How do innovation intermediaries enable knowledge spillovers within industrial clusters? A knowledge-processing perspective

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Abstract: To date, most existing studies concentrate on the impacts of universities and public research organizations on the development of knowledge-intensive industrial clusters. The roles of private technology service agents in regional innovation system are seldom discussed. From a knowledge-processing perspective, this paper proposes a conceptual framework to analyze the roles of private technology service agent in the innovation activities inside an industrial cluster in terms of technology gatekeeper, technology spanner, technical problem solver, and innovation resource integrator. Under this framework, we use an in-depth case study of Zhejiang Institutes of Modern Textile Industry (ZIT) in China to demonstrate how a private technology service agent plays a role of public goods provider in industrial cluster. This study contributes to a better understanding in regional policy-making by helping us rethink the roles and the importance of private technology service agents in regional innovation system.

Key Words: technology service, industrial cluster, regional innovation system

1. Introduction

After the market reformation in 1979, industrial clusters developed very rapidly in both number and scale in China. Industrial clusters have been one of the most important contributors to the higher economic growth rate in the eastern coastal regions of China than that of their inland counterparts (Zhang et al, 2004; Kang, 2007; Zhang and Li, 2010). As described in a report in Los Angeles Times, 'China's advantages in the global marketplace are moving well beyond cheap equipment, material and labor. The country also exploits something called clustering…. China has created giant industrial districts in distinctive entrepreneurial enclaves such as Datang. Each was built to specialize in making just one thing….'. [1]

Innovation intermediaries are "an organization or body that acts as an agent or broker on any aspect of the innovation process between two or more parties."(Howells, 2006). An increasing number of researches have highlighted the importance of a cluster's relations to innovation intermediaries for building and improving their innovative capacity and

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[1] Don Lee, The New Foreign Aid, Los Angeles Times, April 10 2005.

sustainable competitiveness (Owen-Smith et al. 2002; Power and Lundmark 2004; Porter 1998). As such, innovation intermediaries play a critical role in the development of industrial clusters as a main element in regional innovation system (Cooke et al, 1997), a mechanism to share in costs and risks of technological innovation among firms (Katrak 1997), and a kind of technology infrastructure to enhancing the cluster-level innovative capability of knowledge creativity (Lee 2003).

Although rich in conceptual and empirical approaches to the contribution of innovation intermediaries to cluster firms, the literature does not offer us an integrative framework to comprehensively demonstrate the roles played by innovation intermediaries, as well as the interrelationships among those roles in knowledge system within industrial clusters. Moreover, the existing studies generally are not located in the context of industrializing economies. Nonetheless, latecomer firms are different from innovative firms in that they initially survive through external technology acquisition without even basic technological capability (Figueiredo 2003), and put more focus on imitation rather than on innovation (Xu et al, 1998). As such, As such, China's emerging economy provides a rich context in which to investigate the roles of innovation intermediaries in the knowledge system of industrial clusters.

To fill these research gaps, this paper seeks to provide an integrative conceptual framework to examine the roles of innovation intermediaries within the context of emerging economies from the knowledge-processing perspective. More specifically, we attempt to investigate the following questions: What are the roles played by innovation intermediaries within the knowledge system of industrial cluster? How do innovation intermediaries play these roles? What are the influencing factors for the effectiveness of acting these roles? With an in-depth case study conducted on Zhejiang Institute of Modern Textile Industry (ZIT) in Shaoxing textile industrial cluster of China (one of the largest textile industrial cluster in China), this paper reveals that the roles played by ***innovation intermediaries*** in regional innovation system can be categorized into four types, i.e., technology gatekeeper, technology spanner, technical problem solver and innovation resource integrator.

This paper is structured as follows. Section 2 outlines the conceptual framework. The research method and a case-based empirical analysis are presented in Section 3 and Section 4, respectively. Section 5 gives the discussion on empirical findings and the policy implications.

2. Conceptual framework: a knowledge-processing perspective of collective innovation within industrial clusters

Knowledge can be viewed from different perspectives such as an object, a process, or a kind of resources. When knowledge is regarded as a process, the focus of knowledge management will be on knowledge flow and the process of creation, sharing, and distribution of knowledge (Maryam and Dorothy 2001). In parallel to the process view of knowledge management, this study strives to understand the technological innovation process inside industrial clusters with the knowledge-processing perspective.

