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Study on Technological Transfer and Innovation Network: Dynamic Capabilities of Industry Clusters

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Abstract: Enterprises of China's industry clusters are facing pressures to continuously supply new innovative products with increasing speed to market. Various members among the industry clusters contact with each other through technological Transfer & Innovation "spillover", which forms a technology transfer network. Numerous studies of the geographical distribution of China's cluster show that the technological Transfer and Innovation of clusters are with the nature of "Small World network". This research highlights the characteristics of clusters transfer frequency and agglomeration degree among various nodes of technology transfer network with characteristic path length and clustering coefficient. Meanwhile, this study also studies the roles and functions of different members in the technology transfer network.

Keywords: Cluster network, clustering degree, technological transfer and innovation

INTRODUCTION

With increasing globalization, environmental complexity, economic uncertainty, intense competition and pressure to perform that ensues, means that the need to bring innovations to market successfully is greater than ever. To survive firms must continue to innovate and success-fully commercialize these innovations, whether by creating significant improvements to existing products in order to maintain or grow market share, or by creating entirely new products that potentially drive new markets (Jin-You, 2009; Hu *et al*., 2005). That is to say, Innovation is the successful exploitation of new ideas to obtain competitive advantage. It is integral to developing new products for the market and new processes and ways of working.

In general, the formation of new firms has become an attractive alternative by which universities transfer technologies to the commercial realm. Based on the successful examples of the Massachusetts Institute of Technology and Stanford University, credited with playing an active role in the genesis of industrial clusters in Route 128 and Silicon Valley respectively, university spin-offs are seen as a means for local economies to capture the benefits of proximity to local research universities (Foray, 1994). Spin-off firms are local phenomena-the stay close to the source of their competitive advantage. For university-based spin-offs the university serves as the source of advantage providing skilled labor, specialized facilities and expertise. As universities and state governments have provided incentives for faculty to start companies or engage in joint research projects with companies the attraction of proximity to universities has grown. On average, 60% of university licenses are granted to small firms.

Technology transfer is the application of information into use where transfer is essentially the communication of information or technology. Technology transfer is therefore a distinct and important subset of knowledge transfer (Gopalakrishnan and Santoro, 2004). In the management literature, technology transfer is often considered within or across firms, such as the dissemination of information through transfers of employees from one division or country to another. For example, Allen (1984) focused specifically on the flow of technology transfer within a large R&D organization, or an R&D subunit of a larger organization. Agmon and Von Glinow (1991) examined the role of the multinational corporation in facilitating commercial knowledge transfers across countries. Another significant area of technology transfer activity focuses on the process of moving ideas from R&D laboratories into the marketplace (Doloreux, 2004; Dorf and Worthington, 1989).

Innovation is becoming more complex and knowledge relevant to realizing economic value often resides in different organizations. Organizations increasingly work together to realize economic value. Organizations transfer knowledge, either formally through such vehicles as contractual strategic alliances or informally through knowledge spillovers realized through personal friendships or observation.

Technology transfer and innovation also known as the commercialization of research findings, refers to technology transferring from one place to another in a certain form (Jiang-Xue, 2009). It includes the technology transfer among countries, as well as the technology transfer from technology generation sectors (research institutions) to user departments (corporate and business operating division); also, it can be the technology transfer among user departments. In recent years, research on technology transfer has become one of the academic research priorities and hotspots in China, the papers of which can be divided into three categories: the first ones are researches on technology transfer concerning China's research universities and research institutes, Jin-You (2009) considers that technology transfer originate from cooperation by production, study and research and technology R&D and supplying parties represented by colleges and universities play a crucial role in the process of technology transfer (Zahra and Nielsen, 2002). The second ones concentrate on the influencing factors and mechanisms in the process of technology transfer, through structural division and comprehensive analysis of the elements affecting the conversion effects of implicit knowledge in technology transfer. The third ones consist of researches on international technology transfer (i.e., technology transfer in China from multinational corporations) (Kleinberg, 2004). However, there are few papers of research on technology transfer network form a median level in China; therefore, researches and analyses of technology transfer network within industry cluster have a positive and practical significance.

This study highlights the characteristics of clusters transfer frequency and agglomeration degree among various nodes of technology transfer network with characteristic path length and clustering coefficient. Meanwhile, this study also studies the roles and functions of different members in the technology transfer network.

