Interfirm networks of regional clusters in Japan

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***Abstract*— Dense networks among organizations are expected to work as a conduit of resources and knowledge within regional clusters. In this paper, we originally constructed a large database of interfirm networks in eighteen regions in Japan, and compared their inner structures. There is a marked difference among regions in their network structures. The variance is large especially among regions with small number of firms, and as the cluster size increases network structure improves. These results indicate that activities to support regional networking is necessary especially for small clusters. In those clusters, there is a room to improve networking We also analyze the characteristics of hub firms in each region and found that the headquarters location of the hub firms are strongly correlated with topological measures of networks. This suggested that high concentration of headquarters in Tokyo can hamper regional networking in the rest of the country.**

***Index Terms*—regional clusters, innovation, network, headquarter**

I. Introduction

IN the last decades, there has been a widespread resurgence of interest in the economics of industrial locations, particularly in the issue of regional clusters [1]. Innovative milieu [2], technology districts [3], and regional innovation systems [4] are also used as regional innovation models although they tend to be used for different focuses, contexts, and applications. In these models, innovation is associated with places where relevant resources are easily accessed by firms in close proximity. Some regions have superior innovative capabilities, as evidenced by the localized production of patents [5, 6].

Porter argued that enduring competitive advantages in the current global economy lie increasingly in local things - knowledge, relationships, motivation - that distant rivals cannot match, while companies in a global economy can source capital, goods, information and technology from around the world [7]. Silicon Valley and the Route 128 zone of Boston [8, 9], Cambridge [10], Baden-Württemberg [4] and “Third Italy” [11, 12] are typical example of such distinguished regions.

Regional clusters can offer more opportunities for innovation than scattered locations, which is typically driven by reduced transaction cost [13], access to venture capitalists [14, 15], local labor market pooling [16], entrepreneurial activity within the region [17, 18], enhancement of knowledge diffusion [19,20], and localized learning [19, 21]. Regional clusters are distinguished from pure agglomerations by their interconnected nature, i.e. clusters are characterized as collaborative networks and concentrations of collaboration and competition, which offer significant opportunities and stimulate economic development [7]. Another characteristic of regional clusters is the diversity of actors contained within. According to Porter [1, 7, 22], an industrial cluster includes suppliers, consumers, peripheral industries, governments, and supporting institutions such as universities. In sum, the network among actors is the key to understanding the performance of regional clusters [23].

Networks are especially important for small and medium-sized firms, since they lack their own resources to compete effectively with other firms [24, 25]. To overcome these deficiencies they must either depend on resource transfers from large enterprises or be linked to a community of small firms in which productive resources are jointly procured, developed, and utilized. Stinchcombe used the term, ‘liability of newness,’ to explain the higher rate of failure among young firms, which he attributed to the difficulties new firms have in securing the resources they need for survival [26]. This liability arises at least in part because young firms have less of the legitimacy needed to gain trust and support from other actors [27]. Dense networks can reinforce trust building. Trusting behavior affects the persistence of interfirm networks and improves the quality of information flows critical to innovation [26]. The connection to market leaders or highly regarded firms that can give a reputation or legitimacy to the young firm [28]. In this way small firms can become parts of a 'set of organization' [29], enjoy many of the advantages possessed by large firms, and consequently offer jobs of comparable quality. Especially for regional clusters consisting of medium and small firms, networking activity and the resulting network structure should play an important role.

Therefore, understanding the network structure in the focused region is an inevitable step to grasping the current status of regional industrial structure and effective policy development. Owen-Smith et al. [30] and Owen-Smith and Powell [31] investigated network structures consisting of biotechnology firms, pharmaceutical corporations, venture

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capitals, and public research organizations in the United States. They analyzed intra- and inter-cluster linkages, and showed that the Boston cluster occupied a central position in the network by using social network analysis and network visualization. However, except for a few works, literature is not yet rich enough to facilitate understanding and evaluation of the network structure of regional clusters. Given the ongoing lack of a comparative study on inter-firm networks among regional clusters, we have little empirical evidence with which to discuss and understand the similarities and differences among network structures of regional clusters. The aim of this work is to investigate network structures in eighteen regional clusters and to discuss the route to enhance regional networking. We examine the interfirm networks of eighteen regional clusters in Japan. Next, we illustrate our research methodology.

