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Knowledge Base of Industrial Clusters and Regional Technological Specialization: Evidence from ICT Industrial Clusters in China

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Abstract

This study intends to understand the underlying structure and composition of an industrial cluster and explains why certain types of technology appear to blossom and fade in a region over time and sheds light on the question about driving forces behind the evolution of industrial clusters that has long been puzzling. Taking the perspective of technology system this study explores the influence of knowledge centrality of a technology on regional technology specialization (RTS) by taking into account inter-regional effects of the knowledge characteristics and the moderating role of technology markets. Based on the patent data from State Intellectual Patent Office (SIPO) and regional level data of five regions concentrated with ICT industrial clusters in China, dynamic panel regression using difference GMM is adopted to test the hypotheses. The results show that the knowledge centrality of a given technology in the focal region has negative impact on focal RTS and this relationship is not affected by the development of local technology market. Instead, the knowledge centrality of the technology in other ICT regions, on average, has negligible effect on focal RTS but this relationship highly depends on the development of technology market in the other regions. The moderating effect of the technology market is found to be negative and significant.

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ABSTRACT

This study intends to understand the underlying structure and composition of an industrial cluster and explains why certain types of technology appear to blossom and fade in a region over time and sheds light on the question about driving forces behind the evolution of industrial clusters that has long been puzzling. Taking the perspective of technology system this study explores the influence of knowledge centrality of a technology on regional technology specialization (RTS) by taking into account inter-regional effects of the knowledge characteristics and the moderating role of technology markets. Based on the patent data from State Intellectual Patent Office (SIPO) and regional level data of five regions concentrated with ICT industrial clusters in China, dynamic panel regression using difference GMM is adopted to test the hypotheses. The results show that the knowledge centrality of a given technology in the focal region has negative impact on focal RTS and this relationship is not affected by the development of local technology market. Instead, the knowledge centrality of the technology in other ICT regions, on average, has negligible effect on focal RTS but this relationship highly depends on the development of technology market in the other regions. The moderating effect of the technology market is found to be negative and significant.

Key words: regional technology specialization, knowledge centrality, and technology market

INTRODUCTION

Industrial clusters have shown significant influences on the regional performance in terms of growth of employment, wages, establishments and innovation activities due to the agglomeration externalities that are derived either from specialized or diverse economic activities in the region. The structure and composition of an industrial cluster is not given but changes over time. The dynamics underpinning regional performance however has not been fully understood. There are few studies that have examined what are the drivers behind the evolution of the cluster and how the co-location patterns of different industries such as industrial specialization or diversification change over time (Delgado, Porter and Stern, 2011).

Among studies that have paid attention to the determinants behind the dynamics of industrial cluster, some have examined the role of industrial relatedness within a region through affecting the nature and scope of knowledge spillovers in the region (Boschma and Frenken, 2009). Boschma (2004) has shown that once a region specializes in a particular knowledge base, it will act as incentives offering opportunities to local firms for further improvement in familiar knowledge and discourage knowledge creation that does not fit the regional knowledge base. Neffke and Henning (2008) have shown that sectors related to other sectors in the regional portfolio are more likely to enter the region as compared with unrelated sector that are likely to exist the region. Regions showed a high degree of technological coherence between the set of industries over time. Malerba and Montobbio (2003) have shown that international technological specialization of a country is highly path dependent and persistent and it is affected by knowledge spillovers across interdependent sectors within countries. In sum, these studies claim that there is spatial path dependence that is driven by the existing related activities in a region. The rise and fall of industries in a region are conditioned by regional industrial structure in the past and the profile of industries and technologies tends to be stable (Neffke, 2009).

Existing regional studies have treated regions in isolation by focusing mainly on the factors within a region and their impacts on regional performance and dynamics. They have neglected largely inter-regional effects, meaning the interactions between different regions with similar or different characteristics (Zhang, Li and Schoonhoven, 2009). However, as Porter (1998) and some other scholars (e.g. Henderson, 2005; Zhang, et al., 2009) have posited, an industrial cluster could affect the productivities of other clusters in many important ways. The presence of a strong cluster in the other regions can be the source of local competition, especially when resources are limited (Delgado, et. al., 2011). The knowledge flow between related industries is not restricted to a region but will also be manifest between neighboring or connected regions (Neffke, Henning and Boschma, 2009). Therefore, it is important to understand this inter-regional dynamics while carrying out regional studies. Being one of the clusters that specialize in certain industries, the development of this cluster is likely to be influenced by other clusters with similar industrial portfolio and located in different regions within a broader geographical area such as within a country.

In the current study, I argue that the inter-regional relationships between different geographical regions that specialize in ICT industry have substantial influence on the development of the industrial clusters. I investigate and explain why some technologies appear to blossom and fade in certain regions over time and try to make a contribution to the literature by taking into account the inter-regional effects. Specifically, this study explores the influence of the knowledge base of industrial clusters in both the focal and the other ICT regions on the regional technological specialization (RTS) of a given technology in the focal region. Previous studies carried out at the region, cluster or industry level have not disentangled the various driving forces behind the regional economic activities. This study makes analysis at the level of industrial region, which is an appropriate choice especially when the study is conducted within the social context of China. This is because regional economic development and local firms business activities are effectively influenced and sometimes even directed by local government policy measures. China as a transitional economy has been going through an economic reform from a centrally planned economic system to a free market since 1978. During this course, part of the transition occurred through giving local governments more autonomy by central authority. Local government thus retains considerable power and government policy and intervention still plays an important role in many aspects of regional social and economic activities. For example, local officials are motivated to encourage and protect local firms and their business. Sometimes they would maximize their own benefit even if it were not for the interest of the country as a whole (Khanna and Oberholzer-Gee, 2006).

This study views an industrial cluster as a *technological system* which is defined as a dynamic network of agents interacting in a specific economic/industrial area and involved in the generation, diffusion, and utilization of technology (Carlsson and Stankiewicz, 1991). The unit of observation for this study is technology. This is because the production and function of products are based on technologies, and most products use a variety of technologies (Schmoch, 2008). It is the fundamental constituent part of industry and forms the basis for industrial development. In addition to acknowledging the technology imperative, this study takes into consideration the roles played by institutional factor such as the development of technology market in determining regional technology specialization.

Technological knowledge flows through two different mechanisms (Maggioni and Uberti, 2007): the unintended knowledge spillovers and the intended knowledge transfers. The composition and structure of the knowledge base of a cluster affect the nature and scope of knowledge flow. I theorize that the knowledge centrality of a given technology in both the focal and the other ICT regions' knowledge base negatively influences the focal RTS but through different mechanisms. The knowledge centrality of a given technology is defined as the number of connections this technology has with other technological fields and it influences the scope and magnitude of knowledge spillovers across these different but related knowledge domains.

