t	Momentum														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Toyota Gosei Co., Ltd.	1	5822920	18018200	1933340	-1.2E+07	1.05E+08	1.55E+08	-1.9E+08	7.01E+08	-6.1E+08	1.05E+08	-8.6E+07	-4.1E+07	39981000	26262400	8464020
	2	41859400	20918200	-1.3E+07	1.2E+08	2.92E+08	-6.7E+07	6.1E+08	18803400	-4.9E+08	9622150	-1.3E+08	2716450	68263600	35330900	
	3	47659400	-2092130	1.62E+08	3.53E+08	24315700	8.67E+08	-1.7E+08	1.49E+08	-6E+08	-3.9E+07	-8.3E+07	33355900	78029700		
	4	1638650	2.61E+08	4.73E+08	18889400	1.15E+09	-4.2E+07	-2E+07	30831100	-6.5E+08	12881900	-5E+07	43935900			
	5	5.28E+08	7.27E+08	27119200	1.42E+09	54401100	1.32E+08	-1.6E+08	-3E+07	-5.9E+08	49649200	-3.8E+07				
	6	1.46E+09	58697000	1.9E+09	56496200	2.64E+08	-2.6E+07	-2.3E+08	34905700	-5.5E+08	62345200					
	7	1.23E+08	2.86E+09	77261500	3.18E+08	73645400	-1.1E+08	-1.5E+08	80864900	-5.4E+08						
	8	5.73E+09	1.34E+08	4.26E+08	80551500	-2.4E+07	-2.1E+07	-9.8E+07	96734900							
	9	2.74E+08	6.57E+08	1.09E+08	-4.1E+07	80164800	40377900	-8E+07								
	10	1.32E+09	1.82E+08	-5.3E+07	88700900	1.54E+08	61538000									
	11	3.7E+08	-6.2E+07	1.2E+08	1.81E+08	1.79E+08										
	12	-1.2E+08	1.98E+08	2.43E+08	2.12E+08											
	13	4.02E+08	3.82E+08	2.85E+08												
	14	7.7E+08	4.46E+08													
	15	8.97E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		6749890	997512	-2272250	4039570	1154590	-425111	-1220530	58796400	-5.3E+07	-1087040	4355840	-1269860	-2301570	4236160	-2582740
Aisan Industry Co., Ltd.	1	6749890	997512	-2272250	4039570	1154590	-425111	-1220530	58796400	-5.3E+07	-1087040	4355840	-1269860	-2301570	4236160	-2582740
	2	8744920	-2410860	3113840	5482810	644461	-1849060	65975300	-1331910	-5.5E+07	3704390	2970540	-3763220	2260450	1468930	
	3	1928160	5668270	5038160	4845140	-1064280	76546100	-2742720	-2690710	-4.9E+07	2180550	250507	1178960	-719641		
	4	18086400	8554750	4187940	2709210	93009900	-3624950	-4295630	3298570	-5.1E+07	-811482	5641980	-2049470			
	5	23859400	7279420	1340030	1.2E+08	-3195340	-5436680	2549270	1393780	-5.4E+07	5119140	2120060				
	6	21308700	3007560	1.58E+08	45389.2	-5369420	2549030	372363	-2346260	-4.8E+07	1245020					
	7	12765000	2.38E+08	-2211730	-2672210	4213430	9311.78	-3901970	5067010	-5.2E+07						
	8	4.83E+08	-2320090	-5835200	9306360	1165770	-4977420	4570340	224366							
	9	2109720	-7755280	10136200	5496780	-4818300	4906950	-964113								
	10	-8760670	16201900	5056780	-1983310	7042930	-1549910									
	11	39153600	8582690	-4916670	12843200	-705297										
	12	23915300	-6377490	14852100	3157940											
	13	-6005090	23275600	1938340												
	14	53301100	3905020													
	15	14559900														

Results of Momentum (Continued).

Firms	t	Momentum														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Meiwa Corporati on		1176000	-573786	-41242	795090	-609294	5242680	-4449160	301533	78430	-231101	-166346	167697	52461.4	-207084	188945
		28430	-635649	1018880	33472.5	5681920	51991	-4104550	389767	-178349	-414082	16595.8	224530	-170552	-4642.5	
		-95296	954531	3388	7897490	-546905	454035	-4003710	100890	-381661	-212846	78595.6	-17068.3	47461.8		
		3085060	-568704	10488700	111459	-64451.8	571680	-4333860	-127836	-158066	-144646	-184966	219114			
		38594	15159300	107370	714525	76722.2	186511	-4595260	123709	-82288	-434564	72687				
		31494700	-412731	911458	890993	-385481	-118457	-4307780	208959	-404419	-151146					
		350540	793401	1146750	313239	-751442	216937	-4210350	-153438	-89509.7						
		2762800	1146340	376410	-144212	-348970	330603	-4624520	200835							
		3468670	-9171	-233525	358878	-212570	-152593	-4219640								
		1157660	-924074	437261	529377	-792405	319771									
		-672145	82106	664594	-195417	-225569										
		1340210	423105	-301798	513128											
		2022210	-1026480	642929												
		-876964	390608													
		1957220														



Results of Momentum (Continued).

Firms	t	Momentum																
Nihon Plast Co., Ltd.	1	-2937020	-61479.7	19807.9	1186830	-1438710	1144470	-128684	22937900	-2E+07	460485	-804707	5884420	5556570	-9063870	11552500		
	2	-3059980	-31767.8	1602250	-611555	-65339.6	994341	26086000	232546	-2E+07	-424693	5614660	11904000	-4204520	-3313780			
	3	-3000550	2341890	-795599	1105150	-245497	31578200	137083	808152	-2.1E+07	6636620	12181500	1329530	9125260				
	4	1746760	-1254880	1493350	879957	36455100	1304400	794919	-298320	-1.3E+07	13860200	645687	15770100					
	5	-5446770	2178540	1193080	46755700	126576	2071880	-469621	8528320	-4782340	1170740	16399100						
	6	1420060	1728150	62360800	1345050	1047550	596581	9617960	17557700	-1.9E+07	18499500							
	7	519274	93479700	1813210	2496260	-722809	12365400	19937300	1695970	372427								
	8	1.84E+08	2658330	3348160	283317	13399800	24404700	1809570	23356900									
	9	2379640	4960760	397564	17936600	27846900	3255640	26564900										
	10	6984490	534866	23935300	35995400	2468060	32136800											
	11	-1867290	35841400	48013700	4271900	37125500												
	12	68745800	71959100	5715670	47593700													
	13	1.41E+08	8512030	63478000														
	14	14087000	95155600															
	15	1.87E+08																

Results of Momentum (Continued).