II. Methodology

A. Interfirm network

The term "network" refers to a set of nodes and the relationships that connect them (see Fig. 1.). A social network can be defined as 'a set of nodes (e.g. persons, organizations) linked by a set of social relationships (e.g. friendship, transfer of funds, overlapping membership).

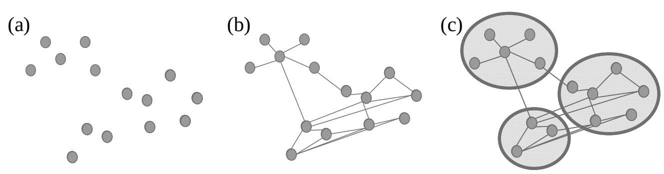

Fig. 1. Levels of analysis. (a) aggregates of firms. (b) interfirm network. (c) firm modules.

Because regional clusters are distinguished from pure agglomerations by their interconnected nature, the level of our analysis is interfirm network and firm modules. In this paper, we regard customer-supplier relationships as links in the network among various relationships between multiple firms, because these relationships are known as the best source of information for Japanese firms. A white paper on small and medium enterprises in Japan reports that the top priority information channel for Japanese firms is the contact with customers and outsourcing contractors [34]. Although there is a variance of emphasis between firms that have entered new fields and those that have not entered, customer-supplier relationships is cited as the remarkable information channel. Researchers also increasingly regard interaction within customer-supplier relationships as key to the successful management of innovation, as customer and supplier relationships play a critical role in knowledge development, resource mobilization and co-ordination [35]. The key characteristic of customer-supplier relationships in Japan is the fact that the relationships with customers are more dedicated and long-term than in other countries [36, 37]. In the following, we explained our data and analyzing schema.

B. Data

We select eighteen clusters as shown in Table 1. We listed firms corresponding with the industrial categories located in each region, using a database provided by NTT. This NTT compiled database includes the addresses and industrial category of the firms registered by themselves. We define business transactions between firms as links. The data by the Teikoku Data Bank (TDB) has up to five suppliers and customers for each firm, meaning each firm can link up to a maximum of ten other firms. Because business transactions include a range of traded volume, this restriction on the number of links enables us to extract not the entire business network in the region but just its essential features. One study reports that firms have an average of 10 important business relationships [38]. These datasets were collected in the year 2007 for cluster B (Chukyo), D (Hiroshima-Okayama), I (Niigata), K (Kyoto), N (Hamamatsu), and R (Okinawa), and 2005 for the rest of the regions. The analysis was performed at the geographic scale of city (cluster # J, M, N), prefecture (A, F-I, K ,L, O-R) and prefectures (B-E). We integrated these two databases by NTT and TDB into a single dataset on networks consisting of nodes and links. The networks are non-weighted and non-directed. Subsequently, we extract the maximum connected component of each network. We analyzed the network structure of firms that locate in the region. The resulting networks have approximately 500 to 9,000 nodes, and 2,000 to 43,000 links for each cluster (Table 1), which is larger in size than those of previous works [30, 31, 39].

TABLE I
Basic Characteristics of 18 Regional Clusters

#	Region	Main industrial category	*n*	*K*
A	Osaka	Manufacturing	8,834	43,092
B	Chukyo	Manufacturing	7,914	34,162
C	Kinki	Pharmaceutical & Medical	5,437	25,310
D	Hiroshima-Okayama	Manufacturing	3,553	13,772
E	North-Kyushu	Manufacturing	3,275	13,420
F	Hukuoka	Enviroment	3,272	14,226
G	Hokkaido	Pharmaceutical & Agriculture	2,038	7,740
H	Nagano	Manufacturing	1,933	10,018
I	Niigata	Manufacturing	1,898	8,426
J	Sapporo	Pharmaceutical & Agriculture	1,871	6,086
K	Kyoto	Manufacturing	1,798	7,362
L	Toyama	Pharmaceutical	1,397	5,364
M	Sapporo	Information Technology	1,113	3,820
N	Hamamatsu	Manufacturing	1,049	4,080
O	Hukuoka	Medical Device	931	2,702
P	Aomori	Agriculture	673	2,164
Q	Yamagata	Manufacturing	625	2,078
R	Okinawa	Food	527	2,594

#: Cluster ID, *n*: number of nodes, *K*: number of links

C. Analyzing Procedures

We investigated the structure of interfirm networks by using average path length ratio and inter-module coordination.

