**University College London**

Bartlett School of Planning

# The market-mediated diffusion of technology across geographical boundaries and the evolving roles of anchor regions

## - Analysis of the Chinese patent licensing network -

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Doctor of Philosophy

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## Declaration of Originality

*I, ILWON SEO confirm that the thesis I have presented for examination of the PhD degree is solely my own work. Where information has been derived from other resources, I confirm that this has been indicated in the thesis.*

*Signature: ILWON SEO*

*Date: 30 July 2019*

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# Abstract

This research explores the characteristics of the market-mediated technology transfer across the regions, the role of a few anchor regions in the technology diffusion process and their contributions as the dynamics in the evolution of a regional network. While extant empirical studies addressed the mechanism of the knowledge spillover, neither literature on innovation study nor regional approach has clearly discerned the market-mediated technology transfer from a pure knowledge spillover. The market-mediated technology that was acquired with the intention of leveraging the economic outcomes is likely to underpin the innovative capacity and lead the economic growth of the region. Thus, this empirical research contributes to the understanding of the pathway between the knowledge spillover and regional economic growth. Moreover, the current study reinterprets the role of a focal node from the perspective of the anchor region in the regional innovation network, focusing on the brokerage role in the local assimilation of exogenous technology. In order to capture the characteristics of the market-mediated technology, this research utilises the Chinese patent licensing dataset from 1998 to 2013, an appealing measure of representing technology flow between the licensor (provider) and licensee (purchaser).

The estimated result of the geographical incidence, calculated by the 'gravity-like model', supports the mutual market uncertainties. It corroborates the preference for proximate partners is not identical for the licensor and licensee. The presence of the dissipation effect, the odds-ratio of being the private firm against the public institutions, demonstrates that licensors utilise the spatial distance as a strategic tool for risk-aversion. This empirical result provides a significant insight to the link in the gap between the innovation system and geographically agglomeration economies in that the location of firms within a proximate neighbourhood might hamper the diffusion of technology which is required for promoting an innovation system.

It is also found that the path-dependency effect works as the dynamics of the regional technology transfer network. The previous experiences as a technology provider and the accumulated partnership matters for the decision of a licensee's decision, which might cause 'the experienced get more experiences' and thus the regional disparity of the technology capacity. Further to the brokerage roles of the anchor regions, Beijing and Shenzhen serve as a 'national anchor', transmitting the technology produced in their megalopolises across the outer regions, while Shanghai sits in a more balanced brokerage position as a 'regional anchor' that connects the outer and inside of its megalopolis. The simulation-based analysis suggests that anchor regions, serving as a conduit for the whole regions rather than a local region anchor in order to contribute to the growth of a national innovation system.

# Impact Statement

This research explores the characteristics of the market-mediated technology transfer across the regions and the role of such anchor regions in the evolution of a regional network, which has been largely neglected in the traditional literature on transfer of technology.

The main contribution of the current research centres on the understanding of the disparity in economic development with the empirical evidence. With the advent of a knowledge-intensive economy, the rise and fall of a region's economic level is likely to be tightly coupled with the capacity of how a region explores, accumulates and recreates the knowledge. This research enhances the mechanism of why the technologies might not cross geographical borders, even the recent development of Internet technology allows one access to technology information in almost anywhere within a minute. One of the main results is that the mutual uncertainty embedded in the market-mediated technology transfer is highly likely to cause the path-dependency effects led by a small number of anchor regions. This mechanism reinforces the capacity of the anchor regions, then eventually the anchor regions dominate the whole network as the network develops.

The study has illustrated the strategy for a regional economy which embraces an interdisciplinary approach geared to delivering applicable research findings. From the perspective of a rapid catching-up, it is a reasonable policy to concentrate the limited resources on the few anchor regions. The current study corroborates that such a policy might trigger the development of a national innovation system. At the same time, it also implicitly presents that the imbalance of the knowledge distribution might be reinforced, causing regional economic disparity. The major implication of this issue, based on the empirical analysis, is that the anchor regions are required to serve as a nation-wide brokerage role, rather than the local-level brokerage hub, which might attract the attention from the policymakers of catching-up countries.

This main result is disseminated to the academic researchers and the non-professional policy makers as well. The basic idea is presented to the policy makers and regional researchers in the three conferences.

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# Thesis Structure

- ***Main research questions***

1. *The characteristics of the market-mediated technology transfer across the regions*
2. *The role the anchor regions in the technology diffusion process at national and megalopolis level*
3. *Their contributions of anchor reigns as the dynamics in the evolution of a regional innovation network.*

**Ch 2. The uncertainty in the market-mediated technology transfer and the role of anchor regions**

- *The characteristics of market-mediated technology in local knowledge spillover in comparison with pure knowledge*
- *Reveal the mutual uncertainties of the both licensor and licensee*
- *The pivotal role to connect the local firms in the regional economy with the global market through.*

**Ch 3. Descriptive analysis of Chinese patent and licensing**

- *The Chinese government policy behind the rise of a patent market*
- *The descriptive statistics of the Chinese patents and licensing information.*
- *National/regional/technology sector level analysis*

**Ch 4. The geographical proximity in the transmission of market-mediated technology**

- *The gravity-like estimation of the geographical reach of market-mediated technology transfer*
- *The licensors and licensees have a different spatial proximity preference in transferring the market-mediated technology*
- *The estimation result represents the each other's a motivation that runs counter to that of the counterpart*
- *The private firm's licensing decision is influenced by the competition level within the region.*

**Ch 5. The evolution of technology transfer network: static and dynamic approach**

**Ch 6. The role of anchor regions as a dynamic of the network evolution**

- *A strong path-dependency effect appears to reflect the mutual uncertainties*
- *Classified the brokerage role in five types*
- *Shanghai positions as a more 'regional anchor', while Beijing and Shenzhen as a 'national anchor'*
- *A 'representative' and 'consultant', rather than other types contributes to the evolution of the network*

**Ch 7. The anchor regions in the hierarchical structure of national innovation system**

- *The patterns of anchor regions in the hierarchical structure of the national innovation system*
- *While the regional innovation network expands, the influence of the traditional core region is even reinforced in the hierarchical network structure as new entrant cities joined the network*
- *The traditional anchor regions have maintained their current positions by reproducing the new technology from the exogenous technology sources*

# Chapter 1. Introduction

### *Research background*

In the past few decades, the advent of seemingly instantaneous communication technology, a knowledge-based economy and an open innovation research network have led to the upsurge of the technology transfer across spatial spaces[1] (Ohmae 1990, Foray and Lundvall 1998, Chesbrough 2003, Morgan 2004, Cooke and Leydesdorff 2006). The scope of exploring knowledge is no longer confined to the internal resources; it takes place within heterogeneous sources, both internal to the organisations but also increasingly from outside them (Ernst and Kim 2002, Chesbrough 2003). The competency of integrating external knowledge acquired across locations and applying a firm's knowledge lies in the firms' core competitiveness, which Teece (1986) coined as "complementary assets".

At the regional level, the contribution of the knowledge in achieving regional economic growth also has been highlighted (Rivera-Batiz and Romer 1990, Breschi and Lissoni 2001, Harris 2001, Huggins, Luo et al. 2014). How regions acquire, assimilate and reproduce knowledge geared toward the innovation outcomes has emerged as one of the critical issue in economic activities (Coe and Helpman 1995, Malecki 2007, Audretsch and Keilbach 2008, Capello, Caragliu et al. 2010, van Hemert, Masurel et al. 2011). The creation and diffusion processes of knowledge at the regional level are facilitated not just by the endogenous knowledge base accumulated from local embeddedness, but also by the exogenous knowledge learning (Asheim 1996, Morgan 1997, Bathelt and Turi 2011).

While many studies corroborate the positive relation between the influx of knowledge

[1] According to WIPO (2017). *World Intellectual Property Indicators, 2017*, WIPO., Global IP (intellectual property) filings have reached for the first time, more than 3 million patent applications a single year. Global patent filings grew by 8.3%. OECD demonstrates an average annual rate of 10.6% between 2000 and 2010, which is well above the growth of OECD GDP. The global size reaches $180Bil dollars in 2009.

and regional innovation outcomes, it remains still unclear about the mechanism of how this exogenous technology is transformed into local knowledge geared toward a region's innovative capacity. In this vein, although the capacity of exploring, creating and assimilating knowledge has been considered as the key factor behind the regional economic growth, little research empirically deals with the transferred technology for economic purposes and its impact on the development of innovative network across the regions (Feldman and Florida 1994, Audretsch and Feldman 1996, Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017).

The recent literature highlights the market-mediated technology, which have still largely been overlooked (Arora, Fosfuri et al. 2001, Nelson 2009, Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017). For instance, the embryonic ideas produced in labs, codified information collected from documents, and 'off-the-shelf' technology-acquired pecuniary in the technology market for commercial use are treated homogeneously (Breschi and Lissoni 2001). It is an important issue to understand the local assimilation process that serves as the precedent for establishing the innovative capacity, revealing a more direct contribution of knowledge to the economic activities across the regions (Coe and Helpman 1995, Morgan 1997, Audretsch and Keilbach 2008, Capello, Caragliu et al. 2010, Bathelt and Turi 2011, van Hemert, Masurel et al. 2011). The paucity of literature of disentangling the market-mediated technology from a pure knowledge spillover might not look at the difference of heterogeneous mechanisms in the market-mediated technology transfer process. This research argues that knowledge that is transferred through a pecuniary compensation does not have an identical effect on the other types of pure knowledge (Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017).

Another paucity of the literature on the technology transfer is the role of a focal region, or anchor region, which serves as a brokerage role across the network. While the rich literature has witnessed the benefits of a brokering node to the innovative activities, it remained silent whether an anchor node serves as the dynamics for leading the evolution of the network (Almeida and Kogut 1999, Breschi and Lissoni 2001, Boschma 2005, Boschma and Frenken 2006, Gluckler 2007, van Oort and Lambooy 2014).

***Aim and scope***

The purpose of this thesis is to investigate the characteristics of the market-mediated technology transfer across the regions, the role of some anchor regions in the technology diffusion process and their contributions as a dynamic in the evolution of a regional network. Within the aim, the theoretical review on prior technology transfer studies, the empirical analysis of measuring the geographical incidence, the static structural properties of the network and a longitudinal network simulation are developed.

In order to address the multiple dimension of technology diffusion in the region, the current research utilises China, an emerging market of intellectual property rights, as a research case. The size of Chinese patent applications has expanded as patents in China increased from 18,700 in 1995 to 1.3 million in 2016, amounting to an average growth of 23% (WIPO 2017). Even from the global perspective, the number of Chinese patents exceeds more than the combined total for US, Japan, Korea and Europe, for which these top five patent offices accounted for 84% of that of the whole world in 2016. As a reflection of the upsurge increase of patents, the Chinese case presents significantly fine evidence of how technology is acquired, transmitted and reproduced across regions. China also presents a perfect research ground because 1) its territory is vast, which makes regional dynamics of innovation more visible (Jiang and Kim 2016) and 2) its technological capacity has grown over the last few decades, after the global flow of information became a natural part of technology development. Based on the patent license data from China, the structure of the thesis is constructed as follows.

Chapter 2 explores the fundamental characteristics of market-mediated technology transfer across geographical space which are homogeneously recognised as pure knowledge spillovers without full pecuniary compensation. The critical review developed in this chapter is expected to explore the market risk embedded in the market-mediated technology, and further to reveal the role of an anchor tenant in the innovation system at the multiple scales of the network. This chapter aims at providing a logical departing point for discerning the technology transfer from a pure knowledge spillover across spatial space. The first section provides a review of the literature on technology transfer across geographical borders, raising the question about the notion of regional externality which has been largely treated as homogenous spillover. The distinction between the pure knowledge spillover and pecuniary compensated technology makes it beneficial to identify the fundamental risks in transferring technology for the commercial use of knowledge across the regions.

Chapter 3 addresses the technology flows of China by combining the information of the patent applications and licensing agreement. The patent application information is recognized as a proxy reflecting the structured information such as which knowledge sector is created, who owns it, which regions are active in producing it, which type of applicant is involved and so on. The information on the patent licensing, on the basis of the structured data, captures the flow of technology by answering who/which type/which region is active in supplying/purchasing in which technology/industry-level sector. Moreover, a market-mediated patent transaction is highly likely to be involved in economic activities, indicating the link between knowledge and economic values.

Chapter 4 examines the geographical incidence of market-mediated technology flow and identifies the different spatial patterns that technology providers and purchasers deal with regarding the risk involved. In order to address the uncertainties of both parties involved in technology transfer contracts, the geographical incidence of technology flow is estimated by using a gravity-like model, then it extends the basic model to capture the experienced group's responsive actions. As a robust check, the binomial logistics analysis assesses whether the competition-level influences the technology provider's decision on licensing within the prefecture area.

Chapter 5 aims to explore how a region's network structure and innovative capacity contribute to the growth of a technology network. For this purpose, this chapter examines the static properties of the network on the basis of the inter-regional (prefecture-to-prefecture) technology flow networks and attempts to measure the influence of dynamics on the longitudinal network evolution. The static approach of this chapter examines the structural properties of a technology licensing network. The dynamic approach estimates the impact of a region's technology activities on the evolution of a market-mediated technology transfer network (Giuliani 2011, Balland 2012, Broekel, Balland et al. 2014).

Chapter 6 implements an empirical analysis to address the research gap between the identification of the specific brokerage roles and the contribution to the anchor regions in the longitudinal network growth. This chapter attempts to investigate the role of different types of brokers and the longitudinal trend of the three major anchor regions. Then, it examines the effects of a gatekeeper and a representative over to the evolution of the total network.

Chapter 7 tackles whether the technological development of a nation relieves the inter-regional hierarchy in knowledge flow within a national innovation system, associated with two specific scenarios. First, the desolation of the inter-regional hierarchy scenario: as many regions develop their own niches in the global economy and become more capable of importing advanced technology directly from overseas, the national core region loses its relative importance as the source of new knowledge, rendering the domestic inter-regional hierarchy less significant as a result. The opposite scenario is the persistence of a spatial anchor scenario. As the economy globalizes further, the nation's traditional core region becomes even more active in importing technology and distributing it to other regions of the country. The last chapter, Chapter 8, summarises the whole chapters and provides the contributions.

# Chapter 2. Critical review: The uncertainty in the market-mediated technology transfer and the role of anchor regions

## 2.1. Introduction

The processes of creation, accumulation and spillover of knowledge are widely recognised as fuelling the engine for stimulating regional economic growth (Romer 1986, Rivera-Batiz and Romer 1990, Grossman and Helpman 1993, Morgan 1997, Audretsch and Keilbach 2008, Capello and Nijkamp 2010, Bathelt and Turi 2011, van Hemert, Masurel et al. 2011). As a reflection of the importance of knowledge, the notion of knowledge spillover was portrayed as a prototypical externality to the development for innovative activities, calling for attention to the mechanisms of 'how geography influences knowledge activity and how geography may be in turn shaped by such processes' (Moreno, Paci et al. 2006, Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017)

Prior research on knowledge has recognised it as non-rival input factor for underpinning the region's externality, by which one's investment in technology development eventually benefits others' innovative outputs (Vernon Henderson 2007). The empirical research, investigating the mechanisms of the process of creation and diffusion of innovative knowledge in the geographical boundary (Acs, Audretsch et al. 1994, Audretsch and Feldman 1996), however, has not clearly discerned a pure knowledge spillover and market-mediated technology transfer (Acs, Audretsch et al. 1994, Audretsch and Feldman 1996, Breschi and Lissoni 2001, Moreno, Paci et al. 2006, Mowery and Ziedonis 2015). For instance, Jaffe (1989) originally introduced the spatial context in order to verify the existence of geographically mediated externalities from university research to commercial innovation. In other words, what he presumes is that knowledge produced by universities is a sort of 'local public good', leaving the knowledge as non-compensated but beneficial for economic activity. Similarly, several empirical works on examining citation data suggest that non-pecuniary public science knowledge from the university is an important input for the innovative activities of co-located firms (Verspagen 1999, Malo and Geuna 2000, McMillan, Narin et al. 2000, Hu and Jaffe 2003).

Compared to a pure knowledge spillover, technology transfer commonly denotes an active process during which the technology is exchanged between two entity units with pecuniary compensations (Autio and Laamanen 1995, Bozeman 2000, Audretsch, Bozeman et al. 2002, Battistella, De Toni et al. 2015, Bozeman, Rimes et al. 2015). It is an intentional, goal-oriented interactive process between two or more involving entities aiming to leverage current technology value, during which the relevant technological knowledge components remain at least stable through the transfer process (Argote and Ingram 2000). Similarly, knowledge transfer also refers to the process through which one unit is affected by the experience of another (Singley and Anderson 1989). However, concepts commonly used in connection with technology are more closely related to the practical application of knowledge implicitly presumed for the economic value (Audretsch, Bozeman et al. 2002). The contribution of a pure knowledge spillover from a public knowledge source, however, has no equivalent impact on the production and innovation activities as commercial technology acquired in the market has[2]. This research raises doubts on the prevailing assumption that these heterogeneous technology spillovers are equally created, transmitted and contributed to economic activities within the region.

Much of the empirical research investigates the mechanisms and determinants of the process of creation and diffusion of innovative knowledge in the geographical boundary, but

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[2] This research distinguishes the knowledge from technology, following Stokes, D. E. (2011). *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press.'s notion. Knowledge is closely related with the notion of 'pure basic' knowledge that seeks to widen the understanding of the phenomena, while technology refers to 'pure applied' knowledge that is guided solely by applied goals for commercial use.

few studies have clearly identified the different geographical incidence of technological spillovers either pecuniary or pure nature (Breschi and Lissoni 2001, Moreno, Paci et al. 2006, Mowery and Ziedonis 2015). For instance, the embryonic idea from research labs and a licensed technology purchased in the technology market for commercial use are treated homogeneously as a local externality (Breschi and Lissoni 2001). If a pure knowledge spillover has a different scope in contrast to the pecuniary compensated or market-mediated technology, then the impact of localised spillover to the innovation activities needs to be reconsidered. In this vein, this research explores a set of questions concerning the geographical incidence of technology transfer disentangling market-mediated technology transfer from pure spillover across geographical borders. To sum up, the research questions are:

*First, what are the major uncertainties for both parties involved in market-mediated technology transfer processes across space, and how does this differ from pure knowledge spillovers?*

*Second, in the presence of the uncertainty in the market, what is the role of anchor regions in transferring the market-mediated technology?*

*Third, to what extent does an anchor region contribute to an innovation system via market-mediated technology transfer process?*

With the aim of exploring the fundamental characteristics of market-mediated technology transfer across geographical space which are homogeneously recognised as pure knowledge spillovers without fully pecuniary compensation, the critical review developed in this chapter is expected to explore the market risk embedded in the market-mediated technology, and further to reveal the role of the anchor tenant in the innovation system at the multiple scale of network. The distinction of the market risk enables investigating how firms behave to avoid the risk of acquiring and transmitting technology across regions. The micro-level mechanism of transferring technology is of particular significance in enhancing the efficiency of a regional innovation system, as a necessary step towards beginning empirical analysis in the later chapters.

This chapter utilises articles pertaining to market-mediated technology transfer by patent licensing as a main data source. The patent licensing provides a notable metric for measuring market-mediated technology transfer diffusion. First, information on licensing data indicates the process by which technology with economic value is produced and transmitted to contribute economic value (Nelson 2009). A second reason is that license represents the conflicting interests of the patent owner and licensees embedded in the process of the license agreement that result in a capture of firms' economic-oriented business contract. Third, the patent licensing data depict the relationship between both parties rather than a one-time knowledge transmission, furthering the comprehensive picture of the transaction.

The remainder of this chapter is structured as follows. The next section discusses studies on technology transfer across the geographical borders in the multiple approaches. Specifically, the discussion focuses on the geographical incidence of the technology spillover. This is a logical starting point for capturing the contradictory mutual uncertainty of two parties - technology producer and purchaser- which participated in the market transactions. Then, section 3 extends the exploration of the anchor tenant into studies on market-mediated technology transfer, verifying whether the presence of an anchor tenant can positively enhance the transfer of technology. The section illustrates the role of anchor tenants, under the presence of reciprocal risks involved in both parties, in the technology transfer with emphasis on the framework on geographical proximity. Drawing upon the social network notions, this research extends the notion of an anchor tenant in order to explore the structural properties and interactive relationships embedded in the innovation system. The research proposes that the structural properties of a network are related to economic geography and regional innovation literature, investigating the presence of an anchor tenant in the regional innovation system and the structure of a small-world network.

## 2.2. Technology innovation and regional growth

While the positive association of technology-driven embeddedness and regional growth has been found in industrial districts (Piore and Sabel 1984), innovation milieu (Granovetter 1985, Camagni 1995, Crevoisier 2004), technopole (Castells and Hall 1994) and regional innovation system (Bjørn T Asheim 1998, Rip 2002, Fritsch and Stephan 2005, Asheim, Smith et al. 2011). The recent literature on regional growth approaches including learning regions and GPN (Global Production Network) tends to presume that the exogenous technology is widely regarded as a fundamental force for fuelling the engine of growth (Morgan 1997, Ernst and Kim 2002, Moreno, Paci et al. 2006, Ernst 2010, Hassink and Klaerding 2012).

For instance, the recent GPN approach explains that regional development is the outcome of the coupling processes between TNC (Trans-National Company) steered networks and regional assets available in regions (Ernst and Kim 2002, Coe, Dicken et al. 2008, Yeung 2008, Ernst 2010). From the perspective of technology transfer, the leading firms with higher value chains act as a technology source channel to connect the global network with the local firms (Boari and Lipparini 1999, Bunnell and Coe 2001, Morrison 2008, Giuliani 2011, Graf and Krüger 2011). At the same time, scholars have strived to explain how knowledge is diffused across geographical boundaries in the local area. Thus, as Bathelt, Malmberg et al. (2004) recognised, the firms are required to establish the balanced channel for an exogenous knowledge source in order to maintain competitiveness, which is depicted as a notion of “pipeline” and “buzz”. Even the technology is transmitted to the region, the local knowledge flows in the regions are also important because assimilation process in the recipient region does not automatically warrant adaptation in another.

Concerning the local assimilation process, neither literature on innovation study nor regional approach is not unanimous in identifying the mechanism of knowledge spillover. For instance, several empirical studies stress the technology proximity as a catalyst for the knowledge spillover (Malerba and Orsenigo 1995, Malerba 2002), while RIS approach, reconciling the technology transfer and innovative activity, highlights the interactive relationships within the spatial proximity as the technology transfer mechanism (Asheim and Gertler 2005, Asheim, Smith et al. 2011). The common assumption in these arguments lies in the preference for the proximity. According to Gertler (2003) and Vernon Henderson (2007), the proximity does not guarantee the knowledge spillover, all actors in being there are allowed to be the beneficiary. They argue that the spillover is rather the result of deliberate exchanges process on the network. In this way, several studies suggest that networking capabilities are highly related with the accessibility of knowledge stock, thus improves the absorptive capacities for an innovative outcome (Cowan and Jonard 2003, Balconi, Breschi et al. 2004).

The structure of a regional network, can promote the trust to accelerate the interactions that typically require for exchanging knowledge flow across the network (Nooteboom, Van Haverbeke et al. 2007, Huggins, Luo et al. 2014). From the systematic view of network, for instance, the network structure may not only enhance the knowledge diffusion on direct linkages, but also on indirect relations resulting from a brokering node that may involve a transformation of the respective knowledge from different sources. The small-world structure endows the nodes of sparse networks with unique capabilities for connectivity of acquiring the new knowledge sources. It is widely recognised that the combination of high connections among the nodes (highly-densed) in the local clusters and the few interconnections between those clusters (loosely-coupled) causes the emergence of small-world networks (Gulati 1995, Newman, Barabasi et al. 2011). From the perspective of regional innovation network, the small-world network structure provides the substantial efficiency in transmitting the technology flows to the whole system. Given the small-world structure, the institutions located in the cluster could acquire the dynamic advantages derived from the structure by keeping the connectivity to the focal hub nodes, interconnecting with the other regions.

These advantages of regional networks are regarded as one of the main factors for the localised knowledge spillover (Audretsch and Feldman 1996, Breschi and Lissoni 2001), thus Fritsch (2013) noted as

> *Regional networks and localized knowledge spillovers may explain why knowledge diffusion is concentrated close to the locus of knowledge generation but also why innovation activity is found to be clustering in space [page 670].*

The discussion on the localisation process of knowledge assimilation in the literature reflects the benefit of spatial proximity that involves the frequent face-to-face contacts. Such a direct transmitting channel, fostering the transfer of complex and uncodified tacit knowledge, promotes activates such as a new collaboration, cooperative research, problem solving as well as strengthening the mutual trust, all of which are more effective knowledge exchange (Fontes 2005). Thus, the knowledge spillover within the spatial proximity encourages the collective learning among the innovative actors in the region. In this way, the regional network structure combined with spatial proximity appears to mediate the technology transmission across the local areas and, eventually, enhance a region's innovative activity which is regarded as a precondition of regional economic development (Capello 1999, Cooke 2004, Moreno, Paci et al. 2006).

## 2.3. Market-mediated technology transfer as regional externality

This section provides a lens into the literature on technology transfer to explore the characteristics of market-mediated technology transfer. This chapter begins by reviewing the literature of technology transfer, before highlighting the characteristics of market-mediated technology transfer in the second subsection. It mainly focuses on the literatures in knowledge transfer as the externality embedded in the region. The market risks which are largely ignored in the discussion of the technology transfer are addressed in the last subsection. This chapter is a logical departing point given the emphasis is on discerning the technology transfer from a pure knowledge spillover across spatial space.

### 2.3.1. Technology transfer across geographical borders

Among the several major directions of the literature on technology transfer, this research mainly deals with the existing empirical studies from the perspective of transmitting via geographical spaces.

The first strand of study is recognising exogenous technology from the multiple locations including other countries as a source for externality. Several empirical studies demonstrate the positive effect of transnational technology acquisition through multinational enterprises (MNEs), highlighting the role of exogenous technology as a conduit for importing advanced technology (Blomström and Kokko 1998, Görg and Greenaway 2004, Meyer 2004, Crespo and Fontoura 2007, Meyer and Sinani 2009). The main advantages of collocated entities include not only technology transfer via licensing (Fu and Gong 2011), skilled labour mobility and spin-offs start-ups originating in MNE (Østergaard and Park 2015), but also the imitation effect by local co-located firms to observe best practices of MNE (Meyer 2004). The competition promotion effect triggered by MNEs improves technology capacity in the local market, all of which benefit the co-located firms within the geographical spaces

(Veugelers and Cassiman 1999, Crespo and Fontoura 2007, Meyer and Sinani 2009). Despite the positive spillover effect, on the contrary, a few studies stress that the presence of MNEs has not guaranteed the positive externalities to the regional economy. For instance, MNEs with advanced technology capability and management skills could dominate the domestic market, attract more highly skilled labour and take up local supplier chains that may, otherwise, be occupied by domestic local firms. Thus, the MNEs might crowd out the local firms' opportunity of investing capital to R&D activities (Aitken and Harrison 1999, Tian 2007, García, Jin et al. 2013).

However, what appears to be lacking is how the exogenous technology from other country reproduces, diffuses and influences the recipient region's economic growth (Veugelers and Cassiman 1999, Meyer 2004, Meyer and Sinani 2009, Ning, Wang et al. 2016). If technology spillovers take place across countries, the exogenous technology flowing into a firm, in the same way, might be transmitted at the regional level. Recently, Ning, Wang et al. (2016) address this issue by examining FDI externalities affecting city innovation both within and across cities in China. They corroborate the existence of positive FDI spillovers on the region's innovation, highlighting the role of FDI as an important external technology and knowledge source for improving local innovation. More specifically, they show that FDI spatial spillovers are contingent upon the intensity of industrial agglomeration within the regions. Specialised industrial structures absorb FDI knowledge spillovers within the cities and also facilitate their diffusion to closely located cities, while diversified ones provide a vibrant environment for local innovation. Nevertheless, the exogenous technology acquired from another country via FDI and region's externality is regarded as a separate issue without considering the type of knowledge transmitted (Ning, Wang et al. 2016).

Second, a strand of study focuses on the technology transfer developed at non-profit institutions including university. The activities include university-industry partnerships, intellectual property licensing and the spin-off firms led by university and research institutions as well has being accepted as a primary input factor for regional externality (Radosevich 1995, Kroll and Liefner 2008, Kirchberger and Pohl 2016).

The primary interest held in the technology management approach has concentrated whether the technology is transmitted successfully and which factors moderate the process (Powers and McDougall 2005, Bozeman, Rimes et al. 2015, Kirchberger and Pohl 2016). For instance, Bozeman (2000) and Bozeman, Rimes et al. (2015) provide a contingency model, consisting of five characteristic categories (the transfer agent, the transfer media, the transfer object, demand environment, and the transfer recipient) as determining the factor for an effective transfer. Powers (2003) and Caldera and Debande (2010) suggest that the organisational capacity factor proxied by TTO ( technology transfer offices) size also influences the technology transfer activities of a university. Based the survey data from the federal laboratories, Adams, Chiang et al. (2003) identified that the presence of prior collaboration experience in the research project (CRADA : Cooperative Research and Development Agreements) serves as a mechanism to promote the technology transfer (D'Este and Patel 2007). Thursby, Jensen et al. (2001) turn attention to identifying the importance of tacit and informal knowledge channels that rely on geographical proximity. In line with them, the informal relationships linking graduates with the business sector (Boardman and Ponomariov 2009), idea exchange at conferences, or joint research (Boardman, Bozeman et al. 2010, Grimpe and Fier 2010) also investigated an important factor for promoting technology spillovers.

Although a vast amount of literature has documented benefits, success cases and the determinant factors in many settings, the impact of technology transfer on the regional economy remained silent (Jaffe, Trajtenberg et al. 1993, Hu, Jefferson et al. 2005, Powers and McDougall 2005, Caldera and Debande 2010, Bozeman, Rimes et al. 2015, Kirchberger and Pohl 2016). That is partly because the technology transfer transaction is considered as a major achievement (Argote 2012, Bozeman, Rimes et al. 2015). The scope of actor-to-actor technology transfer in this vein, does not account for the transformation of transferred technology into the local technology that underpins commercial innovation within geographical space, leaving the question whether technology produced by universities is absorbed and transformed into the local firm’s technology capacity (Jaffe 1989)

Some empirical studies attempted to evaluate the economic value of technology transfer, expanding the scope of technology transfer to the economic impact. The studies on technology transfer evaluation studies have been produced using the market impact model and based on economic impact measures. Bozeman, Papadakis et al. (1995) cast an interesting insight in that the technology partnership in the form of CRADA yield winner-takes-all achievements by examining 219 federal laboratory partnerships, most of them based on CRADAs. After several empirical studies mainly based on public sector institutions, Bozeman, Papadakis et al. (1995) demonstrate the consistent higher tendency of economic value in technology transfer transactions (Bozeman, Papadakis et al. 1995, Crow and Bozeman 1998, Youtie, Bozeman et al. 1999). Roessner, Bond et al. (2013) also corroborate the positive impact of license-based technology transfer to the U.S. economy from 1996 to 2010 in both excessive economic value and job creations. Rowe and Temple (2011), specifically, present a case study of semiconductor industry in NIST (National Institution of Standards and Technology) to show that the benefits of technology transfer based on partnership are far more cost-effective.

Concerning the spatial boundaries of the technology transfer, the RIS (regional innovation system) deals with regional settings as an establishing innovation system in the context of systemic approach (Cooke 2004, Asheim, Smith et al. 2011). The main interest of researchers lies in identifying the region’s innovative factors - R&D intensity, strength of knowledge transfer, the institutional setting, innovative culture, human capital and public policy, and revealing how they are related to the establishment of economic activities (Asheim and Gertler 2005, Asheim, Smith et al. 2011). While not underestimating spillover process as a precursor to the innovation system shaping a region's economic activities, similar notions including industrial district (Saxenian 1990), innovation milieu (Camagni 1991), and learning regions (Morgan 1997) also argue that intra-regional interactions rooted from geographic proximity are the main propelling factor for the technology transfer mechanism.

Although RIS approach takes into account a much wider set of geographical proximity to reconcile the technology transfer mechanism and externality within spatial boundaries, a line of study alternatively views technology proximity as a sectoral innovation process (Malerba and Orsenigo 1995, Malerba 2002). Marshall (1890) presented three factors to explain regional externalities that underpin the spatial concentration of the specific industry sector: specialised labour pool, specialised inputs and knowledge spillovers within firms. The agglomeration economy, later known as Marshall-Arrow-Romer(MAR) externalities, is empirically verified by scholars to explain a firm's decision on location (Belderbos and Carree 2002, Chang and Park 2005), improvement of co-located firm's innovative activity by benefitting from technology proximity (Audretsch and Feldman 1996, Beaudry and Breschi 2003, McCann and Mudambi 2004), and technology spillover from university on the extent to which these are spatially localized (Jaffe 1989, Jaffe, Trajtenberg et al. 1993, Acs, Audretsch et al. 1994, Bercovitz and Feldman 2006, Belenzon and Schankerman 2013). Audretsch and Feldman (1996) also find a positive relationship between local university research funding and local industry value-added in the state. The technology-specific clusters such as biotechnology, S/W, and IT industry in the US also demonstrate the presence of positive regional agglomeration economy (Kenney, Nelson et al. 2009). The knowledge spillover which constitutes the regional externality, however, has been largely treated as a homogenous knowledge, regardless of its specific types.

### 2.3.2. Market mediated technology transfer and market risk

The paucity of literature of disentangling the market-mediated technology from pure knowledge spillovers might not look at the risks embedded in the technology transfer across geographical borders. Jaffe (1989) found a positive and significant relationship between original patents and patents that cite the original patents, attempting to model the geographically mediated externalities from university research as a type of local public good. Even further back to Nelson (1959) and Arrow (1972), economists delineated knowledge as a non-rival input asset and knowledge spillover bounded in space as local externality, by which the source institution(university)'s knowledge flows and ends up promoting other institutions' innovative activities, describing it as 'in the air' (Arora, Fosfuri et al. 2001, Breschi and Lissoni 2001). The typical notion of local externality by MAR assumes: (1) economies of specialisation that provide industry-specific inputs to specialised local suppliers thus inducing economies of scale, (2) economies of labour market that lead to the creation of large skilled labour pools, smoothing the effects of employment stability (3) knowledge spillovers within the local area caused by reciprocal trust and frequent informal contacts. While local externality does not always entail pecuniary compensation, the former two assumptions (economies of specialisation and labour market) occur through market transactions (Krugman 1991). Despite the two different transmitting mechanisms, the empirical studies on regional externality do not seem to disentangle pecuniary and non-pecuniary technology transfer (Krugman 1991). Breschi and Lissoni (2001) demonstrate that the treatment of knowledge spillovers as homogeneous might lead to a biased approach in theoretical ground and policy implications.

After assessing the impact of technology flows by the production function of with patents or innovative activities, several empirical studies report that the economic activities tend to overestimate pure knowledge spillovers but underestimate pecuniary technology transfer, partly due to measurement errors and the difficulty of isolating the entangled nature of knowledge and technology (Griliches 1992, Geroski 1995, Marcotte and Niosi 2000, Breschi and Lissoni 2001). Thus, the blurred distinction makes it difficult to model the region's structural changes of innovative outcomes in case exogenous technology flows into the regional innovation system as a new technology source (Jaffe 1989, Audretsch and Lehmann 2005).