Firms	t	Momentum														
		2814370	-1860690	324220	-195785	2521330	-1997190	230863	3826920	-2302680	-1010110	-106121	-234489	800585	-514252	61593.7
Murakami Corporation	1															
	2	-907012	-1374360	63172.9	2955880	124700	-1727850	4604480	1236400	-3425030	-1126840	-361928	632812	246775	-448259	
	3	65647.3	-1765930	4265390	-39909.8	447908	3374710	1643890	-26238.3	-3554730	-1408230	584219	32850.9	317845		
	4	-717493	4537390	271007	364100	6570980	-79318.7	200876	-172155	-3867380	-367470	-70284	109843			
	5	11889200	-1454180	809686	8017930	2426150	-1762840	34114	-523889	-2710980	-1087420	13707.4				
	6	-93991.7	-646160	11014800	2836900	405927	-1957390	-367867	777062	-3510930	-995032					
	7	1522050	14661500	4106750	311624	172460	-2426370	1118930	-122879	-3408270						
	8	32137400	4299440	739718	19789.7	-390314	-691769	90429.8	-7390.58							
	9	11413200	-751113	350606	-683678	1691210	-1891690	222416								
	10	1312140	-1334780	-587350	1918220	251302	-1737710									
	11	144806	-2741720	2881850	118342	436083										
	12	-2669060	2462090	482010	349319											
	13	7738550	-1137680	789978												
	14	539017	-675722													
	15	1462920														

Results of Momentum (Continued).

Firms	t	Momentum														
		6368650	4589910	2030970	3413620	5255010	-3819980	-3028460	50332500	-4.3E+07	40844.1	-659556	27094800	-1.8E+07	-1.1E+07	3848610
Yorozu Corporati on	1	-2811170	-1543460	6582460	9982380	671025	-7353190	54494400	1488370	-4.3E+07	-684668	28898400	7312550	-3E+07	-6621340	
	2	3281730	5283780	15340800	4252400	-3568820	59756800	-1327470	1539420	-4.4E+07	31829100	7317770	-5223110	-2.5E+07		
	3	16936200	18421300	7700830	-1047410	76963200	-5368700	-1269120	632533	-8051410	8090390	-6357490	-412348			
	4	43211200	6961340	634422	99617600	-1187430	-5300630	-2305570	41274700	-3.4E+07	-6952400	-1109390				
	5	20291300	-3638280	1.35E+08	1929330	-1105750	-6509810	44142600	11601400	-5.1E+07	-1179490					
	6	-907904	1.98E+08	4603400	2031440	-2556770	47679700	10230200	-7202130	-4.5E+07						
	7	4.02E+08	2315200	4739550	217659	62470700	8115280	-1.1E+07	14010.9							
	8	10999000	2519420	2321180	81502000	14993300	-1.7E+07	-3012450								
	9	11407500	-1108140	1.11E+08	22155300	-1.5E+07	-7334510									
	10	4152360	1.61E+08	31571400	-1.5E+07	-3546400										
	11	3.29E+08	42767100	-1.9E+07	-1019390											
	12	91902900	-3.2E+07	671785												
	13	-5.9E+07	-3582230													
	14	-795817														
	15															

Results of Momentum (Continued).

Firms	t	Momentum														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Yachiyo Industry Co., Ltd.	1	297037	7820790	29779700	-2.6E+07	14453600	-1.3E+07	1052310	-3653860	6372340	11545600	17980500	-1.2E+07	-1.5E+07	-1.2E+07	25854300
	2	15938600	52490400	-5355820	-8284670	-685648	-1.1E+07	-3123520	3515020	19200800	31324200	5235980	-2.8E+07	-2.7E+07	16010300	
	3	1.05E+08	-212947	18733500	-2.7E+07	787592	-1.6E+07	5069480	17947000	41177000	17305200	-1.2E+07	-4.1E+07	2592730		
	4	-128857	35921000	-6498570	-2.5E+07	-5058580	-6701630	21563200	42670300	25600300	-1738660	-2.7E+07	-8873710			
	5	72139000	-1927070	-4043170	-3.3E+07	6411630	12541100	49818300	25146500	4440500	-1.8E+07	8300110				
	6	-3557100	1756030	-1.4E+07	-1.8E+07	29502800	45505300	29791200	1341700	-1.4E+07	20675700					
	7	3809100	-1.3E+07	5330220	10526900	69060000	22140400	2585690	-1.9E+07	29345400						
	8	-2.5E+07	15816100	43815600	59973300	41022000	-9599390	-2.1E+07	29359700							
	9	31929300	73544200	1.1E+08	24925900	2934310	-3.7E+07	34606200								
	10	1.47E+08	1.72E+08	63014200	-2.3E+07	-3E+07	27757900									
	11	3.45E+08	1.02E+08	-465297	-6.4E+07	47763100										
	12	2.05E+08	7122840	-5.5E+07	33352200											
	13	14542700	-7.5E+07	74249300												
	14	-1.5E+08	1.19E+08													
	15	2.39E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		-1147880	10610200	-6875310	20171200	-1.2E+07	20604600	-2.1E+07	1.44E+08	-1.2E+08	3661130	-9933300	-1025910	71190900	-7.3E+07	11925200
TS Tech Co., Ltd.	1	-1147880	10610200	-6875310	20171200	-1.2E+07	20604600	-2.1E+07	1.44E+08	-1.2E+08	3661130	-9933300	-1025910	71190900	-7.3E+07	11925200
	2	20072500	297244	20019600	5651570	13109800	-3730040	1.43E+08	5457870	-1.2E+08	-7265500	-1.1E+07	76097500	-7423680	-6E+07	
	3	-553391	40639600	660120	36558400	-1.6E+07	1.88E+08	-1.5E+07	10034300	-1.3E+08	-8496600	73082200	-9068230	6336110		
	4	80131300	11600400	41869200	56517.1	2.14E+08	3547120	-9390480	-3624010	-1.3E+08	84051500	-2E+07	5838200			
	5	22052900	73414000	-6799950	2.88E+08	-7359130	9649000	-2.5E+07	-5162890	-3E+07	-1.8E+07	-3564350				
	6	1.46E+08	410278	3.77E+08	10972300	-36874.1	-8562050	-2.7E+07	1.11E+08	-1.4E+08	-259660					
	7	-327323	5.75E+08	7754360	20125100	-2.2E+07	-1.1E+07	1.05E+08	-1.7E+07	-1.2E+08						
	8	1.15E+09	22241700	19958100	-7191510	-2.4E+07	1.44E+08	-4.1E+07	5133290							
	9	43335600	40547400	-1.6E+07	-1E+07	1.61E+08	-2.7E+07	-1.5E+07								
	10	79946900	-1.4E+07	-2.1E+07	2.21E+08	-4.4E+07	3114350									
	11	-2.9E+07	-2E+07	2.88E+08	-3.4E+07	-7878450										
	12	-4.2E+07	4.42E+08	-5.3E+07	10323100											
	13	8.84E+08	-6.8E+07	6888830												
	14	-1.4E+08	20943400													
	15	40739000														

Results of Momentum (Continued).