TECHNOLOGICAL TRANSFER AND INNOVATION SMALL-WORLD NETWORK MODEL OF CLUSTERS

According to the view of Michael E. Porter, an industry cluster is a sustainable and competitive aggregate of a large number of small and medium enterprises and organizations of a particular industry in a certain geographical area (Jiang-Xue, 2009). The cluster is characterized by collaborative network, i.e., high level of cooperation and competition, which provides important opportunities and stimulates economic development. According to the view of Porter, another feature of the regional cluster is the diversity included in the composition of members and an industry cluster needs supports from suppliers, consumers, peripheral industries, government and universities, etc.

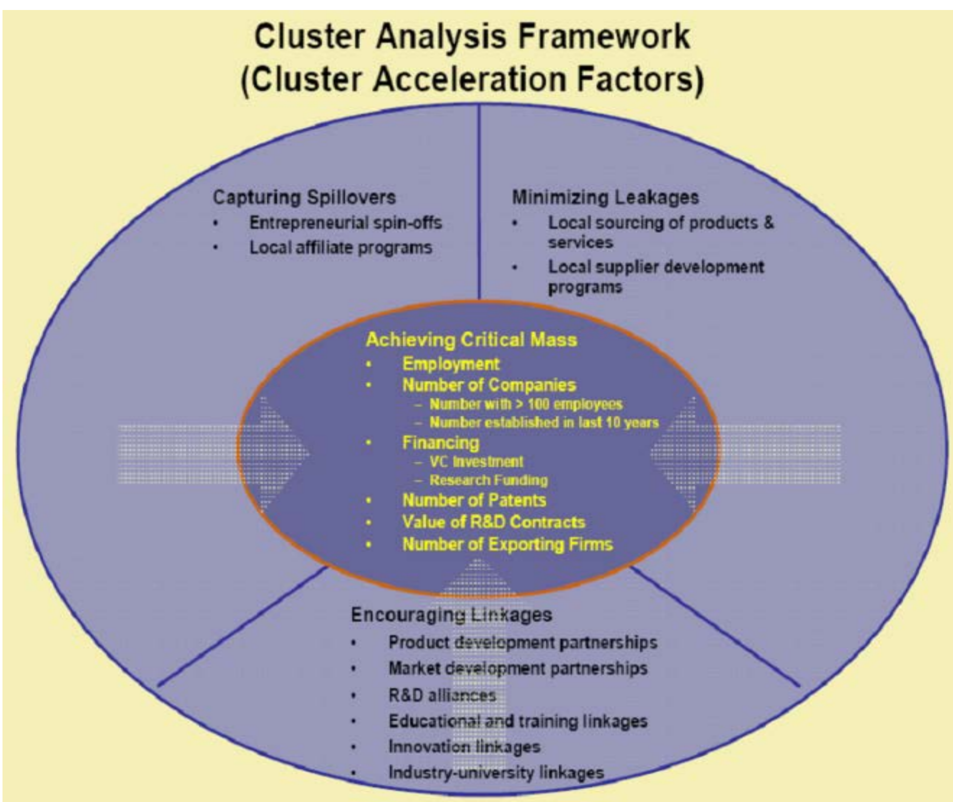

Fig. 1: Key drivers involved in building and accelerating cluster capacity for knowledge transfer and competitive advantage (Grayteck *et al*., 2004)

Technological transfer and innovation network of clusters: Technology transfer network of industry cluster is a social network with the nature of Small World. On the characteristics of cluster innovation network, there were two main opposite ideas, namely, the Closed Network Model of J. Coleman and the Structural Hole Network Model of R. Burt. In 1990, Coleman described a completely closed social network. The members within the network are interconnected; the members within a closed social network trust each other, having the uncertainty among their interaction eliminated and abilities to cooperate in the pursuit of common goals enhanced (Kleinberg, 2004). According to the Burt's Structural Hole Theory, the interests and opportunities of a social network come from the opportunities of connectors resulting from the breakage in connections within the network, namely, there is a lack of closed networks (Foray, 1994). Because of the existence of breakage in connections and small groups independent of each other, the Structural Hole Theory emphasizes that the interests of a social network originate from the access of information and the roles of connecting intermediaries. Connection intermediaries or brokers can get information better to take a relatively favorable position in negotiations, which makes them be aware of more opportunities and can choose more favorable positions. On the contrary, members with strong-tie always have little good position in the negotiations. However, an obvious contradiction lies in the strong-tie of Closed Network Theory and the weak-tie of Structural Hole Theory; but the Small-world Network completely solved this problem with two kinds of quantitative measures, namely, average path length and agglomeration degree (Fig. 1).