A great deal of literature has addressed the process of knowledge management either inside an organization or cross organizational boundaries, some of which can be referred to innovation process inside industrial clusters. For instance, Maryam and Dorothy (2001) posited four sets of socially enacted knowledge process in an organization as creation, storage/retrieval, transfer, and application. Likewise, Gilbert and Hayes (1996) developed a conceptual model to understand the process of knowledge transfer for successful technological innovation, which includes five stages as acquisition, communication, application, acceptance, and assimilation. Moreover, Carlile (2004) identified three progressively complex processes- transfer, translation, and transformation- for managing knowledge across boundaries under innovation context.

Drawing upon the above-mentioned research, it can be found that slight discrepancies in the delineation of the knowledge management processes exist among the literature, mainly concerned with the number and labeling of processes rather than the underlying concepts (Maryam and Dorothy 2001). Depicting the technological innovation process inside industrial clusters, we adopt the knowledge-processing perspective to construct an integrated conceptual framework (see Figure 1). This framework demonstrates the technological innovation process inside industrial clusters and further outlines the corresponding roles of technology service agents.

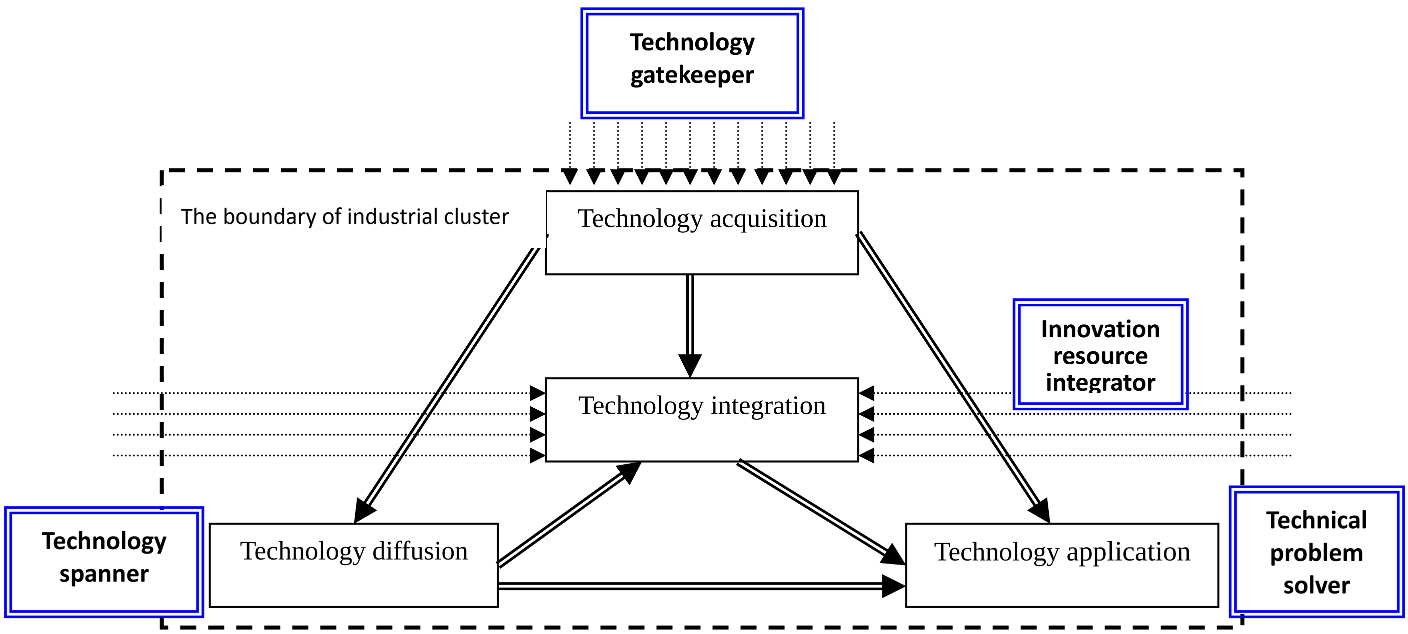

Figure 1 The technological innovation process inside industrial clusters: a knowledge-processing perspective