*Table 1 Comparison between pure knowledge spillover and market mediated technology transfer*

| Criteria | Pure knowledge spillover | Market mediated technology transfer |
|---|---|---|
| Main motivation | Academic learning | Commercial usage for economic activity |
| Economic compensation | Not necessary | Accompanying pecuniary compensation |
| Transmitting mechanism | Informal diffusion | Formal transaction via market |
| Enforcement | Not necessary | Including legal enforcement of rights |
| Information flow | Unidirectional way | Interactive way |
| Intermediary channels | Personal contact<br>Paper trail<br>Informal idea exchange | Patent licensing<br>Official consultancy |

Source: the author

Among a few scholars comparing the incidence of technology transfer through market transactions and pure (non-market) spillover within local areas, Breschi and Lissoni (2001) attempted to reveal the ambiguity of prior studies with the entailed risk of treating knowledge spillovers as homogeneous one. They exemplify that prevailing studies recognised the market-mediated mechanism as pure externalities, or even ignored it under the label of local knowledge spillover. For instance, Audretsch and Feldman (1996) examine the role of university R&D as the input factor for the production of localized innovations in the less aggregated technological areas. Their cross-section analysis finds that the geographical concentration of the innovation output is positively related to the R&D intensity of the industry, interpreting it as knowledge externality. However, Breschi and Lissoni (2001) are more cautious about the evidence of knowledge spillovers, as denoted :

> *This result reveals the 'propensity for innovative activity to cluster spatially', but the authors rush to relate it to what they call the 'considerable evidence supporting the existence of knowledge spillovers'. That is, they do not prove, but rather assume, the existence of knowledge externalities and then recall it as the only reasonable explanation for their results. [page 984-985]*

In a similar way, Feldman and Florida (1994) employ the innovation production function for 13 three-digit industry sectors at state level. Although their goal is to verify the existence of agglomeration externality, they do not discern the kinds of externalities, calling it under the name of the network effect which might be defined either through the market and non-market mechanisms. What they consider the relationship between geographical coincidences of technology transfer as important is for small firms, due to the heavy R&D cost. They simply presume that small firms rely on the university to the extent they could reach, but Breschi and Lissoni (2001) argue that some innovative small firms may be readier to subcontract their research projects to academic institutions. The increase of innovative activities, proxied by patent counts, was explained by the contribution of local knowledge spillovers, however, the robust evidence of direct linkage has still remained unanswered.

In the case of Europe regions, Moreno, Paci et al. (2006) investigate 175 sub-national regions to examine whether the regional externalities come from specialisation or diversity externalities. They regard the innovative activity as patents per capita in a sector and a region. According to their econometric analysis, a region's innovation activity of a given technology sector is affected by the degree of specialisation rather than the degree of innovation diversity. The spatial analysis supports that some externalities flow across the regional borders, but not over the national borders. Technological proximity, however, does not prove to influence innovative activities, if not with geographical proximity. As far as the extent of pure and pecuniary externality are concerned, it is worth noting that the pure spillover turns out to be a positive localisation externality. On the other hand, pecuniary externalities involved in the case of production activities have turned negative, making the delocalisation. Although they did not explain the opposite relationship between two externalities and geographical proximity, they hint at the idea that delocalisation might work for the technology transfer as a more convenient process. Moreover, the result implies that local externality is mixed up of not just a pure one but also of a pecuniary nature, and thus each externality has a different geographical incidence. For instance, market-mediated technology spillover does not have a beneficiary effect or at least is not sensitive to geographical proximity.

Only a few studies directly compare the geographical incidence of the market and non-market technology transfer. Mowery and Ziedonis (2015) recently examine pure and market-mediated outflows of universities' research outcome by comparing the regional incidence of pure knowledge (citations to university patents) with market-mediated technology (license) that originated from identical technology. They count the number of citations to 911 patents of three universities -Columbia University, Stanford University, and the University of California as a proxy of pure knowledge while including both exclusive and non-exclusive licensing contract as for market-mediated technology. Their analysis basically corroborates the well-proved influence of geographic proximity as a determinant factor for both pure knowledge spillovers and market-mediated, but adds further insight in that patent licensing tends to be more sensitive to the distance from a university campus than does citation. The primary reason for such different local proximity, they argue, lies on the tacitness nature of knowledge that establishes the intimate interactive relationship with the patent inventor, which is more likely to be promoted by proximity. Thus, the technology acquisition for the economic purpose including technology commercialisation requires closer geographic proximity for transmitting technology than a pure knowledge spillover does.

Another recent work by Azagra-Caro, Barberá-Tomás et al. (2017) captures the moment in transforming knowledge transfer into the economic impact on local areas. Their case study of top level patent (the comb drive patent) finds that market-oriented activities proxied by licensing are more geographically clustered than are general knowledge activities reflected in publications. The average distance of a licensing firm is 1,880 miles, while the average distance for a publishing firm is 2,832 miles. However, despite their contribution to compare the pure and pecuniary spillover, the case relies on a small number of highly cited patents in a specific technology sector – MEMS (Micro-ElectroMechanical Systems), which makes it hard to control the sector-specific effect. From the U.S. licensing database, Drivas and Economidou (2015) also find the localisation of patent transactions, implying that regional borderlines tend to be more geographically bounded. In sum, the geographical proximity matters even in market-mediated technology diffusion. This is partly because the tacit knowledge (know-how) tends to be imperfectly codified so that the licensee still invests time and resources in order to acquire relevant information for successful commercialisation (Agrawal, 2006).

Previous empirical research disentangles market-mediated technology externality from two types of regional externality and assumes that transmission of technology is a reciprocal activity for all the parties or at least no-risk to the technology inventor. Empirical studies reporting on technology spill-overs mainly rely on the unidirectional linkage from university to industry. Thus, the conflicting interest and motivation of the technology inventor and purchaser, embedded in the pecuniary technology transfer agreement transaction, is not fully reflected in their cases. A corollary of this assumption, however, might not account for the transmission of technology exchanged between firms. What this research emphases is to explore the risk embedded in the market-mediated technology to develop new insights into the process of transmitting technology across the geographical space, in this case drawing upon patent license as for pecuniary technology transfer.

### 2.3.3. The market uncertainty in technology transfer via licensing

***Licensing as a metric fort market-mediated technology transfer***

This research argues that patent licensing may be a highly accurate and notable measure to capture market-mediated transfer nature and the market risks. First, information on licensing data indicates the process by which technology with economic value is produced and transmitted to contribute economic value (Nelson 2009). Compared to other transmission metrics, the technology licensing permits intellectual property from the licensor to licensee via pecuniary compensation (Arora, Fosfuri et al. 2001). Specifically, the trails on patent licensing reveal which technology sectors, the purchaser and the owners, as well as their regions. Thus, the trend of the patent licensing contract is informative to show which technology field is currently commercialised for potential economic value.

A second reason is that a license represents the conflicting interests of the patent owner and licensees embedded in the process of the license agreement that results in a capture of firms' economic-oriented business contract. The motivation of the licensor is to maximise the revenue by allowing a licensee to utilise right-of-use, while the licensee party is willing to not only minimise the license cost including annual loyalty fee but also secure the appropriation of the rights (Wang, Zhou et al. 2013).

Third, the patent licensing data depict the relationship between both parties rather than a one-time knowledge transmission, furthering the comprehensive picture of the transaction. The licensing contract, particularly entailed with contracts enforcing the payment related product revenue, enforces a licensor to monitor the licensee's products during the contract periods. As a result of this long time horizon, licensing is considered an appealing measure to examine long-term network relations between the technology owner and the purchaser compared to other knowledge transfer channels, (Nelson 2009).

***The mutual uncertainties in market mediated technology transfer***

It must be emphasized that the market risk and risk-aversion motivation lies at the heart of explaining the geographical proximity of technology transfer. Compared to pure knowledge spillovers, market-mediated technology transfer proxied by patent licensing is acquired and transmitted through the codified formal channels in the technology market (Azagra-Caro, Barberá-Tomás et al. 2017). Audretsch and Stephan (1996) argue that geographical proximity between licensors and licensees is not necessary for the operation of compensated technology transfer, mainly due to the codified characteristics of patents information. The readily transferable "off the shelf" inventions also found transferring more readily across spatial boundaries (Zander and Kogut 1995). Based on empirical evidence from the German biotechnology sector, Ter Wal (2014) reported that a higher level of codification in the field has relieved the spatial restrictions on technology transfer. Arundel and Geuna (2004) show that the codified form of technology has decreased influence over the spatial proximity on the basis of ordered-logit estimation results from PACE survey data which collected from Europe's largest R&D-performing industrial and manufacturing firms. It is also worth noting that the difference between the average distance of patent citation and patent licensees, has no significant difference (Nelson 2009). Although their cases are based on a small number of top-tier class patents, it implies that the influence of spatial proximity has no fundamental difference between a pure knowledge spillover and pecuniary transfer.

The above studies implicitly presume that the higher codifiability of technology might be interpreted as a means of risk-aversion strategy that a potential licensee could choose for a safe transaction.

In this vein, nonetheless, less attention has been paid to the market risk, the dynamic inter-relationship embedded in the seller and buyer. It is important to note that the market risk and risk-aversion motivation underpinning the local knowledge spillover lies at the heart of explaining the geographical proximity of technology diffusion. The patent licensing allows licensees to profit from the licensor's intellectual property rights (Williamson 1991). The technology licensing transaction generates two effects: (1) the licensor's profit from payment, and (2) the profit dissipation effect caused by potential competition in the market (Arora and Fosfuri 2003). According to Fosfuri (2006), one of the key determinants of the licensing decision is not just the profits from payments by licensee institutions, but also that the potential reduction might occur as a result of an additional firm competing in the market, or even an aggressive strategy from existing competitors. Thus, technology transfer could lead to revenue trade-off between the increase in royalty revenues and the potential risk of decreasing market share within an overlapped market, leading to an even more complicated analysis.

One of the primary risks for the technology licensor in the process of knowledge spillover is to avoid profit dissipation effects. From the perspective of a firm's interests, the licensor firms are highly likely to reduce potential risk by selecting partners in a downstream market, looking to other geographical markets rather than local areas (Fosfuri 2006). When confronted with limited resources, for instance, small firms may have to absorb external technology. In this case, the transferors have incentives to impose limitations on use of the technology in order to inhibit possible opportunistic behaviour by the potential licensees on the basis of a legal contract (Teece 1981). Typical limitations relate to the geographical scope, the duration of the license and the technological specifications to be met among others (Bidault and Fischer 1994). More specifically, the licensor should consider the market condition that may threaten its own profits. Such potential risks of the licensor become more likely when it is from the private sector and the licensee originates from geographically close and highly competitive locations. In such settings, it may be hard for the licensor to make a license contract.

In other attempts to limit risk, the potential licensee also seeks a technology supplier within its trust-built network in order to reduce the uncertainty of the technology and hedge its purchase. The patent licensing might be involved in the transaction risks of a partner's opportunistic behaviour (Bathelt and Henn 2014). The technology transfer contracts are highly likely to consist of explicit licensing rights with intangible know-how. As a technology transfer on a transaction is not a unidirectional activity, the technology purchaser and supplier need to mutually consent to the process of setting the price scheme, negotiating legal rights and providing instructions including tacit know-how.

While the technology transfer via a licensing agreement consists of the explicitly codified type of knowledge with legal rights, the licensee still has market risks in acquiring the technology. First of all, the licensee firm might be involved in the partner's opportunistic behaviour or lack of candour and honesty in the transaction (Bathelt and Henn 2014). The literature is full of accounts about companies that suffer from a lemon problem due to asymmetric information about the quality of the technology, or dear price (Mayer and Salomon 2006). As a decision maker for a commercialising firm, it is particularly difficult for a licensee firm to assess the future potential value of the technology in the market.

Given the uncertainty, one of the strategic decisions of a licensee is to seek the partners within its own trust-based local networks and to monitor the licensor's reputations through different informal channels (Gertler 2003). This action also involves risks related to preventing opportunistic behaviours among partners (Bidault and Fischer 1994). The geographical distance between licensors and licensees might even enhance the risk more than partners located within local areas, as physical distance could obscure the monitoring of other parties' activities. In practice, the incidence of the potential threat of enforcing sanctions, including a legal action and indirect collective action, attenuates along with the distance between the parties.

Second, technology license agreements cover not only explicit legal rights but also tacit knowledge (Horwitz 2007). Technology licensing is rather a process of establishing the network, not a one-off transaction in the market (Nelson 2009). A license agreement builds up the relationship, which acts as a vehicle to convey tacit knowledge from a licensor firm to a licensee firm, in exchange for the monitoring enforcement to the licensee (Hagedoorn 1993). After the agreement, the licensor has incentives or at least an obligation to implement the transmission of a large set of information to the licensee. A package of knowledge set is incorporated in claims of patents or proprietary know-how information (Horwitz 2007). The non-codifiable information including future non-patentable inventions for the improvements, trade secrets, methods of manufacture, or other proprietary or non-proprietary information, all of which are hardly documented, might be transmitted to the licensors in the form of training, regular meetings and informal contacts (Wang, Zhou et al. 2013). A license agreement builds up the relationship, which acts as a vehicle to convey tacit knowledge from a licensor firm to a licensee firm, in exchange for the monitoring enforcement to the licensee (Hagedoorn, 1993). Such kinds of interactive contacts, as the most reliable manner of delivering and acquiring the tacit knowledge that the licensor has, might be through communications, which in turn are promoted by geographical proximity (Bathelt & Turi, 2011; Maskell & Malmberg, 1999). The potential licensee is likely to prefer to explore the experienced master in local neighbours first. As the intimate relationship is built up through past interactions and reputations, the technology purchaser does not just increase the chances for absorbing the master company's tacit knowledge but also facilitates the trust network. Consequently, the strong interactions might serve as a restraint against opportunistic behaviour by the partners in the local network. In other words, the existence of skilled technology providers in the regions also strengthens the centripetal pull, establishing regions' institutional and social idiosyncrasy, reinforcing path-dependent externality and preserving the initial local advantages (Gertler 2003).

Third, the pecuniary technology transfer entails the longer processes for the complementing of a case: identifying the potential partner, negotiating the contract, determining the price, transmitting detailed technological knowledge and monitoring the licensee's utilisation of the technology (Bidault 1989). It is clear that the whole process is involved in the cost shared by both parties. Potential buyers will not be all the same in terms of transaction costs. Obviously, contracting with an already known partner will be different from dealing with a potential licensee that is totally unrelated. For instance, if the licensee has been a subcontractor for many years, the cost of negotiation will be reduced, presumably because a certain level of trust already exists between the partners. For both partners, the supplier and the buyer, the transaction costs will be much less than dealing with a company with which they have had no experience.

## 2.4. Anchor region in transferring market mediated technology

This section discusses the anchor tenant to provide a logical connection linking the relationship between market-risks embedded in the market-mediated technology transfer and the strategic behaviour of avoiding them. The first subsection reinterprets the anchor tenant as a source of technology in the region after reviewing previous notions. The next subsection explores the role of anchor tenants, under the presence of reciprocal risks involved in both parties. Then, the third subsection extends the anchor tenant by providing a lens into the network concept in order to explore the structural properties and interactive relationships embedded in the innovation system.

### 2.4.1. Anchor region in market-mediated technology

The pivotal role played by some key actors in the knowledge diffusion across geographical cluster has been highlighted in the multiple approaches under different concepts (Boari and Lipparini 1999, Agrawal and Cockburn 2002, Feldman 2003, Giuliani 2005, Munari, Sobrero et al. 2012). Lorenzoni and Baden-Fuller (1995) describe the role of focal actors in an industrial district as the 'strategic centers' that lead the survival and development of the district. The effect of an anchor tenant applied to the local development of the shopping centre allures a high volume of customers (Eppli and Shilling 1995, Pashigian and Gould 1998, Feldman 2003). The anchor tenant concept generally denotes large locally embedded institutions including universities, government labs, research institutes and other entities, that is of significant importance to the regional economy where they are based (Feldman 2003). The viability of the co-located smaller sellers within the shopping mall depends on the presence of the anchor tenant's brand recognition that generates a better local externality than they would in other locations (Gatzlaff, Sirmans et al. 1994).

This anchor concept is extended to account for the presence of a leading role in innovation activities including R&D intensive firms (Agrawal and Cockburn 2003), the aircraft industry (Niosi and Zhegu 2010) and the biotech industry (Feldman 2003). Spencer (2013) presents that a large technologically sophisticated global firm serves as a catalyst for innovation, labour force development and trade. Feldman (2003) also stressed the creation of a local labour pool and demand for specialised products in the form of agglomeration driven by anchors to benefit smaller firms including start-ups. Thus, this can positively affect firm survival and growth and subsequently the viability of the regions, providing positive agglomeration effects on a region by spinning off new local innovative firms and by attracting other innovative firms to the region (Feldman 2003, Niosi and Zhegu 2010, Bilbao-Osorio, Dutta et al. 2013).

In the context of technology spillover, Agrawal and Cockburn (2003) argue that the main role of the anchor tenant is creating and transmitting technology to the smaller neighbour firms by establishing technological capacity from R&D activities. For instance, anchor firms attract skilled labour pools, specialised intermediate industries and provide new technology firms in the region. An established anchor tenant provides expertise and knowledge about specific applications, product markets and technical development trajectories that move generic scientific innovations in a particular direction, which, over time, may distinguish the specialisation of the industrial cluster. The research links with local firms, the creation of academic spin-off firms and generation of 'knowledge spillover' more generally, can also enable strong public research universities to become the nucleus of what Markusen and Oden (1996) refer to 'state-anchored industrial districts' in science sectors.

If there is a regional anchor with a complex set of technology in a specific technology sector, the existing firms or start-ups are more likely to specialise in that field. Once the region is noted to have developed professional skills, entities that commercialise the technology into the product market may be encouraged to carry the expertise in the form of licensing or spinoffs in the region. Consequently, a cluster accumulates the knowledge and technology in the region, then reinforces the process of developing that specialised expertise. After the repetitive process, a regional path dependency, derived from the technology created in the anchor, acts as a determining factor for promoting new entrepreneurs in the region (Feldman 2003).

*Table 2 The role of Anchor entity*

| Studies | Area | Main roles of anchor entity |
|---|---|---|
| Eppli and Shilling (1995) | Shopping centre in US | Developing opportunity by increasing cross-patronage effect |
| Pashigian and Gould (1998) | Shopping malls | Alluring customers to the mall and generating mall traffic, thus lead to increased sales and reduced cost of smaller stores |
| Feldman (2003) | Biotech industry in the US | Help start-up firms to find and develop niche market<br>Facilitate the commercialisation process |
| Agrawal and Cockburn (2003) | Research activity in US and Canada metropolitan areas | Enhances the regional innovation system by transforming the local university research into local industrial R&D<br>Stimulate the local industrial R&D |
| Niosi and Zhegu (2010) | Aircraft clusters in the US | Produces positive agglomeration effects by spinning off new companies and attracting other innovative firms to the region. |
| Karlsen (2012) | Oil and Gas industry in Norway (Agder) | Upgrade knowledge stock as a world-class company as an external knowledge source to local firms |

Source: the author

Although there is no consensus in defining an anchor tenant, the anchor tenant generally refers to firms that have a key position in the regional economy through interactive relationship with other entities in the region where the market structure is dominated by one large, vertically integrated firm (Markusen and Oden 1996). They discuss the role as a regional anchor in connection with size. Regional anchors can also have other characteristics than size (Karlsen 2012). One such characteristic is if companies perform their own brand manufacturing (Kishimoto 2004). Goddard, Coombes et al. (2014) refer to large locally embedded institutions, typically non-governmental public sector, cultural or other civic organisations, that are of significant importance to the economy and the wider community life of the cities in which they are based

### 2.4.2. The role of anchor regions and regional innovation outcomes

This section explores the role of anchor tenants, under the presence of mutual risks involved in both parties, in the technology transfer within the geographical space.

First, the anchor firm is likely to act as a primary technology producer in the region or cluster market, which underpins the externality. Nonetheless, this role is clearer if the tenant is in public-purpose institutions including a university, research-oriented hospital, or public-funded institutions. The higher level of R&D capacity and larger size of anchor firms may also be a better position for creating and providing technologies than an equivalent number of small firms. According to Agrawal and Cockburn (2003), anchor firms are engaged in R&D in general and have an absorptive capacity in a specific technology sector. By virtue of its expertise in local markets for technology, the anchor firm contributes significant externalities upon other co-located firms. The impact is even more significant for smaller size firms, suggesting that R&D expenditure is usually too costly for small firms to substitute (Acs, Audretsch et al. 1994). These externalities may promote spillover for firms to seek to lower their costs, and improve their prospects for future growth. It is, therefore, the presence of an anchor tenant firm, which leads to enhance the regional innovation system, in that localised knowledge is absorbed by and to stimulate the knowledge innovation capacity level of the region (Agrawal and Cockburn 2003).

Although the strategic decision of an anchor firm to do license-out is a function of multiple variables including a business value-chain, R&D intensity and competition level in the technology market, a leading-firm is likely to have a motivation to establish an interactive technology value-chain network with the co-located firms. What is important is the extent to which an anchor firm works with other parts of the value chain to integrate smaller co-located firms to function as a regional system of higher efficiency (Breznitz and Anderson 2005). For instance, the anchor firms have incentives to setup a subordinate value-chain network with local suppliers, because suppliers are smaller, less powerful and quite dependent on the anchor (Markusen 1996).

On the demand side, the anchor tenant's demands for local resources such as intellectual-property legal counsel, technology-oriented marketing and human resources services also indirectly generate a local demanding force for smaller neighbour firms. Anchor tenants purchase products, licenses, consulting services and sometimes entire companies. The impact of demand on 'intermediate' markets for the regional smaller firms from large anchor firms provides a quite bigger market than the aggregated demand of many smaller firms. By possessing a better standard of quality level and information about the final demand in the markets, the local suppliers may be able to keep up with the equivalent level of quality and products, which small firms cannot (Agrawal and Cockburn 2003). The volume of their transactions in local markets for R&D inputs and outputs may have a significant impact on liquidity, pricing efficiency and related transaction costs. Then, the anchor firm is in the top position of the technological hierarchy, dominating the majority of creating, transmitting localised technology to the region. In this case, this research proposes that the presence of an anchor firm enhances the efficiency of the innovative system of the region.

Second, an anchor tenant is an entity that has a key position in connecting the local firms in the regional economy with the global market through their interaction with suppliers and other companies (Markusen 1996, Feldman 2003). The connecting role of an anchor firm in supplying advanced technology to the local market firms matters in the development of the regional capacity level. For the smaller firms, it is important that the external sources underpinning internal innovation processes allow firms to access knowledge that they cannot generate with internal resources (Bergenholtz and Waldstrøm 2011). The use of exogenous technology confers firms with strategic opportunities of avoiding the high costs of internal development (Noori 1990), and even gaining access to state of the art technology (Chatterji and Manuel 1993). From the perspective of learning and innovation, external technology acquiring represents the efforts of a firm to gain a means of reaching the technological knowledge that lies outside its boundaries. Thus, the firm may accumulate its technological knowledge (Cohen and Levinthal 1989) and strengthen its technological capability from the search and use of external technology, and then it could enhance greater performance through product or process innovation. Nevertheless, isolated firms no longer meet market demands without a complex set of interactions with the externally acquired set of knowledge (Owen-Smith and Powell 2004, Roper, Du et al. 2008). Recently, the 'open innovation' paradigm motivated institutions to be readier to utilise exogenous technology (Chesbrough 2003). In addition, due to the increased technological complexity, diversification of customer needs, technological convergence and shorter product life-cycles, it is becoming difficult and inefficient for firms to develop all technologies required for providing new products or services by themselves. This suggests the importance of the anchor's external source as a conduit for acquiring exogenous technology to the local market. The high searching and matching costs for identifying external partners leave considerable risk for small firms that are more likely to occur when the size of firms is small with limited capacity. An effective way to reduce risk, therefore, is to utilise the established networks that local anchors already have.

Third, the presence of anchor firms are likely to confer a positive externality on the efficiency of the innovative system with which local firms translate knowledge into local commercial technology. Agrawal and Cockburn (2003), based on three technology sectors, assess the degree to which university research and industrial R&D associated with certain technical areas are concentrated. What they find is the degree to which university research and commercial research activity are geographically concentrated, which represent the pure knowledge spillovers and market mediated technology spillovers, respectively. They interpret the magnitude of this effect as the evidence of the presence of anchor tenant firms in the local economy.

Anchor tenants may be directly involved in the commercialisation of university inventions. There are many examples of large, established firms working directly with universities in the context of collaborative research, co-supervising graduate students, sponsoring labs, licensing the rights to university inventions, recruiting graduate students, and hiring professors as consultants to directly leverage university research (Agrawal and Cockburn 2002).

In sum, the critical point is the extent to which anchor work with co-located smaller firms which is part of the value chain to enable their locations to function as innovative regions in the creation, transfer and commercialisation of technology (Feldman 2003, Breznitz and Anderson 2005).

### 2.4.3. The systematic approach of an Anchor tenant in the innovation network

***Network approach***

This section extends the anchor tenant through providing a lens into the network concept in order to explore the structural properties and interactive relationships embedded in the innovation system (Bergman and Maier 2009, Ter Wal and Boschma 2009, Maggioni and Uberti 2011, Aguiléra, Lethiais et al. 2012, Balland 2012, Knoben and Oerlemans 2012, Boschma, Eriksson et al. 2014, Huggins and Prokop 2016). The network metaphor has been widely accepted in the economic geography and regional innovation literature, suggesting the relevance of networks for a regional innovation system (Asheim, Cooke et al. 2008, Cooke, Asheim et al. 2011, Huggins and Prokop 2016).

Specifically, within a flow of knowledge/technology flow environment, the inter-relationship (firm-to-firm, region-to-region, and country-to-country), the entity of technology activities (sources/target), and the flow are recognised as the relation, links and nodes, respectively, all of which constitute the networks. The network concept, however, confers to better explain how the overall positioning and centrality of the individual entity within networks are linked (Huggins and Prokop 2016).

In recent years, the emergence of the network concept has led to a vast interest in explaining structural properties pertaining to knowledge/technology flows and patterns of innovative activities (Dicken and Malmberg 2001, Bathelt and Glückler 2003, Gluckler 2007, Capello and Lenzi 2013, Huggins and Thompson 2014, Huggins and Prokop 2016). The analytical indices derived from a social network push further to reveal characteristics of structures and actors in technology sourcing and transfer at multiple levels of entities.

The concept of a small-world network refers to clusters of locally dense interaction connected through the small number of bridging ties (Watts and Strogatz 1998). Small-world networks exhibit tight clusters of local interaction linked by nonlocal interactions whereby any node in the network can reach others. From the perspective of information flow, it is highlighted that small-world networks structure facilitate knowledge flow (Fleming, King Iii et al. 2007), and empirical research seeks to forge the relationship between the small-world structure and economic activities (Watts and Strogatz 1998, Fleming, King Iii et al. 2007).

The empirical literature revealing the relationship between small-world network structure and regional innovation activity is not so rich, but one of the few is research by Fleming, King Iii et al. (2007). They use over two million co-authorship data from U.S. patents to measure the influence of small-world properties of regional networks on innovative performance. Their hypothesis that small-world structure properties would positively be associated with patent activities with the region, however, statistically result in being insignificant. Although their analysis is based on the pure-knowledge spillover, it can be argued hat the predictions remain problematic due to the locally contingent effects.

***The anchor entity in the technology transfer network: Small world network***

This research proposes that the presence of an anchor tenant in the regional innovation system is delineated as the structure of a small-world network. First, the anchor tenant connects internal firms to external knowledge sources as the key node acts as a bridging hub that runs between clusters in the network. The bridging ties between clusters provide actors with efficient access to non-redundant knowledge and new ideas which are not acquired within local actors (Granovetter 1983). Burt (2005) finds empirical evidence of the advantage of bridging ties in a person-to-person network and a similar mechanism has been widely suggested for organization level (McEvily and Zaheer 1999, Zaheer and Bell 2005).

The bridging ties can enable organisations to provide local entities with searching, tapping and utilising the external knowledge. The information, knowledge and technology that entity acquires through such hub ties are likely to be non-redundant since they are sourced from otherwise disconnected entities. It is likely that the entities in a highly competitive market, where the viability of firms rely on its capacity of creating technology by exploring and exploiting flows of diverse knowledge sources, are likely to be motivated to pursue bridging ties (Rowley, Behrens et al. 2000). In such circumstances, the new information from other networks serves as pockets of unique knowledge, as an input for effective recombination. Thus, the formation of bridging ties connecting clusters is likely to create shortcuts, where actors can reach one another through relatively short network paths (Cantner and Graf 2006).

Second, an anchor tenant creates knowledge externalities that increase overall innovative outputs of smaller local firms in the region, generating dominant power in the local market. From the perspective of a small-world network, a key node that connects other nodes within a cluster, culminates in a densely connected cluster. Due to the sparse resources and bounded rationality, a node economizes in their cost for searching and selecting those with whom they have some familiarity through prior experiences (Gulati and Gargiulo 1999, Zaheer, Hernandez et al. 2010).

Local partners in a cluster enable nodes to effectively tap into a network that generates background information on prospective partners, which prevents opportunistic behaviour. High-Density clusters create reputational lock-ins to avoid non-cooperative behaviour because of the increased circulation of reputational information. The formation of local ties can also occur as a result of technological proximity among nodes, in the case where nodes are aiming to achieve economy-of-scale, driving the emergence of dense local connectivity (Wang and Zajac 2007). Consequently, the dominant influence of a key node over the whole nodes in a cluster is interpreted as the influence of an anchor tenant in the regional innovation system.

***Glocalisation***

Then, the notion implicit in these two roles of the anchor tenant in the network might be interpreted as that of a glocalisation process in the context of economic geography literature.

'Glocalisation' refers to the twin process whereby, firstly, institutional/regulatory arrangements shift from the national scale both upwards to supra-national or global scales and downwards to the scale of the individual body or to local, urban or regional configurations and, secondly, economic activities and inter-firm networks are becoming simultaneously more localised/regionalised and transnational (Swyngedouw 2010).

The originality of the glocalisation argument lies in the political and economic dynamics derived from the rescaling process of global and local economic flows and networks.

However, what seems to be important from the perspective of the network perspective is both the inter-connecting hub for external cluster and a densely connected node for internal nodes in a cluster. More specifically, the notion of ‘local buzz and global pipelines' suggested by Bathelt and Turi (2011) also made a connection to the role of an anchor tenant in the context of the knowledge transfer process. Thus, if this research extends the scale for firm-to-firm levels to region-to-region level, the notion of an anchor tenant is likely to work due to the fundamental mechanism of how a key hub node behaves in the small-world network.

## 2.5. Conclusion

This chapter aims at providing a logical departing point for discerning the technology transfer from a pure knowledge spillover across spatial space. The first section provides a review of the literature on technology transfer across geographical borders, raising the question about the notion of regional externality which has been largely treated as homogenous spillover. The distinction between the pure knowledge spillover and pecuniary compensated technology makes it beneficial to identify the fundamental risks in transferring technology for the commercial use of knowledge across the regions. The investigation challenges the previous empirical works by Mowery and Ziedonis (2015), who find a consistent tendency for knowledge flows through market transactions to be more geographically localised than those operating through nonmarket spillovers. They argue that the result is mainly due to the incomplete nature of licensing contracts, as well as the need for licensees to maintain access to know how that is difficult to transmit through documents or long-distance communication. However, the hidden risk of a technology provider acts as a counter-force for agglomeration within geographical proximity. Given the technology licensor's strategy in the market, the primary criterion for the decision is to avert profit dissipation effects within the local market. The licensor firms are motivated to avoid potential risk by selecting partners in a distant market (Fosfuri 2006). In contrast, the purchaser tends to prefer local providers not just to avoid the opportunistic behaviour of the provider but also to acquire the intangible know-how by securing a trust- built network, which is likely to be in the local network. The uncertainties of a technology provider act as a counter force to the agglomeration effect within the geographical cluster. Thus, the geographical proximity between technology source and acquirer, which was portrayed as a prototypical externality to the development of innovative activities, needs different approaches depending on the motivation of spill-overs.

By drawing upon the notion of anchor tenant, the role of anchor tenants as a source of technology provider is discussed in the subsequent section. First, the anchor firm is likely to act as a primary technology producer in the spatially bounded market, which underpins the regional externality. On the demand side, the impact of demand from large anchor firms on ‘‘intermediate’’ markets for the regional smaller firms provide a quite bigger market different from the aggregate demand of many smaller firms. Second, anchor companies are companies that have a key position to connect the local firms in the regional economy with the global market through their interaction with suppliers and other companies, suggesting the importance of an anchor's external source as a conduit for acquiring exogenous technology to the local market. Then, the network concept is applied in order to explore the structural properties and interactive relationships embedded in the innovation system. This research proposes that the presence of an anchor tenant in the regional innovation system is described as the structure of a small-world network. First, the anchor tenant connects internal firms to external knowledge sources as the key node acts as a bridging hub that runs between clusters in the network. Second, an anchor tenant creates knowledge externalities that increase overall innovative outputs of smaller local firms in the region.

Recalling the first research question of this study, what is the major mutual uncertainty that both parties involved in market-mediated technology transfer across space, in contrast to those of the pure knowledge spillovers? Answering this question broadens the understanding to the extent which the effects of agglomeration influence the innovative activities in the region. The pure knowledge spillover triggered by a university occurs in a unidirectional way from knowledge source to target, while the market-mediated technology is exchanged in an interactive way with the intentional purpose of maximising profit. Thus, the licensor firms, as technology provider, are highly likely to avoid potential risk by selecting partners in a downstream market, looking to other geographical markets (Fosfuri 2006). Meanwhile, the purchaser tends to still rely on a proximity partner to avert the opportunistic behaviour by maximising the reliability from the local network.

The exploration of the second question of what is the role of an anchor tenant might reveal the contribution of conferring a significant externality upon other co-located firms. What this research argues is that anchor firms have a key position to connect the local firms in the regional economy with the global market through their interaction with suppliers and other companies (Markusen 1996, Feldman 2003). The last question dealing with the extent to which an anchor tenant contributes to the innovation system is addressed by the concept of small-world network. The analysis of the last question reveals the structural similarity in the perspective of small-world network, suggesting that the anchor tenant is highly likely to extend from firm level to region level in the form of a network.

# Chapter 3. Descriptive analysis of Chinese patent and licensing

## 3.1. Introduction

With the growing importance of knowledge-driven innovation, the creation and diffusion of technology have been highlighted as one of the main issues in innovation study and economic geography literature (Romer 1986, Krugman 1991, Audretsch and Stephan 1996, Breschi and Lissoni 2001, Jaffe and Trajtenberg 2002, Fritsch and Franke 2004, Miesing, Kriger et al. 2007). One of the empirical challenge scholars confronted is how to catch the invisible technology flow which they may be measured and tracked, as Audretsch and Feldman (2004) pointed, "How could knowledge spillovers be measured and identified?"

Scholars turned to recognized patent data as a robust proxy for the technology diffusion (Maruseth and Verspagen 2002, Audretsch and Feldman 2004, Nelson 2009, Mowery and Ziedonis 2015).The patent is widely accepted measures of technology innovation in that it is electronically accessible, related with inventiveness; classified by official categories, and contain the geographical information of the originations (Nelson 2009). The last feature, in particular, makes patents useful for tracing technology flows across the spatial boundaries by examining the address of patentee, and citation information (Choe, Lee et al. 2016).