Firms	t	Momentum														
		-733927	-1E+07	1.99E+08	-1.1E+08	10220300	-3.1E+07	356448	-2E+07	12307000	26022100	-1.6E+07	-3434770	1407380	35363100	-4.2E+07
Akebono Brake Industry Co., Ltd.	1	-733927	-1E+07	1.99E+08	-1.1E+08	10220300	-3.1E+07	356448	-2E+07	12307000	26022100	-1.6E+07	-3434770	1407380	35363100	-4.2E+07
	2	-2.1E+07	2.88E+08	48632800	-1E+08	-2.7E+07	-3.1E+07	-2.2E+07	-5770140	41220500	8700840	-1.9E+07	-1910100	39490700	-9458620	
	3	5.74E+08	62745600	65666800	-1.5E+08	-2.7E+07	-5.7E+07	-6238000	26757500	21974600	4579120	-1.8E+07	39346900	-8778820		
	4	1.25E+08	88296400	2950180	-1.5E+08	-5.8E+07	-3.9E+07	30936500	5105910	17394900	6408720	27177200	-1.3E+07			
	5	1.76E+08	-5778430	3781890	-1.9E+08	-3.6E+07	4734290	6191770	-46247.7	19427800	55917100	-3E+07				
	6	-1.2E+07	-4530860	-4.9E+07	-1.6E+08	15901500	-2.4E+07	303594	2240750	74437000	-6833350					
	7	-9795650	-8.3E+07	-1.2E+07	-9.3E+07	-1.9E+07	-3.1E+07	2917310	64126200	4714340						
	8	-1.7E+08	-2.8E+07	75135300	-1.4E+08	-2.7E+07	-2.8E+07	73643500	-1.4E+07							
	9	-5.6E+07	1.02E+08	17397600	-1.5E+08	-2.3E+07	54559200	-1.6E+07								
	10	2.04E+08	15892800	3658570	-1.4E+08	75691400	-5E+07									
	11	31051600	-4715850	9757230	-1.8E+07	-5E+07										
	12	-1E+07	4432140	1.75E+08	-1.7E+08											
	13	8130360	2.52E+08	-3.4E+07												
	14	5.03E+08	-6.2E+07													
	15	-1.2E+08														

Results of Momentum (Continued).

Firms	t	Momentum														
		-3.7E+07	15116600	-1.4E+07	-521525	98910.6	-12174.1	2355550	899013	-2280080	-371968	-38840.8	404816	262022	1763180	-2037720
TBK	1															
	2	-7046610	-5273230	-1.4E+07	-397886	84301.7	2735940	3382970	-1666070	-2693370	-414692	402777	688673	2160830	-420089	
	3	-4.8E+07	-6316280	-1.4E+07	-416147	3382040	3934630	451447	-2131030	-2740840	71086.8	712439	2745720	-190381		
	4	-5E+07	-6069010	-1.4E+07	3706030	4820460	514515	-79934.9	-2184440	-2201090	411716	2956490	198570			
	5	-4.9E+07	-6105530	-8651860	5504050	716328	-105431	-140970	-1577210	-1822610	2880170	177781				
	6	-4.9E+07	2138830	-6254490	373885	-27607.2	-176640	553000	-1151430	920111	-176409					
	7	-3.3E+07	5734880	-1.3E+07	-556034	-113057	632992	1039610	1934140	-2476080						
	8	-2.6E+07	-4525460	-1.4E+07	-662846	858502	1200710	4565970	-1886580							
	9	-4.6E+07	-6385300	-1.4E+07	551602	1539760	5314790	199435								
	10	-5E+07	-6598920	-1.3E+07	1403170	6476660	220500									
	11	-5E+07	-4170030	-1.2E+07	7574300	363511										
	12	-4.6E+07	-2466880	-3494160	-67136.5											
	13	-4.2E+07	9875380	-1.4E+07												
	14	-1.8E+07	-5407510													
	15	-4.8E+07														

Note: the first layer is period  $t=1$ , one year momentum. They are 2002/2001, 2003/2002, ..., 2016/2015 respectively. The second layer is period  $t=2$ , two-year momentum. They are 2003/2001, 2004/2002, ..., 2016/2014, and so on. The fifteenth layer is period  $t=15$ , the momentum of 15 years.

## Footnotes

<sup>i</sup> The difference between degree and fragility is clear. Degree is defined as the summation of the numbers connected with a selected node directly while the fragility is an index of the brittleness of the relationship between any two nodes. Suppose a eight-node network is illustrated in Figure 1.

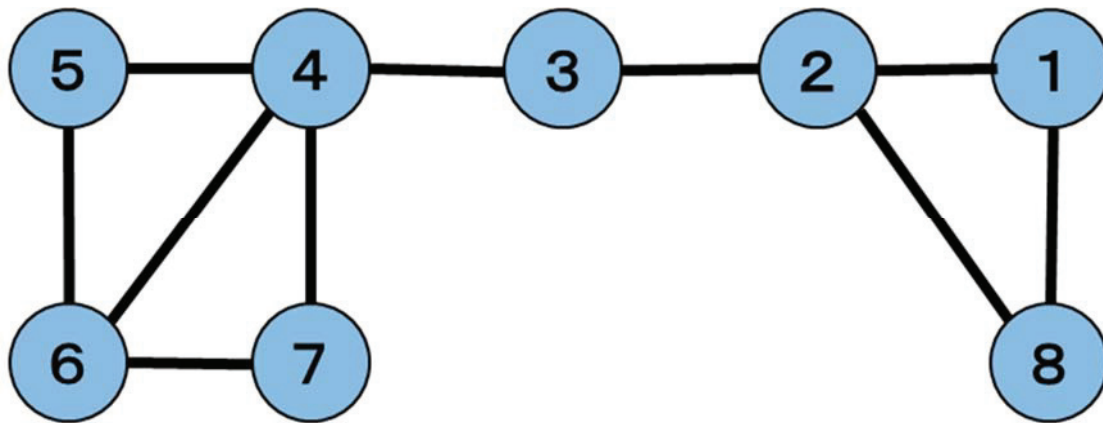


Figure 1 An Example of Eight-node Network.