Based on the previous studies, this paper develops the framework to understand the technological innovation process inside industrial clusters in terms of four knowledge-processing stages. The first is knowledge acquisition, in that knowledge must be acquired (Gilbert and Hayes, 1996) from external sources outside the boundary of industrial cluster before it is able to be transferred. The second is knowledge diffusion, by which knowledge spread broadly among the cluster firms through diverse channels such as labor mobility and interpersonal communication. The third is knowledge application, which adds value to the business processes of intra-cluster firms such as R&D, operations, and customer service (Verkasalo and Lappalainen, 1998). The fourth is knowledge integration, related to identifing and making full use of contributions from multiple expertise areas (Carlile and Rebentisch, 2003).

The model depicted above seems similar to prior studies on knowledge transfer process. However, it is primarily different from the exiting literature in that the process of technological innovation inside industrial clusters is displayed in neither a sequential fashion nor a cycle, but in an interacted and intertwined way. To put it further, integrated technology can be from technology acquisition and diffusion activities. Additionally, technology application can be based on technology acquisition, diffusion, and integration activities. These interconnected set of activities arise from frequent interactions among multiple actors under active industrial atmosphere.

3. Research design

3.1 The empirical setting

China has been the largest textiles exporting country in the world since 1995; the global market share of Chinese textile and clothing products increased from 4.6% in 1980 to 14% (US$52.21 billion) in 2000 (Yeung and Mok 2004). As for the Shaoxing textile industrial cluster which is located in Shaoxing County of Zhejiang Province in China, the textile industry accounts for a majority part in local economic development. In 2008, Shaoxing's export value of textile and clothing products reached US$5.929 billion, which covers 92.3% of local export value (The Statistics Bureau of Shaoxing County, 2009).

Zhejiang Institute of Modern Textile Industry (ZIT), a private technology service agent, was established on Oct, 2006 as the innovation service platform of textile technology and equipment in Zhejiang Province. ZIT has played an increasingly important role in local textile industry. Specifically, the number of technical service provided by ZIT climbed up significantly from 6,000 in 2006 to 25,000 in 2008; in addition, ZIT provided technical training for 1,380 technicians and was granted 206 patents in 2008 (The Science &

Technology Bureau of Shaoxing County, 2009).

3.2 Research methodology

This study seeks to investigate the roles of private technology service agents in industrial clusters from the knowledge-processing perspective. An in-depth case-study methodology was chosen. Zhejiang Institute of Modern Textile Industry (ZIT) in Shaoxing textile industrial cluster of China was selected for the main fieldwork. Specifically, this paper draws on in-depth empirical evidence from three major sources in ZIT: interviews, direct-site observations, and files and archives (see Table 3).

The interviews were conducted with the president, vice president and heads of major departments in ZIT. In total, 17 interviews were undertaken following a predesigned interview protocol, which entailed 15 managers and employees. The interviews typically lasted from 90 minutes to two hours; some informants were interviewed more than once. It was assumed that the interview partners selected would be able to provide suitable information about the roles of ZIT in the industrial cluster. The number of 17 interviews is enough to provide qualitative insights into the roles of ZIT. Interviews were tape-recorded unless informants objected (Yan and Gray 1994). In particular, two rules were followed. First, the "24-hour rule" asked that detailed interview notes and impressions be completed within one day of the interview. Second, all data, regardless of their apparent importance at the time of the interview, were included (Eisenhardt 1989). After that, the empirical evidence was analyzed in terms of a systematic building of analytical tables, which was guided by the integrative conceptual framework presented in section 2.

Table 3 Sources of empirical evidence in ZIT

Sources	Details
(1) 17 open-ended interviews: 15 interviewees can be categorized into three groups	*Group 1*: The president, vice-president, and Secretary of the Communist Party of China(CPC) of ZIT
	Group 2: Managers and directors of administration department, technology development department, industry resource department, and enterprise service department of ZIT
	Group 3: Technicians and non-technical employees of ZIT
(2) Direct-site observations:	The observations of individuals at work
(3) ZIT's files and archives:	Approximately 57 pages of archival data were collected, including annual reports, published case descriptions, newspaper and magazine reports, and news from its internal web.