For a given technology, the negative relationship between its knowledge centrality and regional technology specialization in the focal region is in large part driven by the effective communication between different knowledge domains and the emergence of new technological opportunities due to the prevailing localized knowledge spillovers across various related application fields. While the relationship between other ICT regions' knowledge centrality and the focal RTS of a given technology is largely determined by varying demand for this technology in the focal region, which is realized through intended knowledge transfer across these regions.

Technology market is designed to promote technology exchange and balance the disequilibrium between technology sources and industrial demand. It plays a key role in facilitating knowledge flows both within and across regions and driving the regional labor division and specialization. With the development of the focal technology market, the negative effect of focal region's knowledge centrality of a given technology on the focal RTS is attenuated due to the increasing demand for this particular technology from both the focal and other ICT regions. In this case, for most firms active in the given technology field serving as specialized technology suppliers and engaging in the technology trade with others are likely to be more profitable than to diversify into many related technological fields and exploit all the possible applications by themselves. When the development of the technology market in the other regions is more advanced, the technology supply of other regions is getting more effective and efficient. This can intensify the negative relationship between the other ICT regions' knowledge centrality and focal RTS due to the increasing reliance of the focal region on the technology well supplied by the other regions and the subsequent reduction of its own investment on this particular type of technology.

Based on the patent data from the State Intellectual Property Organization of China (SIPO) and regional level data of five regions concentrated with ICT industrial clusters in China I adopt dynamic panel regression using difference GMM to test the proposed hypotheses. The results show that, both the focal and other ICT regions' knowledge centrality of a given technology have impact on the technology specialization of the focal region. The former relationship theorized to be driven by the prevalence of localized knowledge spillovers is not moderated by the development of the local technology market. The latter one that is hypothesized to be driven by the intended knowledge transfer is highly influenced by the development of the technology market in other ICT clusters located in geographically distant regions.

The rest of the paper is organized as follows. I briefly review the background literature. Thereafter, I develop theoretical arguments leading to the hypotheses, explain the research methodology, present the results and close the study with a discussion of the findings, limitations and avenues for the future research.

BACKGROUND

Characteristics of Regional Knowledge Base

Within an industrial cluster, various types of knowledge with distinctive nature from different technology fields are pooled together. The features of local knowledge such as the variety of the components within the knowledge base and the relatedness among these different types of knowledge in a cluster are considered to have very important implications for the innovation activities, economic performance and the convergence or divergence of a region through impacting the nature and the scope of knowledge spillovers within the region (Bae and Koo, 2008; Boschma and Frenken, 2009).

To better understand and capture the relationship and interaction between different technology domains, Ramani and Looze (2002) define knowledge base as a collection of the technological knowledge that an agent (i.e. an individual, institution, a region or a nation) possesses. Based on patent statistics, they introduced several attributes to characterize the knowledge base of a geographic location, among which

knowledge centrality is defined as the number of connections of a given technology has with other technological fields. It is measured by the number of technology classes with which the given technology has been co-classified in patent applications. Based on the applicability to practical fields, every patent is attributed to one main and several, if any, supplementary technology classes by the national/local patent office according to the IPC classes, which is an internationally agreed, non-overlapping and comprehensive patent classification system. Technology affiliation to one or more technological fields is assigned if the technology can be applied into these fields and the technological fields are therefore related with each other.

This attribute of the knowledge base is particularly useful to understand the components and the structure of the industrial cluster and its dynamics as it indicates the relatedness of the focal technological knowledge with other knowledge domains. The extent to which knowledge domains are connected with each other will influence the way knowledge flow both within and across geographically distant industrial regions. According to the definition and measure, higher knowledge centrality of a technology implies that there are potentially more application fields in which the technology could be used and there are more opportunities and possibilities for firms to enter diverse technology fields. This will have important implications for the technological and industrial evolution in a region.

Mechanisms of Knowledge Flow

To understand the characteristics of regional (focal region and other regions) knowledge base influence focal region's technology specialization we should look at first two different mechanisms through which technological knowledge flows (Maggioni and Uberti, 2007): the intended knowledge transfer such as imports of capital goods, direct investment and technology trade; and the unintended knowledge spillovers via various mechanisms such as the professional associations, social relationships, shared scientists (Zucker et. al., 1998), spin-offs and labour mobility (Neffke, Henning and Boschma, 2009).

Due to the tacit nature of knowledge, unintended knowledge spillovers tend to be more prevalent in the geographically bounded area than between geographically distant regions. Meanwhile, firms are familiar with the local conditions such as the market, social relations, rules and regulations, etc., which give firms more incentive and make it easier to acquire and apply technologies with potential of commercialization. From the viewpoint of the focal region, the level of knowledge centrality of a given technology in the region drives unintended knowledge spillovers through the channels formed according to the structure of local knowledge base. Knowledge centrality also depicts the profile of potential application fields of a technology, which will potentially give rise to the downstream markets. This will influence the demand for this technology and the level of competition and complementarity among regions concentrated with similar industrial clusters, which in turn drives the intended knowledge transfer across these regions.

THEORETICAL DEVELOPMENT AND HYPOTHESES

Conceptual Model

I present in Figure 1 the conceptual model of this study. The focus is first on the relationships between the focal and other the ICT regions' knowledge centrality of a given technology on the focal region's technology specialization. Then the focus shifts to the development of the technology market in both the focal and the other regions and see the extent to which technology market moderates the previous relationship. In the model, the **Focal RTS** stands for the regional technology specialization of a given technology in the focal region. The **Focal and Other Knowledge Centrality** stands for knowledge centrality of a given technology in the focal and the other regions respectively. The **Focal and Other Technology Market** stands for the development of technology market in terms of total value of the technology contract deals in the focal and the other ICT regions respectively.

