A Study of High-End Equipment Manufacturing Industry Cluster Network and Innovation Capability

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Abstract Industrial cluster is the source of international or regional competitive advantage. The characteristics of network structure determine the transfer of knowledge and information in the cluster to a certain extent. In this paper the type and representation of cluster network structure are firstly theoretically analyzed. And then the relation between cluster network cluster and innovation capability is discussed, i.e. whether there is any influence on cluster innovation capability and how to influence it. Based on the analyzed results, Deyang high-end equipment manufacturing industry cluster innovation network in China is empirical studied from a practical point of view. Both the western China equipment manufacturing industry network structure and its effects on cluster innovation capability are considered. Finally some targeted countermeasures to perfect the equipment manufacturing industry cluster innovation network are proposed.
Keywords: High-end manufacturing; The cluster network; Innovation capability

1 Introduction

The essence of innovation is a process of knowledge acquisition and integration, the diffusion of innovation is the main form of enterprises within cluster to innovate. In this way, knowledge and information can be used rapidly and efficiently of the members in the network. Then the innovation performance will also promote quickly. At the same time, due to the effect of the international financial crisis, since the second half of 2008, there is a sharp contraction equipment at home and abroad market demand. Both the enterprise production and management are in difficulties. With the economic downturn, the sustainable development meets up with challenges.

Innovation can be a communication channel between the members of the social system in a particular period of time[1]. And the pattern of innovation diffusion between members in social groups and the structure of social organizations have a complex and deep connection[2]. Bell[3] studied the relation among cluster, network and innovation and pointed out that the location within or outside the cluster and the cluster structure the of enterprises will affect the enterprise innovation effects. Ahuja et al.,[4] believed that the network is made up of a series of the relationship among members. Liu et al.,[5] explored the individual and overall features of cluster innovation network structure and effects on radical innovation and imitation innovation diffusion. Wang and Wang[6] studied the relationships between cluster member characteristics influence on the performance of enterprise innovation from the perspective of social network of industrial cluster. Yang and Huang[7] analyzed characteristic of the mobile phone industry cluster innovation network based on the perspective of network location effect on innovation in Hangzhou. Wei et al.,[8] studied the industrial cluster network process impact on innovation performance with the empirical method. Li[9] studied characteristics of

ceramic industry cluster innovation network structure. Ren et al.,[10] discussed the influence of regional innovation network structure on the regional innovation capability in China. From the point of the object of study, the cluster network research mainly concentrated in traditional industrial clusters and high-tech industry cluster. However there was relatively few works focus on of large equipment manufacturing industry cluster, mainly in the northeast and other old industrial zone of Shanghai[11]. Shao et al.,[12] discussed the equipment manufacturing enterprises and the cause of promoting independent innovation capacity. So that, it is of great importance to deepen the study of equipment manufacturing industry cluster innovation network.

On the basis of the existing literature, this paper analyzes the cluster network structure and its influence on cluster innovation capability. This paper presents the findings of a practical study by answering the questions about what is the cluster network structure characteristics, how to characterize the structure characteristics, and whether the cluster network will pose a impact on the cluster innovation capability. It is hoped that this attempt can deepen the innovation network theory. Based on the example of Deyang high-end equipment manufacturing industry cluster in China, some reference for practice are offered. Some policy suggestions are proposed to promote the development of China's equipment manufacturing industry, especially that the development of regional economy in western China is of important theoretical value and practical significance.

2 Theoretical Basis

Enterprises within a cluster are of greater innovation advantage than its counterparts outside a cluster, the innovation advantages are characterized by the overall structure of the cluster network. Network structure characteristics is an important structure variables of the network. And for the whole cluster innovation network, characteristics of network structure is important influence factors of innovation and the innovation diffusion. Combining with scholar's researches of Qi and Jiang[13], Zeng et al.,[14], Ruan et al.,[15], about effects on cluster innovation capability is explored from the overall structural characteristics respectively, such as network density, concentration coefficient, Network centrality, network node degree distribution, average shortest path and network faction.

2.1 Analysis of the cluster network structure

The cluster network is composed of nodes, such as enterprises, universities and research institutions, intermediary services, government and other nodes, and relations, established through the exchange and communication between each other, that are relatively stable and can promote the formal and informal relations inside the cluster innovation. The characteristics of overall structure between different cluster networks are different.