Compared to other technology flow channels, the patent licensing data is an appealing robust measure of representing technology flow (Hall, Jaffe et al. 2005, Gambardella, Harhoff et al. 2008, Van Zeebroeck 2011, Fong, Chang et al. 2018). First, a licensee makes a conscious decision to use a patent because she well understands the economic value of that patent, which solves the economic value problem that the use of patent records have. Secondly, patent licensing data combine the merit of citation records and co-authorship. Similar to patent citations, patent licensing clearly refers to the source and the destination of technology flow. In addition, the licensing contract requires complex decision making by both parties on the availability, quality, usefulness, and price of patents, each of which requires a good understanding of the two parties and intensive interactions between them. Since the licensing agreements are highly likely to be applied in production or new business, it reflects the firm-level technology transactions.

In this vein, the trail on patent and its official transaction records depicts which regions create, exports, and absorb technologies, which is highly likely to serve as a robust evidence for regions' innovation capacity. The purpose of this chapter is to present a holistic description of patent activities in the region and technology sector levels, hence contributing to further understand the data structure. The remainder of the chapter is organised as follows. The section 2 describes the data construction process and reviews the relevant literature on technology flows and identify the determinants. The next two sections explore the statistical characteristics of the patent application and license dataset, respectively. The last section 5 sums up.

## 3.2. The Chinese government policy for promoting patents

With the aim of promoting technology development, China actively took shape of policies to establish the technology transfer system in the late 1980s. Chinese Communist Party, aiming at promoting technology achievements, publicised series of fundamental plans. In 1985, the publication of 'State Council's Interim Provisions on Technology Transfer' stimulated a market for state-funded technology. After two years, China government set up a new direction of 'Technology Contract Law' which guaranteed technology contracting parties' legal rights as a part of policy means to stimulate technology market, especially technology transfer from universities (Chen, Patton et al. 2016). In 1988, China propelled the 'Torch Program', the initiative plan to trigger the growth of technology firms in specialised zones co-located in universities and research institutes. The program includes the high-technology development plan that lowered regulation barriers, supported for facilities to attract foreign investment, and encouraged the establishment of start-ups in the specialised cluster (Kenney, Breznitz et al. 2013). The policies seemed to pave way for the success case of the spin-off of top-class universities. For instance, Lenovo was a spin-off from the Chinese Academy of Sciences in 1984, and Beijing University rolls out Founder Computer in 1986 (Zhu and Frame 1987, Lu 2000) .

In 1992, the State Council announced ‘Ten-Year Plan for the Development of Science and Technology’. As a part of actions calling for the market mechanism, China also emphasized the technology market. It is notable that the Chinese government established the fundamental infrastructures for settling technology market system in these periods. The authority promoted more technology staff to establish technology-based firms, to construct technological centres at the centre of firms, and to increase intangible assets. The Chinese government passed ‘Scientific and Technological Progress Law’ which permitted university inventors to transfer ownership of patents to licensees; it is similarly regarded as Bayh-Dole Act in the U.S (Chen, Patton et al. 2016).

In 1994, the State Science and Technology Commission stressed to develop technology exchange by establishing the intermediary organizations of the engineering research centre, the productivity promotion centre, and the technology incubation centre. In the late 1990s, the Chinese government led the innovative actors (research institutes and the universities) to transform technology achievements toward the market. Shanghai Technology Property Rights Exchange was established in 1999 so that China would realize resource integration in the technology market, and the property rights market (Wang, Zhou et al. 2013).

In 1999, the several policy mixes further stipulated that universities could use a variety of strategies to commercialize high-technology, including establishing their own firms. In the same year, the Ministry of Education issued regulations allowing researchers to invent and transfer technology by clearly defining university responsibilities in intellectual property protection.

The technology transfer system seems to serve as a conduit for innovation capacity after the mid-2000s. Chinese State Council made a pronouncement on the 'Outline of the Program for the State Long-term Science and Technology Development (2006–2020)'. As a part of consequent technology transfer policy, China stated more than 60 consequent measures to support indigenous innovation such as the fiscal system, taxation, banking, industries, government purchases, introduction and absorption, and intellectual property rights. In 2002, the Ministry of Science and Technology and the Ministry of Education jointly implemented policies to increase the role of universities in the national innovation system (Chen, Patton et al. 2016). It led to support for university science parks and start-up networks. In 2007, the Ministry of Science and Technology, the Ministry of Education, and the Chinese Academy of Sciences publicised the National Technology Transfer Promotion Action Program that is intended for the creation of an enterprise-centric innovation system. The government also revised the Science and Technology Progress Law to enhance technology transfer and encourage local government support for research cooperation between industry and universities. In 2008 the State Council of China issued the National Intellectual Property Strategy Outline to promote intellectual property creation, utilization, protection, and management to establish an innovation capacity.

This government-led policy brings the remarkable growth of Chinese technology licensing market (Zhu and Frame 1987). The technology transfer services organizations have initiated in the 1980s, after three decades, 189,800 services organizations have been established. By the end of 2008, there had been more than 200 standing technology markets and nearly 40 transaction agencies with technological property rights and financial capital (Wang, Zhou et al. 2013). There had been 1,532 state productivity promotion centres which supplied services for small- and medium-sized enterprises, with 164 centres were at the national demonstrated level. The state promoted technology transfer by approving 134 demonstrated transfer institutions at the national level to take the lead, developing the regional alliances for technology transfer to promote technology cooperation in a certain region, and building the innovation relays to support multi-national technology transfer, international cooperation of production, teaching, research, and technology innovation for small- and medium-sized enterprises (Sun and Deng 2012).

It is still arguable that all the government policy is effective, however, the technology market shows a significant increase. Luan, Zhou et al. (2010) compared the remarkable increase in Chinese university patent applications to global trends in university patenting and found that, globally, patent applications increased steadily from 1998 to 2007. In 2008, the total increase was almost due to the increased Chinese university applications. They argued that the Chinese 2003 Bayh-Dole Regulations positively contributed to the increase in university patent activity. Although the increase in patents figure was an evidence of active commercialization activity (Chen, Patton et al. 2016), the activities are concentrated to a few top-class institutions, taking 14.2 % of universities and colleges had licensed the patent (Gao, Song et al. 2014).

At the same time, the efficacy of policy is reflected in the growth of university R&D expenditures. In 1991, China's R&D investment was RMB 15.08 billion, or approximately 0.7 % of the gross domestic product (GDP), and by 2013, R&D investment had increased to RMB 1.185 trillion, or approximately 2.01 % of GDP. The plans announced in 2015 plan to further increase funding to 2.5 % of GDP. Both University and research institute R&D experienced this increase. From 2004 to 2013, university R&D expenditures increased at an 18.9 % compound annual growth rate (CAGR), a historically unprecedented expansion, while the research institutes, which had a CAGR of 20.55 %, increased their budgets even more rapidly (Hershberg, Nabeshima et al. 2007).

## 3.3. The descriptive analysis of patents surge

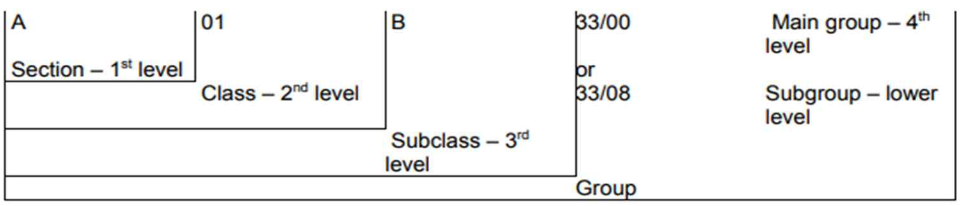
### 3.3.1. Patent data collection

This study selected China, one of the most dynamic economies within decades, as a case for describing technology flow. In its fast growth rate of hi-tech industries based on vast territory, China has spatial disparities in which a small number of leading-economy regions produce a major amount of knowledge-driven technologies. The patent data was retrieved and collected from the official Chinese patent authority SIPO[3]. The data, consisted of basic information (publication number, application number, application year), applicant information (nationality, prefecture-level address), and technology information, yields 1,446,577 cases from 1985 to 2014.

The collected patent is classified by a common classification code, International Patent Classification (IPC) that entered into force in 1975. The IPC, being a means for obtaining an internationally uniform classification of patent documents, has as its primary purpose the establishment of an effective search tool for the retrieval of patent documents by intellectual property offices and other users. The hierarchical structure is comprised of four principal levels: Section, Class, Subclass and Group[4].

*Figure 1 IPC Classification structure*

This scheme, however, is not appropriate for represent the industrial sector information.




Thus, the IPC code needs to be transformed into industry segmentation on the basis of NACE

[3] http://www.pss-system.gov.cn
[4] See the appendix for the further details on code classifications.

code, following the WIPO’s official guide. The technology trend is also captured by 6T classification (Bio, Mechanical, Electronics, CnTel, Chemical, Other technology) in accordance with Peri (2005)’s suggestion.

### 3.3.2. National-level analysis

Figure 2 shows how China has been ramping up patenting activities, both in terms of the Chinese and non-Chinese patent applications. The total number of patent application increased from 6 in 1985 to 12825 after 10 years. Then, it takes two years to reach over 20,000 in two years, consequently exceeds 100,000 in 2005. The highest point reaches at 151799 in 2009, yielding 34% of compound annual growth rate (CAGR).

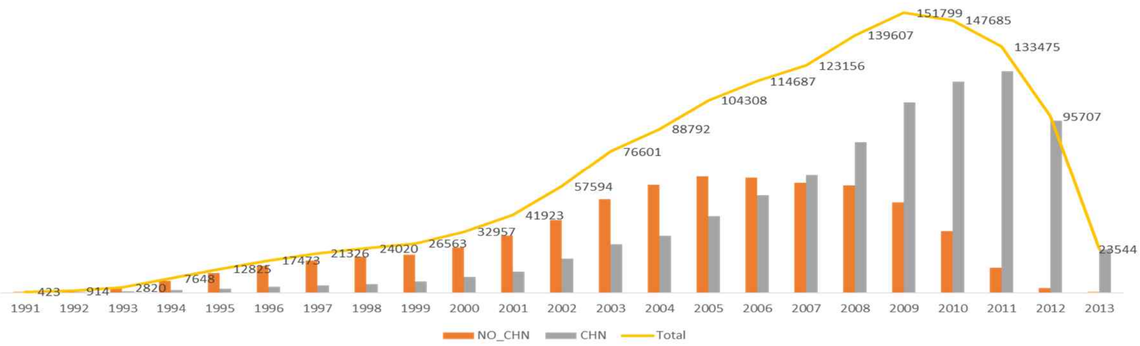



*Figure 2 Patent applications by Chinese nationality*

It is interesting to note that the non-Chinese patentees are China’s major technology sources for the past 15 years, as demonstrated in Figure 2. After non-Chinese patents reached their highest point in 2005 (62,891), they gradually declined to 2,528 in 2012. From 1985 to 2012, the total CAGR was 25%, accounting for dominant shares of the earlier period of total patent size. It is also worth noting that while the non-Chinese patents exert a critical influence on total technology production in the earlier period, the Chinese patentees have taken over rapidly recently. While the number of Chinese domestic owner was below 10,000 until the late of the 1990s, it has surpassed 20,000 in 2003, doubled it in 2005 and exceeded 100,000 in 2009. After 2007, the Chinese patentees went beyond non-Chinese, widening the gap between them. The CAGR of Chinese patentees during 1987 to 2013 even marked 43%.

Among the non-Chinese applications in Figure 3, Japan and U.S. account for 40% and 21%, respectively, which serves as major (over 60%) nationalities. Further, the top 5 countries including Germany, Korea, and France achieved 81% of total non-Chinese applicants, which results in highly skewed distributions of applicants consistent with a power-law distribution. It seems that the two Far Eastern countries - Japan and Korea – might influence the technology trajectories of China.

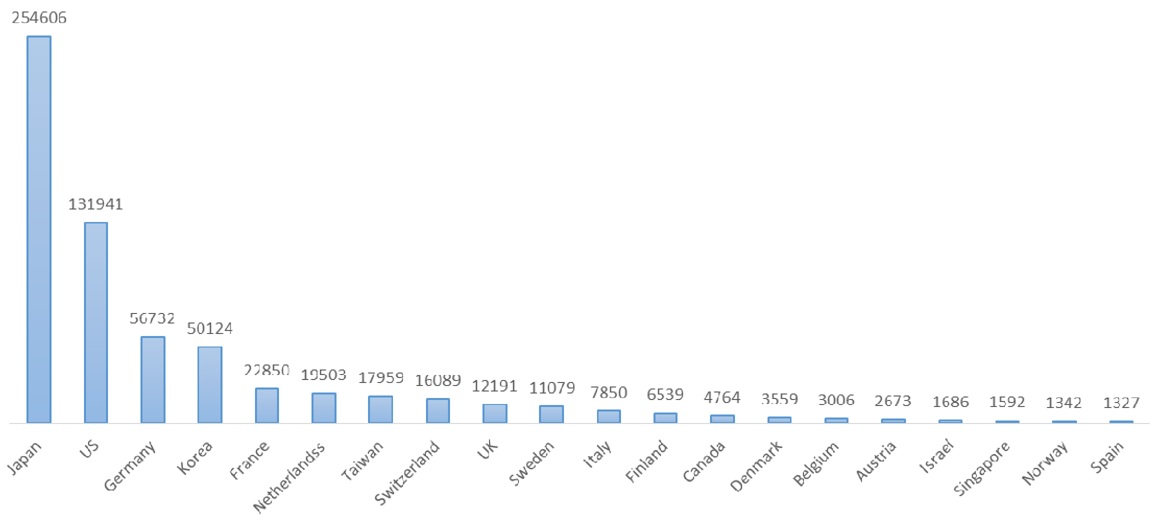



*Figure 3 Non-Chinese patent applications by nationalities*

Figure 4 compares the annual trend of patent applications of top 5 countries. US ranked in the first place from 1985 until 1993, while Japan overtakes it after 1994 and has gradually increased the margins of differences, exceeding 50% after 2009. Germany has maintained as a third rank thoroughly, while it fluctuates during the 2000s. Korea marked the increase from the early in the 1990s and showed a steady position of a second-tier country for technology products.

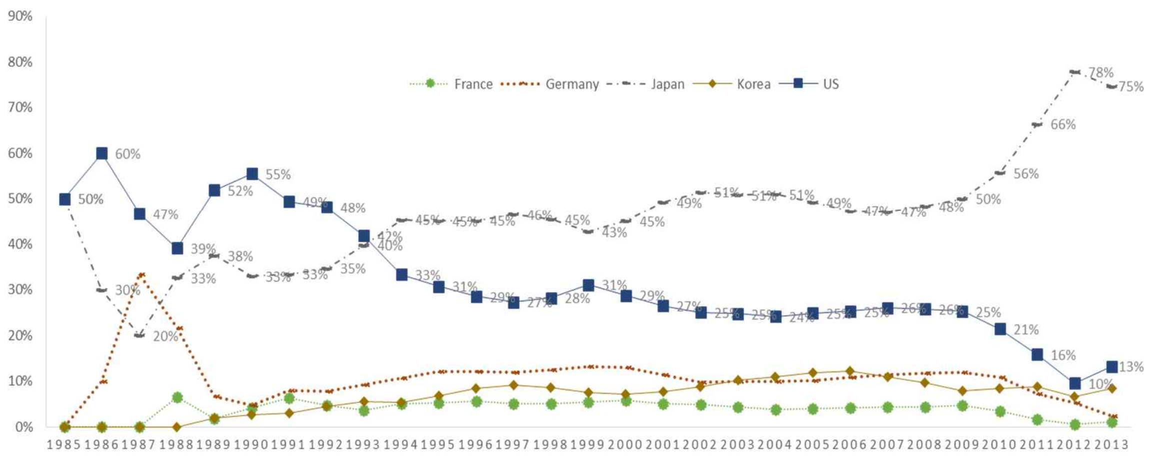



*Figure 4 Comparison of patent applications - top 5 foreign countries*

### 3.3.3. Region-level analysis

Table 3 reveals which major provincial-level regions have played an influential role in patent activities. This study classified 22 provinces, four municipalities, and five autonomous regions as for the provincial regions. The most prominent region of producing patents is Guangdong province, a coastal province of southeast China, accounting for 16% of total patent applications. It sits within its industrial Pearl River Delta (PRD) megalopolis located near Hong Kong and Macau. Beijing, the capital municipality and a core region of Bohai Gulf Rim (BGR), also showed a similar size of patents (15%). Zhejiang and Jiangsu Province, east coastal regions closed to Shanghai ranked third and fourth for the patent production, which leads Yantze Delta Region (YRD). Then, another core region of YRD, Shanghai, followed. Next, Shandong, an eastern area on the Yellow Sea hold 9%. It is interesting to note that the major influential regions sit in the east coastal areas. The landlocked province in Central China - Sichuan, Hubei, Shaanxi and Hunan – ranked below than coastal regions.

*Table 3 The shares of patent applications by Province-level regions*

| Regions | Patents | Shares | Regions | Patents | Shares |
|---|---|---|---|---|---|
| Guangdong | 126108 | 16% | Chongqing | 12488 | 2% |
| Beijing | 125358 | 15% | Hebei | 12139 | 1% |
| Jiangsu | 85555 | 11% | Jilin | 10107 | 1% |
| Shanghai | 70084 | 9% | Shanxi | 8951 | 1% |
| Zhejiang | 65334 | 8% | Yunnan | 8274 | 1% |
| Shandong | 46539 | 6% | Guangxi | 6475 | 1% |
| Liaoning | 26412 | 3% | Jiangxi | 5316 | 1% |
| Sichuan | 26264 | 3% | Guizhou | 5000 | 1% |
| Hubei | 24546 | 3% | Gansu | 4416 | 1% |
| Shaanxi | 22859 | 3% | Inner Mongolia | 3171 | 0% |
| Hunan | 21352 | 3% | Xinjiang | 2879 | 0% |
| Tianjin | 21335 | 3% | Hainan | 1999 | 0% |
| Anhui | 17875 | 2% | Ningxia | 1105 | 0% |
| Henan | 17777 | 2% | Ginghai | 626 | 0% |
| Fujian | 14965 | 2% | Tibet | 205 | 0% |
| Heilongjiang | 14955 | 2% | | | |

Figure 5 compares the patent application of 22 Province-level regions only. It is remarkable that a clear boundary line emerges between Top-tier and normal-tier groups. For instance, top four regions take over 50% of all the applications, suggesting that the distribution of technology source is biased to these major regions. In contrast, 10 low-ranked Provinces have less than 1% of total patents share, reinforcing the technology capacities.

Table 4 lists the top 20 prefecture-level regions of patent applicants. It is no surprise that Beijing shows the highest rank, followed by Shenzhen, and Shanghai. The biased distribution of technology production continues in the prefecture-regions level. While Shenzhen and

Shanghai showed little difference, Shenzhen produces approximately 40% less than those of Beijing. These regions sit on the heart of the three major megalopolises. The other group - except top three tier- shows a uniform but low shares of patents.


*Figure 5 Patent applications by Province-level regions*

Table 4 also corroborates that the top three regions play a critical role in leading three megalopolises. While Beijing and Shanghai ranked as top 3 regions, Tianjin, and Chongqing –two out of the four direct-controlled municipalities – accounted only for 3%, 2%, respectively. Eight regions amongst top ten highest patents regions consisted of three super regions: YRD (Hangzhou, Nanjing, and Suzhou neighbouring with Shanghai), PRD (Guangzhou and Shenzhen), and BGR (Beijing and Tianjin).

*Table 4 Patent applications of top 20 prefecture-level regions*

| Rank | Regions | Patents | Share | Rank | Regions | Patents | Share |
|---|---|---|---|---|---|---|---|
| 1 | Beijing | 125359 | 15% | 11 | Chengdong | 17741 | 2% |
| 2 | Shenzhen | 76949 | 9% | 12 | Changsha | 14019 | 2% |
| 3 | Shanghai | 70084 | 9% | 13 | Wuxi | 12746 | 2% |
| 4 | Hangzhou | 31467 | 4% | 14 | Chongqing | 12565 | 2% |
| 5 | Nanjing | 26774 | 3% | 15 | Ningbo | 12173 | 2% |
| 6 | Guangzhou | 23652 | 3% | 16 | Jinan | 12054 | 1% |
| 7 | Tianjin | 21335 | 3% | 17 | Harbin | 11996 | 1% |
| 8 | Suzhou | 20129 | 2% | 18 | Shenyang | 10844 | 1% |
| 9 | Wuhan | 19978 | 2% | 19 | Qingdao | 10176 | 1% |
| 10 | Xian | 19627 | 2% | 20 | Dalian | 8833 | 1% |

It is worth mentioning that the top 15 regions (at least over 2% of patents share) are located around the major megalopolises. Under the agglomerated economy, the distribution of technology is concentrated at the center of clusters, which reinforces the disparity of the leading and lagging regions. This topic is discussed in the next chapter.

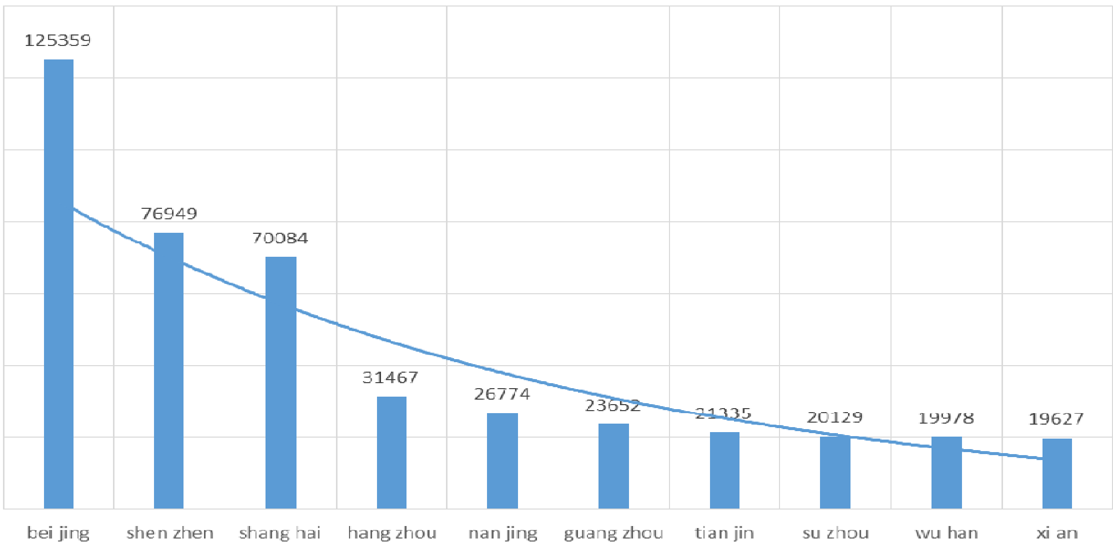



*Figure 6 Patent applications of top 10 prefecture-level regions*

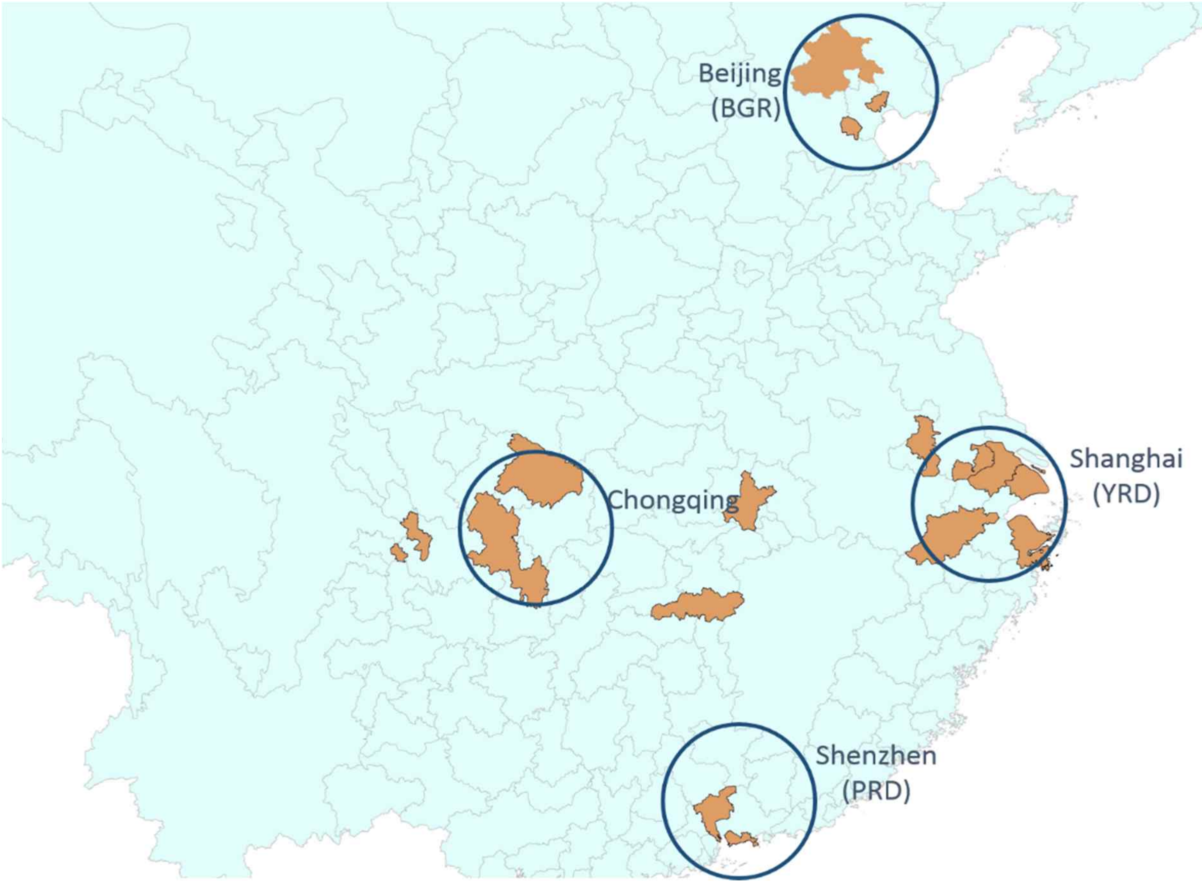



*Figure 7 Geographical distribution of top 7 regions*

Next, Figure 8 identifies top three region's patent applications by annual time periods, taking the period from 1991 to 2014. The hierarchical order of Beijing, Shanghai, and Shenzhen maintained during the earlier period from 1991 to 2003. While the Beijing ranked first, the patents Shenzhen surpassed those of Shanghai in 2004. Shenzhen's steep growth rate continues and reached top rank between 2006 and 2008. After 2008, Beijing recovers its top rank, followed by Shenzhen and Shanghai. The graph reveals that Beijing typically remained as a top technology producer and Shenzhen shows a late but fast following activities in the later period.

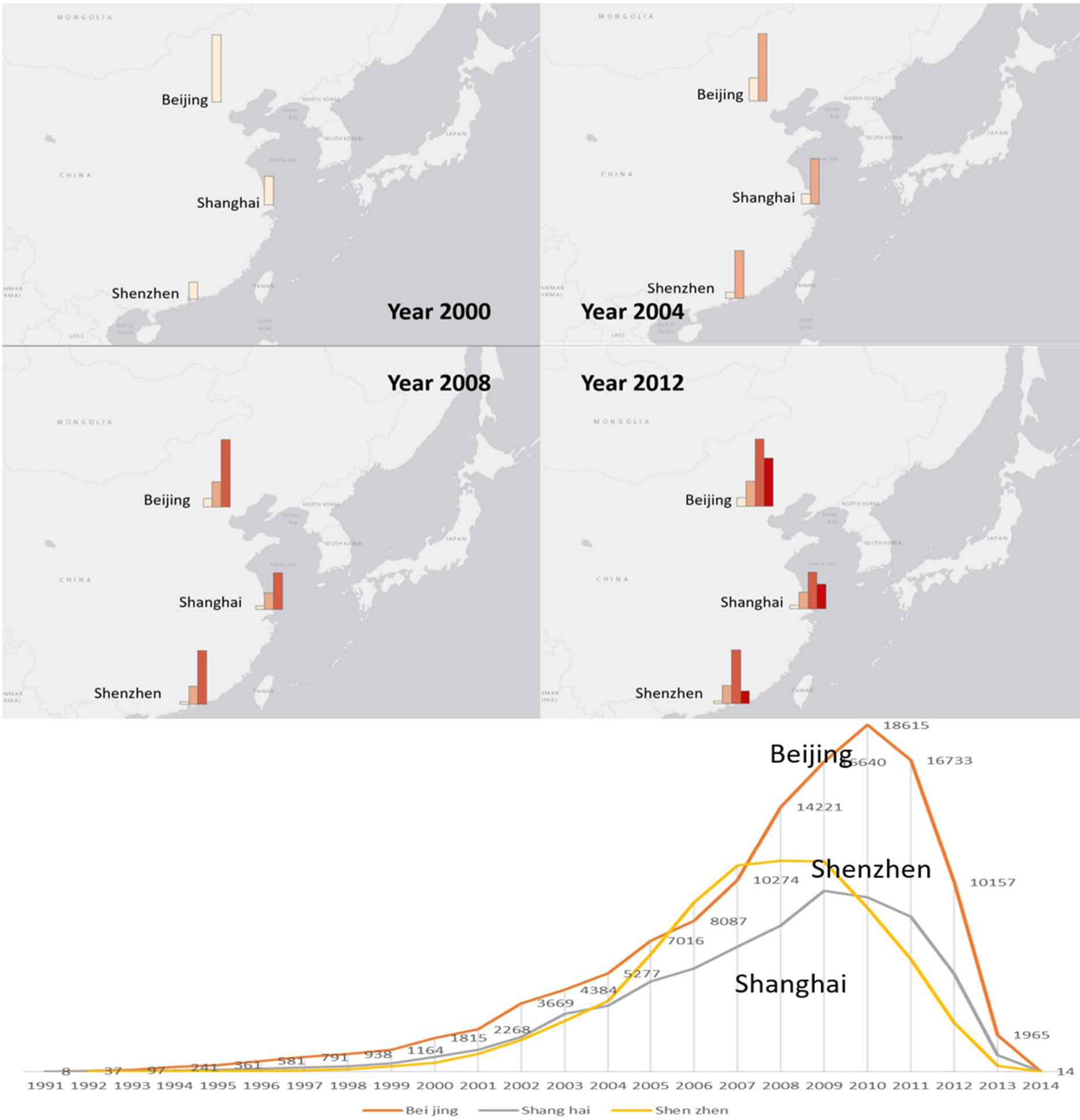



*Figure 8 Annual trend of patent applications by top 3 regions*

Figure 9 further examines the influence of the super regions by comparing the patent applications produced in Super regions (Super) and those of non-super regions (Non_super). The difference between them is found to have been increased. The total patent applications of super-regions was 2965, 22 lesser than those of Non-super, while the difference is reversed no later than a year. In 2000, Super regions produced 390 more patents (4,605), then the difference increases to 8,754 in 2004, 22,857 in 2007, and 29,786 in 2009. Such an accelerated gap signals an increasing return to scale of knowledge productions.

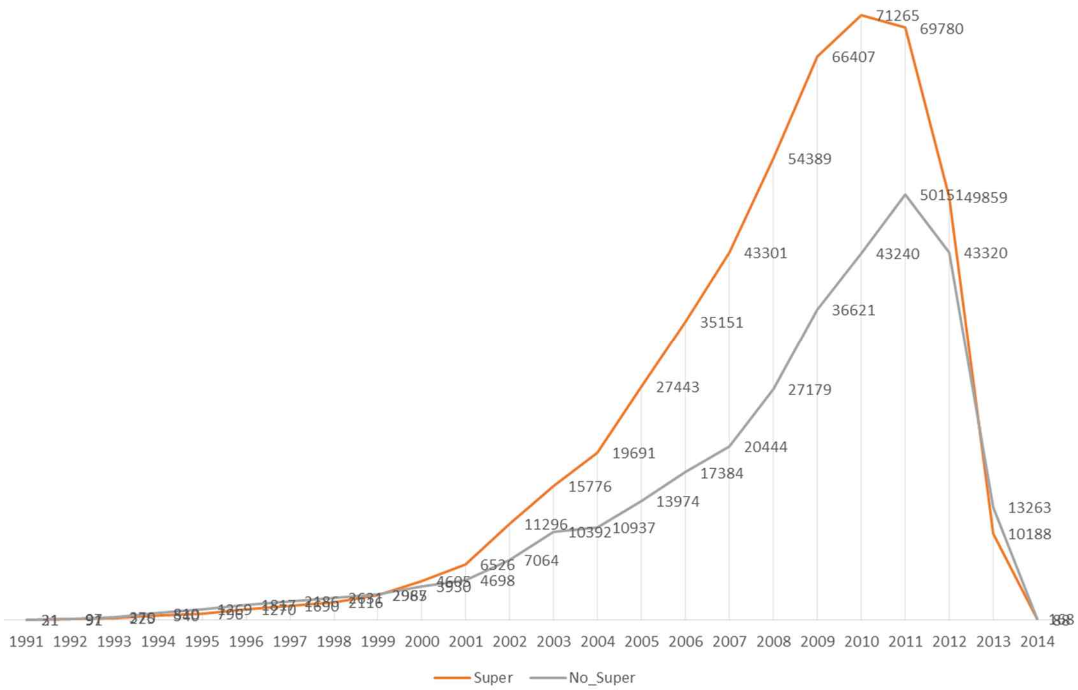



*Figure 9 Patent application by super regions*

### 3.3.4. Technology sector level analysis

Table 5 demonstrates patents frequency in the top 20 technology sectors of in accordance with IPC4 (Sub-class) level. The highest technology sector was A61K (PREPARATIONS FOR MEDICAL, DENTAL, OR TOILET PURPOSES) of Bio materials, accounting for approximately 7% (56571 counts) of total counts. Then, two information and communication technologies (ICT) - H04L (SECRET COMMUNICATION) and G06F (ELECTRIC DIGITAL DATA PROCESSING) - followed with 5% (36,915), and 3% (25,582), respectively.  The measurement technology of G01N (ANALYSING & Investigating

MATERIALS) appears 23733, yielding 3% and then H04W (WIRELESS COMMUNICATION NETWORKS) which belongs to ICT sector comes after it. Another Bio technology of C12N (MICRO-ORGANISMS OR ENZYMES; COMPOSITIONS THEREOF) ranked 6 with 15664 counts. From rank 8 to 15, the difference between technologies remained stable with five material-related technologies (C07C, C04B, C07D, and C08L).