The average path length (L) is frequently used to express the relative accessibility of an average node to the other nodes in a network, is defined as the number of links in the shortest path between two nodes, averaged over all pairs of nodes [40]. Evaluation of the average path length is essential to evaluate network performance. Networks can act as pipes of information about resource opportunities and potential partners. In particular, the individual small firm lacks sufficient resources to compete effectively with large firms. To overcome these deficiencies it must either depend on resource transfers from large enterprises, i.e. on a foster relationship, or be linked to a community of small firms in which productive resources are jointly procured, developed, and utilized. In this way small firms can become parts of "big" organizations, enjoy many of the advantages possessed by large firms, and consequently offer jobs of comparable quality [24]. A small value of L indicates a small diameter of the network and that firms in the network can pool resources over networks via fewer paths, and in a network with small L structural holes are buried.

The average path length of a random network, L_{random}, can be approximated as $L_{random} \sim \ln(n)/\ln(\bar{k})$, where n and $\bar{k}$ are the number of nodes in the network and the average number of links each node has, respectively [40]. Our network is non-directional, and therefore, $\bar{k}$ equals with $2K/n$, where K is the total number of links in the network. In a small world network, L is slightly larger than L_{random}, but relatively smaller than that of a regular network. However, in a network with larger n and lower $\bar{k}$, L becomes larger. In other words, L is dependent not only on the inner structures of a network but also the number of nodes and links within the same. Therefore, to comparatively evaluate network performance, we normalized L by L_{random}, as adopted by Watts and Strogatz [40], i.e. we use average path length ratio (APR) defined by $APR = L_{random}/L$ as a measure of the small world property of the network. Because small world property improves as APR increases it is desirable for a network to have higher *APR*..

When evaluating *APR*, we treat the network uniformly. However, interfirm network is often neither uniformly dense nor sparse. The structure is uneven, composed of regions that are more or less filled with relationships (Fig. 1). A group of firms extensively sharing partners have dense relationships with certain partner groups and sparse or no relationships with others. A business enterprise looks more like a linking unit, where its strategic attributes lie in how it connects other market participants to each other [41]. As such, firms should not be seen in isolation but as being connected in business systems. Therefore, we focus on such 'a set of organizations' [29]. In the following, we name tightly knit groups as modules, where dense intra-group links exist. As noted by Staudenmayer *et al.* [42], industries are characterized by interfirm modularity.

In order to detect modules, we perform a topological clustering of networks. Although such a methodology had been difficult to achieve due to the difficulty in performing cluster analysis of non-weighted graphs consisting of many nodes, recently proposed algorithms [43, 44] facilitate fast clustering with calculation time in the order of $O((l+n)n)$, or $O(n^2)$ on a sparse network with l links; hence this could be applied to large-scale networks. The algorithm proposed was based on the idea of modularity. Modularity Q was defined as follows [43-45]:

$$Q = \sum_{s=1}^{N_m} \left[\frac{l_s}{l} - \left(\frac{d_s}{2l} \right)^2 \right]$$

where N_m is the number of modules, l_s is the number of links between nodes in module s, and d_s is the sum of the degrees of the nodes in module s. In other words, Q is the fraction of links that fall within modules, minus the expected value of the same quantity if the links fall at random without regard for the modular structure.

A good partition of a network into modules must comprise many within-module links and as few as possible between-module links. The objective of a module identification algorithm is to find the partition with the largest modularity. The algorithm to optimize Q over all possible divisions is as follows. Starting with a state in which each node is the only member of one of n modules, we repeatedly join modules together in pairs, choosing the join that results in the greatest increase in Q at each step. Since a high value of Q represents a good modular division, we stopped joining when ΔQ became minus. At the maximal value of Q, Q_{max}, we obtain a modular structure of a network with effective particition.

Inter-module coordination (IMC) is defined by $IMC = 1/Q_{max}$, to evaluate the connectedness among modules. A network with smaller *IMC* means that there are more independent modules in the network, while one with higher *IMC* means that modules are intermixed and the network is more uniform. We can expect that there are a number of structural holes between modules in the network with lower *IMC*. On the other hand, structural holes are buried in the network with higher *IMC*. In other words, in the network with lower *IMC* there is ample room to build bridges between separated modules.