The results of degree and fragility are depicted in Table 1.

Table 1 The Difference of Degree and Fragility.

	1	2	3	4	5	6	7	8
Degree	2	3	2	4	2	3	2	2
Fragility	0.40	0.47	0.17	0.30	0.17	0.23	0.17	0.40

The degree of the node of number 1 is equal to that of the node of number 3. Both of them are 2. But the fragility is 0.40 and 0.17 respectively, differs from the results of degree because the structural importance of those two nodes is different.

<sup>ii</sup> The numbers means firms. They are: Aisin AW Co., Ltd. (63), Ashimori Industry, Co., Ltd. (64), Advics Co., Ltd. (65), Inoac Corporation (66), Imasen Electric Industrial Co., Ltd. (67), Exedy Corporation (68), NTN Corp. (69), Kokusan Parts Industry Co., Ltd. (70), Sumitomo Electric Industries, Ltd. (71), Daido Metal Corporation (72), Chuo Spring Co., Ltd. (73), TRW



Automotive Japan (74), Denso Corporation (75); Keylex Corporation (3), Kubota Iron Works Co., Ltd (4), Kurashiki Kako Co., Ltd. (5), Sankei Industry Co., Ltd. (6), Sigma Co., Ltd. (7), Sumino Kogyo Co., Ltd. (8), Delta Inc. (9), Toyo Seat Co., Ltd. (10), Niitech Co., Ltd. (11), Nishikawa Kasei Co., Ltd. (12), Nishikawa Rubber Co., Ltd. (13), Japan Climate Systems Corporation (14), Hiruta Kogyo Co., Ltd. (15), Hiroshima Aluminium Co., Ltd. (16), Hirotec Co., Ltd. (17), Molten Corporation (18), Lear Corporation Japan (19), Ryobi Limited. (20), Ring Techs Hiroshima Co., Ltd. (21), Y-Tec Corporation (22), Akebono Brake Industry Co., Ltd. (23), Asmo Co., Ltd. (24), Usui Kokusai Sangyo Kaisha, Ltd. (25), NOK Corporation (26), Calsonic Kansei Corporation (27), Kyosan Denki Co., Ltd. (28), Clarion Co., Ltd. (29), KYB Co., Ltd. (30), Koito Manufacturing Co., Ltd. (31), Sanoh Industrial Co., Ltd. (32), GKN Driveline Torque Technology K. K. (33), Jatco Ltd. (34), Showa Corporation (35), Stanley Electric Co., Ltd. (36), Takata Co., Ltd. (37), Tokyo Roki Co., Ltd. (38), Topy Industries Ltd. (39), Nisshinbo Industries, Inc. (40), Nittan Valve Co., Ltd. (41), Nifco Inc. (42).

iii The numbers means firms. They are: Aisin Chemical Co., Ltd. (1), Asmo Co., Ltd. (2), Inoac Corporation (3), Usui Kokusai Sangyo Kaisha, Ltd. (4), Autoliv, Inc. (5), Kanto Auto Works, Ltd. (6), Gifu Auto Industry Co., Ltd. (7), Cable Industry Co., Ltd. (8), Koito Manufacturing Co., Ltd. (9), Kojima Press Industry Co., Ltd. (10), Sanoh Industrial Co., Ltd. (11), Sango Co., Ltd. (12), Jeco Co., Ltd. (13), Stanley Electric Co., Ltd. (14), Sumitomo Electric Industries, Ltd. (15), Sumitomo Wiring Systems, Ltd. (16), Daicel Chemical Industries, Ltd. (17), Pacific Industrial Co., Ltd. (18), Takagi Manufacturing Co., Ltd. (19), Takata Co., Ltd. (20), Takehiro Co., Ltd. (21), Tachi-S Co., Ltd. (22), Tokai Rubber Industries, Ltd. (23), Tokai Rika Co., Ltd. (24), Togo Seisakusho Corporation (25), Toyota Gosei Co., Ltd. (26), Toyota Auto Body Co., Ltd. (27), Toyota Tsusho corporation (28), Toyoda Iron Works Co., Ltd. (29), Toyota Boshoku Corporation (30), Nishikawa Rubber Co., Ltd. (31), Hamanakodensho Co., Ltd. (32), Hayashi Telempu Co., Ltd. (33), Futaba Industrial Co., Ltd. (34), Furukawa Electric Co., Ltd. (35), Howa Textile Industry Co., Ltd. (36), Maruko Keihoki Co., Ltd. (37), Maruyasu Industries Co., Ltd. (38), Mitusyiyu Industrial Co., Ltd. (39), Murakami Corporation (40), Muro Corporation (41), Meiwa Industry Co., Ltd. (42), Art Metal Mfg. Co., Ltd. (43), Aisan Industry Co., Ltd. Hiroshima Sales (44), Aisin AI Co., Ltd. (45), Aisin AW Co., Ltd. (46), Aisin Keikinzoku Co., Ltd. (47), Aisin Seiki Co., Ltd. (48), Aisin Takaoka Co., Ltd. (49), Aoyama Seisakusho (50), Akebono Brake Industry Co., Ltd. (51), Asahi Iron Works Co., Ltd. (52), Advics Co., Ltd. (53), Arai Seisakusho