4. Private technology service agent as public service provider: a case analysis of ZIT

4.1 Technology gatekeeper

Technology gatekeeper can be assigned to either person level or organization level. This paper primarily focuses on the latter. According to Giuliani and Bell (2005), firms that are centrally embedded in knowledge network in terms of knowledge transfer to other cluster firms and that are also strongly linked with external sources of knowledge can be viewed as technological gatekeepers in industrial clusters.

The existing literature related to technology gatekeeper largely concentrates on two aspects. First, the effects of technology gatekeepers on their colleague firms/persons are emphasized. Specifically speaking, technology gatekeeper plays an active role in scanning, selecting, translating external knowledge understandable to their colleagues (Tushman and Katz, 1980; Cohen and Levinthal, 1990; Carbonara, 2004). Second, some research is concerned about whether leader firms perform as technology gatekeeper in regional innovation system (Bell and Albu, 1999; Morrison, 2004; Albino etal, 1999; Boschma and Wal, 2007) and the literature have not yet reached an agreement on this issue.

Different from previous focus on leader firms, this paper asserts that private technology service agents can act as technology gatekeeper in industrial clusters as well. They are important nodes in the linkages between local knowledge system and external source (Mazzoleni and Nelson 2007). In spite of the significant importance of technology service agent’s interactions with external knowledge sources, it is essential to understand how external knowledge is acquired by intra-cluster firms through technology service agents and how technology service agents provide their own expertise to cluster firms with the aim of explicitly investigating technology service agents’ role as gatekeeper inside districts.

(a) **Technology gatekeeper**: searching broadly outside the district, selecting useful knowledge, and introducing or absorbing it for firms to make use of. As technology gatekeeper, technology service agents reduce the cost for cluster firms to acquire knowledge, facilitate them to respond to external technology change and grasp market opportunity more quickly, and hence improve their flexibility and responsiveness to external changes during technological innovation process.

Private technology service agents as gatekeeper are active in three aspects. First, they publicly introduce external knowledge into districts. Second, they absorb and incorporate external knowledge into their own knowledge base, which is further provided to cluster firms when needed. Third, they provide their own knowledge and expertise to cluster firms without integrating external knowledge.

(a) Introducing external knowledge into industrial clusters

Short-term training and seminars/workshops are two popular ways for technology service agents to introduce external knowledge broadly into clusters. As formal learning mechanisms, such practices ensure greater distribution of knowledge (Maryam and Dorothy 2001). However, concerning their individual effects, training sessions mainly facilitate skill development of recipients while seminars/workshops primarily advance information diffusion from outside to inside districts (Table 4).

As for the introduced knowledge, it is codified for fast and reliable transfer (Albino, Garavelli, and Schiuma 1998) and mostly from foreign universities, research institutes, companies, and experts close to international technology frontier, the types of which are related to product, process, and market . For instance, ZIT invited design experts from AKADEIE fashion design school in Germany and Italtex Co., Ltd. in Italy to provide training and give lectures on trends of international textile fabric and pattern designs, through which cluster firms can acquire advanced product design and development knowledge easily and effectively.

With respect to knowledge acquisition process, cluster firms primarily learn through extra-cluster linkages in a formal way. Recipients involved in such knowledge acquisition process are composed of material suppliers, manufacturers, equipment suppliers, and trade dealers, etc.