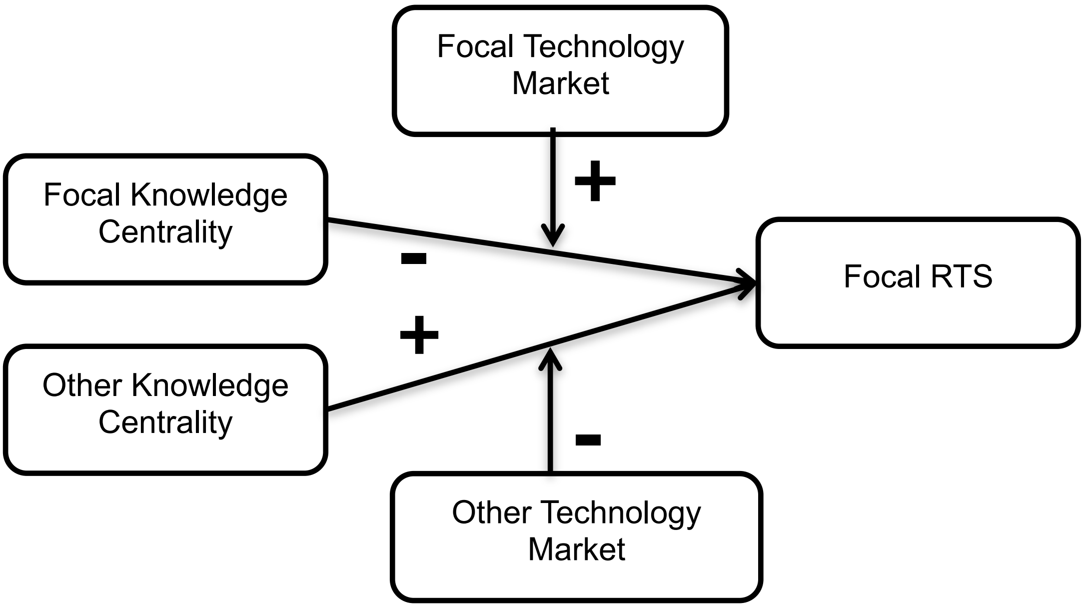

FIGURE 1 CONCEPTUAL MODEL

Knowledge Centrality and Regional Technology Specialization

Studies in the economic geography literature investigating regional growth paths have demonstrated that regions are most likely to branch into new industries that are technologically related to the existing industries in the region (Neffke, Henning and Boschma, 2011). This happens because the diversified economic activities drive division of labor, increase efficiency and most importantly give rise to the opportunities of innovation within a region (Jacobs, 1969; Neffke, et. al., 2009). This is a learning process that is largely driven by the knowledge flows among different industries or knowledge domains in question through various channels. It has been found that there exists an optimal level of cognitive distance (neither too close nor too distant) between these diversified but related industries that can facilitate the effective communications among different knowledge and boost the emergence of new opportunities in the region.

In a technology system, firms from focal region perceive higher levels of knowledge centrality of a given technology in the local knowledge base as greater number of technological opportunities on the one hand. On the other hand, higher levels knowledge centrality also means that there are higher probabilities of knowledge spillovers. This is because higher levels centrality of a given technology indicates that this technology is extensively related with other technological fields in the local knowledge base. Through this well-connected knowledge network a circulation and transfer of related technological knowledge takes place. This will make firms in the region open to other knowledge sources and increase the possibility to broaden the scope of search in responding to the potential technology opportunities. Firms integrate knowledge they receive from different domains and eventually are more likely to explore various technology areas that are related to but different from the one in question.

Moreover, firms located within a region are familiar with the local conditions such as the market, social relations, rules and regulations, etc. They tend to know and get to know each other better and easier in comparison with firms located in distant areas. The probability to learn from each other is also higher due to more frequent formal and informal contacts with each other. Firms experience more intense knowledge spillovers and larger pool of discoveries and ideas from related technological fields with higher levels of diversity than that might be true for technological fields characterized by lower levels of knowledge centrality. So I propose that:

> ***Hypothesis 1 (H1): Regional technology specialization is negatively associated with the knowledge centrality of this technology in the knowledge base of the focal region.***

Now we start looking at how the knowledge centrality drives knowledge flow across geographically distant regions that have similar industrial portfolio (ICT industry in the current case) and the impact of other region's knowledge centrality on the focal region's technology specialization. I propose that knowledge centrality of a technology in the other regions positively influences the focal RTS.

Due to the tacit nature of knowledge, unintended knowledge spillovers tend to be more prevalent in the geographically bounded area than between distant regions (Jaffe, Trajtenberg and Henderson, 1993). Firms located in different geographically distant regions can't easily rely on the convenient informal, face-to-face mechanisms of commutation (Tallman and Phene, 2007) therefore it is difficult, if not impossible, to receive knowledge spillovers from regions that are located far away from them. When knowledge centrality of a technology in other regions is high, although there will be technological opportunities emerging from wildly connected knowledge domain, focal region in this case is less likely to have access to intensive knowledge spillovers even though they are fully aware of the increasing level of applicability of the technology due to the difficulties associated with long-distant knowledge spillovers across regions.

The knowledge centrality of a technology in the other regions therefore gives rise to the competitive tension between the focal and other regions. Specifically, increases in the knowledge centrality of a given technology means there will be more application fields to which this technology could be applied and if applied successfully it will give more access to the downstream markets. This is very attractive to firms in regions with similar industry and technology portfolio because they can easily recognize and realize the value associated with the technology as the cognitive distance between them is relatively close. This will lead to the increases in demand for this technology from the focal region. Moreover, regions specialized in the same industry are naturally compete with each other for the allocation of various resources at national level. Regions would not like to be lagged behind in developing technologies with great commercial potential. This competitive reactions will drive focal region invest more in the technology field in question, which will subsequently increase focal RTS. As a consequence, the technology specialization in the focal region increases gradually. So I propose that:

Hypothesis 2 (H2): Regional technology specialization is positively associated with the knowledge centrality of the same technology in the knowledge base of the other regions.

Moderating Role of Technology Market in the Focal and Other Regions

A technology can be obtained through investing in R&D and developing this technology by oneself or purchasing the technology from others via technology market which is an institution designed to promote technology exchange in order to balance the disequilibrium between the technology sources and industrial demand (Arora and Gambardella, 2010; Johnson and Liu, 2011). In the current study I adopt the definition provided by the State Science and Technology Commission (SSTC), which defines technology market as the various forms of technological trading activities, such as the transfer of scientific achievement, technical consultancy, training, service, contracts, joint technical operations and partnership research-production corporations. This definition has also been adopted by some other studies (e.g. Johnson and Liu, 2011).

Technology market is a place where exchange activities such as buying, selling and licensing of technology and related service between different parties take place in both intra-regional and inter-regional setting. The technology transfer aspects associated with technology market increases the efficiency of technology development across regions. Firms within a region can chose to develop a technology by themselves or buy the technology from others. The development level of technology market can therefore be complementary or substitute to a region's effort devoted into the development of a certain technology depending partly on the development level of technology market in local and other regions, which consequently influences regional technology specialization.