2.1.1 Network density

Network density and concentration coefficient are the most important overall architecture properties of the network. They are the ratios of the number of connection between the nodes and all the possible connections in the network. Network density refers to how closely each node in the network are connected. Relations between the organization of specific cluster network are the combination of dense and sparse networks[16].Network density measurement can be divided into the undirected network density and directed network density. Specifically, in undirected network, density is expressed by the ratio of the actual number of

ties L in the network and maximum possible number of ties.

2.1.2 Concentration coefficient

Concentration coefficient refers to the average network density of all the nodes when self-centered. Strictly speaking, concentration coefficient not only measures the density of the entire network, but also reflects the network connectivity and transitivity. A vertex of the local cluster coefficient is equal to all vertices between attached to it by the number of edges divided by these can even out the maximum number of edges between vertices.

2.1.3 Network centrality

Network centrality characterization is the concentration or centralized degree of the whole network, namely the whole network around a point or a set of points to the degree of organization operation, which is described as one of the whole network structure variables[16]. Degree of nodes in a network refers to the number of edges connected to the node, means that the greater the degree of a node is, the more nodes are directly connected in the whole network.

2.1.4 Network node degree distribution

Network node degree distribution is to measure the distribution of all network nodes with connections. Vertex degree distribution is presented in distribution function $\boldsymbol{P_k}$, It is equal to the ratio of the number of nodes in the network degree for $\boldsymbol{k}$ and the total number of network nodes. The probability of the selected node with $\boldsymbol{k}$ edges is given. Network of distribution shows the distribution of number of each node connected to the other nodes in the network, which is an important geometric feature of the network structure.

2.1.5 The average shortest path length

The average path length of the cluster network reflects the average distance of the nodes in the network connection, which affects resource transfer efficiency of the entire network innovation. For a efficient network, the nodes in the network can quickly reached a lot of other nodes through the relatively small number of nodes, thus makes it much easier to obtain knowledge, information and other resources.

2.1.6 Network factions

Network factions are also known as the clique or small world. In social network analysis, the factions are measured with node degree or calculation on the basis of distance. No matter what kind of calculation, the factions are used to describe such node group: a high degree of connection between the nodes in the group, but a very low degree of connection with other nodes in the network. N-clique and K-plex are two of the most important faction calculation method. In addition, social network analysis of factions processing can also start from the block model. And its essence is in accordance with a standard to divide network for community or block.

2.2 Influence of cluster network structure on innovation capability

The structure feature of the cluster network is by affecting the overall flow of resources in the network to influence cluster innovation. The overall structural characteristics of the network influence the cluster innovation capability in the following four aspects.

2.2.1 The impact of density and concentration coefficient on the cluster innovation capability

Knowledge, information and technology resources are the basis for cluster innovation. Enterprises with a higher level of communication are with high network density. If an enterprise can frequently communicate with the similar enterprise, customers and suppliers to promote mutual communication between each other, it

will not only increase the possibility of understanding and being familiar with other enterprises and units, but also make it possible for the enterprise to use the tacit knowledge of network nodes. The quality of network density determines the enterprise social capital. Companies with higher social capital tend to have higher level of trust between the surrounding enterprises. Thus the information risk of enterprise innovation is reduced while the relationship between the upstream and downstream enterprises is improved in the common social and cultural environment. However, high density is not conducive for enterprises to obtain unique knowledge, then imitation will replace innovation as the main mode[5]. In addition, a high density tends to result in factions, or the formation of small groups, which hinder innovation in production technology for enterprises in the cluster. In conclusion, only when the network density and concentration coefficients are suitable for enterprise, they can be conducive to the cluster innovation. The network with proper density and concentration coefficients are with greater innovation potential.

2.2.2 The influence of network centrality on cluster innovation capability

There is a large number of connections between other nodes for node with high centricity level in the network indicating that in the whole network the node occupies an extremely important position. If a node in the network occupies the central position, then the other enterprises in the cluster will try to contact it. In this case, the central enterprise can more easily access to many scarce resources through the cooperation with other enterprises. As a result, thus it is more conducive to innovation for central enterprise. From the perspective of knowledge and information dissemination, innovation behaviors are more likely to happen in the rich, complicated information environment. Enterprise in the central position is with the precise chance and ability to access to knowledge and information for achieving product and process innovation.