(b) Providing integrated knowledge to cluster firms

In addition to knowledge introduction, cluster firms can also benefit from external knowledge through the integration of private technology service agents into their own knowledge base. That is, when technology service agents interact with knowledge sources outside the districts, they are able to absorb and integrate appropriate knowledge into own knowledge repositories. If needed, the integrated knowledge will be provided to intra-cluster firms when they ask for help from technology service agents. For example, according to the vice president of ZIT:

> A local chemical fiber factory asked us to visit its plant for improving field management. After visiting, we told the factory that its problem arose from temperature control. Compared to common chemical fiber products, the functional ones supplied by this factory need to be manufactured under premise temperature. However, they did not do this very well, whereas a joint-venture company in Shanghai does very well in field management, which pays more attention to the specific details. (Authors' interview, 8th July 2009)

Compared to publicly introduced knowledge, the transferred integrated knowledge is of more tacitness and firm specificity since firms mainly turn to technology service agents for help with highly context specific problems. In this situation, knowledge mostly flows from service agents to cluster firms through informal mechanisms such as unscheduled field visits, personal communication which facilitate socialization but preclude wide dissemination (Holtham and Courtney, 1998). However, under the circumstance of publicly introducing external knowledge, firms acquire codified external knowledge through formal mechanisms. Thus, we can conclude that knowledge transfer mechanism depends on the properties of knowledge, which is coincident with previous literature (Inkpen and Dinur, 1998; Argote et al, 2003).

(c) Providing own knowledge to cluster firms without integration

The flow of knowledge from private technology service agents to cluster firms without integration can not be ignored whereas following the definition of gatekeeper by Giuliani and Bell (2005). In fact, the existing knowledge base of technology service agents underpinning knowledge flow between them and firms can be viewed as the basis for them to participate actively in local innovation process. In other words, with reputation and capability based on rich knowledge base, technology service agents are capable of widely exposing to external knowledge linkages (Allen 1977), scanning and selecting appropriate knowledge to be introduced, identifying best practice inside clusters, and solving technical problems for cluster firms. As for ZIT, it has carried out one national S&T Program and 12 provincial S&T Programs since established and was granted 206 patents in 2008 (Annual Reports of ZIT, 2008, 2009).

As for details involved in knowledge acquisition activities of cluster firms, knowledge transfer without integration from private technology service agents to cluster firms is quite similar to that with integration of external knowledge (see table 4). Both are dealing with tacit knowledge through informal transfer mechanisms, and seem particularly useful when firms want to acquire new knowledge quickly for a specific problem (Carbonara 2004). In the words of the vice president of ZIT:

> A polypropylene fiber company in Shaoxing County has been visiting ZIT since last year. This company wanted to discuss its problem in abnormal super-thin polypropylene fiber, which is similar to the Zhejiang Provincial S&T program assumed by us. However, it refused to cooperate with us. Finally, we told it that the problem lies in the key point of the related technology, the raw material, and the chemical additive. (Authors' interview, 8th July 2009)

4.2 Technology spanner

While private technology service agents as gatekeeper mainly promotes cluster firms to acquire external knowledge, technology spanner is concerned with the impact and contributions of private technology service agents on knowledge diffusion among firms inside industrial clusters.

In clusters, firms are embedded in their ties with regional institutions in addition to interfirm networks. In this way, regional institutions are able to facilitate interactions and exchange of information about innovation among cluster firms (McEvily and Zaheer 1999) since they sit at the intersection of many firms (Wolpert 2002). Similar research findings can be drawn from other empirical studies (Chen 2009; Mazzoleni and Nelson 2007).

(b) **Technology spanner**: promoting the rapid transmission of knowledge and best practice of technological innovation among intra-cluster firms. In this way, technology service agents enable cluster firms to carry out co-invention and collective technological improvements more effectively.

In the case of ZIT, the role of technology service agent in knowledge dissemination can be viewed as a kind of boundary spanning mechanism and hence it can be regarded as a technology spanner. When cluster firms encounter technical problems, they may turn to technology service agents for help. Consequently, technology service agents are able to have effective and direct communication with firms and obtain an understanding of technological knowledge distribution within local innovation system. Furthermore, based on that, those technological service agents may serve as bridging ties to transmit related technological knowledge and best practice of some firms to other local firms.

Knowledge transfer from sources to recipients is central to both roles of private technology service agent as gatekeeper and spanner. However, two primary differences can be summarized between technology spanner and gatekeeper. First, as for knowledge source, the former mainly transmits some firms' knowledge to other local firms, whereas the latter transfers not only external technology but also service agents' own knowledge to cluster firms. Second, with regard to knowledge property and learning mechanism, formal coding is absent in knowledge dissemination (Maryam and Dorothy, 2001) through informal mechanisms based on social relations between firms and employees in technology service agents. Nonetheless, the latter introduces codified knowledge in a formal way as well as providing tacit knowledge informally.