From the perspective of the focal region, technology market in the region serves as a channel linking effectively the suppliers of the technologies in the focal region and the users of them from both the focal and other regions. Firms in the focal region that are active in these technologies can act as specialized technology suppliers thanks to the development of the technology market in this region. Considering the economies of scale in production and limit of resources in a region, for firms in the focal region, technology trade is likely to be more efficient than exploiting all potential applications of their technology by themselves. Given a certain level of knowledge centrality of a technology in the focal region, the more advanced the local technology market is, the more effective communication and interaction between technology suppliers and users are, therefore the specialization of this technology in the focal region will be higher. So I propose that:

> ***Hypothesis 3 (H3): The negative relationship between regional technological specialization and knowledge centrality of a given technology in the focal region is attenuated by the development of the technology market in the focal region.***

As we discussed before, higher knowledge centrality of a technology indicates broader areas in which this technology could be applied. When the knowledge centrality of a given technology in other ICT regions increases, firms in the focal region perceive the potential opportunities brought by this technology and the necessity to adopt it. Since in the current case focal region would suffer from the difficulties in accessing to the knowledge spillovers in other regions which located far away, firms in the focal region then should resort to other solutions. One of the choices would be to access the technology through other mechanisms facilitating intended knowledge transfers across these regions such as imports of capital goods, direct investment and technology trade, if there is any. Then whether or not and the extent to which local firms could access and utilize this technology will be influenced by the channels that link these regions and influence the intended knowledge flow between regions.

Technology markets in the other ICT regions serve as a channel connecting the demands and supplies of the technology between the focal and other regions. The higher the development level of technology market the more effective and efficient the technology trade via the market. Given a certain level of knowledge centrality of a technology in the other ICT regions, the higher the development level of the other regions' technology markets the easier and more efficient firms in the focal region could acquire this technology from other regions through technology trade across regions. This will increase the reliance of focal region on the technology supplies from other regions and subsequently decrease the investment of indigenous research and development in this technology by firms within the focal region. In the end, the specialization and competitiveness of the given technology in the focal region decreases mainly due to the increased efficiency caused by external technology suppliers from other ICT regions. So I propose that:

> ***Hypothesis 4 (H4): The positive relationship between regional technological specialization and knowledge centrality of a technology in the other regions is attenuated by the development of the technology markets in the other regions.***

METHODS

Research Setting

I investigate the research questions in the context of Information Communication Technology (ICT) industry in China during the period between 1985 and 2009. ICT industry is chosen as a representative example of high-technology industries as the knowledge spillovers and transfer play an important role in firm's innovative activities and regional technology specialization. China's ICT industry has experienced rapid growth sine 1990s. It is becoming the most dynamic sector in China's economy and attracting increasing attention from both the academic and business world (Meng and Li, 2002; Wang and Lin, 2008).

ICT industry in China is geographically uneven at the national level. According to the Employment Location Quotient and the share of patent applications in the ICT industry of 31 regions (provinces, autonomous regions, municipalities) in China, there are five regions turn out to be highly concentrated with employment and patent applications of ICT industry. They are Beijing, Shanghai, Jiangsu, Guangdong and Shaanxi. The recent observations from the ICT clusters in China have shown that the patterns of technological specialization of industrial regions actually are more sophisticated than that has been documented in the existing literature. For example, when we look at the regional technology specialization of five regions (i.e. provinces) with the concentration of ICT industry in China, we see that there exist significant increase and decrease in terms of regional technology specialization along some technological fields in a region over time. Surprisingly and interestingly, the changing pattern of specialization of a given technological field in one region is accompanied by the opposite changing pattern of specialization of the same technological field in other regions. These phenomena are have not been investigated nor explained well by the existing theories.

Data and Sample

The data used in this study are the patent applications obtained from the State Intellectual Property Office (SIPO) in China. China joined the World Intellectual Property Organization (WIPO) in 1980 and adheres to most of the international patent agreements (e.g. the Paris Convention, the PCT and the TRIPS). China implements laws for all relevant IPRs such as patents, trademarks and copyrights. According to the patent law, patents can be granted to inventions that fulfill the requirements: novelty, inventiveness and practical applicability, which are comparable to the regulations of other important foreign and international patent offices. SIPO is the governing body and directly affiliated to the State Council with main responsibilities such as organizing and coordinating IPR protection nationwide, standardizing the basic orders of patent administration, drawing up the policies of foreign-related IP work etc. All IPRs are filed directly at SIPO or it’s branches that are responsible for the acceptance, examination and publication of all IPR related documents. After a patent application has been filed it will be classified according to the International Patent Classification (IPC) by patent examiners (The guideline of patent classification is discussed in the response to the question regarding the main and secondary classifications). Applicant may request a substantive examination of the patent within three years after the filing date. If the invention (after notified amendment) is not in line with Chinese patent law, the application will be rejected. Applications that meet the legal requirements of patentability will be granted and the patent right will be effective for up to 20 years after the priority date. Any party could ask the SIPO Patent Re-Examination Board to invalidate a granted patent.

This database covers 4,084,530 patents (include 1,610,798 invention, 1,373,542 utility model and 1,100,190 design) received by SIPO from 1985 (SIPO’s first year of activity) to 2009 by firms, institutions and individuals from any country seeking legal protection for their innovations. SIPO discloses the following information regarding each patent: application number, publication number, application date, publication date, priority information, international classification, applicant(s) name, applicants address, inventor(s) name, patent agency code, patent agent and abstract of the patent. Regional-level data of Beijing, Shanghai, Jiangsu, Guangdong and Shaanxi from 1990 to 2009 is obtained from the China Statistical Yearbook on Science and Technology, the Industrial Economy Statistical Yearbook of China and the regional Statistical Yearbook.

Starting with the patent applications in the five regions concentrated with ICT industrial clusters from 1985 to 2009, and 60 technology classes (International Patent Classification, 8th edition, 2006) of ICT industry that belong to 4 sub-sectors (Telecommunications, Consumer electronics, Computers, office machinery and Other ICT), I identify all ICT patents based on the IPC codes. Every patent is attributed to one main and several, if any, supplementary technology classes by the national patent office according to IPC classes, which is an internationally agreed, non-overlapping and comprehensive patent classification system. Technology affiliations to one or more technological fields are assigned by SIPO to each patent and it will be indexed by j or k = 1, 2, … m. There exists a vector with m components. A component takes value 1 if the patent is affiliated to the corresponding technology and 0 otherwise. In this study, the knowledge base of Shanghai ICT cluster can thus be represented by the following matrix $\mathbf{M_i}$:

$\mathbf{M_i} = \begin{bmatrix} f_1^i & c_{12}^i & \cdots & c_{1m}^i \\ c_{21}^i & f_2^i & \cdots & c_{2m}^i \\ \vdots & \vdots & \ddots & \vdots \\ c_{m1}^i & c_{m2}^i & \cdots & f_m^i \end{bmatrix}$, in which the technology vector of technology k in the knowledge base of region i (ICT cluster in the current case) is: $c_{k1}^i, c_{k2}^i, \cdots, f_k^i \cdots, c_{km}^i$, k ∈ [1, m] and c_{kl}^i is the number of patents that are affiliated both to technology k and l in region i from 1985 until a certain year t.