In cluster network, companies with relatively higher strength are often occupying the position of higher centrality. There is a demand of cooperation with these enterprises for other enterprises and units to carry out business and innovation. And this collaboration itself is also a process of learning. Rossi et al.,[17] believe, as for a technology or innovation, the longer it takes to learn and absorb, the greater loss of technology and innovation for the social value will suffer. Therefore, in order to maintain their position at the center of the exchanges and cooperation, enterprises with high centrality are inclined to learn from external cluster and to create and use the new technology.

2.2.3 The influence of the distribution network node degrees on cluster innovation capability

Depending on the degree of distribution, the cluster network can be divided into shaft type cluster and market-oriented cluster. For the shaft type, nodes with lower vertex degree are developing around a handful nodes with higher vertex degree in the cluster and the nodes with higher vertex degree are enterprises with strong ability of resource acquisition and innovation. The equipment manufacturing industry cluster belongs to the typical shaft type cluster. For market-oriented cluster, it consists of a series of enterprises with roughly the same vertex degree. All these enterprises do not have no absolute access and control of innovation resources. However, because of the pressure of competition and system flexibility, generally there is a strong sense of innovation in these enterprises.

2.2.4 The influence of the average shortest path length on cluster innovation capability

In the network, if some center nodes connect to each other through the redundant connection and form a special group, then these nodes are called the ‘small world’. Due to the nodes in ‘mall world’ are connected to each other, the network becomes more efficient. These non-redundant connections are prevalent between the center nodes. Thus these nodes are able to find new opportunities and take the lead in introducing

external knowledge into their own group. And finally they can enhance their innovation performance of the 'small world' group. Therefore, the smaller the average shortest path length, knowledge, information and technology resources will transmit faster in the network and at the same time resource distortion or loss will be small. That is to say, the network will be creative potential.

2.2.5 The influence of faction characteristic on cluster innovation capability

Faction is universal in the reality of the network world. The exist of faction in the cluster innovation network will inevitably affect the innovation behavior and overall function of the cluster innovation network. Members of the faction are in frequent contact, rarely to communicate via redundant connection. So it is easy to share knowledge, information and technology resources, in the faction which are helpful to increase the innovation capability of the whole faction. However, frequent contact also makes the knowledge and information in fraction homogeneous. If faction members don't exchange knowledge, information and other resources with the outside world, they will not be able to access to heterogeneous information, eventually lose vigor of innovation.

3 Empirical Research

Deyang high-end equipment manufacturing industry cluster is one of the major heavy equipment manufacturing base in China. These enterprises and the organizations form the equipment manufacturing industry cluster innovation network. Within the network, various enterprises and organizations communicate and learn with each other. Knowledge, technology and information flow within the network, which continuously improve cluster innovation capability. For intuitive understanding of the composition and characteristics of the equipment manufacturing industry cluster innovation network, in the case of Deyang equipment manufacturing industry cluster, this study presents on-the-spot investigation in the cluster enterprises and intermediary service institutions, universities and research institutes, government and other nodes. Through the investigation of the relationship between the nodes connected data, the cluster innovation network is depicted.

3.1 Data acquisition and collation

Combined with the form of interview and questionnaire, the on-the-spot investigation is applied to get the data mainly in the large leading enterprises and corresponding small and medium-sized enterprises that supports the production for leading enterprises. Thus 60 enterprises such as China National Erzhong Group Co. (CNEG), Dong Fang Steam Turbine Works (DFSTW), Dongfang Electric Machinery Co., Ltd (DFEM), and Sichuan Honghua Petroleum Equipment CO., Ltd are selected as a characterization of node enterprises. Among the 60 company nodes, 9 are the leading enterprises in Deyang, 32 are to form a complete set of product design and production of small and medium-sized enterprises and 30 of them are the enterprises commended by Deyang Machinery Industry Association. As for the choice of auxiliary nodes, based on the investigation of the actual situation of leading enterprises in Deyang equipment manufacturing industry, the connection relationship among companies and universities, industry association, the intermediary service institutions as well as the information transmission platform are studied.

In the process of data collation, once A chooses B regardless of B dose not choose A or the select value is not consistent, it is considered that there is a link between A and B. The overall structure of the cluster

innovation network characteristics are measured through density, concentration coefficient, the Network centrality, average shortest path length and factional structure variables. In this paper, a software is used to analyze the overall structure characteristics of Deyang equipment manufacturing industry cluster innovation network, and based on the results its impact on cluster innovation capability is discussed.