III. Results and Discussions

Figure 2 shows the relationships between cluster size, i.e., number of nodes in each region and network structures, i.e., APR and IMC. As shown in Fig. 2, APR and IMC improves as n increases especially in the region where $n > 4{,}000$. On the other hand, below $n \sim 4{,}000$, there is a marked variance both in APR and IMC. The variance is large especially among regions with small n, and as n increases network structure improves. These results indicate that activities to support regional networking are necessary especially for small clusters. In those clusters, there is a room to improve networking

But how can we assist regional networking? To answer it, further analysis is performed based on a comparative study. Figure 3 is a rearranged plot of Fig. 2 according to the rank of each region in their size. It is clear that APR and IMC are correlated. And cluster H and N have superior network structures among relatively small clusters. On the other hand, cluster D has inferior structure among larger cluster, and cluster J, K, O, P have low value of APR and IMC among small clusters. Therefore, we compare the detailed structures of interfirm networks at cluster H and N with those of cluster D and J.

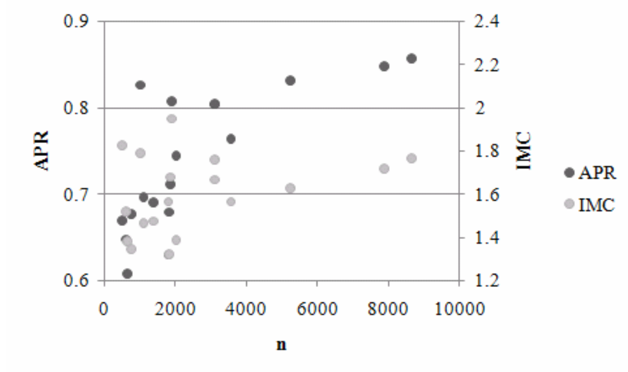

Fig. 2. Size effect on regional networking.

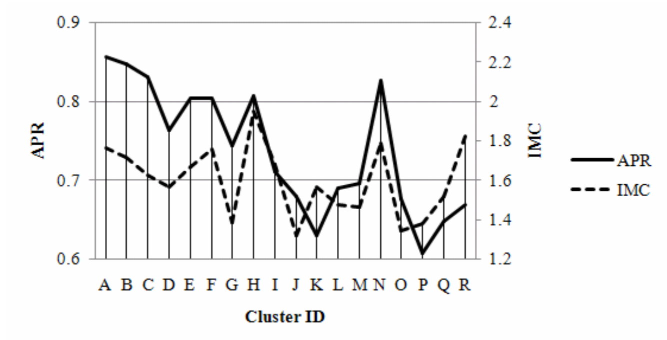

Fig. 3. Network structures in each region.

In the following, we discuss the role of hub firms in Cluster H (Nagano) and Cluster N (Hamamatsu) are typical regions having superior network structures, and Cluster D (Hiroshima-Okayama) and cluster J (Sapporo)

Figure 4 and 5 are visualizations of modular network structures coordinated by spring layout algorithm. We use graph drawing tool, Pajek, to visualize them. The size of node is proportional to the number of firms in each module obtained by topological clustering. The width of lines is proportional to the number of links between two modules. In those figures, hub firms of each module is also shown. When the firm name is surrounded by a rectangle, it means that the headquarter of the firm locate in the region. When the firm name is not surrounded, the headquarter is outside the region.

In cluster H, each module is strongly connected, which apparently contribute to the superior network structures. It can be also seen that most of hub firms have their headquarters at the region. For example, it is well know the Seiko-Epson is the leading firm of the region (Nagano prefecture). Other companies such as Shinko-Denki, Nissei-Jushi, and Tamagawa-Seiki has their original products and services having competitive advantage. Some firms whose headquarters are outside the region such as Fujitsu, Mitsubishi-electronics, Yuasa-Shoji are also seen but are minor components.

Cluster N (Hamamatsu) also has a number of firms whose headquarters are in the region. Examples are Yamaha-motor, Suzuki, Yamaha, Hamamatsu-photonics. Honda has a root in Hamamatsu but the current headquarter of Honda is Iwata city that is the neighbor city of Hamamatsu.