Variables and Measures

Dependent Variable: the dependent variable in the current study is the ***Regional Technology Specialization***[1], *which* is the distribution of a region’s patents (technologies employed) over various technology fields in the industries within the region. A region’s technology specialization in a selected technology field is

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[1]There are also other measures of technology specialization. For example, an often used index is “revealed technological advantage” which can be defined in the current case as a region’s share of patents in a particular technology field divided by the region’s share of patents in all patent fields within the country. However, it cannot serve the purpose of this paper as it indicates the relative specialization of a given region in a selected technological domain, which means that there can be cases that even though the absolute value of concentration of the given technology increases, the region could still be comparatively less specialized in this technology field and vice versa.

measured by the share of patent applications from the technology field in the total patent applications of the region by the year of observation and log transformed (Van Zeebroeck, Van Pottelsberghe de la Potterie, and Han, 2006):

$RTS_i = \frac{p_i}{\sum_i^n p_i}$, Where $\mathrm{p_i}$ is the number of patents applications of a region in the $\mathrm{i^{th}}$ technology field with i =1..., n, where n is the total number of technology fields in the region. The more concentrated the patents are in a certain technology field, the higher the value of concentration is and the more the region is said to be specialized in this technology field.

Independent Variable: the independent variable in this study is the ***Knowledge Centrality*** of a technology in the knowledge base of the focal and the other ICT regions. It indicates the relatedness of a technology with other technology fields. The centrality of a technology in a focal ICT region is measured by the number of technology classes with which this technology is co-classified in the patents in this region filed until one year prior to the observation and log transformed. The knowledge centrality of a technology in the other ICT regions is obtained by taking the average value of knowledge centrality of these regions.

Moderating Variable*:* the moderating variable in this study is the ***Technology Market*** which is defined as an institution designed to promote technology exchange in order to balance the disequilibrium between the technology sources and industrial demands (Johnson and Liu, 2011). It is measured by the total value of technology contract deals[2] of a region as a technology supplier, meaning that the contract deals in a region's technology market includes deals among firms within the region and the outflow of deals from the focal region to the other regions. The measure of technology market of the other regions is obtained by taking the average value of the total contract deals in the technology markets of the other regions.

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[2] Technology contract normally includes 4 types: Technology Development, Technology Transfer, Technology Consultation and Technology Service.

Control Variables**:* to test these hypotheses, I also control for alternative explanations for regional technology specialization at the regional level. ***Science and Technology Personnel is measured by the total number of personnel that work in the fields pertaining to the development of science and technology and log transformed in the prior year of observation. ***Export*** is measured by the total value of export sales of all firms within a region in the prior year of observation. ***Foreign Direct Investment (FDI)*** is measured as capital invested in a region by sources not from China. ***GDP*** is measured by the gross domestic productivity at the regional level. ***Higher Education Institution*** is measured by the total number of colleges and universities in the region. These variables were all updated annually and log transformed in the prior year of observation. Furthermore, I control for time effect by adding ***Year*** dummies. I include the focal and the other regions' ***Technology Specialization lagged*** with one year to the model on account of the path-dependent nature of technology evolution (Arthur, 1994; David, 1988).

Econometric Models

The econometric model of this study is the following:

$$\begin{aligned} \mathrm{RTS}_{\mathrm{i,j,t}} = {} & \beta_1 \mathrm{FKC}_{\mathrm{i,j,t\text{-}1}} + \beta_2 \mathrm{OKC}_{\mathrm{i,j,t\text{-}1}} + \beta_3 \mathrm{FMKT}_{\mathrm{i,j,t\text{-}1}} + \beta_4 \mathrm{OMKT}_{\mathrm{i,j,t\text{-}1}} + \\ & \beta_5 \mathrm{FKC}_{\mathrm{i,j,t\text{-}1}} \times \mathrm{FMKT}_{\mathrm{i,j,t\text{-}1}} + \beta_6 \mathrm{OKC}_{\mathrm{i,j,t\text{-}1}} \times \mathrm{OMKT}_{\mathrm{i,j,t\text{-}1}} + \\ & \beta_7 \mathrm{RTS}_{\mathrm{i,j,t\text{-}1}} + \beta_8 \mathrm{ORTS}_{\mathrm{i,j,t\text{-}1}} + \beta_9 \mathrm{Year}_{\mathrm{t}} + \beta_{10} \mathrm{X}_{\mathrm{i,t\text{-}1}} + \varepsilon_{\mathrm{i,j,t}}, \end{aligned}$$

where subscript i=1, 2, …N refers to the region and its maximum value is 5. Subscript j =1, 2…N refers to the technology class of ICT industry and its maximum value is 60. Subscript t =1, 2…T refers to the year and its maximum value is 24. RTS/ORTS, FKC/OKC and FMKT/OMKT refer to the regional technology specialization, the knowledge centrality and the technology market of the focal and the other region respectively. $\mathrm{X}_{i,t}$ refers to a set of control variables. All variables are transformed with logarithm.

An autocorrelation problem appears due to the inclusion of the lagged term of RTS, which is dependent upon the past disturbances. Knowledge centrality is likely to be endogenous due to the potential correlation with the current and past error terms. I adopt the first differenced generalized method of moments (Difference GMM) estimation, which is firstly introduced by Arellano and Bond (1991) for dynamic panel data in order to deal with simultaneously the problem of the endogenous independent variables, the heteroskedasticity and autocorrelation within individuals. Being aware of the caveats of this method, robustness test is carried out with the number of instruments being properly controlled by limiting the number of lags used in GMM instruments on account of instrument proliferation.

RESULTS

Descriptive statistics and correlations of the variables are presented in Table 1. The correlation matrix shows that regional GDP is highly correlated with regional export, FDI and the number of higher education institutions, indicating that regions with higher level of economic development also tend to export more and attract more foreign investments. The high correlation between the regional technology specialization of the current year and the last year indicates the path dependent nature of the regional technology development.