Small-world network model: Small-world Phenomenon originated from the research on tracking the shortest path of the U.S. social network. According to the theory, there are short paths in the social network, namely, one can soon send information to any remote target provided he/she knows about the targeted person (Foray, 1994). Social network analysis is to explain the behaviors of the elements (nodes) and the overall system based on the specific characteristics of interconnections of the network elements. Based network model of human social networks, Watts and Strogatz (1998) proposed the well-known W-S Small-world Network Model (hereinafter referred to W-S Model) in l998 based on the research on regular lattice and random graph (Gopalakrishnan and Santoro, 2004). The theory is a new progress made in scientific research of complexity and through a large number of interesting experiments carried out by scientists, the mysteries of "the world is small" are revealed. By adjusting one parameter, it can transit from regular lattice to random graph. The construction algorithm of this model is: starting from a circular regular lattice with N nodes, K sides are formed by connecting each node with its nearest neighboring K nodes (N>>k>>ln (N) >>1) and each side has the probability P to change its targeted connection points to re-connect the very side without repetition, then there will be PNk/2 long-range sides connecting one node and the distant nodes. By changing p value, the transition from regular lattice (p = 0) to random graph (p = 1) can be achieved. Figure 2 shows the process of constructing a Small-world Network.

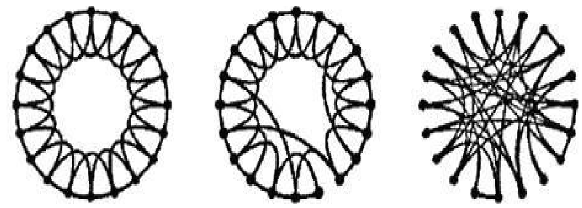

Fig. 2: The process of constructing a small world network

According to Watts and Strogatz (1998), there are a large number of networks in the world neither completely regular nor completely random. In essence, W-S Model is a one-dimensional regular lattice with certain randomness (through the method of "rewiring"). Clustering coefficient can be used in the network structure to describe local features of the network and to measure whether there are any relatively stable subsystems in the network. And characteristic path length, namely the shortest distance between any two points, can be used to represent the global features. Small-world Model has been successfully applied to the statistics of characteristic path length and clustering coefficient of nodes in movie star network, electricity transmission network and C. elegans neural network and it was found that they are all consistent with Small-world Network Model (Kleinberg, 2004). These three actual networks represent the three different types of networks: social network, artificial network and biological network. Therefore, it can be seen from that that the Small-world Phenomenon is pervasive.

TECHNOLOGICAL TRANSFER AND INNOVATION NETWORK OF CLUSTERS BY ADOPTING SMALL WORLD NETWORK MODEL

Technology transfer network refers to the resultant network of activities of enterprises in technological innovation and technology transfer, i.e., the basic institutional arrangements, including the formal and informal cooperation, formed by facing the systemic challenges of complex innovation and intensified market competition during the process of technology transfer by enterprises. If Small-world Network is adopted to describe the characteristics of technology transfer network, the "nodes" are the enterprises, research institutes, technology transfer intermediaries, government agencies, etc., within the technology transfer network and the "connections" are the interactions among various nodes. In this way, quantitative attributes of Small-world Network, including characteristic path length L, clustering coefficient C, rewiring probability P, etc., to describe and analyze the characteristics of technology transfer network industry of cluster. The frequency and agglomeration degree among various nodes of technology transfer network of enterprise and the clustering characteristic path length and clustering coefficient of Small-world Network can be compared in model analysis.

Absorptive capacity is a primary knowledge transfer mechanism among cluster firms and refers to the ability to assimilate and replicate new knowledge gained from external sources. The persistent development of the ability to absorb knowledge is a necessary condition for a cluster firm's successful exploitation of knowledge outside its boundaries. Without such capacity, cluster firms are hardly able to learn or transfer knowledge from outside. On the other hand, cluster firms can assimilate new knowledge more effectively if they possess a high level of absorptive capacity.

Knowledge and technological transfer within cluster firms: Firms within an industrial cluster are in the same-or related-field and linked by a variety of interdependencies and networks. These include academic networks, common funding resources, a common pool of skilled labor and industry associations. An industry cluster is a group of companies that benefit from an active set of relationships among themselves to increase individual efficiency and competitiveness.

In general, it is found that (similar to inter-firm transfer) that direct or codified knowledge is more easily transferred, whereas the transfer of tacit information that would accompany a new technology was more difficult to transfer. This stresses that even within organizations, effective communication and strong working relationships between individual actors and divisions is essential for successful knowledge transfer.