*Table 5 Patent applications by technology sector (IPC Code 4)*

| Rank | Sub-Class | Title | Total | Rank | Sub-Class | Title | Total |
|---|---|---|---|---|---|---|---|
| 1 | A61K | PREPARATIONS FOR MEDICAL, DENTAL, OR TOILET PURPOSES | 56571 | 11 | C02F | TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE | 12455 |
| 2 | H04L | SECRET COMMUNICATION; JAMMING OF COMMUNICATION | 36915 | 12 | C04B | LIME; MAGNESIA; SLAG; CEMENTS; COMPOSITIONS THEREOF, e.g. MORTARS, CONCRETE OR LIKE BUILDING MATERIALS; | 12382 |
| 3 | G06F | ELECTRIC DIGITAL DATA PROCESSING | 25582 | 13 | C07D | HETEROCYCLIC COMPOUNDS | 11633 |
| 4 | G01N | INVESTIGATING OR ANALYSING MATERIALS BY DETERMINING THEIR CHEMICAL OR PHYSICAL PROPERTIES | 23733 | 14 | C08L | COMPOSITIONS OF MACROMOLECULAR COMPOUNDS | 11168 |
| 5 | H04W | WIRELESS COMMUNICATION NETWORKS | 16816 | 15 | H04N | PICTORIAL COMMUNICATION | 11085 |
| 6 | C12N | MICRO-ORGANISMS OR ENZYMES; COMPOSITIONS THEREOF | 15664 | 16 | B01D | LIQUID/LIQUID, LIQUID/GAS OR GAS/GAS SEPARATION | 9664 |
| 7 | A23L | FOODS, FOODSTUFFS, OR NON-ALCOHOLIC BEVERAGES, | 14517 | 17 | C01B | NON-METALLIC ELEMENTS; | 7882 |
| 8 | C07C | ACYCLIC OR CARBOCYCLIC COMPOUNDS | 13752 | 18 | C22C | ALLOYS | 7649 |
| 9 | H01L | SEMICONDUCTOR DEVICES; ELECTRIC | 13729 | 19 | G01R | MEASURING ELECTRIC | 7095 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | SOLID STATE DEVICES | | | | VARIABLES; MEASURING MAGNETIC VARIABLES | |
| 10 | B01J | CHEMICAL OR PHYSICAL PROCESSES | 12487 | 20 | H01M | PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY | 6965 |

The distribution of technology sector in Figure 10 was biased toward leading technologies, implying that majority (over 600) of technologies accounted for less than 1% of shares in the whilst top 5 technologies' shares approximately 20%.

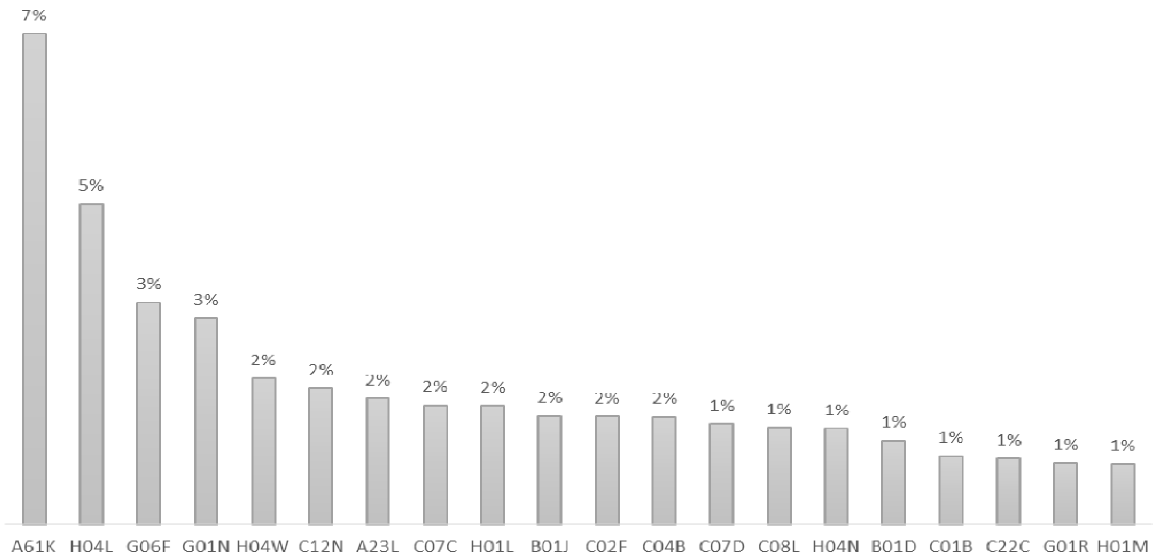



*Figure 10 Shares of technology sectors by IPC code 4*

The five highest technologies from 1990 to 2013 is shown in Figure 11. A61K emerged as the most frequent one from 1992 and has remained the highest rank until 2005. Even it showed a sudden decline between 2006 and 2010, ranked as the second, but recovered its leading position from 2010, producing highest peak (7,068) in 2012. The two ICT technologies H04L, H04W demonstrate a late, but steep upsurge in the 2000s. The sharp increase of H04L starts after 2001, achieving top rank during the late 2000s from 2006 to 2010. The wireless technology (H04W) also demonstrates sharp rises after 2005, coupling with software technology of G06F. A macro point of view signifies that bio-technologies dominate the overall periods, while H/W based ICT technologies led to the expansion of patents, following S/W in the late 2000s.

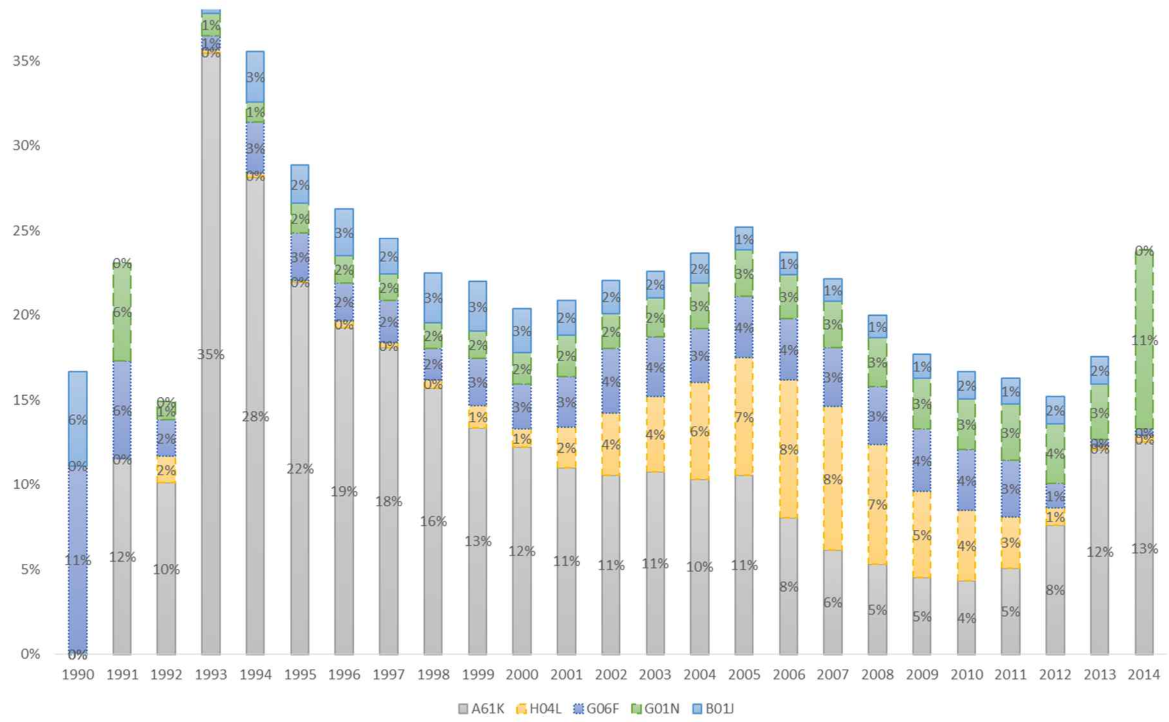



*Figure 11 Annual trend of top 5 technology sectors*

The advantage of IPC code is that it clearly provides a descriptive analysis on the trajectories of elementary technology, but it also has an obvious limitation of failing to deliver the industry-level information. The transformation of IPC into NACE code overcomes such a restriction by applying a matching table 'IPC and Technology

Concordance Table' published by WIPO[5] on Feb. 2009. In this study, the technologies are classified into 35 sub-sections, summarising the counts of industrial sectors.

*Table 6 Shares of industry sectors by NACE Codes*

| Rank | Sector | Total | Shares | Rank | Sector | Total | Shares |
|---|---|---|---|---|---|---|---|
| 1 | Digital communication | 55368 | 7% | 18 | Audio-visual technology | 16822 | 2% |
| 2 | Pharmaceuticals | 54466 | 7% | 19 | Thermal processes and apparatus | 16308 | 2% |
| 3 | Measurement | 53382 | 7% | 20 | Medical technology | 16079 | 2% |
| 4 | Basic materials chemistry | 45907 | 6% | 21 | Textile and paper machines | 15559 | 2% |
| 5 | Electrical machinery, apparatus, energy | 45488 | 6% | 22 | Optics | 15064 | 2% |
| 6 | Materials, metallurgy | 44837 | 6% | 23 | Surface technology, coating | 14852 | 2% |
| 7 | Computer technology | 35912 | 4% | 24 | Mechanical elements | 13892 | 2% |
| 8 | Organic fine chemistry | 33401 | 4% | 25 | Semiconductors | 13729 | 2% |
| 9 | Food chemistry | 32745 | 4% | 26 | Handling | 13263 | 2% |
| 10 | Biotechnology | 31087 | 4% | 27 | Transport | 13224 | 2% |
| 11 | Chemical engineering | 28329 | 3% | 28 | Control | 13077 | 2% |
| 12 | Machine tools | 27873 | 3% | 29 | Other consumer goods | 13027 | 2% |
| 13 | Civil engineering | 26808 | 3% | 30 | Engines, pumps, turbines | 11227 | 1% |
| 14 | Other special machines | 25811 | 3% | 31 | Furniture, games | 7418 | 1% |
| 15 | Macromolecular chemistry, polymers | 25497 | 3% | 32 | Basic communication processes | 4036 | 0% |
| 16 | Telecommunications | 20945 | 3% | 33 | Analysis of biological materials | 3588 | 0% |
| 17 | Environmental technology | 20174 | 2% | 34 | Micro-structure and Nano-technology | 855 | 0% |
|  |  |  |  | 35 | IT methods for management | 419 | 0% |

[5] http://www.wipo.int/

Table 6 shows that Digital communication, Pharmaceuticals and Measurement sector ranked first, second and third with a marginal difference. It is remarkable that Measurement is a general-purpose sector compared to the other two sectors. Material sectors consisted of Basic materials chemistry, Materials, metallurgy, sits in between 40,000 and 50,000.

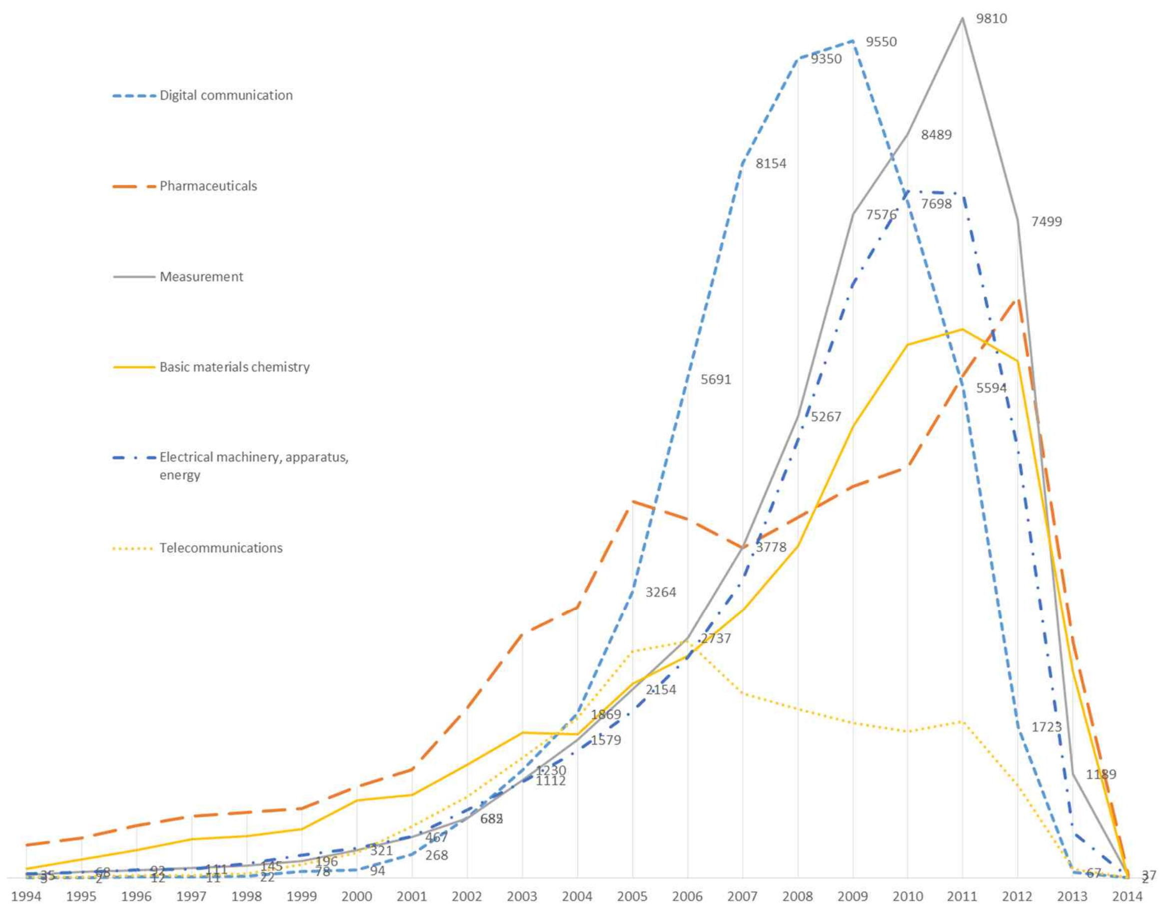



*Figure 12 Annual trend of major industry sectors*

Figure 12 demonstrates that the Pharmaceutical sector was dominating with the highest patent applications up to the year 2005. Even the growth rate of slightly declined over the two years, it starts to recover from 2007. It also demonstrates a surge in applications by Digital communication sector since 2000, yielding the highest rank of patent activities during 2006 and 2009. A similar pattern emerges in Measurement sector, reporting its steep growth rate in the early 2000s, and hitting its peak in 2001. Electrical machinery sector also has an identical trend with a slightly less amount of activities. This graph reveals that the traditional industrial sectors comprised of Pharmaceutical, basic material led the Chinese patent activities, but after mid of the 2000s the new high-tech industries - Digital communication, Electrical machinery sector –dominates rapidly the activities.

Next few graphs reveal how the technology portfolios that is produced by major regions are involved in producing what technologies. For a clear and simple comparison, this study re-classified NACE code into six major technologies suggested by Peri (2005).

First, a traditional industry of Beijing is dominated by Chemical technology before 2004, showing the highest rank in patent activity in Figure 13. Chemical technology maintained a steady growth rate through the periods, despite its rank fallen to second after 2005. Communication and telecommunication technology (CNTEL, hereafter) rose as the first top technology as a new technology driver in Beijing. In comparison with the earlier period, it is notable that the breadth of technology portfolios has widened in the late 2000s.

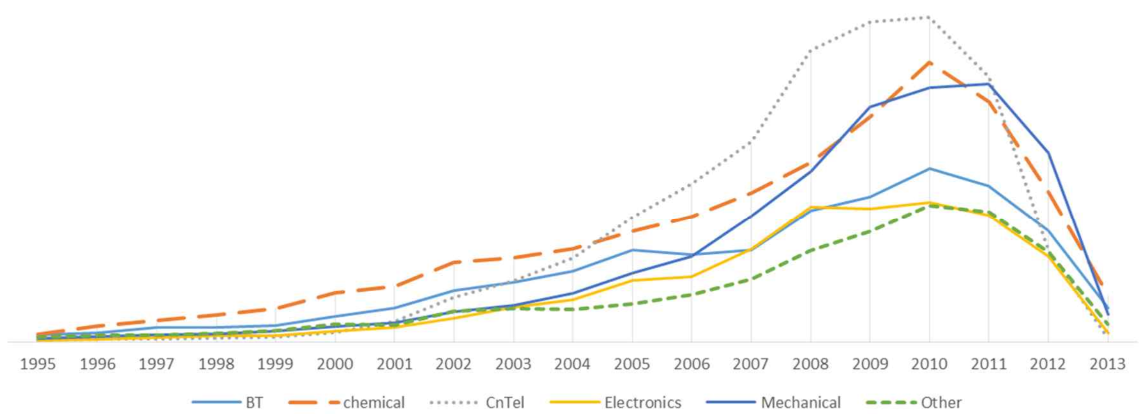



*Figure 13 Technology portfolio trend – Beijing*

Shanghai, however, maintained a relatively balanced technology portfolio in Figure 14 . Chemical technology maintained as a leading technology with a narrow margin of other technologies. The steep growth rate of biotechnology in the mid of the 2000s makes its highest peak in 2009.

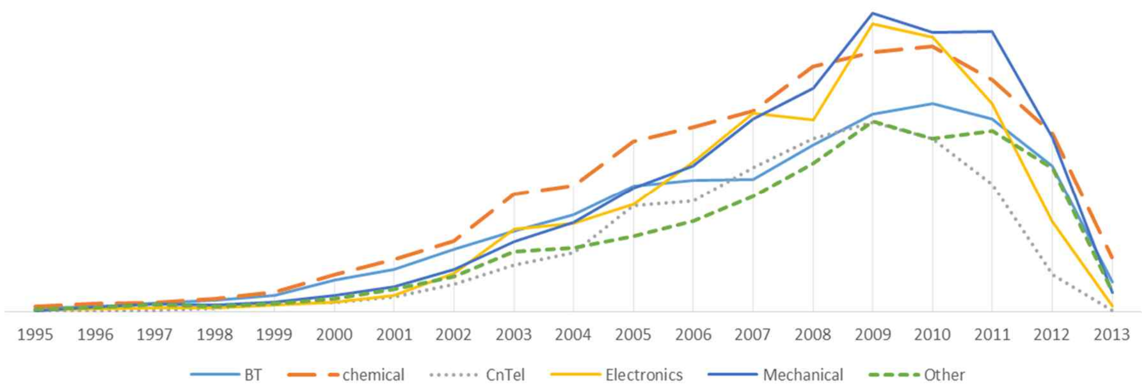



*Figure 14 Technology portfolio trend – Shanghai*

Figure 15 reveals that CNTEL has played a critical role in the patents activities in Shenzhen. The distribution of technologies has reported being biased through the periods. Coupling with CNTEL, Electronics technology also remained as the second rank, which signifies that the region is specialised for ICT-related technologies.

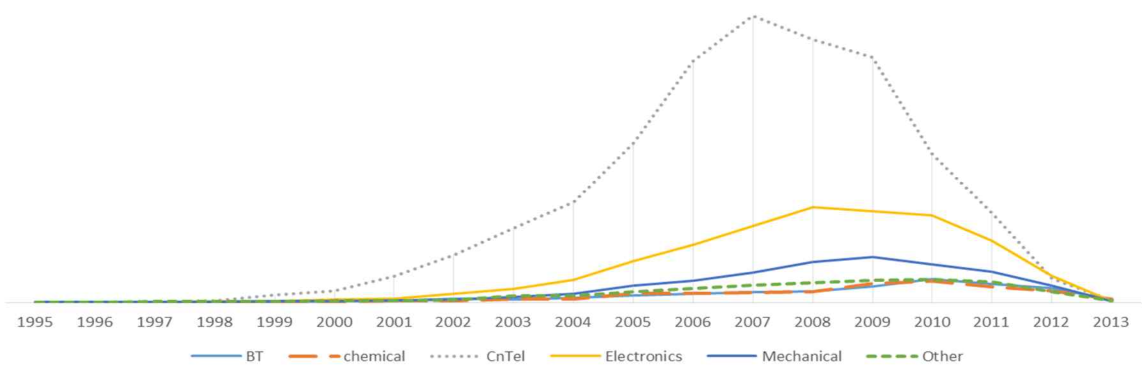



*Figure 15 Technology portfolio trend – Shenzhen*

## 3.4. The rise of patent licensing

China is one of the few countries to collect the licensing contract information between the two parties under the regulation of PLCRP (Patent Licensing Contract Recordal Procedures). The patent licensing contract data was consisted of patent information (publication number, application number), licensor/licensee data (affiliation, nationality, prefecture-level address) and transaction data (exclusiveness, contract date). For the reliability of collected data, the patent number is identified and matched with the official patent application DB in order to re-fine the dataset.

### 3.4.1. A holistic view

Figure 16 reveals how Chinese patent licensing has expanded after 2001, yielding 70% of CAGR. It remained below 1,000 after started 2 in 2001, but surged explosively after 2009. The growth seems to be downward after reaching the highest peak (3,576) in 2011, however, the non-disclosure patents which might not be counted are highly likely to further increase the size. The accumulated contracts, exceeding 10,000 in 2011, reached 15,000 in 2013, providing a proper size to analyse the market dynamics.

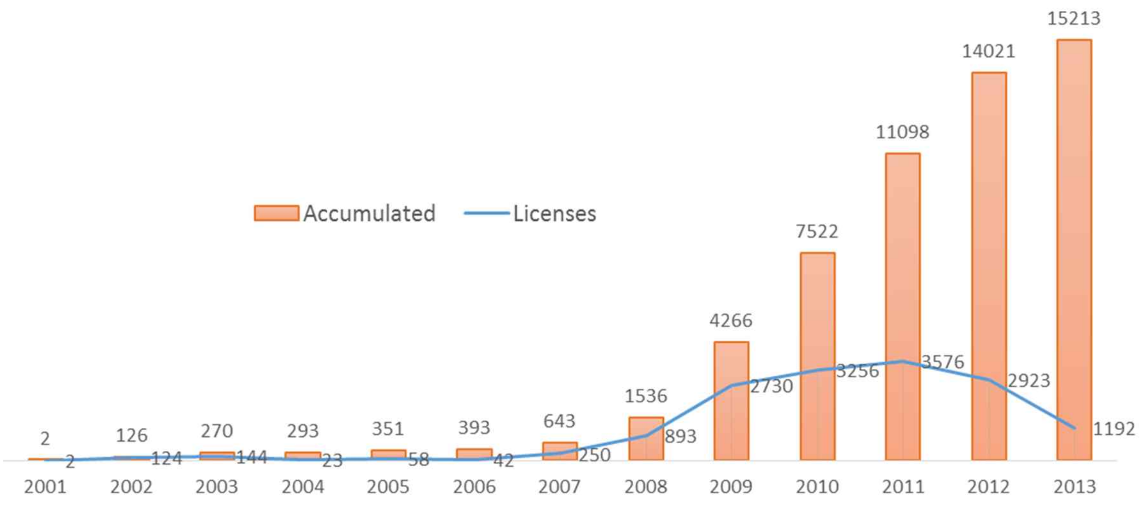



*Figure 16 Trend of licensing contracts*

The information of the patent licensing contract helps to trace the source of knowledge/technology diffusion by identifying the address of a patentee (patent owner) and licensee (purchaser). In the same way, it also provides which country's technology is transferred to which domestic regions by collecting non-Chinese applicant's patents. The total number of license contracts is 15,213, comprising 72% of Chinese nationality applicants

(10,911) and 28% of Non-Chinese (4,302). Table 7 demonstrates the patents owned by the Netherlands (33%) are the most frequent one to be imported, followed by Japan, and US. The influence of other countries, after Swiss and Germany, seems to be not significant with less than 100 license contracts.

*Table 7 Top 5 nationalities of patentees*

| Rank | Countries | Licenses | Shares |
|---|---|---|---|
| 1 | Netherlands | 1420 | 33% |
| 2 | Japan | 904 | 21% |
| 3 | US | 496 | 12% |
| 4 | Taiwan | 476 | 11% |
| 5 | Switzerland | 257 | 6% |

Table 8 answers which actor types exchange with whom, comparing actor-level analysis. It is expected that the majority (99%) of technology licensee are corporates. But, the proportions of the technology provider is more balanced: University (30%), Research Institutes (8%), and Firms (63%). It is found that the technology licensing market is largely dominated by Corporations.

*Table 8 Types of licensors and licensees*

| | | Licensees | | | |
|---|---|---|---|---|---|
| | | University | Research Institution | Firm | Licensors |
| Licensor | University | 27 | 31 | 4,435 | 4,493 (30%) |
| | Research Institution | 1 | 25 | 1,137 | 1,163 (8%) |
| | Firm | 1 | 32 | 9,524 | 9,557 (63%) |
| | Licensees | 29 | 88 | 15,096 | 15,213 |

### 3.4.2. Region-level analysis

Table 9 summarises the top 20 licensor/licensee regions. Given the overseas countries as 'Out_China', it provides the most of technologies to Chinese licensing market. Beijing dominates the licensor regions among the domestic regions, accounting for 10%, and Shanghai transmitted the third largest number (1,050) of patent licenses. The frequency, however, dropped sharply, so that Shenzhen provided 40% lesser (637) than those Shanghai. Then, Nanjing, Tianjin, Xian reported similar counts around approximately 500. It is interesting that the disparity between higher –Beijing, Shanghai - and lower municipalities - Tianjin, and Chongqing.

The analysis turns to the frequency of a region's patent in the right columns of Table 9, which shows that three top domestic licensor regions also purchase the majority of patents. The top patent licensee region is Shenzhen, followed by Beijing, and Shanghai. Shenzhen, Beijing and Shanghai is the third, first, and the second, respectively, a largest domestic region of supplying patents, implying that these regions have played a significant role in both producing and purchasing patents. These three regions accounted for 25% of the total licensed patent; whilst the next regions following Suzhou, Nanjing, and Tianjin licensed less than 1,000 patents. It is clear that the regions have a tendency toward technology exchange. For instance, top 3 regions, Nanjing, and Tianjin are balanced in both purchasing and providing patents. Suzhou, and Dong guan tend to have higher patent licensee but lower patent provided. In contrast, Xian seems to be an active technology provider, accounting for 3% (7th) of total technology licensed contracts, however, it purchases only 1% of patent in the Chinese patent exchange market.

*Table 9 Top 20 licensors and licensees by regions*

| Licensor's region | Licenses | Shares | Rank | Licensee's region | Licenses | Shares |
|---|---|---|---|---|---|---|
| Out_China | 4302 | 28% | 1 | Shenzhen | 1305 | 9% |
| Beijing | 1458 | 10% | 2 | Beijing | 1275 | 8% |
| Shanghai | 1050 | 7% | 3 | Shanghai | 1172 | 8% |
| Shenzhen | 637 | 4% | 4 | Suzhou | 916 | 6% |
| Nanjing | 570 | 4% | 5 | Nanjing | 831 | 5% |
| Tianjin | 466 | 3% | 6 | Tianjin | 492 | 3% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Xian | 426 | 3% | 7 | Dongguan | 476 | 3% |
| Hangzhou | 404 | 3% | 8 | Wuxi | 461 | 3% |
| Wuhan | 313 | 2% | 9 | Guangzhou | 388 | 3% |
| Wuxi | 300 | 2% | 10 | Hangzhou | 377 | 2% |
| Zhenjiang | 265 | 2% | 11 | Changzhou | 338 | 2% |
| Huizhou | 263 | 2% | 12 | Foshan | 256 | 2% |
| Chongqing | 242 | 2% | 13 | Zhenjiang | 250 | 2% |
| Guangzhou | 219 | 1% | 14 | Ningbo | 239 | 2% |
| Chengdu | 212 | 1% | 15 | Huizhou | 224 | 1% |
| Harbin | 204 | 1% | 16 | Chengdu | 198 | 1% |
| Suzhou | 204 | 1% | 16 | Wuhan | 193 | 1% |
| Changsha | 199 | 1% | 18 | Taizhou | 187 | 1% |
| Taizhou | 168 | 1% | 19 | Xian | 184 | 1% |
| Nanchang | 142 | 1% | 20 | Zhongshan | 176 | 1% |

The high self-sufficiency rate of a region induced to explore the ratio of regions' self-supporting patent, which is expressed in a map in Figure 17, and charted in Figure 18. The dark blue represents the higher rate, as the light colour does lower. It is worth mentioning that the majority of central and west regions are light, while the east-coastal regions have a dark color. The three major megalopolises, specifically seem to have a dark colour.

*Table 10 Geographical distribution of Top 20 licensors and licensees regions*


<Licensor Regions>


<Licensee Regions>

The bar graph represents the ratio of licensed patents originated from own region over its all licensed patents. Suzhou and Tianjin provided 53% of patent to the institutions located within their own boundaries. Then, Beijing, and Shenzhen also supplemented about 50%. The ratio of licensed patents originated from own region over its total licensed patents is expressed in line graph, which yields Beijing, and Tianjin the first and second rank (58%, 50%, each). This result implies a notion that BGR megalopolis area seems to supplement what they needed within the local region.

On the contrary, Shenzhen purchased 24% of technology produced within their own region, while it provides almost a half patents to the institutions located within own region. A similar gap-pattern is found in Suzhou, and Dong guan, suggesting that they are highly likely to need to more than the region produced, or their technology capacity could not meet the need. Shanghai, Hangzhou, and Tianjin, however, showed a balanced ratio.

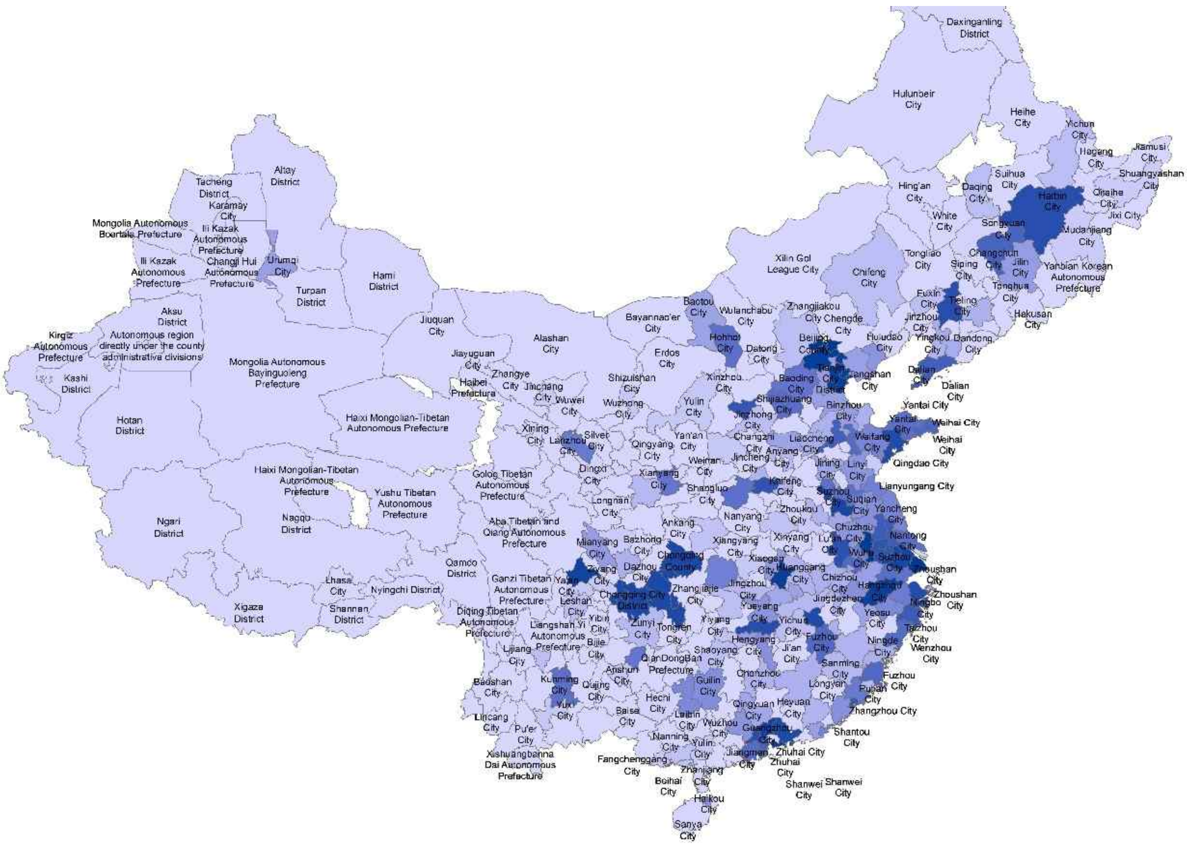



*Figure 17 Geographical distribution of technology self-sufficiency rate*

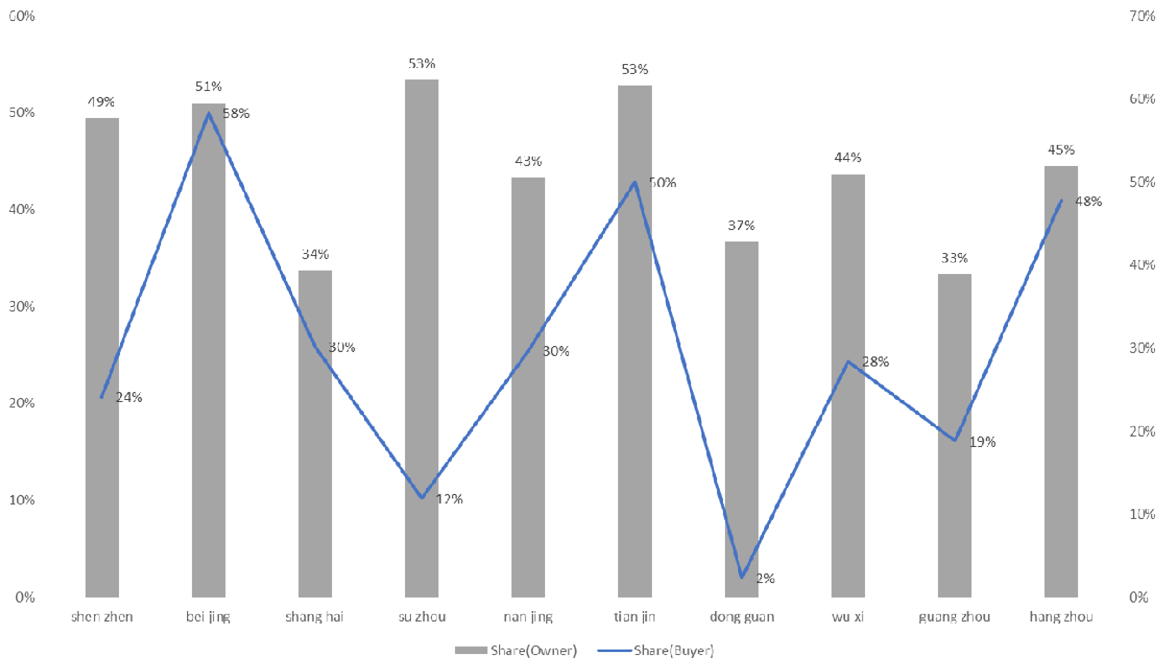



*Figure 18 Rate of technology self-sufficiency*

In order to explore the inter-region technology flows, next three graphs demonstrates the top major three region's source of licensed technology. Table 11 shows that Beijing adopted from two major (over 70%) sources - Beijing (58%) and overseas patents (19%). Then, ratio dropped sharply to Xian (3%), Shanghai (3%), and Shenzhen (1%). The biased distribution suggests that Beijing mainly could supplement their own technology.

*Table 11 Shares of inward / outward licenses - Beijing*

| Regions | Inward | Shares | Regions | Outward | Shares |
|---|---|---|---|---|---|
| Beijing | 744 | 58% | Beijing | 744 | 51% |
| Out_China | 244 | 19% | Nanjing | 49 | 3% |
| Xian | 40 | 3% | Suzhou | 48 | 3% |
| Shanghai | 36 | 3% | Wuxi | 35 | 2% |
| Shenzhen | 16 | 1% | Shanghai | 34 | 2% |

On the contrary, Table 12 reveals that Shanghai mainly rely on overseas technology (52%), and then Shanghai (30%). The share of other regions are extremely low below 3%.