TABLE 1 DESCRIPTIVE STATISTICS AND CORRELATIONS OF THE VARIABLES

	1	2	3	4	5	6	7	8	9	10	11	12
Mean	0.003	0.003	0.003	0.000	0.000	0.000	0.091	7.861	12.138	13.695	2.601	4.000
Std. Dev.	0.009	0.009	0.007	0.378	0.352	1.377	1.125	1.298	0.510	1.893	1.876	0.396
Min	0.000	0.000	0.000	-0.268	-0.346	-2.793	-2.162	5.198	9.649	9.246	-2.128	3.367
Max	0.160	0.160	0.070	3.268	3.408	3.250	2.115	10.513	13.176	17.518	5.526	4.990
1Focal RTS	1.000											
2Lag focal RTS	0.990	1.000										
3Lag other RTS	0.732	0.739	1.000									
4Focal knowledge centrality	-0.157	-0.158	-0.147	1.000								
5Other knowledge centrality	-0.228	-0.227	-0.278	0.227	1.000							
6Focal technology market	0.119	0.113	0.100	0.033	-0.128	1.000						
7Other technology market	0.123	0.118	0.147	0.046	-0.185	0.616	1.000					
8 Focal GDP	0.120	0.115	0.105	0.006	-0.143	0.662	0.784	1.000				
9 Focal sci.& tech. personnel	0.095	0.098	0.076	0.031	-0.105	0.667	0.417	0.548	1.000			
10Focal export	0.113	0.109	0.079	-0.039	-0.112	0.635	0.573	0.909	0.489	1.000		
11Focal FDI	0.080	0.075	0.055	-0.002	-0.079	0.601	0.477	0.881	0.480	0.911	1.000	
12Focal University	0.117	0.116	0.126	0.044	-0.166	0.622	0.805	0.785	0.692	0.583	0.527	1.000

The results of estimating the focal regional technology specialization are presented in Table 2. Model 1is the baseline model including only the control variables. Model 2 is used to test Hypothesis 1 and Hypothesis 2, which concern the relationship between the knowledge centrality of a given technology in the focal and the other ICT regions and the technology specialization of this region (focal RTS). Model 3 includes the main effects of technology market of the focal and other regions. Model 4 is the full model including the interaction terms of knowledge centrality and technology market of the focal and the other regions in order to test Hypothesis 3 and Hypothesis 4, which focus on the moderating role of the technology market on the relationship between knowledge centrality and RTS.

For each regression, Arellano and Bond test for the first and second order serial autocorrelation is calculated. As it is shown in Table 2, Arellano-Bond AR(1) is found to be negative and significant at 0.01 level, while the Arellano-Bond AR(2) is not significant meaning that there is no second order correlation. Hansen test for the over identification is calculated and the null hypothesis cannot be rejected which indicates the validity of the instruments in the difference GMM estimation. All models are significant at the 0.001 level.

The results in Model 2show that, knowledge centrality of a given technology in the focal region has significant negative main effect (-0.0004) on focal RTS at 0.01 level. The economic meaning of the result can be understood as other things being equal, for any 50% increase in the focal regional knowledge centrality of a given technology we would expect about 0.016%[3] decreases in focal regional specialization in the given technology. Hypothesis 1 predicts that focal RTS is negatively associated with focal knowledge centrality is therefore supported. On average, knowledge centrality of a given technology

[3]Because both the dependent variable and the independent variables in the analysis are log- transformed (expect dummy coded variables), I interpret the coefficient (β) of key explanatory variable as the elasticity between x (the independent variable) and Y (the dependent variable):y(x2)/y(x1) = (x2/x1)^β. So, when focal knowledge centrality increases by 50%, the expected percentage change in RTS is therefore ((1+0.5)^(-0.0004)-1)= 0.016%.

in the other regions has negligible effect (0.0002 but not significant) on focal RTS. When the value of technology market in the other regions is fixed at its mean, the effect of knowledge centrality of a given technology in the other ICT regions turns out to be significant and negative (-0.0004) at 0.1 level. In other words, when the value of technology market in other ICT regions is fixed at its mean, for any 50 % increase in the knowledge centrality of a given technology in other ICT regions, we will expect about 0.016% decreases in focal regional specialization in the given technology. Hypothesis 2 predicting that focal RTS is negatively associated with other knowledge centrality is partly supported.

The results in Model 4 show that, the interaction effect (0.00002) of knowledge centrality of a technology and the development of technology market in the focal region on the focal RTS is not statistically significant, thereby providing no support for Hypothesis 3 which predicts that the negative relationship between focal RTS and focal knowledge centrality is attenuated by the development of the focal technology market. However, it is worth noting that focal technology market has a direct positive effect (0.0005) on the focal RTS at 0.01 level which means when keep other factors constant, any 50% increases in the total value of contract deals in focal technology market will lead to 0.02% increases in the level of focal region's technology specialization. The interaction effect of knowledge centrality of a given technology and the development of technology market in the other ICT regions on the focal RTS is statistically significant and negative (-0.0005). Hypothesis 4 predicting that the negative relationship between RTS and the knowledge centrality in the other regions is intensified by the development of technology market in the other regions is supported.

To elaborate further the negative moderating effects of the technology market, I represent it graphically in Figure 2 by plotting different regression lines of focal RTS on knowledge centrality of a given technology at three different levels of the technology market in the other regions, low level (minus one standard deviation from the mean), medium level (mean value of technology market) and high level (plus one standard deviation from the mean). As it is shown in Figure 2, the effect of knowledge centrality of the other regions on focal RTS depends on the development level of their technology market. When the development level of technology market in the other regions is high or medium, their knowledge centrality negatively influence the focal RTS. However, when the development level of technology market in the other regions is low, their knowledge centrality is positively associated with the focal RTS.

Some of the control variables such as the lag term of focal and other region's technology specialization, regional GDP and year dummies also show significant and positive effects on the focal RTS.