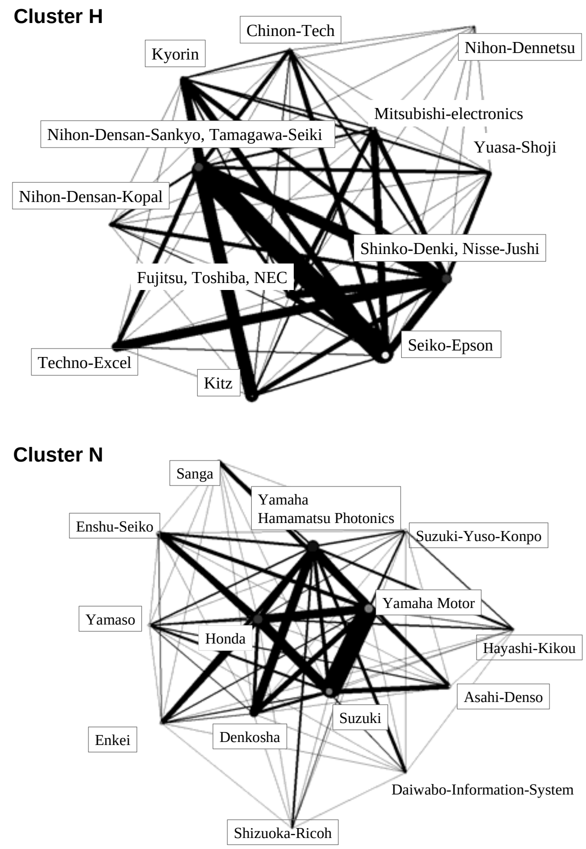

Fig. 4. Modular network structures in superior each regions.

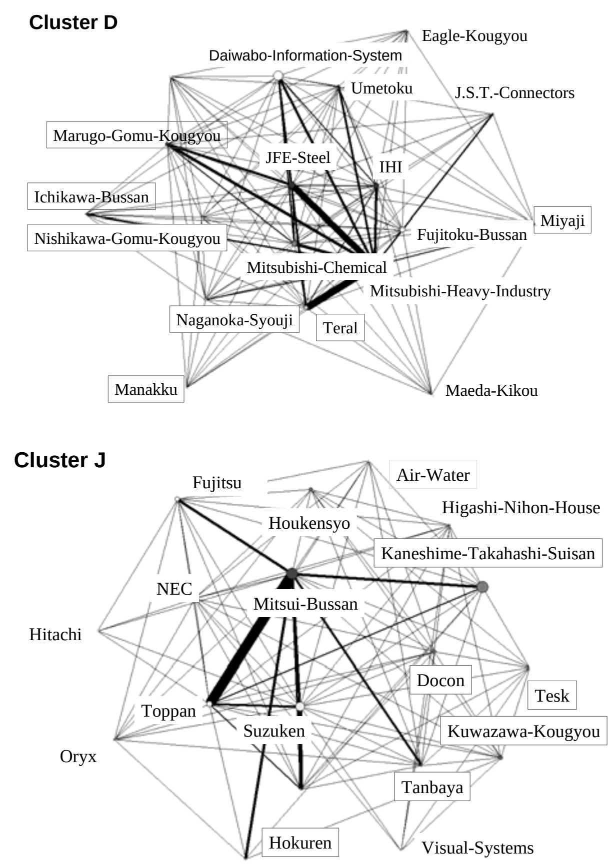

Fig. 5. Network structures in each region.

In cluster H and N, regional firms locating their headquarters at the focal region are hub firms of the main modules located in central positions in the networks.

On the contrary, in cluster H and N, modules which regional firms belong to located at the peripheral positions in the network. For example, in the modules located at the central positions of cluster H, hub firms are JFE-steel, IHI, Mitsubishi-chemical, Mitsubishi-heavy-industry and so on. In these regions, we can see agglomeration of firms not but well-networked regional clusters.

According to these results, we conclude that the variance in network structure among regional clusters is derived from the location of headquarters of hub firms. A plausible reason of the intense networking in the region beneath headquarters of hub firms is face-to-face communications among persons having the rights of decisions. This hypothesis drawn from our case comparative case study suggested the difficulty to promote industrial policy based on the concept of regional cluster or regional networking especially at the region where there is less headquarters in the region. In these regions, policy to promote the relocation of headquarters from the metropolitan area to the region or the development of regional firms whose headquarters are at the region are critical factor to enhance the regional networking.

IV. Conclusion

There is an increasing interest in interfirm networks which is expected to work as a source of innovation by circulating resources and knowledge within the network. In this paper, we analyzed network structures of eighteen regional clusters by average path length ratio and inter-module coordination. We found that these network properties among regional clusters show marked differences.

These differences seem to be controlled by the number of firms in the region and the location of the headquarters of hub firms. Because the variance in network structure is large in relatively small clusters, policy for networking can work effectively for small clusters. To develop dense networks, rearing regional firm or attracting headquarters from the other regions especially Tokyo is are necessary.

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