A primary mechanism for knowledge transfer between cluster firms is through collaboration. Formally, this may be defined by any joint activities undertaken by two or more firms or between cluster firms and institutions with a common objective.

A secondary knowledge transfer mechanism that may technically be considered a pseudo intra-firm is transfer through Merger or Acquisition (M&A). M&A is a very common event especially for small start-up companies whose goal is to develop their business to a point where their company and technology make excellent take-over targets for larger multinational companies. This is especially prevalent in the biotech industry.

Research indicates that knowledge transfer performance is positively affected by the explicitness of knowledge and the firm's absorptive capacity; that equity-based alliance will transfer tacit knowledge more effectively, while contract-base alliance is more effective for the transfer of explicit knowledge (codified). The ability to transfer knowledge will be impacted by the nature and strength of the relationship formed.

Knowledge transfer process in acquisitions is distinctly different from the process under other modes of governance, because of the rapidly-evolving relationship between the two parties. While many of the facilitators of knowledge transfer are likely to be the same (tacitness of knowledge etc.), their relative importance and the process itself is dynamic. In the early stages, knowledge transfer is undertaken in a

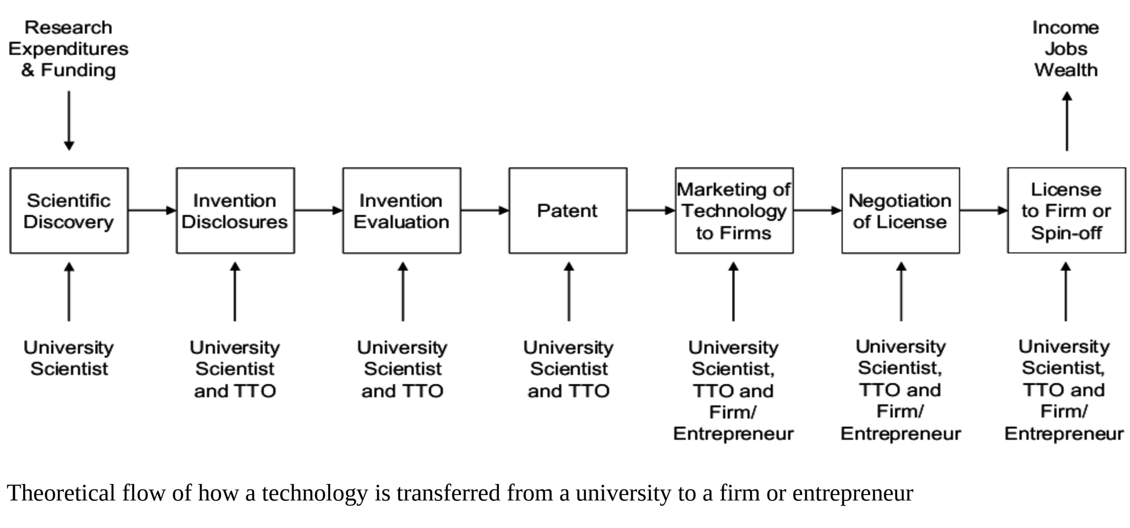

Fig. 3: Theoretical flow of how a technology is transferred from a university to a firm or entrepreneur

relatively hierarchical manner (dictated by management), but this then gives way to a more reciprocal process. And over time the type of knowledge being transferred shifts in emphasis from relatively articulate (e.g., patents) to more tacit (know how). Figure 3 shows theoretical flow of how a technology is transferred from a university to a firm or entrepreneur.

For a cluster to become competitive it must have access to a rich infrastructure present in the local economy that can provide specialize services and resources to support activities at each stage of translating an idea into a commercial product, or a viable self sufficient company. This includes access to human capital from scientific and management capability.

Technological transfer frequency among members of clusters: Connected graph of knowledge transfer network in the cluster is represented by G, N is the number of nodes in the network (namely, the number of members in the cluster), d_{ij} is the length of the shortest path between any two nodes i and j in Small-world Network Model (Fig. 2), the relation between which and characteristic path length L (G) (Watts and Strogatz, 1998): can be presented by Eq. (1):

$$L(G) = \frac{1}{N(N-1)} \sum_{i \neq j \in G} d_{ij} \tag{1}$$

It shall be noted that in technology transfer network d_{ij} represents not only the physical distance between members, but also the social distance between members of (social distance refers to the social relations, the degree of similarity, etc., between the two ones).