*Table 12 Shares of inward / outward licenses – Shanghai*

| Regions | Inward | Shares | Regions | Outward | Shares |
|---|---|---|---|---|---|
| Out_China | 615 | 52% | Shanghai | 354 | 34% |
| Shanghai | 354 | 30% | Suzhou | 91 | 9% |
| Beijing | 34 | 3% | Nanjing | 46 | 4% |
| Shenzhen | 18 | 2% | Wuxi | 40 | 4% |
| Xian | 16 | 1% | Beijing | 36 | 3% |

Table 13 shows that Shenzhen also imports overseas technologies most frequently as Shanghai does. The sum of ratio of two major sources – overseas and Shenzhen- exceeds over 80%. The neighbour regions - Guangzhou and Foshan – also provides the technology to Shenzhen, but the ratio is less than 3%.

*Table 13 Shares of inward / outward licenses– Shenzhen*

| Regions | Inward | Shares | Regions | Outward | Shares |
|---|---|---|---|---|---|
| Out_China | 707 | 54% | Shenzhen | 315 | 49% |
| Shenzhen | 315 | 24% | Yantai | 50 | 8% |
| Guangzhou | 39 | 3% | Huizhou | 23 | 4% |
| Foshan | 34 | 2% | Suzhou | 21 | 3% |
| Shanghai | 31 | 2% | Dongguan | 18 | 3% |

### 3.4.3. Technology sector analysis

The NACE code indicates that the most frequent industry sectors are related with ICT sectors - Audio-visual technology (10%), Electrical machinery, apparatus, energy(8%), and followed by Chemical and Materials sectors - Basic materials chemistry (6%), Organic fine chemistry (6%), Materials, metallurgy (5%), as shown in Table 14. It is interesting that the top 3 patent application sectors – (1) Digital communication, (2) Pharmaceuticals, (3) Measurement - do not correspond with the licensing sector ranking – (1) Audio-visual technology (10%), (2) Electrical machinery, apparatus, energy, and (3) Basic materials chemistry. Chinese technology market does not prefer to exchange deal with the technologies originated from Pharmaceuticals (4%) and Biotechnology (3%) sector, despite higher shares of patents.

*Table 14 Technology sectors of licensing contracts*

| Rank | NACE | Licenses | Shares | Rank | NACE | Licenses | Shares |
|---|---|---|---|---|---|---|---|
| 1 | Audio-visual technology | 1508 | 10% | 18 | Digital communication | 344 | 2% |
| 2 | Electrical machinery, apparatus, energy | 1264 | 8% | 19 | Food chemistry | 306 | 2% |
| 3 | Basic materials chemistry | 893 | 6% | 20 | Telecommunicati ons | 290 | 2% |
| 4 | Organic fine chemistry | 865 | 6% | 21 | Mechanical elements | 283 | 2% |
| 5 | Materials, metallurgy | 779 | 5% | 22 | Transport | 270 | 2% |
| 6 | Measurement | 770 | 5% | 23 | Thermal processes and apparatus | 259 | 2% |
| 7 | Macromolecular chemistry, polymers | 765 | 5% | 24 | Semiconductors | 238 | 2% |
| 8 | Civil engineering | 613 | 4% | 25 | Optics | 226 | 1% |
| 9 | Machine tools | 609 | 4% | 26 | Engines, pumps, turbines | 221 | 1% |
| 10 | Pharmaceuticals | 589 | 4% | 27 | Handling | 204 | 1% |
| 11 | Computer technology | 576 | 4% | 28 | Other consumer goods | 194 | 1% |
| 12 | Textile and paper machines | 536 | 4% | 29 | Control | 172 | 1% |
| 13 | Chemical engineering | 534 | 4% | 30 | Medical technology | 166 | 1% |
| 14 | Biotechnology | 440 | 3% | 31 | Basic communication processes | 116 | 1% |
| 15 | Surface technology, coating | 374 | 2% | 32 | Furniture, games | 101 | 1% |
| 16 | Other special machines | 350 | 2% | 33 | Micro-structure and Nano-technology | 6 | 0% |
| 17 | Environmental technology | 347 | 2% | 34 | IT methods for management | 5 | 0% |

Figure 19 also displays how major technologies are exchanged annually. Chinese patent licensing market mostly dealt with Electronics before 2008, Chemical technology shows a sharp upswing rate after 2009, reaching a peak in 2011. Electronics technology, however, has a contrary trend in that it remained a top rank around 2008, but steadily declined after its highest mark in 2010. Recently, the technology of CNTEL has increased recently, despite its smaller size of the market.

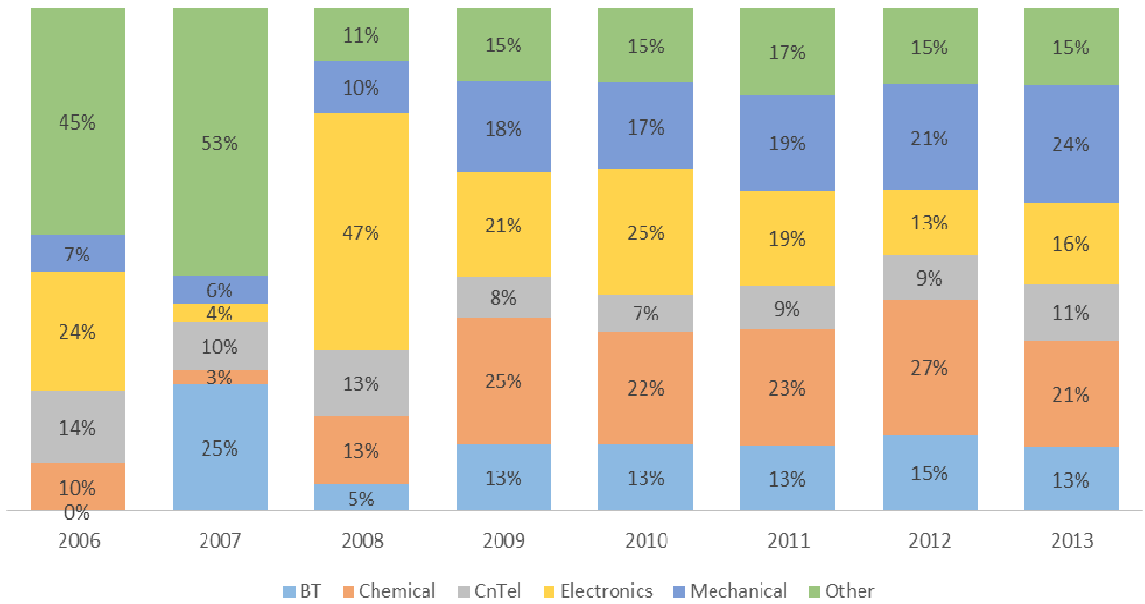



*Figure 19 Shares of licenses by six technologies*

Figure 20 describes that the transaction of technology is mainly dominated by CNTEL, except 2009, making a wider difference with other technologies in Beijing. Mechanical technology also recently emerges as a fast-growing. Chemical technology reported a steady growth rate whilst Electronics technology slightly declined.

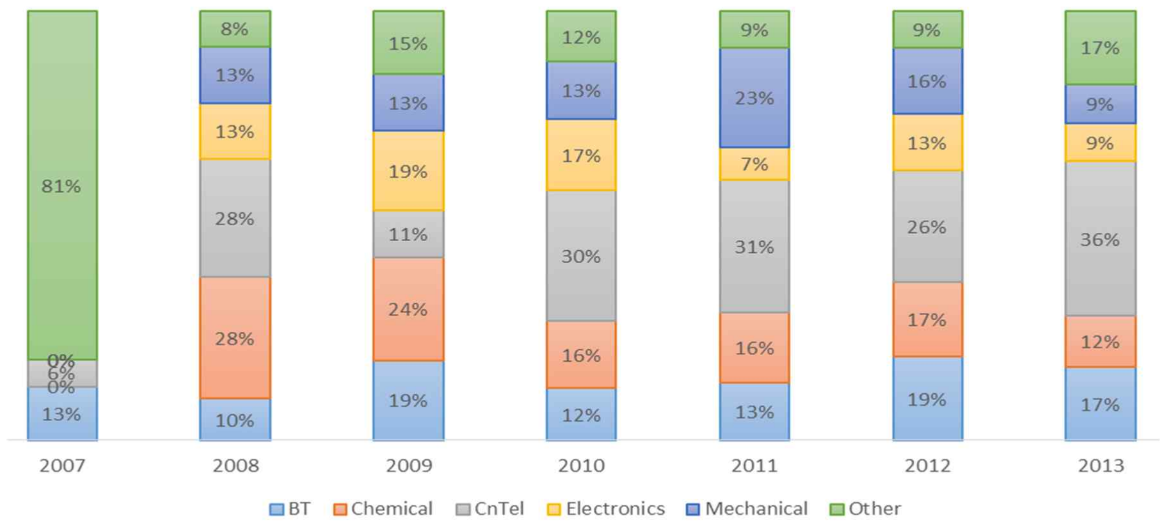



*Figure 20 The annual trend of licenses by six technologies – Beijing*

Compared to the technology portfolio of Beijing, Shanghai has acquired more diverse technologies as shown in Figure 21. Other, and Biotechnology accounted for the majority of adopted technologies in 2007, then the number of total licensed technologies plunged in 2008 which recovered steadily afterwards. Chemical technology reported the up-surging growth rate with its maximum counts of 129 in 2012. Considering the recent downward trend shown in Mechanical and Electronics together, it is expected that Shanghai is likely to transform its portfolios from H/W based electronics to Chemical technology.

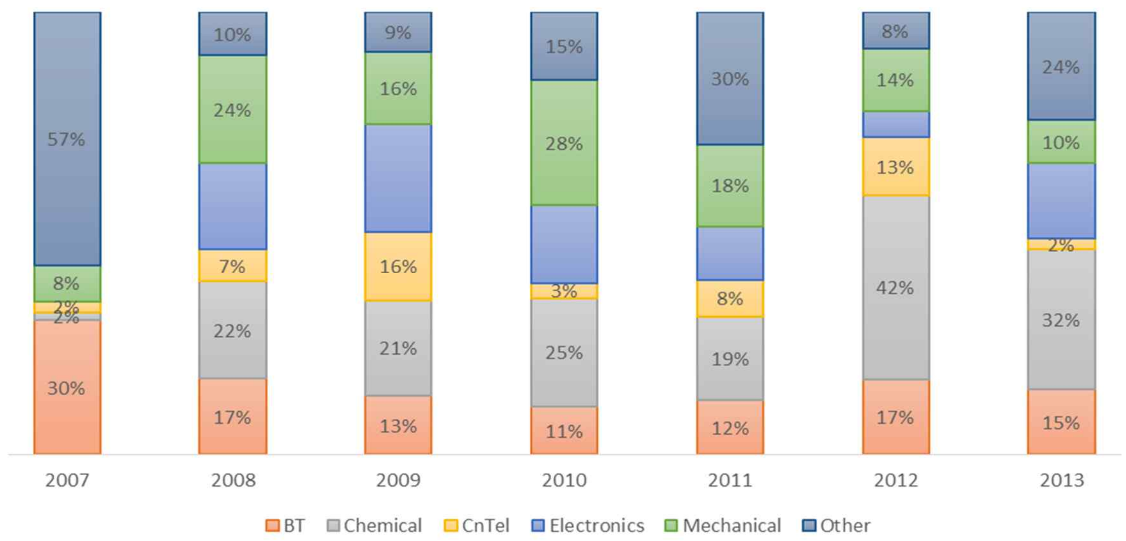


*Figure 21 The annual trend of licenses by six technologies - Shanghai*

Contrary, Figure 22 reports that Shenzhen has a distinctive pattern of concentrating a specialised technology of Electronics. From 2008, Electronics technology has dominated the technology inflow. The ratio of the other technologies seems to be insignificant influences.

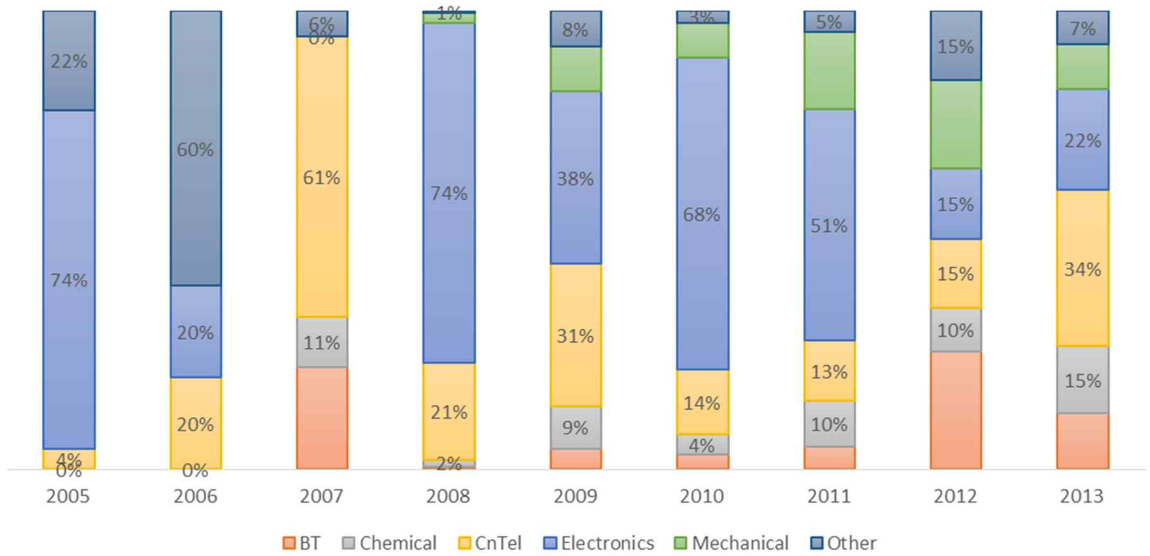



*Figure 22 The annual trend of licenses by six technologies - Shenzhen*

## 3.5. Conclusion

This chapter explores the technology flows of China by exploring patent activity and patent transfer contract information. The patent application information is recognized as a proxy reflecting the structured information such as which knowledge sector is created, who owns it, which regions are active in producing it, which type of applicant is involved and so on. The information on the patent licensing, on the basis of the structured data, captures the flow of technology by answering who/which type/ which region is active in supplying/purchasing in which technology/industry-level sector. Moreover, a market-mediated patent transaction is highly likely to be involved in the economic activities, indicating the link between knowledge and economic values

China has achieved a remarkable growth of patent activities of size (number of applications) and transmission (number of licensing contracts) over the past three decades. The earlier period of patent activity was dominated mainly by foreigners – mainly Japan and US, but Chinese domestic patents exceeded from 2007. It is worth noting that three major regions – Beijing, Shanghai, and Shenzhen - play a critical role in creating technology the patents, signifying the influence of super regions over the Chinese patent activity. The analysis of licensing data also corroborates the impact of three main regions in that they are the largest purchasers, and providers as well.

The descriptive analysis gives a further explanation of Sun and Du (2010)'s work, which demonstrates that neither exogenous technology from other countries nor domestic technology market is not significantly related with the innovation of China. They argue that the spillover effect of foreign direct investment works as a critical factor for the growth of the patent, rather than the contribution of the patents transfer. Their analysis, however, is on the basis of the dataset in 2004, when the endogenous capability of technology transfer market is yet to be established. This chapter shows that the size of the domestic technology transfer market shows a sharp expansion after the mid of the 2000s, reducing the dependency of foreign technology imports. Thus, this research is likely to offer a clearer point of view of the transferred technology and Chinese innovation growth.

# Chapter 4. The geographical proximity in the transmission of market-mediated technology

## 4.1. Introduction

In the past few decades, the advent of knowledge-based economies and open innovation paradigms have extended the scope of exploring connections to the external sources (Chesbrough, 2003; Ernst & Kim, 2002). The contribution of knowledge spillover in achieving stimulating innovative activities has been recognised as a propelling engine for achieving regional economic growth (Rivera-Batiz and Romer 1990, Coe and Helpman 1995, Harris 2001, Malecki 2007, Audretsch and Keilbach 2008, Capello, Caragliu et al. 2010, van Hemert, Masurel et al. 2011, Huggins, Luo et al. 2014). The exogenous knowledge, as a critical determinant to innovation-based regional growth, is more widely recognised, leading to the upsurge of technology transfer across geographical boundaries (Chesbrough, 2003; Cooke & Leydesdorff, 2006; Foray & Lundvall, 1998). According to WIPO (2017), the licensing market size in the world reached \$372 billion in 2016 from \$75 billion (US dollars) in 2000. Despite the emerging presence of compensated technology acquired through market mechanisms, the empirical studies on spatial knowledge diffusion have not clearly distinguished between market-mediated technology and knowledge spill-overs (Acs, Audretsch et al. 1994, Audretsch and Feldman 1996, Breschi and Lissoni 2001, Moreno, Paci et al. 2006, Mowery and Ziedonis 2015).

Compared with a pure knowledge spillover, the market-mediated technology transfer denotes an active process during which the technology is exchanged with pecuniary compensations through market transactions (Autio and Laamanen 1995, Bozeman 2000, Arora, Fosfuri et al. 2001, Audretsch, Bozeman et al. 2002, Battistella, De Toni et al. 2015, Bozeman, Rimes et al. 2015). It is a rather intentional, goal-oriented and interactive process between the entities aiming at leveraging current technology value geared toward the practical application of knowledge (Argote and Ingram 2000, Audretsch, Bozeman et al. 2002). The presence of a well-functioning technology market mechanism confers more opportunities for participants to find more potential partners (thick market) and reveal the preferences without the risk of undermining their bargaining power (safe market) (Lamoreaux and Sokoloff 1999, Arora, Fosfuri et al. 2004). The technology market, from the perspective of geographical incidence, alleviates the geographical distances between the licensors and licensees. The patent system provides codified and structured technology information of knowledge channels, all of which mitigate the asymmetry of technology information (Gambardella, 2002; Azagra-Caro et al., 2017). Thus, Audretsch and Stephan (1996) argue that spatial closeness between licensors and licensees is not necessary for the transmission under the market- mediated technology transfer, mainly due to the codified characteristics of patents information. It confers more chances for the participants to find the potential licensees and licensors, alleviating the physical distances. For instance, the specialised agents became active in connecting the demand side (potential licensees) and the supply side (patentees), helping patents to be commercialised in the market. The patent system itself is a fundamental supporting institution for technology transfer, because it provides well-recognised legal rights to inventions and codified formal transmission channels, all of which mitigate the asymmetry of technology information (Gambardella 2002, Azagra-Caro, Barberá-Tomás et al. 2017).

Despite these differences in the underlying mechanism of technology transfer, prior research on knowledge spillover has not disentangled the market-mediated technology from a pure knowledge spillover (Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017). Since they treated the different motivations of knowledge transfers identically, it is hard to explain the seemingly conflicting tendencies between a technology provider and purchaser that might counter-act the geographical agglomeration effect (Radosevich 1995, Kroll and Liefner 2008, Kirchberger and Pohl 2016). In this vein, the current study explores the geographical reach of a market-mediated technology, identifies the spatial preferences of each party and examines whether the market uncertainties affect the licensors' decision within the proximate areas if they face potential uncertainties (Shapiro 1985).

The remainder of the paper is organised as follows. The next section reviews the literature on technology flows and identifies the risks and incentives of the licensor and licensee party. Section 3 constructs the estimation method and describes the data. Following the estimation report of the gravity-like model in Section 4, Section 5 measures the odd-ratio of the presence of a dissipation effect. The last section concludes and discusses the significance of the implications of the research.

## 4.2. The market-mediated technology diffusion across geographical boundaries

The literature on the knowledge transfer across geographical borders has not clearly discerned the different mechanism between pure knowledge spillovers and market-mediated technology transfer (Spulber 2008, Nelson 2009, Laursen, Leone et al. 2010, Wang, Zhou et al. 2013, Mowery and Ziedonis 2015). Back to Nelson (1959) and Arrow (1972), economists delineated knowledge as a non-rival input asset and knowledge spillover was bounded in space as a local externality, by which the institution's knowledge ends up stimulating other institutions' innovative activities (Arora, Fosfuri et al. 2001, Breschi and Lissoni 2001). The studies tracking the trails in the documents as an index of knowledge flows across spatial boundaries have presumed knowledge as a type of non-compensated public good (Jaffe 1989, Jaffe, Trajtenberg et al. 1993, Maruseth and Verspagen 2002, Boschma 2005, Sonn and

Storper 2008, Shearmur 2011, Liu 2013, Balland, Boschma et al. 2015, Caragliu and Nijkamp 2015, Mowery and Ziedonis 2015). The fundamental assumption underlying these studies is that they commonly treat a pure knowledge spillovers and market-mediated knowledge transfer as a homogeneous effect (Breschi and Lissoni 2001).

The recent empirical evidence suggests that market-mediated knowledge flows do not have an identical geographical incidence of a pure knowledge spillover (Nelson 2009, Mowery and Ziedonis 2015, Azagra-Caro, Barberá-Tomás et al. 2017). Audretsch and Stephan (1996) argue that the compensated technology transfer through a market transaction is not necessarily constrained by the geographical distance between the partners, mainly due to the high level of codification that makes it easier for transmission. For instance, the readily transferable 'off the shelf' inventions, often depicted as the characteristics of biotechnology, also make it easier to transmit technologies across spatial boundaries (Mowery and Ziedonis 2015). Based on the empirical evidence from the German biotechnology sector, Ter Wal (2013) reported that a higher level of codification in the field has decreased the influence of spatial proximity for exchanging knowledge. In this vein, the transmission of the compensated technology through a market mechanism is presumed to expand the spatial scope of technology transmission (Lamoreaux and Sokoloff 1999, Arora, Fosfuri et al. 2004).

On the other hand, some empirical evidence maintains that market-mediated technology is affected by spatial proximity. Mowery and Ziedonis (2015) compared the market-mediated technology flow channel through patent license contracts and the non-market flow through patent citations, revealing that market-mediated technology is more geographically bounded. They account for the tacit nature of the compensated knowledge as the spatial proximity between the source and target, implying that close-interactions still matter even more for the technology market. They argue that the risk is positively associated with the tacit nature of technology which is alleviated by the higher level of exclusiveness of contract rights. This research interprets it as reflecting the inherent uncertainty of technology transaction which calls for the need for proximity.

Nelson (2009) also conducted a comparison analysis, seeking to show how far license and publication activities reached, with data being gathered from Stanford University's patents. His result shows that market-mediated knowledge is more geographically clustered than pure knowledge. Another campus-oriented knowledge spillover compared by Gittelman (2007) also corroborated that market-oriented technology is more geographically clustered. These studies commonly examined the biotechnology patents from major universities to US industries, reaching a consistent conclusion on the geographical proximity of market-mediated technology. Despite the recent empirical studies suggesting that the contribution of market-mediated technology flows from universities tend to be geographically concentrated, these studies rely on a relatively small number of campus-oriented patents. Such a paucity of cases leaves the unanswered about the relationship between spatial proximity and market-mediated technologies. In this vein, the first research question is to what extent market-mediated technology transfer is restrained by the spatial distance between two parties.

The lack of unanimity partly lies in the lack of understanding of the interactive relationship between the technology provider and purchaser. It is important to note that the market risk and risk-aversion motivation underpinning the local knowledge spillover lies at the heart of explaining the geographical proximity of technology diffusion. The patent licensing allows licensees to profit from the licensor's intellectual property rights (Williamson 1991). The technology licensing transaction generates two effects: (1) licensor’s profit from payment, and (2) the profit dissipation effect caused by potential competition in the market (Arora and Fosfuri 2003). According to Fosfuri (2006), one of the key determinants of the licensing decision is not just the profits from licensing payments, but also the potential reduction occurring from an additional competing firm, or even an aggressive strategy from existing competitors. Thus, technology transfer could lead to revenue trade-off between the increase in royalty revenues and the potential risk of decreasing market share within an overlapped market, leading to an even more complicated analysis (Fosfuri 2006).

One of the primary uncertainties for the technology licensor in the process of knowledge spillover is to avoid profit dissipation effects. In the perspective of a firm's interests, the licensor firms are highly likely to reduce potential risk by selecting partners in a downstream market, looking to other geographical markets rather than local areas (Fosfuri 2006). The licensor, in the meantime, is likely to consider the market condition that may threaten its own profits. Such potential risks of the licensor become more likely when it is from the private sector and the licensee originates from geographically close and highly competitive locations. In such settings, it may be hard for the licensor to make a license contract.

On the other hand, in another attempt to limit risk, the potential licensee also seeks a technology provider within its trust-built network in order to reduce the uncertainty of the technology and hedge its purchase. The patent licensing might be involved in the transaction risks of a partner’s opportunistic behaviour (Bathelt and Henn 2014). The technology transfer contracts are highly likely to consist of explicit licensing rights with intangible know-how. Under the technology licensing process, the technology purchaser and supplier need to mutually consent to the process of setting the price scheme, negotiating legal rights, and providing instructions including tacit know-how. From the perspective of the potential technology licensee, it is difficult to forecast the unforeseen risk of absorbing the tacit knowledge. One of the effective strategies for a licensee to deal with these uncertainties is to seek partners within their own networks in order to monitor the patent owner’s records, the reputations from the buyers as well through the different forms of trust-based local networks (Gulati 1995, Gertler 2003). The firms' preference for a partner within the spatially proximate network also involves the risks related to preventing opportunistic behaviours among partners

(Bathelt and Henn 2014). The geographical distance between two parties might even enhance the risk more than the closely-located partners, as physical distance could obscure the monitoring of other parties' activities. In practice, the incidence of the potential threat of enforcing sanctions, including a legal action and indirect collective action, attenuates along with the distance between the parties (Bathelt and Henn 2014).

Indeed, Maskell and Malmberg (1999) contend that the potential licensees tend to seek the experienced in a local area. As the relationship is likely to be established through past interactions, the licensees can increase the opportunity to absorb the patentee's informal tacit knowledge, developing the trust between them. The relationship based on interactivity, then might serve as an invisible restraint against opportunistic behaviour. The licensee, who needs non-market and informal relationships for managing risks in the transmission process, has an incentive to be geographically close to the technology provider. Within this argument, the mutual uncertainty and risk in the market-mediated technology have not received the attention it deserves, which this study tackles.

The second question is to identify whether the two parties involved in the transaction have an identical preference over the geographical proximity. If so, thirdly, do technology providers consider the dissipation effect in the proximate area as a determining factor for a licensing decision?

## 4.3. Data and Method

### 4.3.1. Data

Most of the literature that examines technology flow mainly grounds its analysis on patent citation data (Jaffe, Trajtenberg et al. 1993, Maruseth and Verspagen 2002, Mowery and Ziedonis 2015). Compared to the other knowledge flow trails, which has little relation with pecuniary-motivated technology transfer, patent licensing is an appealing measure for the innovative activities. First, patent licensing data indicate the flow of technology with economic value geared toward innovative outcomes. Arora and Gambardella (1990) emphasised the role of the technology market as an efficient channel for providing specialised and innovative technology; the licensees are highly likely to purchase technology from a licensing market for commercialisation rather than embryonic knowledge for the future utilisation. The empirical studies on any significant correlation between patent trade and economic value corroborate that licensed patent is more closely related to the realised innovative capacity of a region (Tong and Frame 1994, Reitzig 2003). Second reason is that the patent licensing process shows the dynamic and interactive relationship between licensor and licensee that results in a description of regional networks of all relevant organizations. Third, a licensing contract reflects the organisation's strategic decisions. In order to complement the transaction, it usually takes longer and encompasses complicated interactions. For instance, the potential technology purchasers are likely to seek the technologies, explore them, and negotiate with the patent assignee to set-up institutional protocols for transfer, each of which requires a good understanding of the two parties and intensive interactions between them.

Recent research pays attention to the patent licensing transactions as a good indicator of market-mediated knowledge flows (Spulber 2008, Nelson 2009, Laursen, Leone et al. 2010, Wang, Zhou et al. 2013). Mostly, the licensing agreement indicates the activity by which presumes that technology is aimed at contributing to the economic value (Nelson 2009). Compared to other knowledge types, the licensing permits intellectual property from the licensor to licensee via pecuniary compensation (Arora 2001). Specifically, the trails on patent licensing reveal which technology sectors, the purchaser, and the owners, as well as their regions. Thus, for instance, the trail of patent licensing reveals which technology field is currently commercialised for potential economic value.

The analysis sets the prefecture-level as a geographical unit of analysis because Provinces are not economic units but political and administrative units. Even if there are Province-level economic and technology policies, national policies influence economic space across the boundaries of these political units. Secondly, province borders do not bind the daily activities of economic actors. Commuting and travel behaviours are influenced by time and distance rather than by the Province boundaries. For daily economic activities, city region or metropolitan area is a more appropriate unit of analysis (Jaffe, Trajtenberg et al. 1993, Audretsch 1998, Feldman and Audretsch 1999).

This paper utilises domestic inter-regional technology flows from Chinese patent licensing data. China, a fast catching-up economy with spatial and technology disparities across a vast geographic territory, attracting attention from scholars in that the size of technology trade market has been sharply expanded, providing a dynamic feature in localising exogenous knowledge (Wang, Zhou et al. 2013). China is one of the few countries to collect the contract information between the two parties under the official regulation imposed by State Intellectual Property Office of China (SIPO). Then, 32,551 records of institution-level license contracts including patent titles, application numbers, and the addresses of assignees were collected. For data reliability, the challenge was to find the link between official patent application DB and licensing dataset on the basis of patent number. This process ended up having 10,048 transactions of prefecture-to-prefecture cases.

#### 4.3.2. Analysis model and variables

The current research consists of a two-part estimation analysis. The first analysis employs a 'gravity-like model' in assessing the extent to which spatial distance serves as a resistance factor. The second step of the model, based on the experienced group, is extended to examine whether the licensor and licensee have an identical preference for the proximity level. The second analysis utilises a binomial logistic regression to confirm the presence of the licensor's dissipation effect in the local area.

The first analysis presumes that the total innovative outputs $(Q)$ are produced by a function of endogenous technology stock $(A)$ and accessible exogenous technology stock $(A^{a})$ outside of region $i$ at time $t$ with each elasticities, $\gamma$ and $\mu$ (Griliches 1980, Peri 2005). Let $X_{ct}$ be a specific factor of a country $(c)$. Then, the total innovative outputs of region $i$ at time $t$ $(Q_{it})$ are defined as :

$$Q_{it} = X_{ct}(A_{it})^{\gamma}(A^{a}{}_{it})^{\mu}. \tag{1}$$

Since the technology stock outside of a region is not perfectly reachable, the probability $(\phi)$ of non-obsolete technology stock, produced in another region $j$ but absorbed in region $i$, is introduced $(\phi_{ijt})$, which yields

$$A^{a}_{it} = \sum_{j \neq i} \phi_{ijt} A_{jt} \tag{2}$$

where $\phi_{ijt} \in [0,1]$. Then, equation (1) is transformed as below with logarithms form:

$$\ln Q_{it} = \ln X_{ct} + \gamma \ln A_{it} + \mu \ln(\textstyle\sum_{j \neq i} \phi_{ijt} A_{jt}). \tag{3}$$

Following Jaffe and Trajtenberg (2002), and Peri (2005), the probability $(\phi_{ijt})$ that a non-obsolete idea produced in region $j$ is learned in region $i$ by the time $\tau$ is assumed to be consisted of the potential resistance factors and the cumulative probability of learning technology stock in a region $j$. Here, in order to characterise the diffusion of knowledge, the resistance factor is assumed to be a time-fixed function of geographic (*DIST*) and technological (*TECH*) characteristics in the basic analysis model (Peri 2005, Burhop and Wolf 2013, Drivas and Economidou 2015).

$$\phi_{ijt\,(\tau)} = e^{f(i,j)}(1 - e^{-\beta\tau}). \tag{4}$$

The factor $(1 - e^{-\beta\tau})$ in equation (4) indicates the idea that the likelihood of technology in region $j$ becoming available in region $i$ in a cumulative probability function. The factor

$e^{f(i,j)}$ indicates that the intensity of learning between source region $j$ and purchasing region $i$ depend on the potential resistance factors in equation (5).

$$\begin{aligned}\phi_{ij} = e^{f(i,j)} = \alpha + \beta_1 DIST\ [1]_{ij} + \beta_2 DIST\ [2]_{ij} + \beta_3 DIST\ [3]_{ij} \\ + \beta_4 DIST\ [4]_{ij} + \beta_5 DIST\ [5]_{ij} + \beta_6 TECH\ [Sim\ ]_{ij} \\ + \beta_7 TECH\ [Pat\_o]_i + \beta_8 TECH\ [Pat\_b]_j \\ + \beta_9 TECH\ [Type\ ]_i + \varepsilon_{ij}\ .\end{aligned} \quad (5)$$

The dependent variable (*Flow*) is the number of patent flows from licensor region $i$ and the licensee region $j$. The distance variable dummies (*DIST*) distinguishes five geographic distance levels; 'DIST[1]' equals 1 if licensor and licensee are located within 124km[6] of one another and 0 otherwise; 'DIST [2]' takes 1 if they are located within 486km[7] of each other; 'DIST[3]', '[4]' takes the value of 1 if the licensor is located within 1,000km of the licensee, and 2,000km respectively; 'DIST[5]' equals 1 if the distance is further than 2,000km.

The technology sector is controlled by technology proximity (TECH[Sim]), the technology stock (TECH[Pat]), and the type of technology source (TECH[Type]). First, the cosine similarity of the patent portfolio between the regions of licensor and licensee as a proxy of technology proximity was calculated (Breschi, Lissoni et al. 2003, Beaudry and Schiffauerova 2009). The cosine similarity represents how two cities have a similar distribution in creating technology portfolios from patent applications. Total technology sectors were set in accordance with 35 NACE fields (n=35). It measures the angular separation between the vectors of the co-occurrences of fields, where $C_{ij}$ represents the

[6] It represents an averaged diameter of prefecture-level region.
[7] It is an averaged diameter of provinces borderline distance.

number of patents classified in both fields: $\mathrm{Tech[Sim]_j} = \frac{\sum_{n=1}^{35} C_{in} C_{jn}}{\sqrt{\sum_{n=1}^{35} C_{in}^2}\sqrt{\sum_{n=1}^{35} C_{jn}^2}}$. The closer $\mathrm{Tech[Sim]_j}$ is to 1, the more the two regions are likely to have an identical technology portfolio, while it goes to 0 for pairs of the technology portfolio that do not have fields in common.