3.2 Connection density, centrality and average shortest path length

Through the data collation of Deyang equipment manufacturing industry cluster innovation network four binary matrixes are obtained, such as enterprise and enterprise; Enterprise, intermediary and industry association; Enterprise and university, Enterprise, university, intermediary and industry associations. Calculated by network analysis tool, connection density, cluster coefficient, Network centrality and average shortest path length are shown in **Table 1**.

Table 1 Measure Based on the Main Structure Characteristics of Deyang Equipment Manufacturing Industry Cluster Innovation Network

Network	Connection Density	Cluster Coefficient	Network Centrality	Average Shortest Path Length
Enterprise and Enterprise	0.958	0.563	34.62%	1.102
Enterprise, Intermediary and Industry Association	0.200			
Enterprise and University	0.153			
Enterprise, University, Intermediary and Industry Associations	0.164	0.277	56.19%	1.873

Shown in table 1, the relationship between the enterprise network density is very high of the value 0.958. This conforms to the characteristics of the equipment manufacturing industry cluster that several leading enterprises are as the core, other small and medium-sized enterprises are developed around these leading enterprises and supporting those leading enterprises. At the same time, such high density between enterprises, in addition to demonstrate a close connection between supporting enterprises inside the cluster and leading enterprises, there is also a close relationship between leading enterprises. The whole cluster in a benign connection. However as for the density of Enterprise, intermediary and industry association, and enterprise and university the level is low, its density of 0.200 and 0.153 respectively. Such a connection density shows that the cluster on the resources, especially the use of the source of innovation and control is not enough, the cluster external knowledge acquisition and utilization degree are low, the cluster innovation is not able to gain new blood. Cluster coefficient not only reflects the network connection density but also reflects the connectivity of network. From the point of the connection between the enterprise network, the connectivity between enterprises is good. But the comprehensive network connectivity coefficient is only 0.277, showing that overall network connectivity is poorer, knowledge and information are not well spread and used within the cluster.

Network centrality reflects the centralized degree of the network. From table 1 integrated connection between networks and enterprise Network Centrality coefficient, the numbers are large, 56.19% and 34.62%, respectively. This shows that there is a group of enterprises in the center position of the network, these enterprises are an important force in the cluster innovation. Because the cluster enterprise and the connection

between the university and the mediation is evacuated, as a result, a lot of knowledge and information of cluster innovation are from leading enterprises. These enterprises act as an important 'bridge' between cluster innovation network and external connection to acquire new knowledge and information.

The average shortest path length reflects the transfer efficiency of network innovation resource. From the perspective of the data of table 1, the average shortest path lengths of the connection between the network of Deyang equipment manufacturing industry cluster enterprises and the comprehensive network of are 1.102 and 1.873. From the point of the contrast of real network, average shortest path length of Deyang equipment manufacturing industry cluster enterprise between connected network is in a better state, and the comprehensive network in the medium level. This fits the characteristics of the equipment manufacturing industry cluster, the axle type of industrial clusters supporting small and medium-sized enterprises cluster. However innovation resources in the network transmission efficiency is not ideal, there is a certain degree of distortion and loss.

3.3 Faction and node analysis

Faction is called group or clique within the network, the judgment standard is the tightness of the connection between the group members. Factions characteristics of Deyang equipment manufacturing industry cluster enterprise network are considered with software UCINET 6.0.

Through the investigation of 54 enterprises it can be seen, they can be divided into four cliques. The four cliques include 10, 10, 8 and 16 enterprises respectively. From the point of the density of each faction, the densities of clique 1 to 4 are: 0.130, 0.130, 0.250, 0.130, the density between each clique is shown in table 2. From the data in the table, the factions division is reasonable, and its Fitness=786.000 which is a relatively optimal value.

Table 2 Density Distribution between the Four Cliques

	Clique1	Clique2	Clique3	Clique4
Clique1	0.130	0.110	0.060	0.000
Clique2	0.110	0.130	0.050	0.040
Clique3	0.170	0.060	0.250	0.020
Clique4	0.210	0.190	0.230	0.490

There are three leading enterprises in Deyang equipment manufacturing industry cluster, and these three distribution companies in the fourth faction, illustrates the cluster network is a typical shaft of industrial cluster. From the perspective of the enterprise node degree distribution of four factions, each clique has its own core enterprise. By analyzing the composition of the core enterprise in the network, the connection density is high, illustrating there is a close relationship existing in the three core companies. Knowledge connection and information channel of the whole enterprise network are unblocked.