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Co., Ltd. (54), Ito Metal Industry Co., Ltd. (55), Exedy Corporation (56), NOK Corporation (57), NTN Corp. (58), Ohashi Iron Works Co., Ltd. (59), Otis Corp. (60), Kyosan Denki Co., Ltd. (61), Kuzeh Co., Ltd. (62), KYB Co., Ltd. (63), Suncall Corp. (64), JTEKT Corporation (65), Nippon Steel Corporation (66), Somic Ishikawa Inc. (67), Daido Metal Corporation (68), Taiho Kogyo Co., Ltd. (69), Central Motor Wheel Co., Ltd. (70), Chuo Spring Co., Ltd. (71), Tsuda Industries Co., Ltd. (72), Teikoku Piston Ring Co., Ltd. (73), Denso Corporation (74), Toshiba (75), Topy Industries Ltd. (76), Toyota Industries Corporation (77), Nichias Corporation (78), Nissin Kogyo Co., Ltd. (79), Nisshinbo Industries, Inc. (80), Nisshinbo Brake Inc. (81), Nippon Gasket Co., Ltd. (82), NSK Ltd. (83), NGK Spark Plug Co., Ltd. (84), NHK Spring Co., Ltd. (85), Nippon Piston Ring Co., Ltd. (86), Pioneer Corporation (87), Hi-lex Corporation (88), Hitachi, Ltd. (89), Fuji OOX Inc. (90), Fujitsu Ten Limited (91), Bridgestone Corporation (92), Hosei Brake Industry Co., Ltd. (93), Bosch Corporation (94), Matsushita Electric Industrial Co., Ltd. (95), Mannoh Kogyo Co., Ltd. (96), Mitsubishi Electric Corporation (97), Midoh Co., Ltd. (98), Yamaha Motor Co., Ltd. (99), Riken Corporation (100), Ryoden Corporation (101), Mazda Motor Corporation (102), Toyota Motor Corporation (103), Nissan Motor Co., Ltd. (104), Honda Motor Co., Ltd. (105), Mitsubishi Motors Corporation (106), Fuji Industries Ltd. (107), Daihatsu Motor Co., Ltd. (108), Suzuki Motor Corporation (109), Isuzu Motors Limited (110), Hino Motors Ltd. (111), Nissan Diesel Motor Co., Ltd. (112).

<sup>iv</sup> The numbers means firms. They are: Asteer Co., Ltd. (1), Ishizaki Honten Company, Limited (2), Keylex Corporation (3), Kurashiki Kako Co., Ltd. (4), Sankei Industry Co., Ltd. (5), Nishikawa Rubber Co., Ltd. (6), Japan Climate Systems Corporation (7), Hiruta Kogyo Co., Ltd. (8), Hiroshima Aluminium Co., Ltd. (9), Molten Corporation (10), Yumex Corporation (11), Ryobi Limited. (12), Ring Techs Hiroshima Co., Ltd. (13), Y-Tec Corporation (14), Akebono Brake Industry Co., Ltd. (15), Asmo Co., Ltd. (16), Usui Kokusai Sangyo Kaisha, Ltd. (17), NOK Corporation (18), Autoliv, Inc. (19), Calsonic Kansei Corporation (20), Kyosan Denki Co., Ltd. (21), Clarion Co., Ltd. (22), KYB Co., Ltd. (23), Koito Manufacturing Co., Ltd. (24), Sanoh Industrial Co., Ltd. (25), GKN Driveline Torque Technology K. K. (26), Jatco Ltd. (27), Showa Corporation (28), Stanley Electric Co., Ltd. (29), Takata Co., Ltd. (30), Tokyo Roki Co., Ltd. (31), Topy Industries Ltd. (32), Nisshinbo Industries, Inc. (33), Nifco Inc. (34), NSK Ltd. (35), NHK Spring Co., Ltd. (36), Nippon Piston Ring Co., Ltd. (37), Japan Brake Industrial Co., Ltd. (38), Pioneer Corporation (39), Piolax, Inc. (40), Hitachi Metals, Ltd. (41), The Furukawa Electric

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Co., Ltd. (42), Press Kogyo Co., Ltd. (43), Bosch Corporation (44), Marui Industrial Co., Ltd. (45), Mikuni Corporation (46), Mitsuba Corporation (47), Mitsubishi Electric Corporation (48), Meiwa Industry Co., Ltd.(49), Unipres Corporation (50), Yorozu Corporation (51), Riken Corporation (52), Aisan Industry Co., Ltd. Hiroshima Sales (53), Aisin AW Co., Ltd. (54), Ashimori Industry, Co., Ltd. (55), Advics Co., Ltd. (56), Inoac Corporation (57), Imasen Electric Industrial Co., Ltd. (58), Exedy Corporation (59), NTN Corp. (60), Kokusan Parts Industry Co., Ltd. (61), JTEKT Corporation (62), Sumitomo Electric Industries, Ltd. (63), Daido Metal Corporation (64), Chuo Spring Co., Ltd. (65), Denso Corporation (66), Tokai Rubber Industries, Ltd. (67), Tokai Rika Co., Ltd. (68), Toyota Gosei Co., Ltd. (69), NGK Spark Plug Co., Ltd. (70), HI-LEX Corporation (71), Hanshin Electric Co., Ltd. (72), Matsushita Electric Industrial Co., Ltd. (73), Maruyasu Industries Co., Ltd. (74), Mazda Motor Corporation (75), Toyota Motor Corporation (76), Nissan Motor Co., Ltd. (77), Honda Motor Co., Ltd. (78), Mitsubishi Motors Corporation (79), Fuji Industries Ltd. (80), Daihatsu Motor Co., Ltd. (81), Suzuki Motor Corporation (82), Isuzu Motors Limited (83), Hino Motors Ltd. (84), Nissan Diesel Motor Co., Ltd. (85).

<sup>v</sup> To understand the meaning of degree, suppose five-node network exists as below.

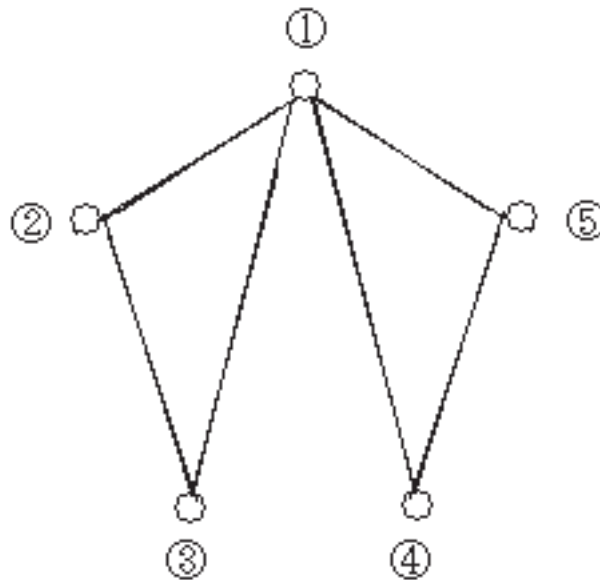


Figure 2 Five-node Network.