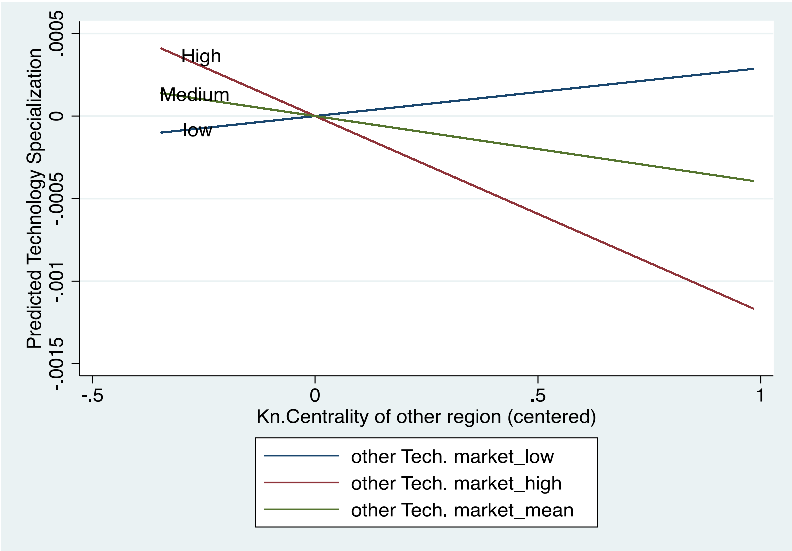

FIGURE 2 INTERACTION EFFECTS BETWEEN OTHER KNOWLEDGE CENTRALITY AND OTHER TECHNOLOGY MARKET ON FOCAL RTS

TABLE 2 REGIONAL TECHNOLOGY SPECIALIZATIONS

(DYNAMIC PANEL REGRESSION USING DIFFERENCE GMM)

Focal tech specialization	**Model 1** Coefficient	**Model 2** Coefficient	**Model 3** Coefficient	**Model 4** Coefficient
Focal knowledge centrality		-0.0004**	-0.0002†	-0.0002†
Other knowledge centrality		0.00002	0.0002	-0.0004†
Focal technology market			0.0005**	0.0005**
Other technology market			0.0011†	0.0008
Focal Kn. Cent X Focal Tech Market				0.00002
Other Kn. Cent X Other Tech Market				-0.0005**
Lag focal tech specialization	0.8157***	0.7806***	0.7767***	0.7746***
Lag other tech specialization	0.0953*	0.1102*	0.0924†	0.0839†
Focal GDP	0.0018*	0.0013†	0.0013	0.0013
Focal Sci. & Tech. personnel	0.0000	0.0000	0.0000	0.0000
Year_1990	0.0052*	0.0038		
Year_1991	0.0050*	0.0036	0.0093*	0.0084*
Year_1992	0.0045†	0.0032	0.0083*	0.0075*
Year_1993	0.0041†	0.0029	0.0075*	0.0068*
Year_1994	0.0036†	0.0026	0.0072*	0.0065*
Year_1995	0.0032†	0.0023	0.0066*	0.0060*
Year_1996	0.0029†	0.0021	0.0063*	0.0057*
Year_1997	0.0028†	0.0020	0.0058*	0.0053*
Year_1998	0.0028*	0.0020†	0.0054*	0.0050*
Year_1999	0.0025†	0.0018	0.0049*	0.0045*
Year_2000	0.0026*	0.0020†	0.0045*	0.0042*
Year_2001	0.0025*	0.0019†	0.0041*	0.0039*
Year_2002	0.0022*	0.0018*	0.0036*	0.0035*
Year_2003	0.0020*	0.0016*	0.0032*	0.0030*
Year_2004	0.0015*	0.0013*	0.0022*	0.0021*
Year_2005	0.0013*	0.0011*	0.0020*	0.0019*
Year_2006	0.0007*	0.0006†	0.0012*	0.0012*
Year_2007	0.0002†	0.0002	0.0005*	0.0005*
Number of Observations	5400	5389	4972	4972
Arellano-Bond test for AR (1)	-3.48**	-3.23**	-3.03**	-3.01**
Arellano-Bond test for AR (2)	-0.15	-0.05	-0.43	-0.42
Hansen test	297.89	297.08	293.78	293.14

******* p< 0.001, ******p<0.01, *****p<0.05, † p<0.1

DISCUSSION

Existing studies on the regional innovation and technology development have been mainly focusing on factors within a region. This study takes into consideration inter-regional effects and explores specifically the influence of the characteristics of the knowledge base of industrial clusters in both the focal and other regions on the development of the focal region's technology specialization and the moderating role of the regional technology markets.

As expected, from the viewpoint of the focal region, focal knowledge centrality of a given technology has negative effect on focal RTS meaning that increases in the level of knowledge centrality of a given technology in the focal region leads to the decreases of focal region's specialization in that particular technological field. This result is explained by the effective communication between knowledge domains and emergence of new technological opportunities driven by the prevailing localized knowledge spillovers across various but related application fields in which the given technology could apply. Firms within a region are tempted to enter these diverse fields by taking advantage of their technological capability and familiarity with the local conditions.

However, knowledge centrality of a given technology in the other ICT regions does not show the expected negative effect on focal RTS. This result can be understood by looking at the moderating effects of technology market at different development levels. Given the technology market in the other regions is more developed, increases in the knowledge centrality in the other ICT regions reduces the focal RTS. This is because the effective knowledge trade between the focal and other regions, which is supported by well-developed technology market, leads to the subsequent reliance of the focal region on the technology supply from other regions. The technology specialization of the focal region is reduced thereafter. Instead, when the development level of other technology market is low, higher knowledge centrality in the other regions surprisingly increases the focal RTS. This is probably because on the one hand, the demand of a given technology from the focal region increases due to the observation of the increasing knowledge centrality in the other regions and the realization of the increasing potential application fields in which this technology could apply. On the other hand, under-developed technology market can't provide sufficient support to the inter-regional technology trade. Under this circumstance, focal region may be forced to invest in and develop this particular technology by itself and the focal RTS is likely to increase. The main effect of other knowledge centrality therefore shows negligible effect on focal RTS as it is obtained by taking the average effect of other knowledge centrality over all the values of other technology market.

The development of the focal technology market does not moderate the relationship between the focal knowledge centrality and RTS. Instead, I observe that focal technology market has significant direct positive effect on RTS. The development of focal region's technology market serves as a channel linking effectively the technology supplier and user of any kind. This in turn drives technology specialization in the focal region regardless of the level of knowledge centrality of that technology. Moreover, after adding the focal technology market into the regression model (see Model 3) the effect of focal knowledge centrality on RTS is reduced from -0.0004 at 0.01 level to -0.0002 at only 0.1 level. This indicates a partial mediation effect of the focal technology market. The speculation is confirmed by the post hoc analysis, which regress focal knowledge centrality on the technology market of the same region.

As to the effects of control variables, path-dependent nature of technology development explains the positive effect of the lag term of focal region's technological specialization on focal RTS. Demonstration, imitation and duplication of industry or technology development across regions at the national level may explain the positive effect of lag term of other region's technological specialization on focal RTS.

Overall, the results of this study support the existence of inter-regional effects of knowledge centrality of a given technology on the development of technology specialization of a region. The hypotheses on moderating effects of technology market are also partially verified.

CONCLUSIONS AND IMPLICATIONS

This study explores the influence of the knowledge centrality of a technology in the knowledge base of industrial clusters in both the focal and other regions on the development of the focal region's technology specialization by taking into account inter-regional effects and the moderating role of the regional technology markets.