The size of a region is controlled by adding the number of patent applications (TECH[Pat]) that represents the total domestic patent applications per region's size (total population) to capture the knowledge production capabilities of the region (Varga, Pontikakis et al. 2014). As an index for describing the discrepancy, the patent owner's regions (TECH[Pat_O]) as well and buyer's (TECH[Pat_B]) were respectively considered in the model. The source of technology (TECH[Type]), a dummy variable, proxies whether the patent originated from a public (TECH[Type_Pub]) or private institution (TECH[Type_Pri]). The motivation of creating, and transferring a patent might be different from the source of technology, which might have a different impact on the knowledge flows (Kalapouti and Varsakelis 2015). Then, the basic model for the estimation yields as below:

The last variable vector extends the basic model. The presence of 'experienced' institutions within the area were followed in order to reflect the extent to which the city has experienced market participants, following the arguments of Maskell and Malmberg (1999). Indeed, the 'experienced' refers to the institutions that transformed themselves from the technology purchaser in the previous period to the provider afterwards. It is expressed as the ratio of formerly experienced technology providers over the number of total technology supplies. The geographical distance was classified into three categorical variables within the prefectures, within the province and the other regions. Thus, if the 'within the city' variable is higher, the potential purchaser in the prefecture is likely to have more skilled potential technology owners within the prefecture, enhancing the chances for absorbing the assimilated local knowledge. Then, equation (4) is extended by adding EXPR variable as below:

$$\phi_{ij} = \exp[a + DIST + TECH + EXPR]. \quad (6)$$

As an estimation econometric technique, equation (6) is familiar with linear regression with non-negative count data, which is fit for a negative-binomial regression in addition to handling the over-dispersion problem that the counts data commonly have (Branstetter 2001). In order to handle the issue, the generalisation of the Poisson model, or negative binomial estimation, is widely used to lessen the restricted assumptions about the variance of observations. It is also accepted in the patent citation literature as similar to the contexts (Peri 2005, Rond and Hussler 2005). Table 15 and Table 16 summarise the definitions and descriptive statistics.

*Table 15 Variable definitions*

| Variables | Definition |
|---|---|
| *Dependent Variable* | |
| Flow | Count number of license contract between two regions |
| *Independent Variable* | |
| DIST[1~5] | Dummy variables of distance form licensor's region to licensee's region |
| TECH[Sim] | Cosine similarity of patent portfolio |
| TECH[Pat] | Number of patent application per population |
| TECH[Type] | Dummy variable if the licensor is public sector |
| EXPR[City] | Probability of experienced groups located within city |
| EXPR[Prov] | Probability of experienced groups located within province but city |
| EXPR[Other] | Probability of experienced groups outside of province |

*Table 16 Descriptive Statistics*

| | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Flow | 1 | 1453 | 13.59 | 63.16 |
| TECH[PAT_O] | .2 | 74.3 | 17.08 | 17.82 |
| TECH[PAT_B] | .12 | 74.31 | 12.84 | 16.17 |
| TECH[Sim] | .00 | 1.00 | .83 | .212 |

| | | | | |
|---|---|---|---|---|
| EXPR[City_O] | .00 | 1.00 | .36 | .328 |
| EXPR[Prov_O] | .00 | 1.00 | .14 | .244 |
| EXPR[Other_O] | .00 | 1.00 | .29 | .294 |
| EXPR[City_B] | .00 | 1.00 | .29 | .328 |
| EXPR[Prov_B] | .00 | 1.00 | .18 | .291 |
| EXPR[Other_B] | .00 | 1.00 | .38 | .360 |

The second part deals with how the level of competition affects the patent owner firm's decision on technology licensing in the region. The probability of the presence of non-public sector on the condition of distance level was calculated by employing binomial logistics regressions. Here, let the dependent variable (TECH[Type_Pri]) be value of 1 if the patent is owned by a non-public firm, and 0 if otherwise. In this case, the odds ratio that the licensor would be a non-public owner compared with the probability of non-firm owner is determined by the competition level (COMP), distance level, and interactive terms. As the technology portfolio is not distributed uniformly, this model considers the technology specialisation index represented as location quotient or technology revealed comparative advantage (TECH[LQ]). It measures concentration of region $i$'s patent activity in technology sector $k$ relative to the national level: $LQ_{\boldsymbol{k}} = \frac{n_{\boldsymbol{k}}/n_i}{n_k/n_{a\boldsymbol{l}}}$, where $n_{\boldsymbol{k}}$ is number of patents in region $i$ and technology sector $k$ while $n_{al}$ is the toral number of patents in all technology sector and regions (Malerba, Orsenigo et al. 1997, Catherine 2002). Here, the technology sector is set to 35 in order to be consistent with the NACE codes.

The competition level is calculated by a reverse of HHI index, measuring whether the technology flow is dominantly concentrated or not: $COM\,P = {}^{1}/_{\sum_{n=1}^{35} S^2}$, where S denotes the technology sector's shares of licensing flows in a prefecture. As total range of HHI is from zero to 1, the higher COMP implies a highly competitive condition in a relative comparison. The continuous variable (COMP) value is converted into a categorical variable; the upper (lower) 25% of distribution is expressed as a high (low) criteria. The geographical proximity level (DIST[<City]) equals 1 if the licensor is located within the city borderline, and 0 otherwise (DIST[>City]). The, the main focus on this model is to measure the interactive terms of both independent variables ($COMP \times DIST$) to test whether the proximate intimacy and competition condition affects the firm's decision on licensing. Table 17 describes the statistics.

$$\begin{aligned} \mathrm{logit(TECH[Type\_Pri])} &= \alpha + \beta_1 LQ + \beta_4 Comp[Low] + \beta_5 Comp[Med] \\ &+ \beta_6 Comp[High] + Interactive\ terms + \varepsilon_{ij} \end{aligned} \tag{7}$$

*Table 17 Description of Data Set for Logistics Regression*

| Cases | Total Sample | Competition Level | | |
|---|---|---|---|---|
| | | Low | Medium | High |
| DIST[City] | 4,561 | 1,061 (23%) | 2,368 (52%) | 1,132 (25%) |
| DIST[Out] | 5,932 | 1,490 (25%) | 2,889 (49%) | 1,553 (26%) |
| Total | 10,493 | 2,551 (24%) | 5,257 (50%) | 2,685 (26%) |

## 4.4. The geographical incidence of market-mediated technology

Table 18 reports the estimation result of the basic and full models of two types of regions. First, the goodness-of-fit of the basic models which measured by deviance over the degree of freedom (*d.f.*) was appropriate in that two types of regions were 0.941, 0.965, which are all close to 1. All coefficients show a stable significance level of under 10%. The estimated DIST coefficient vectors of all regions exhibit a sharp decrease as the spatial distance between licensor and licensee increases. While the first coefficient (DIST[1]) serves as a base reference of value of 1 ($e^0$), if the licensed technology crosses the prefecture-level region's borderline (DIST[2]), then, compared to what they would exchange within prefectures, the technology flow diminishes to 12.2% ($e^{-2.10}$). Then, the decreasing trend (7.1%, 5.6%, and 4.5%) continues as the distance level further increases from DIST [3] to [5], respectively. These figures indicate that a technology exchange tends to be localised in the bounded spatial limit. The result corroborates that spatial proximity between the technology producer and purchaser exerts a heavy toll on their transaction, which was consistent with the result from patent citation data (Jaffe, Trajtenberg et al. 1993, Peri 2005, Drivas and Economidou 2015).

Although Audretsch and Stephan (1996) argued that geographical proximity does not matter for the formal knowledge transmission, one of the most codified type of knowledge exchange via licensing contract also showed a strong local spill over. The one responsible reason for the geographical constraint might relate to the attribute of the 'highly-involved' nature of licensed or purchased technology. In contrast to patent citations which are widely accepted as a measure of technology flows the patent licensing process requires more complex procedures such as patent navigations, scrutinisation of rights, negotiation for license fees, and terms for the completion of transaction. The complexity and the interactive relationship behind the patent licensor and licensee might hamper the technology diffusion over spatial spaces. For instance, in addition to the explicit rights of usage, the underlying purpose for a licensee is to acquire the tacit knowledge through informal interactive channels (Chatterji and Manuel 1993, Horwitz 2007). The other explanation points to the concentrations of innovative resources within a small number of cities in an economy that is still catching up. The developing countries have fragmented innovation components, reinforcing the unequal quality of capabilities across regions and institutions. The highly innovative organisations with the advanced knowledge creation capacity might co-locate with the majority of low-capacity firms, causing the biased distribution of technology (Lundvall, Joseph et al. 2011).

The estimated coefficient of technology sources (TECH[Type]) reported that non-public sector (TECH[Type_Pri]), relative to public sector (TECH[Type_Pub]), has had a positive impact on technology licensing flow by 133.8% ($e^{0.291}$). Although some studies explore the localizing trend of technology transfer from public sector - mainly Universities- to non-public sectors during the earlier years of 1985–2004, the role of the private sector in technology diffusion in the regional level has not been highlighted (Hong 2008, Wang, Pan et al.). The coefficient value gives a signal for the influential role of the private sector in knowledge diffusion as a technology source. The differences in a region's capabilities between the licensor (TECH[PAT_O]) and licensee (TECH[PAT_B]) that was measured by the number of total patents per population size showed almost no marginal difference (-0.027, -0.028).

*Table 18 Negative binomial coefficients estimation result*

| Independent Variables | Negative binomial coefficients | | | |
|---|---|---|---|---|
| | Basic Model | | Full model | |
| | All regions | Super regions | All regions | Super regions |
| Intercept | 2.21*** | 2.62*** | 1.86*** | 1.99*** |
| | (.248) | (.342) | (.248) | (.356) |
| DIST[1] | 0[a] | 0[a] | 0[a] | 0[a] |
| DIST[2] | -2.10*** | -2.33*** | -2.14*** | -2.38*** |
| | (.105) | (.180) | (.106) | (.182) |
| DIST[3] | -2.64*** | -3.00*** | -2.67*** | -3.01*** |
| | (.101) | (.173) | (.102) | (.174) |
| DIST[4] | -2.88*** | -3.22*** | -2.92*** | -3.22*** |
| | (.099) | (.172) | (.099) | (.173) |
| DIST[5] | -3.10*** | -3.47*** | -3.06*** | -3.39*** |
| | (.104) | (.178) | (.105) | (.180) |
| TECH[Type_Pri] | .291** | .353* | .269** | .380* |
| | (.126) | (.202) | (.128) | (.207) |
| TECH[Type_Pub] | 0[a] | 0[a] | 0[a] | 0[a] |
| TECH[PAT_O] | .027*** | .025*** | .024*** | .025*** |
| | (.001) | (.001) | (.001) | (.001) |
| TECH[PAT_B] | .028*** | .024*** | .024*** | .021*** |
| | (.001) | (.001) | (.001) | (.001) |
| TECH[Sim] | 1.20*** | 1.18*** | .891*** | .922*** |
| | (.179) | (.195) | (.186) | (.206) |
| EXPR[City_O] | | | .370*** | .180 |

| | | | | |
|---|---|---|---|---|
| | | | (.086) | (.120) |
| EXPR[Prov_O] | | | $.576^{***}$ | $.650^{***}$ |
| | | | (.106) | (.138) |
| EXPR[Other_O] | | | $.592^{***}$ | $.753^{***}$ |
| | | | (.093) | (.124) |
| EXPR[City_B] | | | $.469^{***}$ | $.676^{***}$ |
| | | | (.093) | (.126) |
| EXPR[Prov_B] | | | $.314^{***}$ | $.384^{***}$ |
| | | | (.100) | (.131) |
| EXPR[Other_B] | | | $.387^{***}$ | $.346^{***}$ |
| | | | (.081) | (.114) |
| No. observations | 2232 | 1497 | 2232 | 1497 |
| Deviance/d.f. | .941 | .965 | .902 | .917 |
| Likelihood Ratio Chi-square | 2775.305(<0.001) | 1754.395(<0.001) | 2866.127(<0.001) | 1832.094(<0.001) |
| Log Likelihood | -6387.093 | -4352.019 | -6341.632 | -4313.169 |

*, **, *** represents significance level at 10%, 5%, 1% respectively. ([a]) denotes the reference basis.

The next coefficients (TECH[Sim]) examined the technological proximity between the technology portfolios of two regions. The estimation result (1.202) demonstrates that technology proximity between the two cities tends to encourage technology transactions by approximately 332% higher. It also supports the MAR-externality notions in that the proximate technologies enhances the frequent transactions, which is considered in the form of spill over, derived from intended learning processes (Breschi, Lissoni et al. 2003, Boschma, Eriksson et al. 2014).

The second column of Table 4 provides the estimation of technology flows among the three leading 'Super regions' in the Chinese economy. The geographical coefficients slope declined more sharply compared to all cities model, suggesting that local knowledge spill over is reinforced within the leading regions. Compared with all regions, DIST[2] of 'Super regions' decreased from -2.10 to -2.33, the next variable (DIST[3]) also dropped from -2.64 to -3.00, consequently, DIST[4] and [5] fell to -3.22 and -3.47, respectively. This sharp slope drop suggests that technology produced in the leading regions is more likely to remain with the proximate regions, which might reinforce the disparity of knowledge distribution across domestic regions. The private sector also led technology-licensing contracts within three megalopolises on the basis of TECH[Type_Pri]. The other variables - technology proximity and region's patents stock - showed a significant, but little difference with the result of all regions.

The next model extends the basic model to capture the impact of experienced assimilator groups within the regions over the technology transmission. The full model enters six coefficients representing the ratio of assimilators within the three different geographical scales for both licensor and licensee. Here, the goodness-of-fit for two region types (all super regions) was reported well fitted on the basis of deviance over d.f. (0.902 and 0.917, respectively). The experienced assimilators coefficients reported a different geographical pattern according to the technology owner and buyer’s region. The highest order of coefficient value in owner’s regions was EXPR[Other_O], followed by EXPR[Prov_O], and EXPR[City_O]. Contrary, the purchaser region’s proximity proves that EXPR[City_B] has the most influential, followed by EXPR[Other_B], and EXPR[Prov_B]. Based on the estimation results, the experienced technology owners do not prefer the proximate purchasers rather than those of outside prefecture regions; however, experienced purchasers prefer their providers to be in close regions. This inconsistent order of proximity preference seems to be embedded in the risk of technology licensing transaction. The technology proximity result supports the tendency to avert potential competition within the closed market. Interestingly, the province border line seems to be the most proper distance of not too far from losing its motivation for licensors, while not too close for competition, which is examined in the next analysis part.

Another plausible explanation for the proximity level is relevant to the motivation of acquiring the licensor’s tacit knowledge. In response to the risk of transmitting tacit, the licensee might rely on the informal network within a city-level borderline. The intangible determinant factors for a technology purchase such as reputation, trust, and networking opportunities embedded in the region’s atmosphere appear to make the buyers prefer the experienced partners within the prefecture area. The lowest estimation result of province level (EXPR[Prov_B]) implies that the purchaser prefers to choose on either side of proximity - in the closest or the farthest regions outside of province level. This underlying strategy behind the partner choice is that, if the purchaser fails to acquire the patent within the city, then they do not seem to consider the proximity because they did not expect the advantages from it. Therefore, the former experiences as a the strategic response of the licensing risk exert an influence on the technology flows rather than the city's patents or external technology inflows, which has seldom been highlighted in the previous literature.

The last column of Table 4 provides the estimation results of ‘Super regions,’ which were found appropriate goodness-of-fit (0.917). The geographical coefficients slope declined sharper than the ‘All region’ model, suggesting that leading regions tend to have more localised and concentrated technology flows. The decreased slope change suggests that technology produced in the leading region is highly likely to remain with the proximate region, which might reinforce the disparity of knowledge distribution across the domestic regions. Both technology proximity (TECH[Sim]) and region's patents sources (TECH[Type_Pri]) showed significant, but approximately, similar results with the previous model.

Here, a noticeable point is that characteristics of experienced technology owner (EXPR) reinforced, while the ranks hold. For instance, the furthest distance (EXPR[Other_O]) was 0.753, followed by Province level (0.650). The prefecture level has a minimum value (0.18), however it is not significant. In the risk perspective, the sharper decline of the slopes implies that the institutions located in leading regions are more sensitive to the risk-aversion strategy. The owner of the technology in the leading city tends to provide it to the experienced groups within the province border and even outside of the province rather than the buyers within the city level. The buyer, however, also shows strong preferences for the experienced provider within the city border, compared to the all cities. The province level, and the other regions are followed, suggesting that the buyers in the leading regions are more motivated to exchange technologies within the spatially proximate institutions than do the cities outside the leading cities.

## 4.5. The dissipation risk in market-mediated transfer

Table 19 shows the estimated coefficients from a binomial logistic regression. In order to represent the fact that competition level might influence the firm's strategic decision on a licensing contract, the dependent variable is set to the odd ratios of the presence of a private-sector owner. The chi-square value of 698.156 with a p-value of less than 0.0005 indicates that the model as a whole fits significantly. All the estimated variables reported at the statistically significant level of 10%. The control variable TECH[LQ], the distribution of technology across the regions, is 0.334, suggesting that a unit of LQ increase leads to $1.396(e^{0.334})$ times of odd-ratios of private sector. The DIST[City] was 0.838 implying that, the city-level distance has approximately 2.3 times more influential power than that of reference variable (DIST[Out]). Thus, it corroborates the previous model in that the technology flow within the prefecture-level region is led by private sectors rather than public sectors. Next, the coefficients of COMP shows that the higher competition level (COMP [Med]), versus a Low reference variable (COMP[Low]), decreases the log odds of private sector by $67\%(e^{-0.403})$. Consequently, the more competition level increases (COMP[High]), the odds ratio further decreases (-.446). The results imply that the competition level in the market serves as a factor for firms to determine the licensing decision in an inversely proportional way.

*Table 19 Binomial logistics coefficients estimation result*

| Variables | β | S.E. | Wald | df | Sig. | Exp(β) (odds ratio) |
|---|---|---|---|---|---|---|
| TECH[LQ] | .334 | .025 | 182.015 | 1 | .000 | 1.396 |
| DIST[City] | .838 | .088 | 90.359 | 1 | .000 | 2.312 |
| Comp[Low] | | | 46.517 | 2 | .000 | |
| Comp[Med] | -.403 | .066 | 37.723 | 1 | .000 | .669 |
| Comp[High] | -.446 | .075 | 35.431 | 1 | .000 | .640 |
| DIST[Out] * Comp[Low] | | | 7.739 | 2 | .021 | |
| DIST[City] * Comp[Med] | -.210 | .105 | 4.003 | 1 | .045 | .811 |
| DIST[City] * Comp[High] | -.328 | .119 | 7.612 | 1 | .006 | .720 |
| Constant | -.499 | .064 | 61.335 | 1 | .000 | .607 |

The interactive terms of two category variables – COMP and DIST – indicate more clearly whether the competition level within the prefecture region has positive or negative impact on the private sector owner's decision. A reference variable here is DIST[Out] * Comp[Low], then the negative value (-0.210) for DIST[City] * Comp[Med] represents that the more competition at the city-level region has decreased the odd ratio of the private sector's licensing decision. Further, the negative, and significant, coefficient estimation of DIST[City] * Comp[High] (-0.328) suggests that licensing contracts complemented by private-firms are hampered by strong competition condition in the city-level region. This analysis consistently reflects that the competition level within a proximate space at least city borderline deters firm's form providing patent to the purchasers.

## 4.6. Conclusion

Previous studies have argued the importance of technology transfers as strategic means to trigger innovative activities in a region, but have neglected the in-depth understanding of the dynamics and uncertainty within proximate geographic space. This study reveals the geographical influence of market-mediated technology diffusion by identifying the risk-aversion patterns in the geographical space. The market-mediated technology flow exemplified by patent transfer dataset, combining Chinese patent licensing data with domestic application information, describes the inter-city market-mediated technology flows in China, which is seldom attempted on a national level, identifying a never before seen analysis. As Peri (2005), Drivas and Economidou (2015) presented, this regression result similarly corroborates that spatial distance takes a heavy toll on their technology transfers and even further reinforces it in the leading megalopolis regions. The experienced technology transfer groups that served as a conduit for the technology provider also showed that the differential preference over proximity on licensing and licensor is pronounced for all models, which represents a motivation that runs counter to those of market-mediated technology transaction.

The additional analysis provides empirical evidence that geographical proximity served as a constraint on the licensor's decision on technology transfer, achieved by assessing the log-odd ratio of non-private sector as an alternative for the local competitive intensity. The negative coefficients for the two interactive terms provide empirical evidence that more intensive competition within the local area deters firms significantly from providing knowledge spill over. The results supported a consistent tendency toward a different preference over technology licensor's and licensees spatial tendency via market transactions. This result plausibly reflects the hidden and interactive motivation nature of market-mediated technology transfer, as well as the need for the licensor to utilise the spatial distance as a strategic tool for risk-aversion.

These findings contribute substantively to the literature: First, the analysis identifies that geographical proximity served as a risk-aversion means for the licensor and licensee. The highly involved knowledge with economic compensation, even though it is transmitted in the most codified transmitting vehicle, the distance between provider and consumer paid a heavy toll for transferring it. But, it is also found that the provider and consumer have different preferences of geographical proximity. On the micro-level, the technology diffusion is driven by the interplay of the provider's motivation of revenue between the dissipation effect comes through competition level and the pecuniary compensation paid by the licensee (Arora, Fosfuri et al. 2001). Accordingly, technology diffusion by licensing contract is not always likely to be occurred in proximate areas rather the distant space might promote the exchange of knowledge. This empirical result provides a significant insight to the link in the gap between the innovation system and geographically agglomeration economies in that the location of firms within a proximate neighbourhood might hamper the diffusion of technology which is required for promoting innovation system (Pascal and McCall 1980, Wheaton and Shishido 1981, Rauch 1993, Ki 2010).

Second, the empirical analysis also provides compelling evidence which factors influence the diffusion of technology in light of growing interest in understanding the process of shaping technology capability within the regions in the catching-up country. It supports the notion that geographical boundaries still hinder the transmission of technology diffusion at the city level, even given several recent changes in the concept of ‘weightless technology.’ The analysis in leading megalopolises also demonstrates the stronger concentration in knowledge creation and consumption that might be implicit the more biased distribution in economic outputs (Radosevic 1999, Asheim and Isaksen 2002, Capello, Caragliu et al. 2010).

Lastly, this analysis provides the strategy for knowledge-driven economic growth for catching-up countries with relevant evidence. Given the fragmented innovations system components in developing countries, the exogenous inflows of technology are essential for facilitating technology capabilities. While many researchers argue this point, my empirical study demonstrates the importance of balance between internal and external sources of technology for learning (Bathelt, Malmberg et al. 2004, Wang, Zhou et al. 2013). To reap the benefits of exogenous technology inflows, the catching-up countries are required to establish their internal knowledge base for assimilating them into local knowledge. The analysis also points the role of experienced assimilators in the proximate regions. One of the policy makers' roles in the process seems to establish the opportunity to accumulate the technology transfer practices, accelerate the spill over of the tacit knowledge, and reduce capability gap between the leaders and other institutions. Moreover, due to the existence of externalities in the market, there are important policy interventions that provide incentives, as well as the necessary support for diffusing knowledge even at the long-distance regions from technology sources.

# Chapter 5. The evolution of technology transfer network: static and dynamic approach

## 5.1. Introduction

The aim of this chapter is to understand how the structure of a network and a region's innovative capacity contributes to the evolution of a technology transfer network. For this purpose, the current analysis explores the static properties of network on the basis of the inter-regional (prefecture-to-prefecture) technology flow networks, and then attempts to measure the influence of dynamics on the network evolution. The contribution of this empirical analysis is to challenge the question of what propels market-mediated technology transfer network evolution.

The prior literature on the dynamics of network has centered on the structural benefits of nodes to explain the innovative activities and the performances at institution and region level (Almeida and Kogut 1999, Breschi and Lissoni 2001, Boschma 2005, Boschma and Frenken 2006, Gluckler 2007, van Oort and Lambooy 2014). The structural advantage of a brokerage role is to mediate or control knowledge flow between its own group and another. In the context of the innovation system, the bridging institutions establish ties with other different kinds of other institutions and support the viability of the whole system (Sapsed, Grantham et al. 2007). Studies of geographical clusters also highlight the linkages within and outside their cluster, connecting with knowledge sources (Ter Wal and Boschma 2009, Maggioni and Uberti 2011, Munari, Sobrero et al. 2012, Boari and Riboldazzi 2014). On the other hand, extant studies highlight the importance of attributes of the individual nodes such as the absorptive capacity of the node (Spencer 2003, Giuliani and Bell 2005), internal skills and experiences (Stam 2010, Giuliani 2011).

Although the above empirical works contribute to the current literature by articulating the relationship between network and innovation activities, they might not consider the dynamic processes that sustain the development of network. The temporal development of a network is highly likely to be the consequence of interaction between the structural and propensity factors of a node. In the context of the mutual uncertainty of pecuniary-compensated technology transfer, the actors involved in the patent licensing also are expected to be affected by formerly established relations. Hence, it is plausible that the network structure matter as a dynamics for its evolution, as is corroborated by former studies (McEvily and Zaheer 1999, Zaheer and Bell 2005, Graf and Krüger 2011). On the other hand, still prior studies emphasis the attributes of individual nodes for the actions taken which is largely suggested by extant works related with the absorptive capacity of a node (Spencer 2003, Giuliani and Bell 2005, Giuliani 2011).

This research focuses on investigating these two factors whether they empirically contribute to the evolution by applying network analysis in two ways: static and dynamic approach. The static approach addresses the structural properties of network in order to answer the questions such as how the network size increases, which regions have the central positions, and which regions serve as a brokerage role. The dynamic approach measures the impact of a region's technology activities to the evolution of a market-mediated technology transfer network by employing stochastic actor-oriented models (SAOM) that are recently recognized as a robust model technique for dealing with the longitudinal issues in network studies (Giuliani 2011, Balland 2012, Broekel, Balland et al. 2014).

The structure of this chapter is constructed as follows. The next section is dedicated to present the literature on the network evolution and measurement method. Section 3 briefly describes the network data construction, then followed by the static analysis of the network. Next, section 5 addresses the dynamic analysis on technology flow network and the last section summarizes the results.

## 5.2. The dynamics of network evolution

When innovation studies adopt the concept of network, one of the main concerns is to reveal the linkage between the structure of knowledge flow and performance of the network (McEvily and Zaheer 1999, Zaheer and Bell 2005, Lazaric, Longhi et al. 2008, Graf and Krüger 2011). The research has focused on the benefits derived from these network positions and the contingencies of these benefits. The fundamental assumption of these studies is consistent with the idea that the structure determines the performance of a system that comes from SCP (Structure-conduct-performance) framework in economics (Fu 2003, Ralston, Blackhurst et al. 2015). The SCP framework finds its roots in industrial organization. The theoretical framework argues that firms derive competitiveness by responding to the environmental characteristics (Caves 1972). The key idea is that environmental and institutional forces around organisation have a structural influence on the decision-making process, then thus affect the performance (Sundaram and Black 1992). Then, in the same way, the decision of a node in the network under the linkages with others is also influenced by the intangible forces and incentives derived from the relations with others that constitutes the structural effect.

This attention to the structural determinants of network call for a strand of empirical studies. Zaheer and Soda (2009) study the origins of structural holes through network evolution at an individual level and highlight the roles of prior position centrality, as well as of structural holes spanned in the past. Balland (2012) examines the impact of proximity dimensions on the evolution of collaborating networks in the global navigation satellite industry in Europe. The insight from the quantitative modelling the network dynamic is that the structural factors hold significant power for explaining the longitudinal evolution of the network. The empirical works on economic geography have been dedicated to describe the structural properties of knowledge networks, arguing that geographical clusters are influenced by a different kind of information networks (Giuliani and Bell 2005, Vicente, Balland et al. 2011), and measured the impact of positions in the network on the performance (Boschma and Ter Wal 2007, Morrison 2008). Capello (1999) also argues that knowledge is shared in the cohesive structure such as communities of practice, implying that the structure of a network is highly likely to determine the knowledge transmission within the network. The transfer of knowledge occurs through an intangible structure originated from the interactive relationship among nodes and groups (Almeida and Kogut 1999).

Nonetheless, a node benefits from its structural position, and the decision of a node is dependent on the attribute of an individual node. A strand of empirical works on the absorptive capacity corroborate the importance of attributes of a node in network studies. For instance, several researches highlight the effect of the knowledge capacity of a node to serve its role in the whole network (Spencer 2003, Giuliani and Bell 2005, Giuliani 2011, Graf and Krüger 2011). Even a node has the chance to take advantage of a network position, it could not have the benefit from the network effect if the node has limited competences. Belso-Martínez, Expósito-Langa et al. (2017) also emphasizes the behaviours and processes over the structural position for the dynamics of network development on the ground of foodstuffs cluster data in Spain.

In the context of the dynamics of network, what has remained silent is the longitudinal evolutionary process. While there is a surging interest about the network, there is relatively little empirical evidence on how the dynamic is established and progressed over time periods (Giuliani 2013). To the best of knowledge, no empirical studies address the evolution of market-mediated technology network. In the current analysis, given the debates on the structure effects and attribute effect, the quantitative estimation is attempted in order to examine which effects matter for the development of network.

## 5.3. The static characteristics of technology transfer network

This section captures the trails of technology flows among regions based on the patent licensing records, then examines the structural properties of the networks. The technology flow trails in patent license records provide a robust dataset for revealing which technology is produced, and delivered to which regions, which is the proper setting for the evolution of the network.

### 5.3.1. Network data construction

The Inter-regional technology flow network captures the direction of technology flows from source (the patentee's region) to target (the licensee or buyer's region), as shown in Figure 23. Then, the nodes are regions, and the edges are the direction of technology, constructing an adjacency matrix. The adjacency network is constructed on the addresses of patent applicants from the China patent search system[8]. The collected data set is refined by excluding the individual level application and the unidentifiable address information. Given the overseas patent adoption, 6,778 of the non-Chinese owner's patents are included. The other 25,773 cases of Chinese-owned patent transferred within domestic cities are selected, which makes total 32,551 records available for analysis.

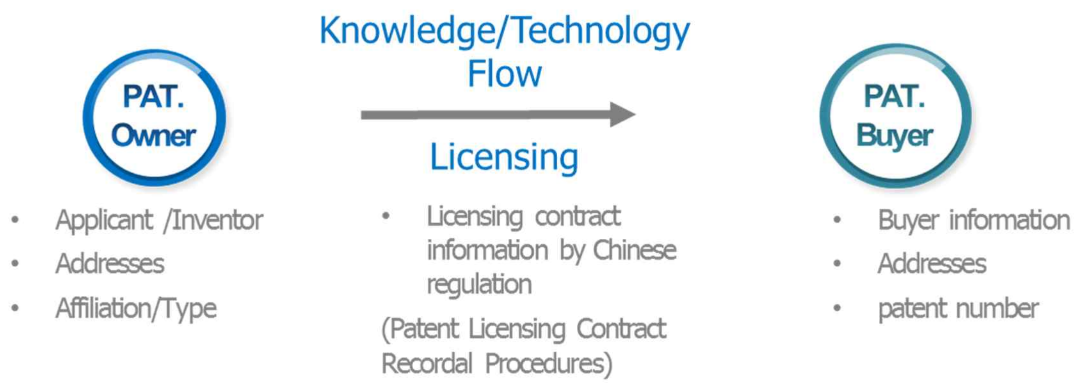



*Figure 23 Inter-regional network construction*

[8] http://www.pss-system.gov.cn

In order to identify the patterns of exchanging technology, the directed networks between patent licensor and licensee from Chinese patent licensing DB provided by SIPO (State Intellectual Property Office of China) were established. The PLCRP (Patent Licensing Contract Recordal Procedures) regulation forces the contract information including the addresses and patent number to be submitted and examined by the authority. The annually updated data set was collected from 1999 to 2013 containing 32,551 cases of patent licensing information including patent title, the address of the licensee, application number, the assignee and date of filing, and license type. Prefecture-level was used as a geographical unit of analysis because, as in the U.S., Chinese providence is not an economic unit but a political and administrative unit. Secondly, the daily activities of economic actors are not bound by province borders either. Commuting and travel behaviours are influenced by time and distance rather than by the Providence boundaries. Then, for daily economic activities, prefecture-level region or metropolitan area is more appropriate for exploring the question at hand (Audretsch 1998). The patents' locations could be identified by the address information, using China's patent search system. Patents with unidentifiable addresses or those licensed by individuals were removed because the main focus is inter-organizational transactions. Therefore, 25,773 Chinese-owned patents transferred between domestic cities and 6,778 non-Chinese-owned patents were selected.

Figure 24 indicates the link between source and target regions in China. It is notable that the regions located on the east-coast of the mainland have a denser connection, signalling that the concentration of economic-resources and technology flows are highly correlated. The three megalopolises centred on Beijing, Shanghai, and Shenzhen have dominated the majority of links.

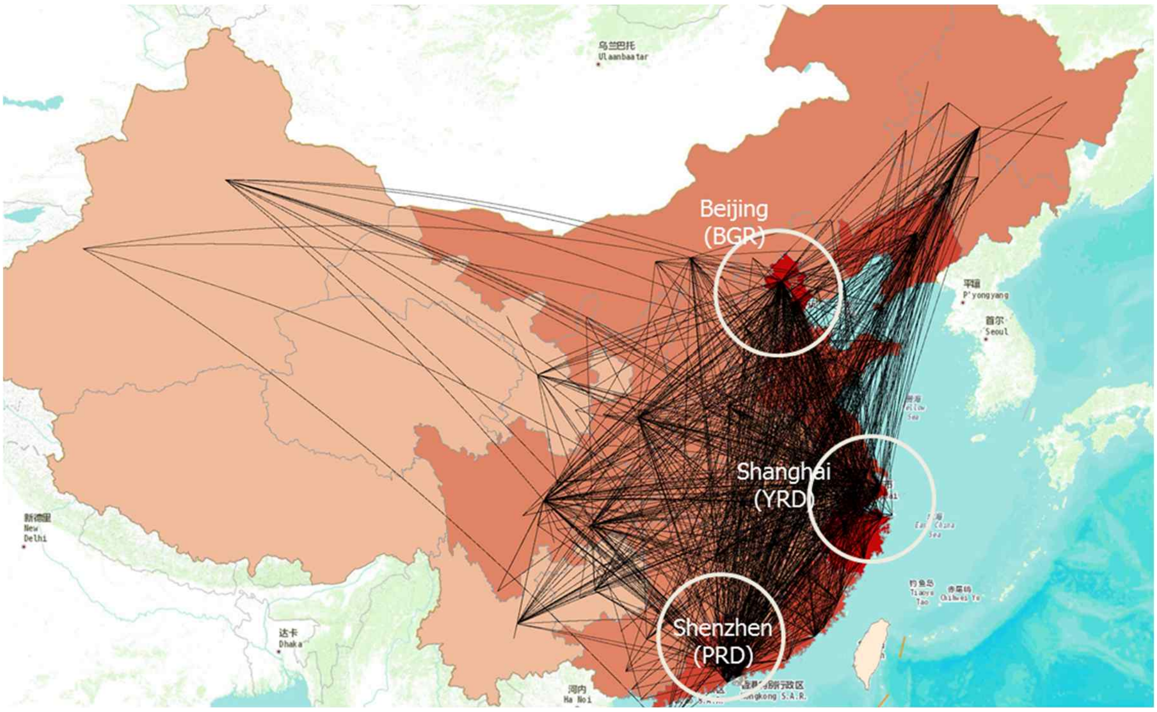



*Figure 24 Inter-regional technology transfer network*

### 5.3.2. The static characteristics of regional technology transfer network

This section begins by examining the network-level analysis in order to reveal the structural properties. Table 20 lists the network measures originating from social network analysis.