Table 2 shows the detailed results of degree because this is a symmetric organization.

Table 2 Degree of the Five-node Network.

Node	Degree
1	4
2	2
3	2
4	2
5	2
The entire centrality= 66.67%	

Three-dimensional configuration of the five-node network will be illustrated as below.

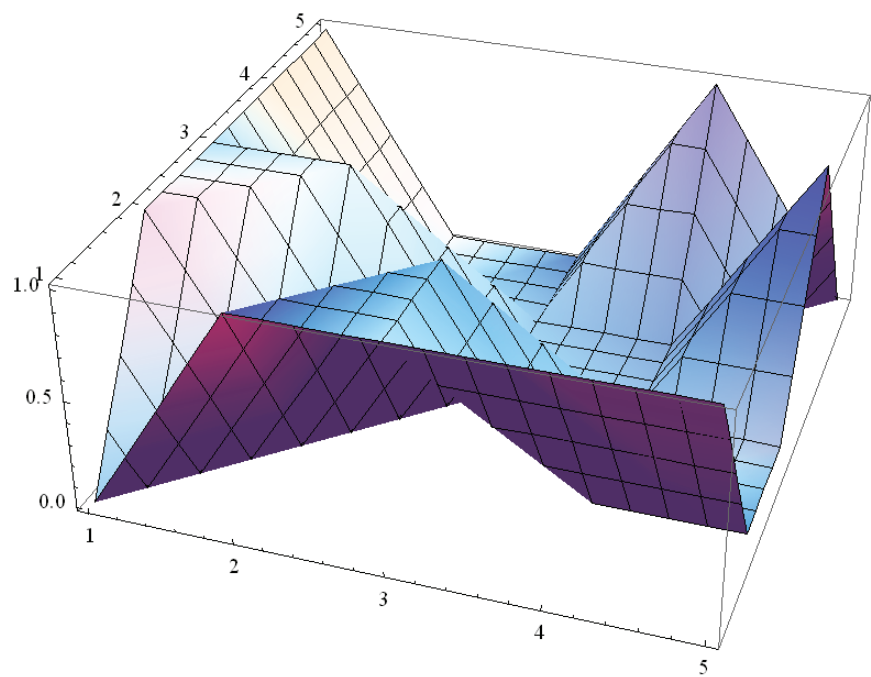


Figure 3 Three-dimensional Configuration of the Five-node Network.

Figure 4 shows the result if node 1 is removed from Figure 1.

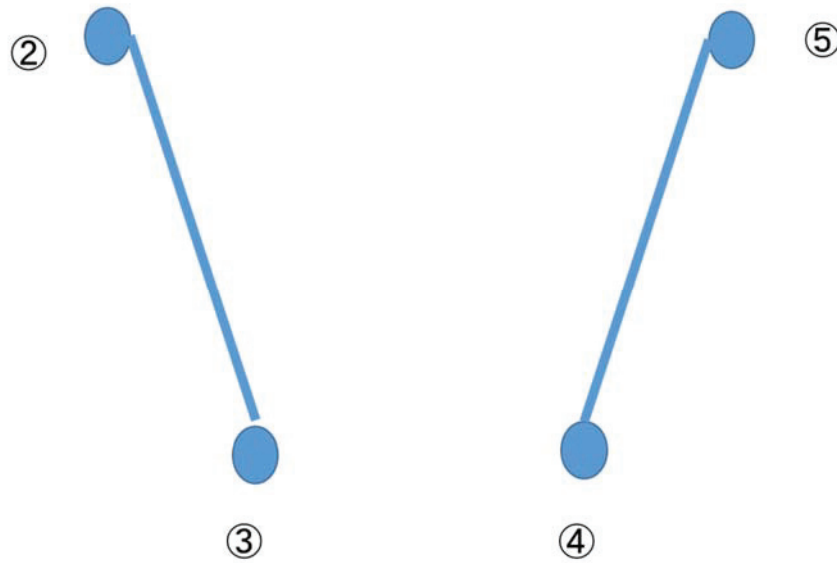


Figure 4 Five-node Network After Removing Node 1.

And then the new results of degree will be expressed as in Table 3.

Table 3 New Result of Five-node after Removing Node 1.

Node	Degree
2	1
3	1
4	1
5	1
The entire centrality= 0.00%	

Compared the result shown in Table 1, the entire centrality is 0. Therefore, node 1 will be considered as the key player in this network. in other word, the fragility of node 1 is low. Figure 3 will be changed as follows.