Informal mechanism of knowledge transfer based on interpersonal relationships can be particularly important for technology service agents to diffuse knowledge among cluster firms. In other words, knowledge or best practice acquired by engineers in technology service agents during the process of technical consultancy or problem-solving from one firm is much likely released to their acquaintance in other firms inside the clusters. Despite previous literature posits that sometimes confidential information shared between technology service agent and its partners can also be leaked informally (Chen 2009), this study finds that only non-confidential part of technological knowledge or best practice will be released by ZIT. As the manager of enterprise service department in ZIT points out:

> PTT/T-400 is a kind of new fabric, which has lots of technical problems in the manufacturing process. Some local firms in Shaoxing solve these problems very well. Therefore, we promote the common part of related technology to other fabric manufacturers primarily through informal communication. (Authors' interview, 9th July 2009)

4.3 Technical problem solver

In contrast with the role of technology gatekeeper and spanner which explore how private technology service agents perform in knowledge acquisition and diffusion process of cluster firms, the role of technical problem solver focuses on the effect of private technology service agents in technology application during the innovation process inside clusters, and the process in which private technology service agents provide specific technical solution for cluster firms. In particular, technical solution is different from knowledge transfer in that it concerns with working out the problem directly while the latter is mainly related to the dissemination of know-how and know-what.

Despite a large amount of literature has discussed the impact of technology service agents on knowledge dissemination in industrial clusters, research on technology service agents as problem solver is rather limited(Chen 2009; Izushi 2005). However, the source of competitive advantage resides in the application of knowledge rather than in the knowledge itself (Maryam and Dorothy 2001), which means that the role of technology service agents as problem solver engaged in knowledge application can not be neglected.

(c) **Technical problem solver**: providing technical solutions to firms for specific technological problems in the development of technology and product. Most cluster firms in China are small in size and lack of R&D resources and technological capabilities. Therefore, this role can be regarded as one mechanism of complementary capability provision for small and medium sized enterprises (SMEs) in industrial clusters. To be technical problem solvers, technology service agents should possess strong business understanding and business operation experiences as a basis of combining technology and market elements, as well as deep understandings of manufacturing process as a basis of integrating product design and process improvements, during the process of providing technical problem-solving service for their industrial clients .

To put it further, when facing problems about products, manufacturing process, and equipments during the process of incremental innovation, cluster firms may consult technology service agents for possible solution or commission it to do related research to solve the problems (Chen 2009). Especially for latecomer firms which depend primarily on imitation rather than innovation and are small in size as well, most of their problems are due to low-level R&D capability in product development and lack of development capability for related manufacturing process.

As to the process of problem-solving, some is sequential while other is interactive (see table 6), which results from two primary factors: the complexity of problems, and the existence of relevant manufacturing process in firms. On one hand, if problems are not complex, technology service agent is able to provide technical solution directly without many interactions with its clients. However, when firms confront complex problems possibly caused by multiple factors, technology service agents need to visit their clients' plants, know about their manufacturing process and equipments, and discuss with their engineers in order to find out the causes and solutions in an interactive approach. According to a technician of new material unit in ZIT:

> When there is something wrong with the fabrics which results in the rejection of products by customers, trade dealers will turn to us for fabric analysis. We will provide a process report to point out the solution as well as the improvements on equipments and production process. If the problem still can not be well solved, our experts will visit the plant on site for further investigation and finding solution. (Authors' interview, 10th July 2009)

On the other hand, if the problems stem from the relevant manufacturing process and are complex, technology service agent will be inclined to work out the problem interactively with its clients' engineers. Another technician in ZIT comments that:

> A local company carried out research collaboration on dyeable polypropylene fibers with ZIT because of the lack of in-house development capability. ZIT sent experts to visit the client's plant site, get to be familiar with the production process and equipments, and discuss the potential solution about process and equipment improvements with the engineers in this company. In sum, the engineers of this company took less part in the initial stage of developing raw material, but participated more in the following process activities. (Authors' interview, 8th July 2009)

In addition, sometimes private technology service agents are able to solve technical problems on their own, whereas under some circumstances they need to seek for external source of complementary knowledge to support their problem solving. In doing so, technology service agents tend to establish horizontal linkages with research organizations or universities outside clusters.