*Table 20 Network analysis indices*

| Measures | Definition |
|---|---|
| Number of nodes | The total number of nodes in a network |
| Density | The ratio of actual links to all possible links in a network |
| Average degree | The degree is the number of links that a node has to other nodes. The average degree is calculated by dividing the sum of all node degrees by the total number of nodes in a network |

| | |
|---|---|
| Number of components | The component is an isolated sub-network in a network. The number of components indicates the number of independent groups in a network |
| Number of nodes in the largest component | The total number of nodes in the largest component |
| Average path length | The average value of the geodesic path length between any pair of nodes in a network |
| Diameter | The length of the largest geodesic path in a network |
| Clustering coefficient | The ratio of the number of actual links between the node's neighbours, to the number of the maximum possible links between those neighbours. The network's clustering coefficient is the average of the clustering coefficients for all the nodes |
| Degree Centrality | $a(N_i, N_k)$ is 1, if and only if Node i ($N_i$) and Node k ($N_k$) are connected by a line; otherwise it is 0. n is the number of nodes in the network; therefore, (n-1) is the theoretical maximum degree of a node in the network $$C_d(\mathrm{i}) = \left[\sum_{k=1}^{n} a(N_i, N_k)\right] / (\mathrm{n}-1)$$ |
| Closeness centrality | If the shortest distance of the path linking two nodes $i$ and $j$ is $d_{ij}$, the closeness centrality of node $i$ can be written as $C_i = \left[\sum_{j=1}^{n} d_{ij}\right]^{-1}$. |
| Node betweenness centrality | When $g_{jk}$ is the number of the shortest paths existing between two certain nodes ($j$, $k$) and $g_{jk}(i)$, the number of stops at $i$ as a point existing between the points $j$ and $k$, the node betweenness centrality of node $i$ is: $C_i = \sum_{j<k} g_{jk}(i) / g_{jk}$ |
| Centralisation index | This indicates the extent to which a network is concentrated in the centre. The centralisation analysis suggests whether the network has a centralized structure or not. This study uses the degree centralisation to calculate the centralisation index. The degree centralisation is calculated by finding the total sum of values gained by subtracting the degree centrality of each node from the maximum degree centrality within the network, followed by dividing the total sum by the theoretically possible maximum of degree centrality |
| Efficiency | It measures the extent of a single node's ability to approach a large number of nodes via a relatively small number of links. It is derived from the redundancy of Burt's structure hole index (efficiency = 1 - redundancy) |

Table 21 reports the network property analysis results. First, the analysis utilises the average degree, dividing the sum of all node degrees by the total number of nodes in a network, is 8.465. The regions have approximately 8 to 9 connected technology flows with neighbour regions. The ratio of actual links to all possible links in a whole network, represented as density, is 0.029. In networks with a minimum density (0.0), no ties exist between actors, whereas in networks with a density of 1.0, all possible ties exist between actors. Considering the high diameter, and the low density lead us to suspect that the network structure is loosely connected or connected via few nodes.

The centralisation index in this case (0.46) corroborates the latter hypothesis. Centralisation is the ratio of the actual sum of differences in node centrality over the theoretical maximum, yielding a score somewhere between 0 and 1. The larger a centralisation index is, the more likely it is that a single node is very central, whereas the other nodes are not. The number of components indicates that the network is comprised of 109 isolated sub-networks. The result also reflects that the regions are highly likely to exchange technologies within specific boundaries.

*Table 21 Network properties*

| Measures | Result | Measures | Result |
|---|---|---|---|
| Avg Degree | 8.465 | Closure | 0.301 |
| Indeg H-Index | 25 | Avg Distance | 2.626 |
| Deg Centralisation | 0.461 | SD Distance | 0.753 |
| Out-Central | 0.459 | Diameter | 6 |
| In-Central | 0.27 | Component Ratio | 0.365 |
| Density | 0.029 | Connectedness | 0.644 |
| Components | 109 | Fragmentation | 0.356 |

Table 22 demonstrates which region plays a brokerage role in transmitting technologies across geographical boundaries. The 'brokerage role', derived from the social capital concept, represents the connection between two nodes that is bridged by a broker (Burt, 1992). A highly efficient node can reach the entire network with a small number of links, so it can access new technologies in different fields, functional areas, quality information, and problem-solving sources quickly and efficiently (Koka and Prescott, 2008). In this sense, efficiency may be considered as an alternative variable to measure the capabilities of accessing knowledge in different disciplines, the importance of which is growing as convergence research is actively undertaken nowadays. If a node sits on the brokerage position, it could be more favourable in acquiring information benefits from heterogeneous sources, and autonomy benefits from less constraints. The notion of constraints denotes the extent to which time and energy are concentrated within a single cluster. It depends on three network characteristics: size, density, and hierarchy. Constraint on an individual node would be generally higher in the case of a small network, and if links are highly connected between each other (either directly as in a dense network, or indirectly, through the mutual central contact as in a hierarchical network).

Chengdu, the capital of Sichuan province, has the highest efficiency value (0.932) with lowest constraints (0.091) and hierarchy (0.355). Beijing ranked second in efficiency level, then Wuhan, unexpectedly followed. It is worth noting that two regions at the centre of the mainland - Wuhan in Hubei province, and Xian in Shaanxi province - have a higher rank in efficiency. It is highly likely that these two regions are playing a hub-role in transmitting the technologies from major big regions such as Beijing, Shanghai, and Shenzhen.

*Table 22 Structural holes result of inter-regional technology network*

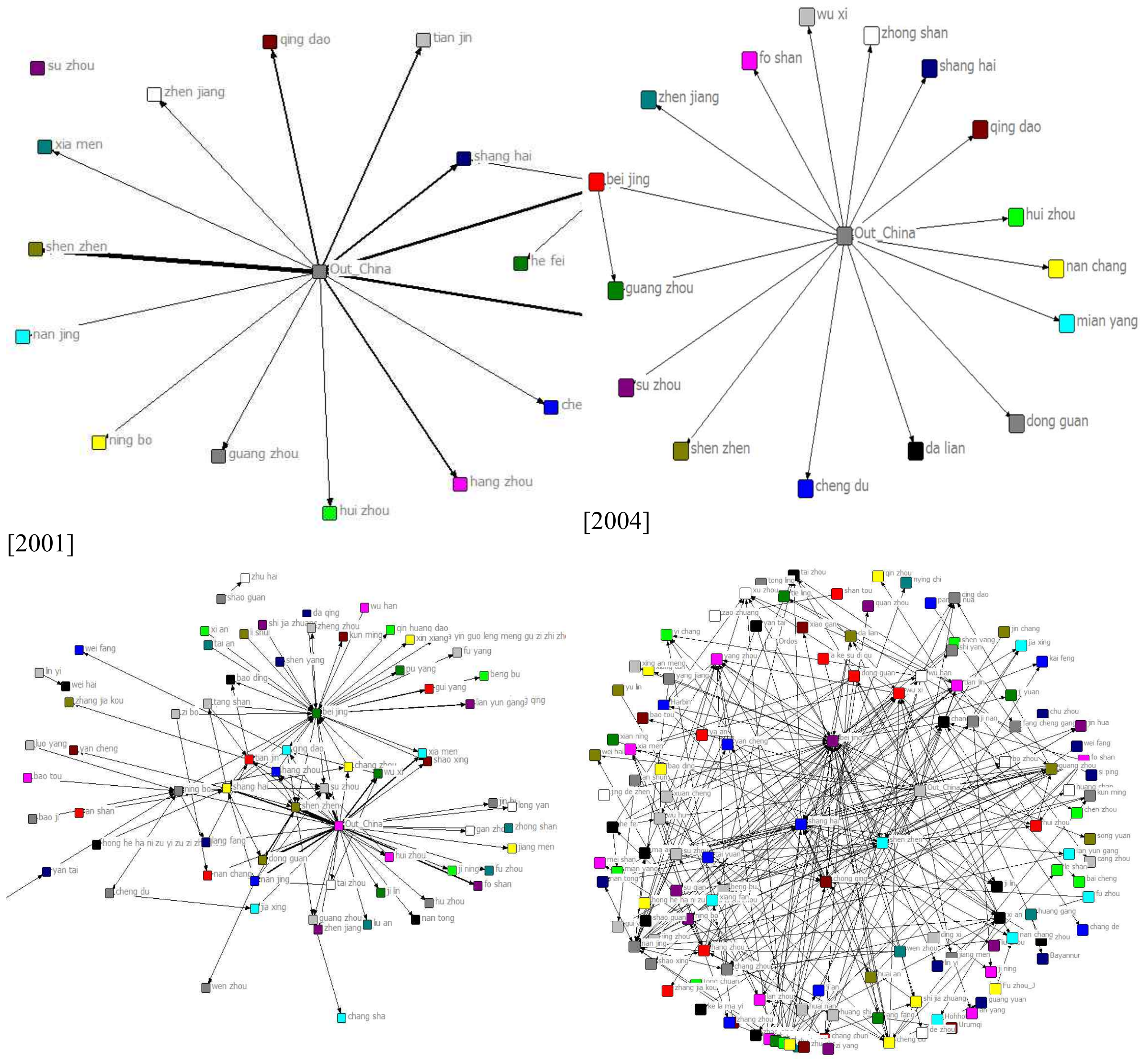
| Ranking | Regions | Efficiency | Constraints | Hierarchy |
|---|---|---|---|---|
| 1 | Chengdu | 0.932 | 0.091 | 0.355 |
| 2 | Beijing | 0.917 | 0.147 | 0.646 |
| 3 | Wuhan | 0.916 | 0.104 | 0.389 |
| 4 | Nanjing | 0.895 | 0.168 | 0.497 |
| 5 | Xian | 0.883 | 0.171 | 0.501 |
| 6 | Out_China | 0.879 | 0.144 | 0.509 |
| 7 | Hangzhou | 0.876 | 0.168 | 0.543 |
| 8 | Shanghai | 0.859 | 0.26 | 0.719 |
| 9 | Tianjin | 0.829 | 0.23 | 0.64 |
| 10 | Shenzhen | 0.817 | 0.335 | 0.76 |

The structural property analysis calls for more ego-centric analysis in order to find the roles of individual nodes. Table 23 reports the centrality measures of the top 20 regions in descending order of out degree centrality. It is not surprising that foreign countries (Out China) have the highest value in out degree value. The three major regions – Beijing, Shanghai, and Shenzhen – dominate the out-degree, signalling that these regions play a critical role in providing domestic technologies. Shanghai outweighs the in-degree than out-degree centrality while the direction of its close centrality is reversed. It implies that Shanghai tends to absorb the technologies from directly-connected neighbour regions than from the in-directly connected regions. This engenders an idea that Shanghai is an active technology absorber within its cluster (component). Given the higher level of betweenness centrality (0.072), Shanghai also seems to transmit the technologies in/out of its cluster.

*Table 23 Centrality result of inter-regional network (Top 20)*

| Rank (byOutDegree) | Regions | Between | Degree centrality | | Close centrality | |
|---|---|---|---|---|---|---|
| | | | Out | In | Out | In |
| 1 | Out_China | 0 | 22.926 | 0 | 0.49 | 0.143 |
| 2 | Shanghai | 0.072 | 4.662 | 5.706 | 0.507 | 0.288 |
| 3 | Beijing | 0.182 | 4.142 | 3.659 | 0.553 | 0.298 |
| 4 | Shenzhen | 0.046 | 2.993 | 5.267 | 0.484 | 0.286 |
| 5 | Foshan | 0.012 | 1.912 | 1.027 | 0.43 | 0.28 |
| 6 | Nanjing | 0.051 | 1.774 | 3.919 | 0.471 | 0.289 |
| 7 | Zhenjiang | 0.004 | 1.615 | 0.949 | 0.429 | 0.273 |
| 8 | Xian | 0.025 | 1.534 | 0.321 | 0.478 | 0.263 |
| 9 | Hangzhou | 0.042 | 1.301 | 1.139 | 0.47 | 0.284 |
| 10 | Wuxi | 0.014 | 1.081 | 1.618 | 0.453 | 0.278 |
| 11 | Tianjin | 0.037 | 1.041 | 1.517 | 0.477 | 0.279 |
| 12 | Huizhou | 0.012 | 1.037 | 1.111 | 0.44 | 0.266 |
| 13 | Wuhan | 0.028 | 1.007 | 0.544 | 0.468 | 0.277 |
| 14 | Chongqing | 0.023 | 1.003 | 0.476 | 0.466 | 0.273 |
| 15 | Suzhou | 0.015 | 0.953 | 5.598 | 0.453 | 0.283 |
| 16 | Chengdu | 0.041 | 0.895 | 0.807 | 0.458 | 0.275 |
| 17 | Guangzhou | 0.038 | 0.878 | 2.145 | 0.456 | 0.286 |
| 18 | Qingdao | 0.012 | 0.811 | 0.605 | 0.441 | 0.271 |
| 19 | Changsha | 0.024 | 0.764 | 0.784 | 0.445 | 0.271 |
| 20 | Changzhou | 0.005 | 0.709 | 1.517 | 0.415 | 0.279 |

Both out-degree and out-closeness centrality of Beijing are higher than in-centralities, leading to it also having a tendency to provide technologies outward rather than import the inward technologies. Shenzhen's higher value of in-degree centrality (5.267) than out-degree (2.993) hints at its role as a conduit of importing technologies, but its low betweenness centrality (0.046) indicates that it is not an active broker. It is also found that Nanjing, Suzhou, and Guangzhou have a higher tendency for an active technology absorber, while Xian and Wuhan have a significant influence of technology provider on the basis of the difference between degree centrality measures.




[2001] [2004] [2008] [2012]

*Figure 25 Evolution of technology transfer network (2001, 2004, 2008, 2012)*

Figure 25 compares China's inter-regional technology flow by time periods, taking the period from 2001 to 2012 in four slices respectively. The first period (2001) shows a highly centralised structure, centred on overseas countries. The highly centralized structure remains in 2004, signalling that the main source of technology is outside of the mainland with unidirectional flows. In 2008, the structural change emerges in that the size is sharply increased with more new entrant nodes, and the major regions shape the clusters. Three major regions rise as a new source of technology, relieving the dependency of overseas technology inflows. The network size shows a remarkable expansion in 2012. Even when the cut-off value was set to 7 for readability, the number of nodes was sharply increased during three years. It suggests that the innovative actors in the region actively participated in the technology exchange activities. Specifically, three major cities – Beijing, Shanghai, and Shenzhen, - sit on the centre of clusters, shaping the big-hub. The role of overseas technology as a conduit for technology seems to be gradually decreased.

*Table 24 Annual properties of technology transfer network*

| Year | Avg. Degree | Diameter | Connectedness | Density | Centralisation | Clustering Coefficient |
|---|---|---|---|---|---|---|
| 2001 | 0.941 | 2 | 0.063 | 0.059 | 0.925 | 1.835 |
| 2002 | 1.087 | 2 | 0.053 | 0.049 | 0.892 | 1.669 |
| 2003 | 0.875 | 1 | 0.038 | 0.038 | 0.907 | 0 |
| 2004 | 1 | 1 | 0.063 | 0.063 | 1.000 | 1.501 |
| 2005 | 0.957 | 1 | 0.043 | 0.043 | 0.998 | 0 |
| 2006 | 1.065 | 2 | 0.037 | 0.035 | 0.995 | 3.446 |
| 2007 | 1.056 | 3 | 0.041 | 0.03 | 0.755 | 14.27 |
| 2008 | 1.597 | 6 | 0.207 | 0.022 | 0.455 | 11.797 |
| 2009 | 4.533 | 7 | 0.451 | 0.023 | 0.303 | 1.967 |
| 2010 | 4.298 | 7 | 0.444 | 0.02 | 0.324 | 2.168 |
| 2011 | 4.264 | 7 | 0.49 | 0.019 | 0.28 | 1.718 |
| 2012 | 3.238 | 7 | 0.415 | 0.014 | 0.218 | 2.085 |

Table 24, Figure 26 represents the in-depth analysis on the evolutionary properties of network and the annual trend of degree centrality, respectively. It is worth observing the growth of network size. The average degree, which has maintained around 1 until 2007, then shows a surging increase from 2008 reaching the maximum point 4.53 in 2009. Accordingly the diameter of a whole network also rises from 1 in 2005 to 7 in 2009. As the network size increases, the density of a whole network is generally likely to decrease. The network hits its highest density value of 0.063 in 2004, then gradually declines to around 0.02. The connectedness has a similar pattern of slow downturn after its peak (0.49) in 2001.

The centralisation index indicates that technology flow was aggregated to the small number of regions in the earlier period. In 2001, overseas technology totally dominates the whole network with the high (0.925) centralisation point. The high values remained in the mid 2000s, hitting 1 in 2004, but it fell to less than 0.3 with the advent of new entrant regions. Given the surging number of new regions in the network, a new entrant might choose incumbent regions in the network. The clustering coefficient corroborates that idea in that it jumped from around 3 in 2006 to 14.27 after just one year, implying that some clusters emerge within a short period.

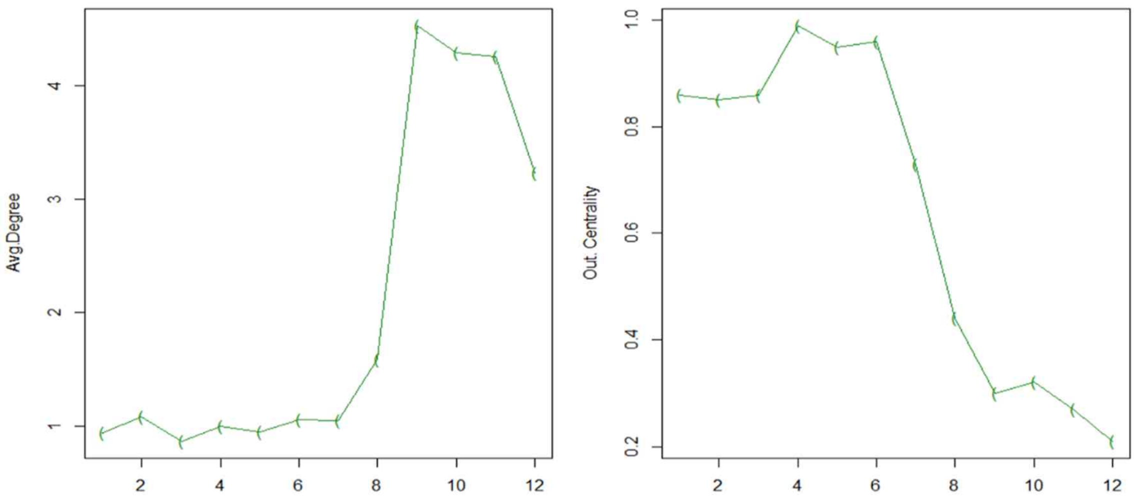



*Figure 26 Annual trend of whole network properties*

Table 25 describes the characteristics of licensing activities of an individual region. First, Beijing has the greatest number of neighbours of 167 with 1793 links, which is the first rank of size. Beijing seems to serve as the transmitter of technology flow with higher points of brokerage and betweenness centrality. The next big node, Shanghai, has 119 nodes connected, linking regions most actively (20.881). In rank of size follow Nanjing, Shenzhen, and Tianjin. It is interesting that Guangzhou and Wuxi, despite their relatively smaller size, have higher closeness and density, implying that they have closed-but highly connected relationships with few regions.

*Table 25 Ego network result by major regions*

| Regions | Size | Ties | Density | Broker | Closed | Ego Bet. |
|---|---|---|---|---|---|---|
| Beijing | 167 | 1793 | 6.468 | 0.935 | 1793 | 33.74 |
| Shanghai | 119 | 1623 | 11.558 | 0.884 | 1623 | 20.881 |
| Nanjing | 90 | 1288 | 16.08 | 0.839 | 1288 | 20.013 |
| Shenzhen | 87 | 1166 | 15.584 | 0.844 | 1166 | 19.483 |
| Tianjin | 83 | 1080 | 15.868 | 0.841 | 1080 | 17.839 |
| Wuhan | 81 | 1187 | 18.318 | 0.817 | 1187 | 13.946 |
| Out_China | 79 | 1124 | 18.241 | 0.818 | 1124 | 0 |
| Hangzhou | 79 | 1180 | 19.15 | 0.809 | 1180 | 15.81 |
| Chengdu | 75 | 913 | 16.45 | 0.835 | 913 | 23.113 |
| Xian | 75 | 924 | 16.649 | 0.834 | 924 | 14.809 |
| Guangzhou | 73 | 1092 | 20.776 | 0.792 | 1092 | 18.091 |
| Wuxi | 69 | 1034 | 22.038 | 0.78 | 1034 | 9.254 |
| Suzhou | 67 | 1119 | 25.305 | 0.747 | 1119 | 8.633 |
| Chongqing | 65 | 860 | 20.673 | 0.793 | 860 | 12.656 |
| Huizhou | 56 | 692 | 22.468 | 0.775 | 692 | 10.412 |
| Nanchang | 56 | 573 | 18.604 | 0.814 | 573 | 19.384 |
| Qingdao | 55 | 699 | 23.535 | 0.765 | 699 | 10.426 |
| Ningbo | 54 | 752 | 26.275 | 0.737 | 752 | 13.942 |
| Harbin | 53 | 602 | 21.843 | 0.782 | 602 | 16.74 |
| Changsha | 53 | 521 | 18.904 | 0.811 | 521 | 17.9 |
| Foshan | 53 | 824 | 29.898 | 0.701 | 824 | 10.072 |

## 5.4. The dynamic approach of technology transfer network evolution

Neither the traditional econometric method for longitudinal data nor static network analysis indices could deal with the longitudinal network evolution issue. From the perspective of inferential statistics, the dependent variable is highly related with the structure of the network, which caused a biased result. The discrete time-series econometric model explains the totality of changes in a single regression model, causing the limitation to isolate the change in networks structures (Balland 2012). The panel data analysis also has not provided a robust econometric model for network dynamics (Baltagi 2008).

Recently, it has been recognised that SAOM provides a robust analytic tool for understanding the evolution of networks (Ter Wal and Boschma 2009, Maggioni and Uberti 2011, Broekel, Balland et al. 2014). The model is widely accepted not just in management (Checkley and Steglich 2007, Van de Bunt and Groenewegen 2007), but also in economic geography (Giuliani and Bell 2005, Ter Wal 2013). The basic idea of SAOM stems from Markov random graphs, presuming that the probability of network evolution depends on the current state of the network. The network dynamics, the transformation from one to another state, is caused from the aggregated decision from the nodes. These micro-level decisions are based on the attribute of the individual node, which is determined by the previous network structure settings. The algorithm calculates the estimated coefficients based on the iterative Markov chain Monte Carlo model (Steglich and Snijders 2010). It stochastically approximates the parameters in the way of minimising the deviation between observed and simulated networks. The parameters are adjusted to fit the observed results at the each simulated step during the iterations. The estimated parameters are then evaluated for the goodness of the fit of the model to compute the standard errors in a familiar form to interpret the power of estimated power.

### 5.4.1. Estimation methodology of network evolution

If the evolution of network is considered as a longitudinal time-series change, then let network structure as $x_t$, $t \in \{t_1, \dots, t_m\}$ for the number of nodes of $N$ from 1 to n. In the Markov chain $(X_t)$, each observation is represented as matrix set, or $x = (x_{ij})$, whereby node $i$ has a relation with $j$. According to the fundamental assumption of Markov chains, the evolution of network is influenced by the current state of the network to the extent of probability (Hansen and Scheinkman 1993). In this light, SAOM addresses the network dynamics by modelling the change process through two directions. One is the change opportunity process and the other is the change choice process which is also referred to as rate function and objective function, respectively.

The nodes can change their relationship with others - create, maintain, or dissolve- at stochastically determined moments. These opportunities are determined by the Poisson distribution function that Steglich and Snijders (2010) refers to as rate function $(\lambda_i)$ for each actor $i$. For a formal expression, the opportunities for node $i$ to change one of the tie parameters $X_{ij}$ $(j = 1, \dots, n, ; j \neq i)$ happens at the probability function $(\lambda_i)$.

Given the heterogeneity in change opportunities, the individual attributes of nodes is highly likely to affect opportunities to change relationships. Thus, under the individual attribute $(v_i)$ and degree $\sum_j x_{ij}$ , the rate function is given as below :

$$\lambda_i(x^0, v) = p_m \exp\left( \alpha_1 v_i + \alpha_1 \sum_j x_{ij} \right) \tag{8}$$

Following on a current state $(x^0)$, the set of permitted new states $C(x^0)$ is the product function of two model components $\lambda_i$and $p_i$ that determines the transition rate matrix of which the elements are given by

$$q_{x^0,x} = \lim_{dt \downarrow 0} \frac{P\{X(t+dt) = x | X(t) = x^0\}}{dt} \tag{9}$$

where $q_{x^0,x} = 0$, in case $x_{ij} \neq x_{ij}^0$ , and $q_{x^0,x} = \lambda_i(x^0, \upsilon, \omega) p_i(x^0, \upsilon, \omega)$ for digraphs $x$ and $x^0$. As the rate function process sets the frequency of opportunities to change ties, network structures with high values signify the strong dynamics.

***Choice opportunities modelling***

Let us turn to the choice opportunity modelling, given that a node $i$ has the opportunity to make a relational change, the choice for this actor is to change one of the set of relation parameters$x_{ij}$ . If there is a change in the relation parameter$x_{ij}$ , then it will lead to a new state $x, x \in C(x^0)$. The multinomial logistic regression objective function $f_i$ is applied to the choice probability of a node (Steglich and Snijders 2010):

$$P\left\{X_{(t)} \mathit{changes\ to}\ x \,|\, i\ \mathit{has\ a\ change\ opportunity\ at}\ t, X_{(t)} = x^0\right\} \tag{10}$$

$$= p_i(x^0, x, \upsilon, \omega) = \frac{\exp(f_i(x^0, \mathrm{x}, \upsilon, \omega))}{\sum_{x' \in X(x^0)} \exp(f_i(x^0, \mathrm{x}', \upsilon, \omega))}$$

When a node has the opportunity to change their tie, it chooses its partners by trying to maximize objective function $(f_i)$ that accounts for the preferences and constraints of the node. The process is interpreted as the idea that nodes determine to change their position, myopically maximizing their objective function. For a formal expression, the objective function is defined, as the choices are then determined by a linear function comprised of the current state $(x^0)$, the potential new state $(x)$, individual attributes $(\upsilon)$, and attributes at a dyadic level $(\omega)$ as below:

$$f_i(x^0, x, v, \omega) = \sum_k \boldsymbol{\beta_k} s_{ki}(x^0, x, v, \omega) \qquad (11)$$

The weight $\boldsymbol{\beta_k}$ , indicating the power of the different variables $s_{ki}$, is estimated by simulations. Snijders (2001) suggests an iterative Markov chain Monte Carlo algorithm as a method of the estimation method in SIENA. One of the advantages of SAOM is that the estimation value is constant to its final value, in order to evaluate the goodness of fit of the model and the standard errors so that the different parameter estimates of SAOM can be interpreted as non-standardized coefficients obtained from logistic regression analysis. Thus, the parameter estimates are log-odds ratio, and they can be directly interpreted as how the log-odds of link formation change with one unit change in the corresponding independent variable.

### 5.4.2. Data and variables

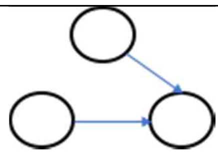
The current analysis constructed four technology transfer networks from 2009 to 2012. The primary reason this period was chosen is that the structural change seems to occur on the basis of the structural network analysis in the above section. In order to model the clearer effect of variables, 130 nodes (regions) were selected as a data set. Then, the region-to-region network has $130 \times 130$ binary directed networks where $x_{ij} = 1$, when a region $(i)$ has license-out to region $(j)$ $(i, j = 1, n)$.

*Table 26 Descriptive statistics of the longitudinal data*

| Time (Year) | Nodes (regions) | Links | Average degree. | Density |
|---|---|---|---|---|
| $t_1 = 2009$ | 130 | 840 | 5.667 | 0.043 |
| $t_2 = 2010$ | 130 | 800 | 5.492 | 0.043 |
| $t_3 = 2011$ | 130 | 817 | 5.600 | 0.043 |
| $t_4 = 2012$ | 130 | 663 | 4.400 | 0.034 |

In this model, the structural effect is controlled by the density and reciprocity effect. The density effect is calculated by out-degree of longitudinal network analysis. According to Snijders, Van de Bunt et al. (2010), the density effect needs to be included in the models using SIENA in order to control for the observed density of the network and to explain the general likelihood to transmit. The reciprocity effect is also included because the technology transfer network is a directed relation network. The underlying assumption is that regions will exchange technology with those from whom they already import technology, which is also considered as a basic variable in the directed network analysis. In the context of the uncertainty of pecuniary-compensated technology, reciprocity is interpreted as the path-dependent feature in that the region tends to transfer already-proven partners.

*Table 27 Description of rate function variables*

| Variables | Description | Diagram | Formulation |
|---|---|---|---|
| Density | The propensity of total regions to transfer technology (Network level) |  | $D_i = \sum x_j$ |
| Reciprocity | The propensity of mutual technology transfer (Node level) |  | $R_i = \sum_j x_j \, x_j$ |

***Objective function variables***

In order to measure how regions are involved in technology activities, the individual attributes of regions include four variables: foreign technology acquired, patents per population, technology licensing-in, and technology licensing-out. The number of foreign patents represents the exogenous inflow of technology that enhances the capacity of a region. The innovative capacity is reflected in the total number of patents normalised by population

(Breschi and Lenzi 2017). If the estimated coefficient of a foreign patent has a positive signal, then the exogenous technology flow contributes to the evolution of network. On the other hand, the positive effect of the patent number signals that domestic patent growth significantly determines the region's technology flows. The licensing activities – licensing out and in – are included in the model as the attributes. The licensing-out of a patent implies that a region has enough innovative capacity and quality of technology to diffuse its technologies to the other regions. The licensing-in, however, represents how a region actively imports other region's patent. The descriptive statistics are presented as below.

*Table 28 Descriptive statistics of objective function variables*

| Variables | Average | Standard Deviation | Min. | Max. |
|---|---|---|---|---|
| Foreign license-in (Foreign) | 51.49 | 159.77 | 0 | 961 |
| Number of patent per population (10,000) (PAT_PP) | 7.05 | 10.38 | 0 | 74.30 |
| Number of license-in (No_In) | 190 | 328.04 | 0 | 2109 |
| Number of license-out (No_Out) | 196.33 | 384.01 | 0 | 2679 |

### 5.4.3. Stochastic actor-oriented model estimation result

This model is estimated by applying a conditional method of moments for a longitudinal dataset. The convergence ratio value that compares the deviations between simulated values and observed values is 0.283 indicating that the goodness-of-fit of the model is appropriate for the model. Table 29 reports three models starting from a structure effect-only (Model 1) to the full model (Model 3).

*Table 29 Simulation analysis results*

| | Model 1 (n=130) | | Model 2 (n=130) | | Model 3 (n=130). | |
|---|---|---|---|---|---|---|
| | Estimation value | Standard error | Estimation value | Standard error | Estimation value | Standard error |
| *Rate function* | | | | | | |
| Rate $\lambda_{2009-2010}$ | 27.11 | $1.041^{***}$ | 26.903 | $0.971^{***}$ | 26.926 | $1.052^{***}$ |
| Rate $\lambda_{2010-2011}$ | 0.007 | $0.006^{***}$ | 0.006 | $0.007^{***}$ | 0.007 | $0.007^{***}$ |
| Rate $\lambda_{2011-2012}$ | 0.007 | $0.008^{***}$ | 0.007 | $0.007^{***}$ | 0.007 | $0.008^{***}$ |
| Density | -1.435 | $0.025^{***}$ | -1.473 | $0.025^{***}$ | -1.508 | $0.03^{***}$ |
| Reciprocity | 1.09 | $0.055^{***}$ | 1.127 | $0.058^{***}$ | 1.149 | $0.065^{***}$ |
| *Objective function* | | | | | | |
| Foreign | | | 0.0019 | $2.685^{***}$ | 0.0011 | $3.309^{***}$ |
| PAT_PP | | | -0.0397 | $0.005^{***}$ | -0.083 | $0.009^{***}$ |
| No_In | | | | | 0.0002 | 3.594 |
| No_Out | | | | | 0.0016 | $2.969^{***}$ |

$^{***}P<0.001$.

Let us turn to Model (1) that includes only structural effect variables. The rate function explains the longitudinal progression of the technology transfer network. The rate refers to the expected frequencies with which regions have the opportunity to change a network tie from between from $t$ to $+1$. . The rate ($\lambda_{2009-2010}$) plunges from 27.11 to 0.007 ($\lambda_{2010-2011}$); then it maintains 0.007 at the end of the period ($\lambda_{2011-2012}$). The network is highly likely to be changed from 2009 to 2010, then a sharp decrease rate of the next period (2010 to 2011) indicates that there are fewer opportunities to change relationships in the last two periods than in the previous ones. After the relationship is established, then the nodes do not seem to easily change their relationships with their partners, which is interpreted as the path-dependency in market-mediated technology. A similar pattern is consistent through all three models. The density of network has a significant but negative value (-1.435), on the other hand, the reciprocity has a positive coefficient (1.09). According to Vicente, Balland et al. (2011), it is general in empirical network analysis works. In the social network context, the higher density level is related to the high opportunity cost in the establishment of a relation. If a node is positioned in the highly dense position, then the node is less likely to have an opportunity to change the previous relationship. Thus, given the high density effect, the probability of changing its tie decreases that yields a negative sign of a variable. The positive and significant value of reciprocity also reflects that technology is transmitted with the partners that have already connected, denoting that mutually-proven partners are likely to involve another transfer.

Model 2 is dedicated to explaining the longitudinal change of network through the individual attribute of each region. The interpretation of coefficient is non-standardized coefficients, similar to that of the logistics regression model. Each coefficient is basically log odds-ratio, that is it indicates how the log-odds of relation formation change with a unit change in the corresponding independent variable. The exogenous foreign technology has a positive and significant but weak value (0.0019). The patent number of a region, however, has a negative effect (-0.0319). Then, regions have a tendency to transmit technology to other regions when they already accumulated technologies from overseas countries. At the same time, even if the region has a higher level of domestic patent, they do not seem to be involved in exchanging technology with others. This result confirms the idea that the Chinese technology market is led by foreign technology in the mid 2000s in the previous chapter. It also corroborates the idea that nodes exposed to direct relationships with foreign nodes, through formal technology agreements or informal know-how contact, are expected to gain preferential access to knowledge (Spencer 2013).

The last model examines whether a region’s previous licensing activity matters in the evolution of the network. It is interesting to note that the foreign technology and region’s patent converges to zero after two licensing variables are included. While the observed license-in value has not gained statistically significance, license-out has a positive effect with a significance level of 0.01 (0.0016).

The result confirms that the regions prefer to transmit technology to other regions that already have a previous experiences of technology transfer, which is consistent with the Belso-Martínez, Expósito-Langa et al. (2017)'s work in that the previous knowledge mediating experience facilitates the creation of partnerships, fostering brokerage. The influence of accumulated licensing-out experiences also seems to be determined by strategic risk-aversion decisions of licensor regions. The interpretations of the contradictory significance level of two licensing variables would be that the potential licensing-in regions do not consider how many technologies are imported to the partner regions, rather they seem to consider the licensing-out records matter more.

## 5.5. Conclusion

This chapter began by looking at the overviews and background of the Chinese technology transfer policy to examine the growth of the technology transfer market. Next, in order to identify the patterns of exchanging technology, the directed networks between patent licensor and licensee from Chinese patent licensing is established by the Chinese patent office. Then, the structural characteristics of the entire network are examined in the following section by employing centrality, centralisation, density, average path length and diameters. It is notable that the regions located on east-coast of the main land dominate the technology flows, signalling that the concentration of economic-resources and technology flows are highly correlated. Specifically, the three megalopolises centred on Beijing, Shanghai, and Shenzhen have dominated the majority of links.