According to the research of Deng Dan and others, exchange frequency is inversely proportional to the shortest distance between nodes (Kleinberg, 2004). Namely, the exchange frequency ε_{ij} is inversely proportional to the shortest path length d_{ij}, as shown in formula (2):

$$\varepsilon_{ij} K \neq d_{ij} \tag{2}$$

where, k is a non-determined constant. In industry clusters, technology transfer among members vary between one and another because of the differences in their size, culture, etc., therefore, taking the actual situation of each member into consideration, different k values can be granted to different connecting sides. The greater the k is, the easier the technology transfer is; when K tends to 0, there is almost no exchange between the two members, namely, ε_{ij} = 0. Use (1) and (2), Eq. (3) is:

$$L(G) = \frac{1}{N(N-1)} \sum_{i \neq j \in G} \frac{K}{d_{ij}} \tag{3}$$

It can be seen from the formula that technology transfer frequency in industry clusters is inversely proportional to characteristic path length.

Agglomeration degree of technology transfer network among members of clusters: The so-called network agglomeration degree is used to represent connecting density among one certain node and its surrounding nodes in the cluster network. In the rapid development of a cluster, its stability is also important, which mainly depends on the stability of technology transfer among members determined by the agglomeration degree of technology transfer network. The clustering coefficient C of Small-world Network Model reflects the average agglomeration degree of the network; herein, G is still used to represent connected graph of knowledge transfer network in the cluster, m is the linking number of a node i, the total linking number of connected graph is M, then the local clustering coefficient of i G (G_i) can be defined in the following formula (Watts and Strogatz, 1998):

$$C(G_i) \frac{m}{M} = \frac{m}{k_i(k_i - 1)/2} \tag{4}$$

where,

G_i : The local graph of node I and its adjacent nodes

k_i : The number of its neighboring nodes

And there are k_i (k_i-1) /2 links at most in G_i (each neighboring node of node i is linked to another neighboring node). Therefore, the average agglomeration degree of knowledge transfer network G is:

$$C(G) = \frac{1}{N} \sum_{i \in G} G(G_i) \tag{5}$$

C (G_i) represents the local clustering coefficient of node i (namely, the ratio of the number of linking sides and the permissible number of sides of node i), the clustering coefficient C (G) represents the average value of local clustering coefficient of all the nodes in graph G (Gulati, 1998). Combining (4) and (5), the following formula is obtained:

$$C(G) = \frac{1}{N} \sum_{i \in G} \frac{m}{k_i(k_i - 1)/1} \tag{6}$$

Accordingly, it can be seen that because of no increase or decrease in the number of nodes (i.e., the denominator keeps the same), when the number of linking sides increase (i.e., the numerator m increases), the network clustering coefficient C (G) will increase, namely, the average agglomeration degree of the network will be strengthened.

DISCUSSION AND CONCLUSION

The discussion on the structure and properties of technology transfer network of industry clusters aims to promote the technical innovation and technical progress among various members in industry clusters. Network cluster degree C_i reflects the connection density around a certain node i. The more exchanges with surrounding nodes each node i have, the higher the network clustering degree is and the higher the network robustness is. However, the excessive agglomeration degree means that there are more small groups with intense exchanges, which form a strong-tie network. The excessively high agglomeration degree may cause the existing open network pattern become closed, forming obstacles to the technical exchange with outside and technology transfer activities, which is counterproductive to the open innovation network of industry cluster, leading to the weakening of cluster abilities to response to market changes and technological innovation.

Being technology transfer & innovative is one of the key attributes to a firm's success in regional industry cluster. The Small-world Network within regional cluster's firms make technology transfer & innovative be the characteristics of network. Some conclusions and policy proposals are as follows: firstly, there are significant correlations between technology transfer frequency and "distance" among members of cluster network, thus, industrial policy makers shall focus considerations on lowering the "distance" when developing a industry planning, which will help speed up technology transfer activities, achieve higher transfer frequency, withstand risks and reduce resistances in technology transfer. Secondly, the agglomeration degree of cluster is determined by the connections between principals of technology transfer within regional cluster. In order to promote positive interaction between members of cluster networks and to maintain healthy and stable development of technology transfer networks, the technology transfer relations should be timely adjusted; by adjusting clustering coefficient, the operational efficiency of technology transfer networks can be improved and a good acquisition and transmission mechanism for technical information resources can be formed. Therefore, the Small-world Network Model has provided a new way of thinking for researches on technology transfer networks within industrial clusters.

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