4.4 Innovation resource integrator

Private technology service agent as innovation resource integrator is concerned with the integration of distributed technology, expertise and resources from multiple sources within intra-cluster and extra-cluster linkages (see Figure 1). Having been illustrated in the part of technology spanner, through their interactions with a large number of firms and organizations in clusters, technology service agents can gather and disseminate information regarding the products other firms provide, the resources and capabilities they have, the problems they encounter in product innovation and how they solve the problems(Zhang and Li, 2010). Moreover, technology service agents as gatekeeper have established strong linkages with external knowledge sources as well. As a result, technology service agents are able to combine and integrate various innovation resources inside and outside clusters together with the aim of grasping business opportunities or solving technical problems. However, the role of innovation resource integrator is dissimilar to that of problem solver in that the former mainly seeks to solve key or long-term problems in common within a cluster in comparison to the latter's focus on short-term technical problem of a certain firm.

Previous literature has pointed out that technology service agents play an important role in facilitating inter-firm cooperation between firms in a localized industry (Yamawaki, 2002), which is a primary way of resource integration. Nonetheless, in-depth investigation is still missing in the literature on how technology service agents promote inter-firm cooperation and further perform as innovation resource integrator in regional innovation system.

(d) **Innovation resource integrator**: seeking opportunity to integrate technological knowledge and expertise distributed inside industrial clusters, or serving as an integrator or a bridging agent to help integrate technological, financial and manufacturing resources both inside and outside clusters with the aim of grasping the market-driven or technology-induced opportunities that individual firms might be incapable of.

With regards to the way of integration, research collaboration can be common between different organizations. However, the establishment of a collaborative centre between resource-holders can be also an effective way. For instance, ZIT established Textile Design Center through introducing Korea designer team in 2007. This centre has provided 3,000 original artifacts for customers since then and improved the competitiveness of local firms in international market in a certain degree. (ZIT annual report, 2008)

One important impact of resource integrator is that it concerns the complementarities among various innovation resources. In other words, it helps distinguish and combine distributed expertise and resources as complementary assets (Teece, Pisano, and Shuen 1997) together for specific innovation goals. According to Table 7, types of resource integrated between research organizations (or universities) and firms are different from those among research organizations (or universities). As to the former, research organizations (or universities) are responsible for core technology development while firms provide equipments as testing site and manufacturing process expertise. In the words of the vice president of ZIT:

> ZIT bridged the research cooperation on PTFE film between East China University of Science and Technology and a local firm. During the cooperation process, the University focused on experiment while the firm concentrated on industrialization of the technology. (Authors' interview, 8th July 2009)

In comparison, integration among research organizations (or universities) is dealing with technology complementarities. The vice president of ZIT points out:

> ZIT conducted research collaboration with Zhejiang Sci-Tech University on the electrical conductivity fiber. Under the instruction of the University, both sides were involved in the whole process from developing master batches to equipment design. The collaboration turned to be very successful. (Authors' interview, 6th July 2009)

5. Discussion and conclusions

5.1 The roles of *innovation intermediaries* in regional innovation system

Central to technological capability building and industrial development in regional innovation system, the impact of universities and public research organizations has been addressed a lot in previous research. However, it is still argued that the roles of universities and research organizations have not been analyzed systematically in the experience of catch-up (Mazzoleni and Nelson 2007), and the popular "spillover" perspective obscures the multiple mechanisms through which those actors (including cluster firms and service intermediaries) actually contribute to local and non-local firms' innovation activities (Breschi and Lissoni 2001).

An integrated conceptual framework from a knowledge-processing perspective is employed to shed light on the roles of private technology service agents within the technological innovation process inside industrial clusters. More specifically, in correspondence with the interactive processes of technology acquisition, diffusion, application, and integration within industrial clusters, private technology service agents contribute to cluster firms' technological development and business growth as technology gatekeeper, technology spanner, technical problem solver and innovation resource integrator, respectively.