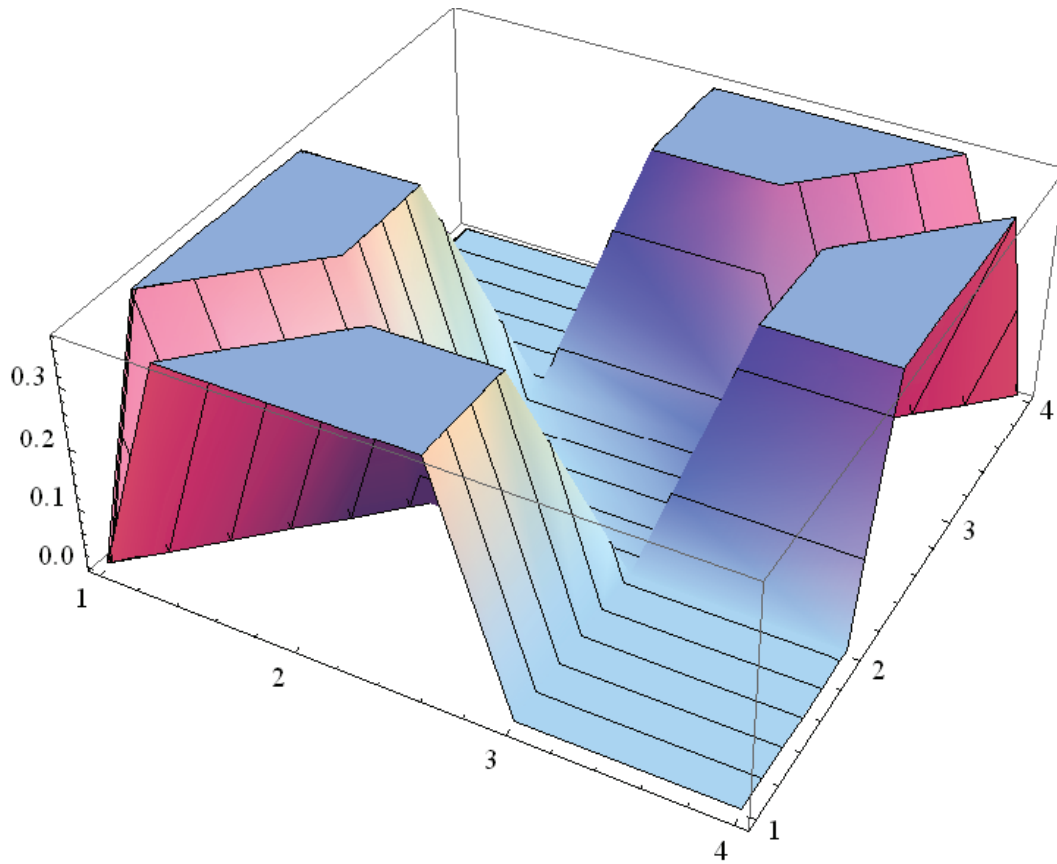


Figure 5 Three-dimensional Configuration of Five-node Network after Removing Node 1.

<sup>vi</sup> Evidently, different node will have same value of the different criterion because it is the result of summation. Accordingly, I suggest to calculate the square value of efficiency criterion to express the extent of its importance. It indicates that as the square value of the efficiency criterion increases, the company becomes much more important. To ascertain the relative importance of each node, the square value of difference criterion will be useful in case there is no difference among the difference score of the nodes or transactions. The square value of difference criterion of node A is shown as in Figure 6.

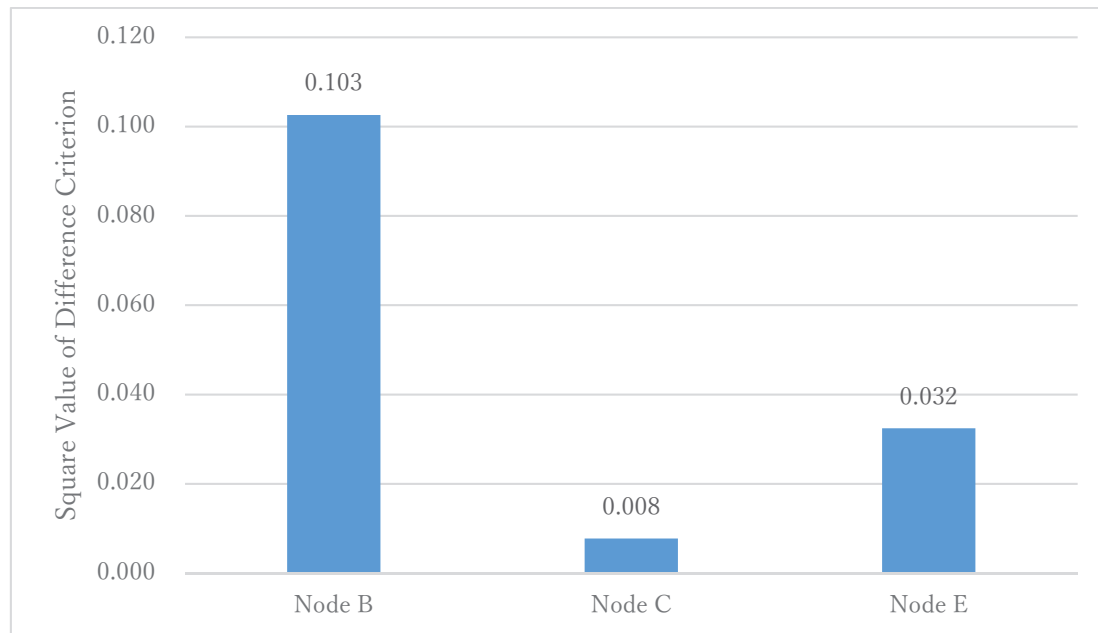


Figure 6 Square Value of Difference Criterion of Node A with Node B, Node C, and Node E.

vii The detailed information of Sumino and Climate Systems in 2004 and 2005 are shown as below.

Table 4 Detailed Transaction Information and Sales Revenue in Sumino. (%)

	2004		2005	
	To Sumino	From Sumino	To Sumino	From Sumino
Climate Systems	0	2	0	2.4
NSK	0	2	0	2.5
Mazda	0	83	0	79.7
Sales Revenue	5,433 Million Japanes Yen		6,099 Million Japanes Yen	

The transaction volume of Sumino with Visteon Asia Pacific Inc. is 2. Priority calculation is omitted because of lack sales information. Rear corporation is new deal of Sumino, the volume amount is 1.7.

Table 5 Detailed Transaction Information and Sales Revenue in Climate Systems. (%)

	2004		2005	
	To Climate Systems	From Climate Systems	To Climate Systems	From Climate Systems
Mazda	0	92	0	85
Sumino	2	0	2.4	0
Sales Revenue	22,450 Million Japanes Yen		22,985 Million Japanes Yen	

<sup>viii</sup> I accessed Yahoo webpage and browsed “strategy momentum” in Japanese on October 23, 2015. The term of “strategy momentum” in Japanese hits 3,200,000 on January 10, 2017.

<sup>ix</sup> The numbers means firms. They are: Toyota Motor Corp. (1), Nissan Moto Co., Ltd. (2), Mitsubishi Motors (3), Honda Motor Co., Ltd. (4), Mazda Motor Corp. (5), Suzuki Motor Corp. (6), Daihatsu Motor Co., Ltd. (7), Isuzu Motors Limited (8), Hino Motors, Ltd. (9), Fuji Heavy Industries Ltd. (10), Kawasaki Heavy Industries, Ltd. (11), F-Tech Inc. (12), Musashi Seimitsu Industry Co., Ltd. (13), Nissan Shatai Co., Ltd. (14), Jidosha Buhin Kogyo Co., Ltd. (15), Tachi-S Co., Ltd. (16), NOK (17), Shiroki Corporation (18), Keihin Corporation (19), Kasai Kogyo Co., Ltd. (20), Aishin Seiki Co., Ltd. (21), Ikuyo Co., Ltd. (22), Showa Corporation (23), Koito Manufacturing Co., Ltd. (24), Mitsuba Corporation (25), Toyoda Gosei Co., Ltd. (26), Aisan Industry Co., Ltd. (27), Meiwa Corporation (28), Nihon Plast Co., Ltd. (29), Murakami Corporation (30), Yorozu Corporation (31), Yachiyo Industry Co., Ltd. (32), TS Tech Co., Ltd. (33), Akebono Brake Industry Co., Ltd. (34), TBK (35).