3.4 Deyang high-end equipment manufacturing industry cluster and its influence on innovation capability

From analysis of the structure characteristics of Deyang equipment manufacturing industry cluster

network, we can see the channel of knowledge network, information dissemination is not smooth. It will seriously affect the growth innovation capability and can be mainly manifested in the following aspects:

(1) Connetion density of overall cluster network is low, making the transmission of information and knowledge within a cluster ineffective. Although the connection density is higher between enterprises the transmission of information and knowledge between enterprises can be effective, the connection density is lower for mediation, industry association, as well as to the universities and research institutes. Thus information and knowledge acquisition and utilization degree are low. And this will serious affect the access and control of innovation resource in the cluster. As a result the cluster's overall efficiency becomes low and the risk of innovation is on the high side.

(2) Cluster coefficient of enterprise network is high, and average shortest path length is superior, which is good for the connectivity between cluster enterprises. Such features not only are more conducive to communication and learning between cluster enterprises, but also are beneficial to transfer innovation resources in enterprise cluster. This is relatively good to improve the cluster's overall innovation capability.

(3) The characteristic of enterprises between factions is obvious, and each faction has its own core enterprises. The network connection density of the core enterprises is high as well as the information and knowledge transmitting channel between each faction is unobstructed. So that each clique can receive heterogeneous information from other factions, especially the tacit knowledge and information between factions, which is favorable to improve cluster innovation capability.

(4) Network centrality of the whole cluster is high indicating that there are a number of large-scale leading enterprises in the cluster. They lead the direction of development of the whole cluster. It is the main external power for the acquisition of innovation resources. From the aspect of the situation of research, there is a high degree of close connection between leading enterprises and universities and research institutes. In addition they also cooperate with foreign big companies outside the cluster and set up long-term and stable relationship. By external links, they get a lot of innovation resources, and also has a high ability of product design, operation and management themselves. They are the main object for local other enterprises to learn and imitate. Such structure characteristics play an important guiding role of the whole cluster innovative ability.

4 Conclusions and Discussion

Through the empirical analysis of the structure of Deyang equipment manufacturing industry cluster, following conclusions can be drawn. In Deyang equipment manufacturing industry cluster innovation network, the connection density of the whole cluster innovation network is low, making the transmission of information and knowledge within the cluster not efficient. Cluster coefficient of enterprise network is high, and average shortest path length is superior, which is good for the connectivity between cluster enterprises. They are conducive to both the communication and learning between cluster enterprises and the transmission of innovation resources in enterprise cluster. The characteristic of enterprises between factions is obvious, and each faction has its own core enterprises. The network connection density of the core enterprises is high as well as the information and knowledge transmitting channel between each faction is unobstructed. Network centrality of the whole cluster is high indicating that there are a number of large-scale leading enterprises in the cluster. They lead the direction of development of the whole cluster. It is the main external

power for the acquisition of innovation resources.

According to aforementioned conclusions, to perfect the network structure characteristics, this paper puts forward the following countermeasures of improving the capacity of the equipment manufacturing industry cluster innovation.

(1) Develop the guiding role of government, strengthen the industry association/chamber of commerce for promoting, enhance the communication and learning between the cluster internal actors.

Private communication will not only promote mutual trust and generate the cultural level of geographical areas, but also spread the knowledge, information and innovation. The cooperation and exchanges between enterprises and industry associations need to be strengthened where intermediary needs to continue to play a key role. In this process, the government can guide from the aspects such as policies, laws and regulations, for the cluster industry enterprises to provide information and resources to promote exchanges and cooperation between enterprises making it possible to a more fully and effectively use of innovation resources.

(2) Create culture of innovation and cooperation, promote cooperation between enterprise and university

From the point of the present situation of Deyang equipment manufacturing industry cluster, the cluster has a batch of higher vocational college and technical training schools and structure, however there is no national key universities in the cluster. Basically enterprises cooperate with other colleges and universities in Chengdu outside of Deyang. In the long run, the cooperation between enterprises and universities within the cluster should be emphasized. University is always the important source of knowledge creation and dissemination. Keeping a long-term and stable relationship with the university is advantageous to the enterprise management, scientific research and technology innovation and development.

(3) Improve the regional public facilities and attract more well-known enterprises to join

It is the most important factor in supporting cluster development for government to create a good external environment for the formation and development of the cluster. The government can strengthen the funds, personnel training and other public facilities construction, such as land regulations. On the one hand, it can promote the development of local enterprises. On the other hand it can attract more well-known enterprises to join, bring new blood to the innovation and development of the local cluster.

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