More specifically, private technology service agent as public goods provider can impose the following impacts on regional innovation system.

First, it lows down the prerequisites of entrepreneur activities to a certain degree and hence facilitates the formation of new business in industrial cluster due to two primary reasons. On one hand, new ventures can benefit largely from knowledge spillover through direct ties (Ahuja, 2000) with private technology service agent, which adds strength to both their R&D capabilities and production/processing expertise. On the other hand, new ventures can seek for technical solution or innovation resource from private technology service agent to share in high risks and costs mostly accompanied with technological innovation at the initial stage (Katrak 1997). In doing so, they are supported by technology service agent to achieve success and sustainable development.

A second aspect, closely related to the above one, is that it enables small-sized cluster firms to focus on the improvement of relevant manufacturing process and become profitable in their niche market with the complementary R&D capabilities provided by private technology service agents, in spite of their limited in-house R&D capacities. In this way, private technology service agent backs up and accelerates indirectly the process of incremental technological innovation inside cluster firms.

The last impact arises from the differences between private technology service agents and public research organizations. In the first place, with rich understandings of business operation and technology commercialization, private technology service agent is able to provide cluster firms with suitable technology and products for commercial use through combining market pull and technology push appropriately, rather than having unrealistic considerations about the kind of technology and services firms need (Altenburg, 1999). Additionally, due to their long-term interactions and geography proximity to cluster firms, private technology service providers can effectively share the costs associated with technology development and technical problem solving through continuously serving the same clients and duplicately transferring the common technologies among cluster firms. As such, the long-term interactions with cluster firms can greatly help private technology service agents to overcome the short-termism in providing technology services, and better play as public goods provider with steady income sources.

5.3 Policy implication

In comparison to the focus on governments' supporting universities and public research organizations in the literature (Katrak 1997; Mazzoleni and Nelson 2007; Yamawaki 2002), we particularly stress the role of active government support underlying the success of private technology service agent as public goods provider, in addition to the importance of business/industrial application understanding and flexible management mechanism.

It has been acknowledged that active government support characterizes industrial development in terms of successful catch-up experience in latecomer countries (Mazzoleni and Nelson 2007). As far as private technology service agent is concerned, government support is indispensible and featured by two aspects. First of all, with financial and policy support from government, private technology service agents are able to build trust with cluster firms, which is otherwise less available in industrial cluster with vigorous competition (Porter, 1998). In the mean time, such trust based on the public image of private technology service agent is a powerful instrument of building industrial atmosphere and social capitals inside industrial clusters. That is, it facilitates the long-term cooperation (Putnam, 1993; Coleman, 1990) between cluster firms and private technology service agent, which further promotes private technology service agent to assume public responsibilities in regional innovation system. In addition, given the consistent anticipation for active government supports, private technology service agents will hold a long-term perspective to carry out technological services. In other words, they will be more willing to invest into expensive R&D and testing equipments, technical experiments and developments with high technological uncertainty, and time-consuming expertise and high talents development, considering their future contributions to cluster firms. Under such circumstances, private technology service agents enhance their in-house R&D capabilities steadily and gradually, which in turn guarantees their role as public goods providers in regional innovation system.

All in all, it can be concluded from the case of ZIT in China that private technology service agents are able to play a significant role in forming innovative clusters and fostering indigenous technological capability in clusters, and active government support is necessary for private agents to perform actively and sustainably in regional innovation system. Therefore, this paper argues that the development of private technology service agents ought to be an alternative of major policy instrument as well as that of public research infrastructure (Mazzoleni and Nelson, 2007) to promote innovative clusters in developing countries. In other words, in addition to the establishment of public technology infrastructure, policymakers in developing countries may consider to promote the emergence of private technology service agents to advance the technological development in industrial clusters. In particular, this paper does not suggest that private technology service agents are sufficient to substitute for public technology infrastructure. On the contrary, we argue that they are complementary to each other (Tether and Tajar 2008) when contributing to cluster firms' research efforts.

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