<sup>x</sup> Sales and operating income also could be considered as useful indices to measure fluctuation of external environment. Sales and operating income from 2002 to 2017 are illustrated in Figure 7 and Figure 8.



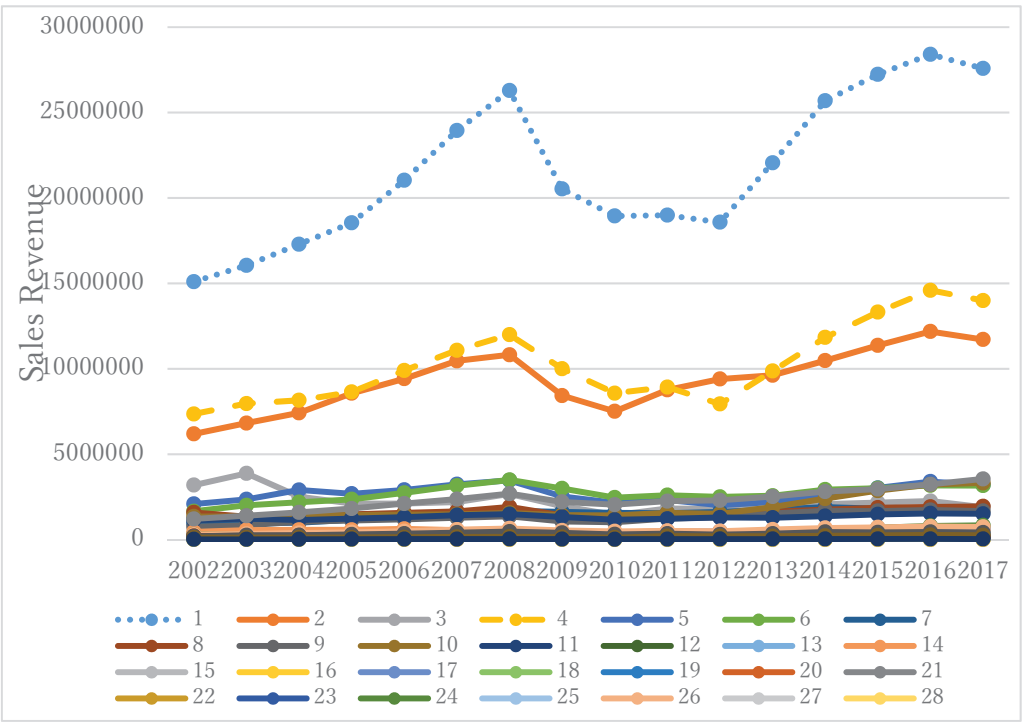


Figure 7 Sales revenue of Each Firm (2002-2017).

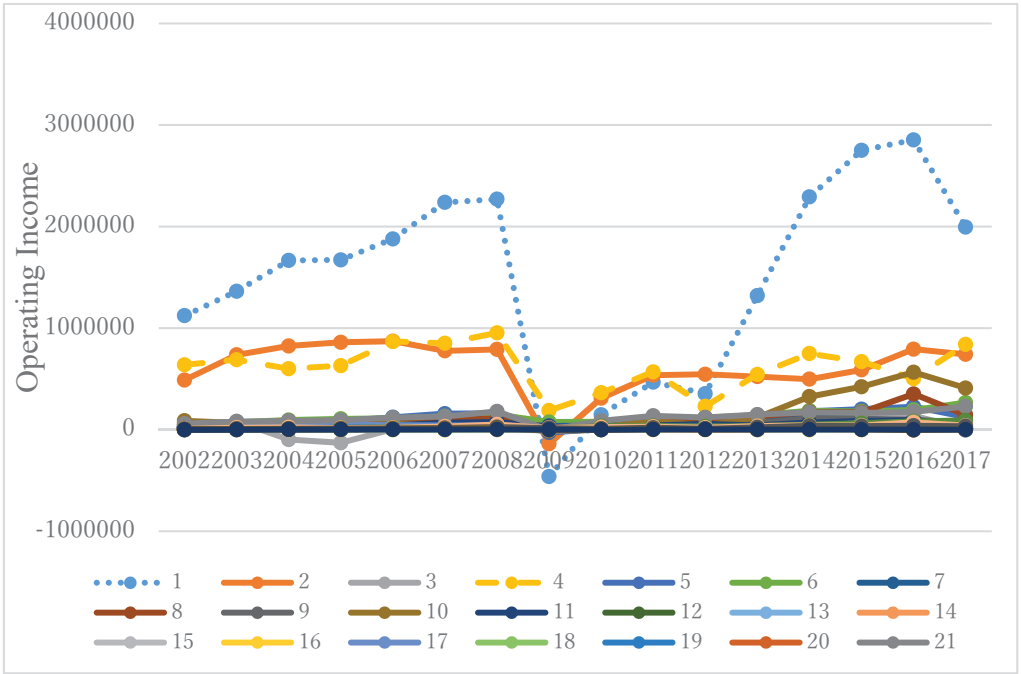


Figure 8 Operating Incomes of Each Firm (2002-2017).

The coefficients of variation of momentum, sales revenue, and operating income are calculated as below.

Table 6 Results of the Coefficients of Momentum, Sales Revenue and Operating Income.

	Momentum	Sales Revenue	Operating Income
Standard deviation	3.24E+14	4188731.22	326519
Mean	6.23E+12	1824149.31	108396
Coefficient of variation	52.04	2.30	3.01

Compared with the results of sales revenue and operating income, the coefficient of variation of momentum apparently looks more sensitive to the external changes.

<sup>xi</sup> Close correlation between total assets/ total liabilities and sales revenue/ profit is possible to be considered. The regression model between sales revenue or profit (explained variable) and total assets and total liabilities (explanatory variables) has been tested. The result in 2006, as one of the examples, could be shown as below.

Table 7 Regression Models between Sales Revenue/Profit and Total Assets/Total Liabilities.

2006	Partial Regression Coefficient	Standard Coefficient	Probability
Sales Revenue			
Total Assets	0.2309	0.3035	0.3939
Total Liabilities	0.8418	0.6900	0.0582
Profit			
Total Assets	0.0445	0.6484	0.0472
Total Liabilities	0.0382	0.3466	0.2781

Obviously, all partial regression coefficients are statistically insignificant except total assets in profit-total assets and total liabilities model. Thus, it is invalidate to use total assets and total liabilities to explain sales revenue or profit.