I argue that there exist two different mechanisms of knowledge flow, unintended knowledge spillovers and intended knowledge transfer. From the viewpoint of the focal region, both the knowledge centrality of a given technology in the knowledge base of the focal and other region have influences on the focal region's technology specialization, but through different mechanisms. Due to the tacitness of the technological knowledge, unintended knowledge spillovers tend to be more prevalent within the geographically bounded locations than across distant areas. Technology market which is designed to promote technology exchange in order to balance the disequilibrium between the technology sources and industrial demand plays a key role in driving the knowledge flow across regions. Based on Chinese patent data from SIPO and region-level data of five ICT industrial clusters in China, dynamic panel regression using "xtabound2" STATA command is adopted in order to deal simultaneously with the problems such as endogenous independent variables and the heteroskedasticity and autocorrelation within individuals due to the introduction of the lag term of the dependent variable.

The estimation results from the full model have shown that, focal region's knowledge centrality of a given technology has negative impact on RTS due to the prevalence of localized knowledge spillovers and this relationship is not moderated by the development of the focal technology market as it is the channel dedicated to promote the intended technology trade. Instead, other knowledge centrality on average has no influence on focal RTS but as soon as the technology market of other region is included in the model the relationship becomes negative and get intensified when the level of technology market increases. The results indicate that the effect of intended knowledge transfer on focal RTS highly depends on the development level of technology market in the other ICT clusters, which is a channel promoting the technology trade across regions.

There are several limitations of this study. The measure of focal and other technology markets is based on the total value of technology contract deals in a given region. It is not distinguished between technology fields or between different industries. Therefore, it is a measure containing noise that may misrepresent the moderating effect of technology market. However, according to regional statistical reports on the development of technology market of the five regions concentrated with ICT industrial clusters, the value of contract deals from ICT industrial account for about 30% to 40% of the total contract deals of the region over the observation period, which is the largest share compared with other industries. The dominating role of ICT industry in these regions reduces the concern on the measurement issue. Due to the lack of data, I do not able to detect the magnitude of the technology trade between different regions but adopted only the contract deals of a region as the supplier of technology, which assumes that regions have equal accessibility to the technology market of each other.

REFERENCES

Arellano, M. and Bond, S., (1991) Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, Review of Economic Studies, Wiley Blackwell, vol. 58(2), pages 277-97.

Arora, A. and Gambardella, A., (2010) Ideas for Rent: An Overview of Markets for Technology, Industrial and Corporate Change, Vol. 19 (3), 775-803

Arthur, W. B. (1994). Increasing Returns and Path Dependence in the Economy, University of Michigan Press, Ann Arbor.

Bae, J. and Koo, J. (2008). Information Loss, Knowledge Transfer Cost and the Value of Social Relations. Strategic Organization, 6 (3), 227-258

Boschma, R. (2004) Competitiveness of regions from an evolutionary perspective, Regional Studies 38(9): 1001-1014.

Boschma, R. and Frenken, K. (2009). Chapter for book H. Bathelt, M.P. Feldman and D.F. Kogler (eds.). Dynamic Geographies of Knowledge Creation and Innovation, Routledge, Taylor and Francis.

Carlsson, B. and Stankiewicz, R. (1991). On the nature, function and composition of technological systems. Journal of Evolutionary Economics, Vol. 1 (2): 93-118.

David, P. A. (1988). Path Dependence: Putting the Past into the Future of Economics, Technical Report No. 533, The Economic Series, Institute for Mathematical Studies in the Social Sciences, University of Stanford, Stanford, CA.

Delgado, Porter and Stern, (2011). Clusters, Convergence, and Economic Performance

Khanna, T. and Oberholzer-Gee, F. (2006). The Political Economy of Firm Size Distributions Evidence from Post-Reform China. Working paper

Malerba, F. and Montobbio, F. (2003). Exploring factors affecting international technological specialization: the role of knowledge flows and the structure of innovative activity. Journal of Econ. Vol.13: 411–434

Jacobs, J. (1969) The Economy of Cities. New York: Vintage Books.

Jaffe, A. B., Trajtenberg, M., Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics, 63: 577–598.

Maggioni, M.A., Uberti, T.E. (2007) Inter-regional knowledge flows in Europe: an econometric analysis. In: Frenken, K. (ed.) Applied Evolutionary Economics and Economic Geography, pp. 230–255. Edward Elgar Publishing, Cheltenham.

Meng, Q.X. and Li, M.Z. (2002). New Economy and ICT development in China. Information Economics and Policy 14, 275–295

Neffke, F. (2009) Productive Places. The Influence of Technological Change and Relatedness on Agglomeration Externalities, PhD thesis, Utrecht University, Utrecht.

Neffke, F. and Henning, M. S. (2008) Revealed relatedness: Mapping industry space. Papers in Evolutionary Economic Geography, Utrecht, University of Utrecht.

Neffke, F., Henning, M. and Boschma, R. (2009). How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. Papers in Evolutionary Economic Geography (PEEG) 0916,

Neffke, F., Henning, M. and Boschma, R. (2011). How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions, Economic Geography, vol. 87(3), pages 237-265, 07.

Porter M. E. (1998). Clusters and the new economics of competition. Harvard Business Review 76(6): 77–90.

Ramani Shyama V. and Looze De Marie-Angele (2002). Using patent statistics as knowledge base indicators in the biotechnology sectors: An application to France, Germany and the U.K. Scientometrics. Vol. 54, No. 3

Schmoch U., (2008). Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Organization (WIPO)

Stephen B. Tallman and Phene, A. (2007) Leveraging Knowledge across Geographic Boundaries, Organization Science, 18(2): 252-260

Van Zeebroeck, N., Van Pottelsberghe de la Potterie, B., and Han, W. (2006) Issues in measuring the degree of technological specialization with patent data. Scientometrics, Vol. 66, No. 3, pp. 481-492.

Wang Cassandra C. and Lin George C.S. (2008). The Growth and Spatial Distribution of China's ICT Industry: New Geography of Clustering and Innovation Issues & Studies 44, no. 2, 145-192.

William H.A., Johnsona and Qing Liu, (2011) Patenting and the role of technology markets in regional innovation in China: An empirical analysis, The Journal of High Technology Management Research. Vol. 22, Issue 1, 14-25

Zhang, Li and Schoonhoven, (2009) Strategic Management Journal, 30: 163–183.

Zucker, Lynne, Michael Darby and Brewer, M. (1998). "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises." American Economic Review. Vol. 88, No. 1, 290-306.