The time-sliced analysis reveals that a highly centralised structure emerges in the first period (2001), centred on overseas countries. The existing pattern signals that the main source of technology is outside of the mainland with a unidirectional flow. In 2008, the structural change emerges in that the size sharply increases with more new entrant nodes, and the major regions shape the clusters. Three major regions emerges as a new source of technology, relieving the dependency of overseas technology inflows. The network size shows a remarkable expansion in 2012. The network analysis result implicitly suggests that few top regions dominate the whole network. A notable finding in this static analysis is that the traditional principal regions play a critical role as creators and brokers, suggesting that the underlying mechanism needs to be further addressed in the next chapter.

The dynamic approach on the evolution of the technology transfer network can be summarized as follows. First, the probability of changing the relationship sharply dropped if they had already established a partnership. The path-dependency in this analysis appears to reflect the potential risk of pecuniary-compensated technology transactions. The significant coefficients of reciprocity also confirm in that regions prefer to transfer technology when they already shared the technology with others. Second, the overseas technology inflow influences the decision-making process more than domestic patent applications. The dependency of overseas technology inflow decreases, however, it does not seems to influence the relation change choice of the region. Lastly, the records of licensing-out have a positive effect on the network evolution, while licensing-in activity has no significant effect. In sum, the structural effect rather than the attributes of the region has more influence on the evolution process.

# Chapter 6. The role of anchor regions as a dynamic of the network evolution

## 6.1. Introduction

Drawing upon the analysis on propelling dynamics behind the evolution of technology transfer network in the previous section, this chapter attempts to deepen the understanding of an anchor region on the network development. The literature has highlighted the key role of anchor nodes, being responsible for sourcing heterogeneous knowledge in the network (Boari and Lipparini 1999, Morrison 2008, Giuliani 2011, Graf and Krüger 2011). The idea that some focal nodes are likely to control the flow of information than others originally comes from social science context (Everton 2012). Back to Burt (1992)'s notion of structural holes, which builds upon the seminal work of Mark Granovetter's weak ties, a node connecting both sides of the gaps in the structure is in a position to broker the information flow across the network. The brokerage position confers to a node the benefits from new information flows and access to non-redundant resources even if it has no direct connection with the others. The broker activity reinforces the centrality power of focal node to the extent where its capacity maintains the advantages inherent to the position.

Allen (1977) applies the concept to refer to it as 'technological gatekeeper' who keeps his/her organizational colleagues in touch with the informal connections with the outside. The technological gatekeepers were found to be advantageous in a creative and highly technical capacity (Tushman and Katz 1980, Tushman and Scanlan 1981). Hargadon and Sutton (1997) argue that advantages of some efficient firms utilise the knowledge connections combining different industrial sectors, acquiring technologies from one industry and then applying them to another. In a similar way, several empirical works corroborate the positive relationship between brokerage role and its performance. For instance, Cross and Cummings (2004) demonstrate a positive correlation between performance and betweeness amongst engineers. Rodan and Galunic (2004) surveyed 106 middle managers in a European company to demonstrate that a manager's innovation performance correlates with the sparseness of their network. Nerkar and Paruchuri (2005) found a weak relationship between brokerage and future patent citations amongst inventors.

The structural advantage of a brokerage node does not seem to be solely limited to the network field. The idea, however, was already acknowledged in the other context: Focal firms in an industrial district (Munari, Sobrero et al. 2012), technological gatekeepers (Allen 1977), and global pipeline (Bathelt, Malmberg et al. 2004). Studies of geographical clusters also emphasise the linkages within and outside their cluster, connecting with knowledge sources (Ter Wal and Boschma 2009, Maggioni and Uberti 2011, Munari, Sobrero et al. 2011, Boari and Riboldazzi 2014). The notion of global pipelines appropriates knowledge from foreign countries and conveys it to the domestic neighbour regions, thus guiding knowledge from foreign countries into its innovation system (Bathelt, Malmberg et al. 2004). One common notion for brokerage in these studies is that the nodes play a leading role in transferring exogenous technologies into the co-located nodes within the group. (Boari and Lipparini 1999, Morrison 2008). The brokerage metaphor, under the network framework, allows us to treat a 'brokerage region' like a broker node in the inter-regional knowledge flow networks. It, therefore, seems plausible that a brokerage region might play a critical role in producing and connecting exogenous knowledge within a national system of innovation (Seo and Sonn 2019). In the same vein, the empirical works on the function of a region in the national innovation system have been illustrated as a knowledge hub (Mayer and Cowell 2016) and super-regions (Huggins, Luo et al. 2014).

Despite the recent surging interest in the importance of a brokerage role, little has articulated the specific type of brokerage roles of transferring external knowledge to neighbour nodes, assimilating it into local knowledge and contributing to the growth of the whole network (Morrison 2008, Wink 2008, Giuliani 2011, Graf and Krüger 2011, Munari, Sobrero et al. 2012). This chapter intends to investigate the role of different types of brokers, as suggested by the network literature (Gould and Fernandez 1989), reinterpret them in accordance with the geographical proximity and then examine the contribution of the two key types – gatekeeper and representative – of the roles over to the evolution of network.

The analysis begins with establishing the sub-group network in order to identify three super regions (BGR, YRD, PRD) and the others (non-super region and out-china). Then, section 2 demonstrates the annual tendency of the connecting directions of super-regions in order to show the extent to which a super region has an interactive relationship with other super-regions. Then, section 3 identifies the brokerage roles on the basis of typology from social network context and estimates the effects of each roles by applying SIENA analytical model.

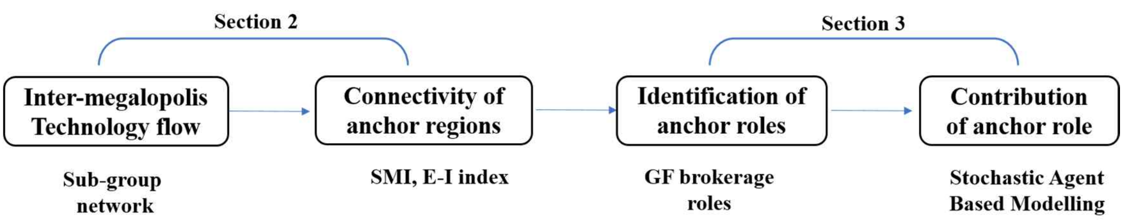



*Figure 27 Analysis procedure*

## 6.2. Global and local connectivity of anchor regions

### 6.2.1. Technology flows among super-regions

This section aims to give an empirical analysis of the brokerage role of anchor regions with emphasis on the evolutionary concept which has originated from the social network. The hypothesis, here, is that the role of an anchor region has a distinctive role as a hub region connecting the neighbour regions within a megalopolis with others; then the role appears to be converged as a specialised pattern. The central contribution has been to highlight the trend around the mid 2000s. In the meantime the size of technology transfer network expands, showing an emergent picture of an anchor around the megalopolises. The analysis will answer the questions whether an anchor plays a connecting role within the megalopolis (Intra-regional flow), or importing exogenous technologies into the megalopolis, or diffusing the endogenous technologies.

Figure 28 visualises the established inter-group network and technology flows by counting the licensing contract numbers, listed in Table 30. It is notable that the YRD is the largest technology importing regions from foreign countries, then followed by PRD and BGR. The target group where BGR delivers technologies is the non-super group (742), except for the BGR itself (2196). YRD licenses-in the largest amount of technologies from foreign countries (2944), then followed by non-super regions (1483), BGR (542), and PRD (530). At the same time, YRD transmits most of the technologies to the Non-super regions (1098), then followed by PRD and BGR (296, 235, respectively). It is notable that the quantity gap between the Non-super group and two super regions is wide, suggesting that YRD mainly delivers technologies to the non-super regions compared to super-regions. Lastly, PRD also actively absorbs foreign technologies (2382), then followed by Non-super (523), YRD (296), and BGR (142).

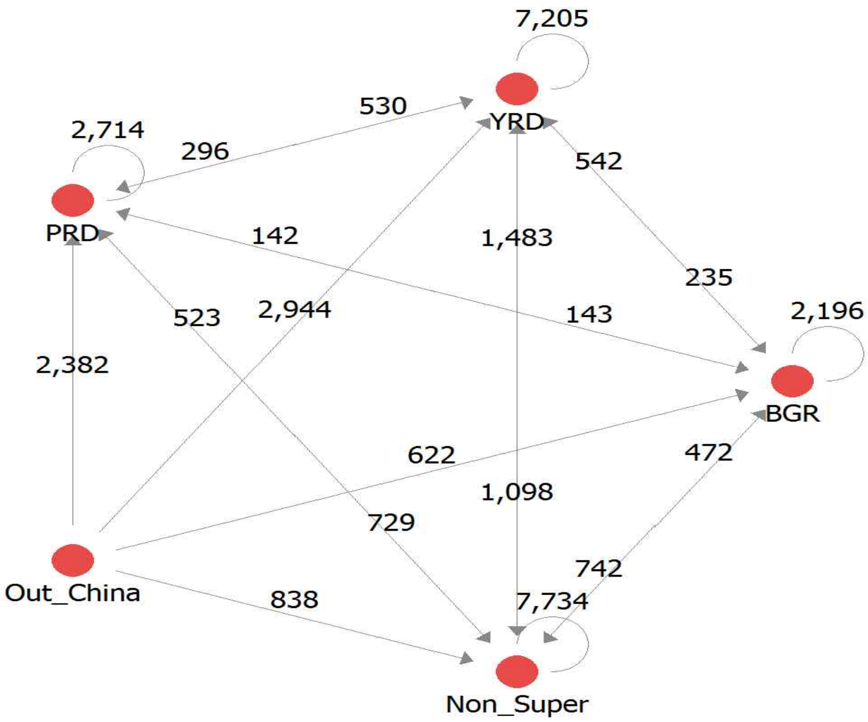



*Figure 28 Technology flows between Super-regions*

*Table 30 Technology flows*

| | BGR | Non-Super | PRD | YRD |
|---|---|---|---|---|
| BGR | 2196 | 742 | 142 | 542 |
| Non-Super | 472 | 7734 | 523 | 1483 |
| Out_China | 622 | 838 | 2382 | 2944 |
| PRD | 143 | 729 | 2714 | 530 |
| YRD | 235 | 1098 | 296 | 7205 |

Next, Table 31 lists the centrality result of super-regions. Indeed, it is not surprising that foreign countries have the highest out-degree centrality (1696.5). Comparing the ratio between out and in- degree centrality, BGR has a balanced tendency (1.03) between inflow and outflow, while YRD (3.38) and PRD (2.38) tend to import rather than export technology. Beijing, an anchor region in BGR, is presumed to have a different pattern of brokerage activities other than the two super-regions. The close centrality that measures the extent to which glocally connects a whole network was all the same (0.8), while in-close centrality remains as 1.

*Table 31 Degree and close centralities by Super-regions*

| Super regions | Degree Centrality | | Close Centrality | |
|---|---|---|---|---|
| | Out | In | Out | In |
| BGR | 356.5 | 368 | 0.8 | 1 |
| YRD | 407.25 | 1374.75 | 0.8 | 1 |
| PRD | 350.5 | 835.75 | 0.8 | 1 |
| Non_Super | 619.5 | 851.75 | 0.8 | 1 |
| Out_China | 1696.5 | 0 | 1 | 0.5 |

### *6.2.2. The connectivity measures*

In the next procedure, two indices were employed to describe how each group is connected with each other. The first index is the E-I (External-Internal) index suggested by (Krackhardt and Stern 1988, Hanneman and Riddle 2011). It compares the number of internal links between nodes of a group with that of external links to other group nodes to yield the differences between those, which is described as below.

$$E - I\ index \quad = \frac{EW - IW}{EW + IW} \tag{12}$$

The index compares the amount of internal flows ($IW$) to the amount of external weights ($EW$). It is used as a simple measure for the extent to which a group (Super region) exhibits local (intra-megalopolis strengths) and global (inter- megalopolis strengths) cohesion. The possible scores of E-I index range from 1 to -1. As the E-I index goes to 1, all the links would be external to the group; in the opposite way, -1 indicates that all the links are internal. If the links are divided equally, the index goes to zero. Several facets of this index are worth noting. One may note, for example, that the index is a measure of the dominance of external over internal ties, not simply a measure of external links. Thus the index not only decreases with a decrease in external ties, as can be deduced directly but also can be decreased by increasing the internal ties. Despite its simplicity, E-I index is not normalised with the size of a group.

The second index- SMI (Segregation Matrix Index) –is not dependent on the size of the population, free of most restrictions and can be subjected to a test of significance. It is asymmetrical and assigns a segregation score to each group separately, which consists of several indices together for an index (Fershtman and Chen 1993). Given $d_{AA}$ is the average number of links made by a member of $A$ towards a member or non-member ($d_{AB}$), then SMI is calculated as below.

$$SM\,I = \frac{d_{AA} - d_{AB}}{d_{AA} + d_{AB}} \tag{13}$$

These two indices together compare the tendency of interactivity whether it is outward or inward super-regions. The total network of all periods by all groups was calculated and then further to the annual trend of each group. The total period, listed in the table, demonstrates that BGR has a lower SMI score (0.588) than the other super regions, implying that BGR is less separated from other regions. In other words, BGR keeps more interactive connections with other regions; YRD and PRD relatively appear to have a tendency of an interconnection with internal regions based on a high score of 0.7. It is not a surprise that the non-super region has a score below zero (-0.651), meaning that non-super regions have more connections with super-groups, rather than within non-super groups.

It is worth noticing that the E-I index has a slightly different pattern. BGR has the highest score (0.893), followed by PRD (0.815), and then YRD (0.615). The regions belong to BGR, and PRD has more external links with other regions. YRD, relatively, has preferred to keep internally cohesive relationships, exchanging the technologies within its megalopolis independently. BGR, however, seems to be less independent, transmitting technologies through the whole domestic regions. PRD also remains a cohesive relationship with a strong outbound tendency.

*Table 32 SMI, E-I indices results by Super-regions*

| | BGR | YRD | PRD | Non_Super |
|---|---|---|---|---|
| SMI | 0.588 | 0.712 | 0.773 | -0.651 |
| E-I | 0.893 | 0.615 | 0.815 | 0.255 |

Next, Table 33 reports the annual trend of two indices by region groups. It is not a surprising result that two indices show fluctuations between -1 to 1 with many zeros. As the descriptive chapter already revealed that Chinese technology transfer network is dominated by foreign technologies, the results show an extreme bias until around 2006. Recalling that the purpose of this chapter is to find an evolutionary figure of super-regions, The values after 2006 were focused on.

*Table 33 Annual trend of SMI, E-I indices of Super-regions*

| Year | BGR | | YRD | | PRD | | Non-super regions | |
|---|---|---|---|---|---|---|---|---|
| | SMI | EI | SMI | EI | SMI | EI | SMI | EI |
| 2001 | -1.0 | 1 | 0.0 | 1 | 0.0 | 1 | 0.0 | 1 |
| 2002 | 0.9 | 0.667 | 1.0 | 0.778 | 0.0 | 1 | 1.0 | 0.714 |
| 2003 | 0.0 | 1 | 0.0 | 1 | 0.0 | 1 | 1.0 | 0.5 |
| 2004 | -1.0 | 1 | 0.0 | 1 | 0.0 | 1 | 0.0 | 1 |
| 2005 | 0.0 | 1 | 0.0 | 1 | 0.0 | 1 | -1.0 | 1 |
| 2006 | 0.0 | 1 | 1.0 | 0.833 | -1.0 | 1 | 0.0 | 1 |
| 2007 | 0.7 | 0.75 | 0.8 | 0.857 | -1.0 | 1 | 1.0 | 0.867 |
| 2008 | 0.8 | 0.75 | 0.8 | 0.667 | 0.9 | 0.714 | -0.9 | 0.846 |
| 2009 | 0.6 | 0.882 | 0.8 | 0.405 | 0.9 | 0.685 | -0.7 | 0.377 |
| 2010 | 0.4 | 0.927 | 0.8 | 0.558 | 0.9 | 0.773 | -0.7 | 0.345 |
| 2011 | 0.7 | 0.827 | 0.8 | 0.475 | 0.9 | 0.735 | -0.6 | 0.244 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | 0.6 | 0.887 | 0.8 | 0.452 | 0.7 | 0.801 | -0.7 | 0.313 |

First, BGR appears to keep a high E-I value of no less than 0.7 from 2007, implying that BGR has external links in Figure 29. The SMI line shows a sharply increasing trend until it peaks (0.8) in 2008, then dropped to 0.4 in 2010 which ends up 0.6 in 2012. It suggests that regions in the BGR seem to establish internal links, separating themselves from other super regions until 2008. Then, after 2009, the increasing gap between SMI and E-I hints that BGR tends to have more external linkages with other regions outside of BGR with a close connection with them. In 2011, the gap narrows but E-I index remained over a higher level (0.8). It is arguable that BGR tends to have a majority of external links after it established internal cohesiveness within BGR in the earlier period.

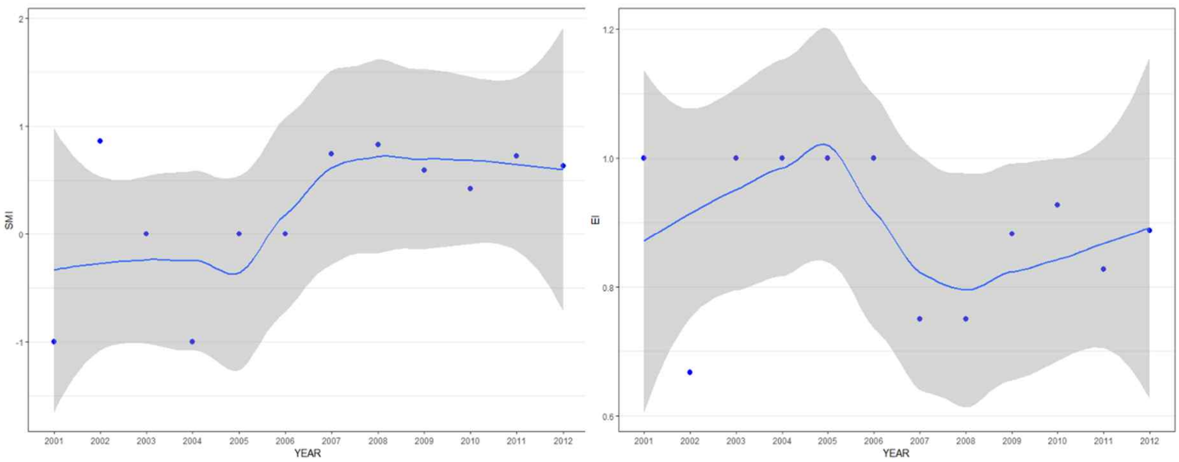



*Figure 29 Annual trend of SMI, E-I indices - BGR*

Second, YRD maintains a more stable trend compared to BGR. While the E-I index has a downward trend from 2006 (0.833) to 2012 (0.452), SMI is around 0.8 until 2012. The lower E-I index and higher SMI index indicates that the regions within YRD tend to exchange technologies with each other, maintaining the megalopolis independent from others. In other words, YRD has a preference for exclusiveness, deterring technology outflow.

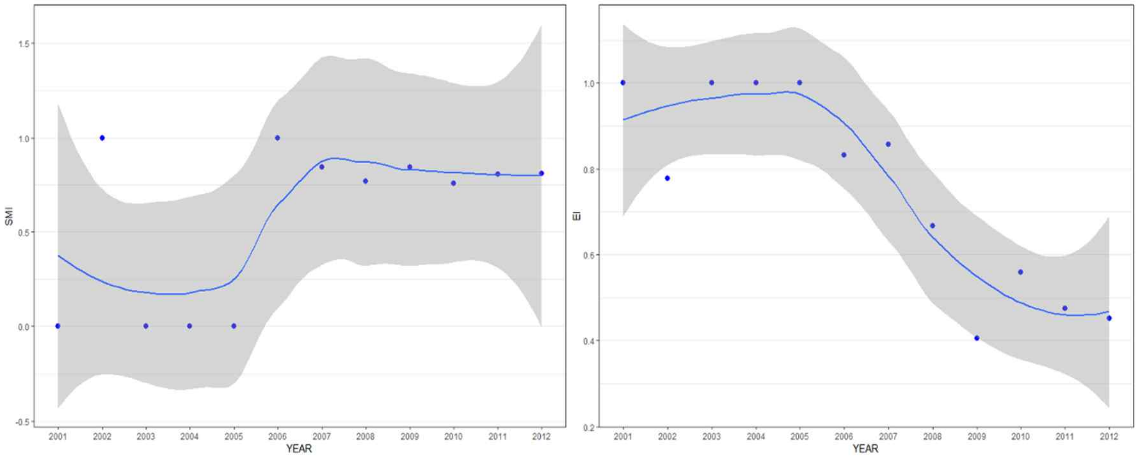



*Figure 30 Annual trend of SMI, E-I indices - YRD*

Lastly, PRD also shows a late surge of SMI after 2008. The gap between the two indices does not seem to be wide but attenuates. A higher SMI with lower E-I also implies that PRD is segregated with other super regions but maintained the external linkages with other regions outside of PRD.

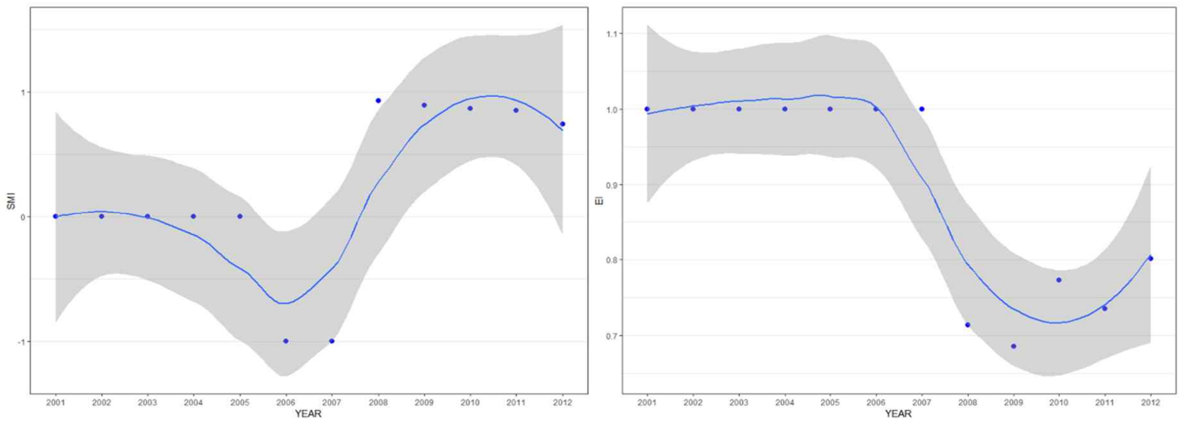



*Figure 31 Annual trend of SMI, E-I indices - PRD*

## 6.3. The brokerage types of anchor regions and the evolution of network

### 6.3.1. The typology of brokerage roles and anchor regions

One of the main concerns of the brokerage concept in social network studies is to reveal the linkage between the structural characteristics of a broker node and its interactive influences on the performance of network (Fernandez and Gould 1994, Hargadon and Sutton 1997, McEvily and Zaheer 1999, Zaheer and Bell 2005, Lazaric, Longhi et al. 2008, Graf and Krüger 2011). Hargadon and Sutton (1997) present empirical evidence that firms exploit the combined knowledge that acquired technologies from one industry and then apply them to another sector. The competitive capacity of the gatekeeper, such as creativity and higher skills, were reinforced from the network effects (Tushman and Katz 1980, Tushman and Scanlan 1981). In the same way, several empirical works corroborated the positive relationship between the importance of a brokerage role and network performance. For instance, Cross and Cummings (2004) find a positive correlation between network performance and betweenness centrality amongst engineers in a petrochemical company, indicating that the structure was significant in controlling the information flows of a network. Rodan and Galunic (2004) surveyed 106 middle managers in a European company to demonstrate that a manager's innovation performance correlates with the sparseness of their network. Capello (1999) also argues that knowledge is shared in the cohesive structure, such as communities of practice, implying that the structure of a network is highly likely to determine the knowledge transmission within the network.

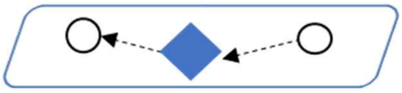
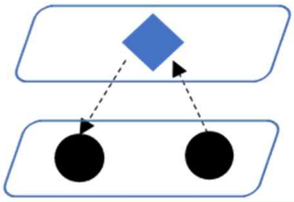
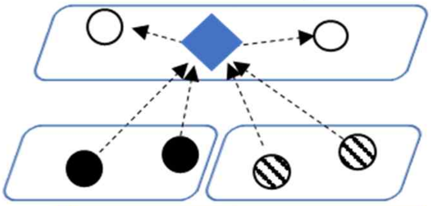
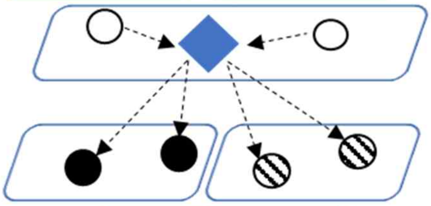
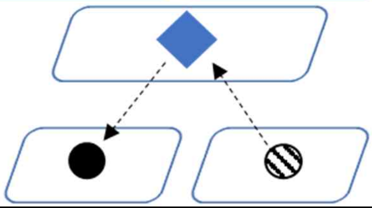
A brokerage position combines and diffuses existing information and knowledge among unconnected nodes, generating a competitive advantage to the network by drawing on internal and external information (Graf and Krüger 2011). Thus, it influences the network nodes between both internal and external nodes, producing higher innovative outcomes (Gould and Fernandez 1989, Burt 2005). The fundamental idea underlying these empirical works is that linkages around the nodes have the structural influence on the decision-making process, thus affecting the performance of a total network system (Sundaram and Black 1992). Then, the presence of a focal brokerage node is highly likely to affect the decision of other nodes that underpin the performance of the others in the network (Zaheer, Hernandez et al. 2010).

Scholars addressing the local knowledge spillover also recognised the significant role of a brokerage node as a conduit of new knowledge. Extant empirical studies use the analogy of a brokerage node to refer the inter/intra-regional channels of knowledge. Bathelt, Malmberg et al. (2004) argue that the presence of 'global pipelines' connecting the internal cluster to the external knowledge source can be beneficial in two ways: By acquiring new and valuable knowledge externally created, and by disseminating it to other firms in the cluster. Giuliani and Bell (2005), based on the geographical wine cluster in Chile, argue that focal firms play a leading role in transmitting the new knowledge and provide support to co-located firms, contributing the positive externalities to the cluster network. Research on clusters focuses on the gatekeepers to accessing external knowledge (Giuliani and Bell 2005, Wink 2008, Graf and Krüger 2011, Munari, Sobrero et al. 2012). According to the above literature, the main role of focal nodes within the network share some typical features, being characterized by conferring the chances to access the external knowledge sources.

While not diminishing the importance of these brokerage roles in the geographical space, scholars have further revealed the specific types accounting for the brokerage roles, which has largely remained void (Gould and Fernandez 1989, Messeni Petruzzelli, Albino et al. 2010, Munari, Sobrero et al. 2012). Gould and Fernandez (1989) suggest a formal typology of the brokerage role, attracting the attention not just from the social context (Neal, Neal et al. 2015), but also several relevant studies (Spiro, Acton et al. 2013, Boari and Riboldazzi 2014, Boari, Molina-Morales et al. 2017). According to their classification, a coordinator connects the nodes that belong to the same group, so the information flows remain inside the group. A representative delegates its member nodes in order to deliver or exchange the information with the other outside members. On the contrary, a gatekeeper selectively endows the inflow of information from outside groups. A liaison, positioned outside of both groups, connects the source and receiver outside of the own group. While a consultant (itinerant) located outside transmits the information between the two nodes that are co-located within a group.

The major role of a brokerage node in the network is often largely denoted as 'gatekeeping' that drives the processes of connecting the new knowledge and supports to achieve higher performance in innovation activities (Messeni Petruzzelli, Albino et al. 2010, Munari, Sobrero et al. 2012). According to the social network literature, Gould and Fernandez (1989) suggest a more detailed description of brokerage roles which attracts attention not just from the social context (Neal, Neal et al. 2015) but also several relevant studies (Boari and Riboldazzi 2014, Boari, Molina-Morales et al. 2017). Gould and Fernandez (1989) distinguished five different types of brokerage: coordinator, itinerant (consultant), gatekeeper, representative and liaison. Table 34 provides a conceptual description of each of the brokerage roles, and illustrates what each type of brokerage might look like in the context of technology flow. The five types of brokerage have the same structure, consisting of three nodes with two links. In this study, a brokerage node (actor B) connects a region (actor C) in the megalopolis and the other region (actor A) outside. Although the five types of brokerage have the same relational structure, they differ in terms of their configuration of subgroups.

*Table 34 GF brokerage types in technology flows*

| Brokerage type | Structure* | Descriptions of the brokerage roles |
|---|---|---|
| Coordinator |  | provides mediation between members of one group where the mediator is also a member of the group |
| Consultant |  | provides mediation between members of one group where the mediator is not a member of the group |
| Gatekeeper |  | provides mediation between two groups where the mediator regulates the flow of information or goods to its group |
| Representative |  | provides mediation between two groups where the mediator regulates the flow of information or goods from its group |
| Liaison |  | provides mediation between two groups where the mediator does not belong to either group |

(*) Symbols are represents in the bracket : (▱: Megalopolises), (◆: Brokerage), (○: Regions co-located with the broker), (●⊘: Regions outside of the broker's)
Source : Author's elaboration

A coordinator transmits technology to unconnected clusters that belong to the same subgroup. A high-tier actor of the technology production hierarchy might share technology with a middle-tier actor, which later delivers a low-tier actor. Then, the middle-tier actor plays a coordinator role in the network. On the other hand, a consultant broker belongs to a different subgroup than the clusters that it connects. In this case, a broker actor shares technology from one actor with the other actor in the same group.

A gatekeeper broker is part of the same subgroup as a cluster of individual actors receiving technology. It could have a privilege whether to accept access to this cluster from other actors which transfers technology. For example, a gatekeeper region, as a member of a megalopolis, could determine the adoption of new technology flow from the other regions. Similar to a gatekeeper, a representative broker is part of the same subgroup. In contrast, a representative broker delivers technology to another cluster in a different subgroup. A representative region might be linked to a technology push in technology diffusion. Liaison brokers are part of their own subgroup which links unconnected clusters that belong to the different subgroups. For instance, an actor in the megalopolis might work with another actor in a different region, then distribute it to the other regions.

According to the GF brokerage framework, Neal, Neal et al. (2015) examine what types of brokerage facilitate information spread between researchers and educational practitioners. They find three types of brokerage (gatekeepers, representatives, and liaisons) were involved in the flow of information between school administrators and researchers. It is worth noting that Boari, Molina-Morales et al. (2017) investigate how different types of

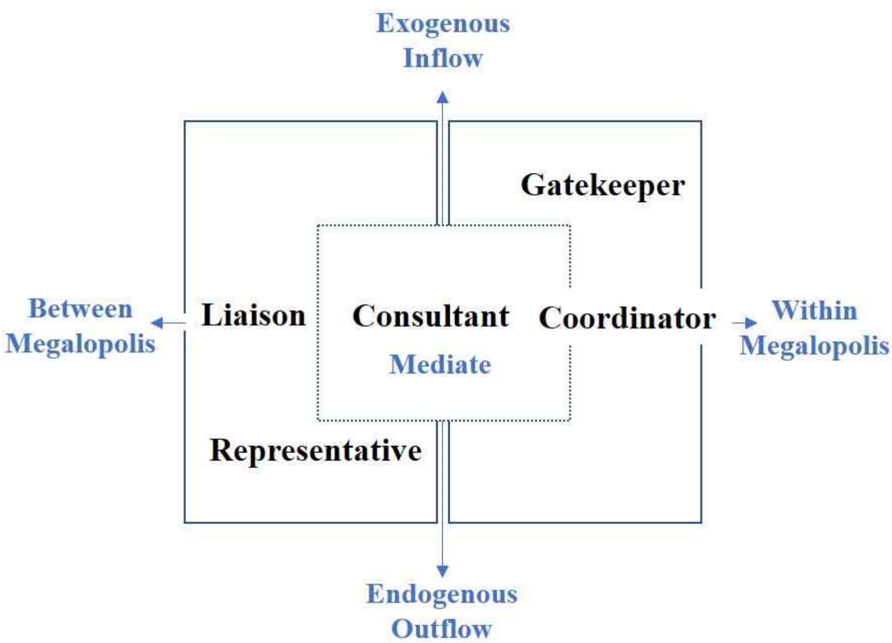


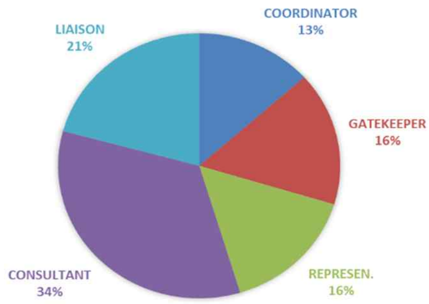

*Figure 32 Mapping the brokerage roles by geographical proximity*

brokerage activities affect the innovative performance of a clustered firm. They hypothesise that a liaison role has the highest innovative performance, then a gatekeeper and a representative positions in-between, while a coordination role has the lowest. Their regression model finds a positive relation between the liaison role and innovative performance, suggesting the opportunity for a broker to benefit from intermediating between different subgroups. What their analysis did not find as a significant result is the positive relationship between the other two roles (gatekeeper and representative) and innovative performance.  The quadrant in Figure 32 further clarifies the contribution of an individual broker to the neighbour regions in the megalopolis by reclassifying the roles into four quadrants: a gatekeeper (Upper right quadrant) imports external technology into the neighbour regions within the megalopolis (intra-megalopolis), a representative diffuses the endogenous technology to the other regions outside of the megalopolis (lower left quadrant), or intermediate combinations (remaining two quadrants). A coordinator mediates the technology between the regions within a megalopolis, which has little influence on the other regions outside of the megalopolis. In contrast, a consultant exchanges technology between regions within the same megalopolis, leaving the neighbour regions untouched. A liaison, however, involves the technology exchange between regions where two regions do not belong to the same group. For instance, Beijing transmits technology originating from YRD to the regions in Non-super regions. In the perspective of the national innovation system, a consultant node plays a global connecting role between the regions.

Table 35 summarises the average values of GF brokerage roles of all 296 nodes, revealing that the major brokerage role is a consultant (34%), then followed by a liaison (21%).  The two brokerages commonly transmit the technology between the regions where it does not belong to the broker's megalopolis.

*Table 35 GF brokerage types - all periods*

| Types | Mean value |
|---|---|
| COORDINATOR | 22.159 |
| GATEKEEPER | 27.115 |
| REPRESEN. | 25.895 |
| CONSULTANT | 56.267 |
| LIAISON | 34.473 |
| TOTAL | 165.909 |




The Table 36 lists the top 20 regions of brokerages roles of all periods.

Beijing, a most active broker region out of all regions, is mainly in the position of consultant (6149), liaison (3800), and then gatekeeper out of total roles (10,970). The figure implies that the main role of Beijing is to mediate technologies outside of BGR, connecting the regions within the national-wide links. The next two regions in YRD, Shanghai, and Nanjing, then serve as top brokerage hubs; however, an interesting result emerges on inspecting the results of the different patterns more closely. While the principal role of Shanghai and Nanjing commonly is a consultant position, Shanghai, plays a rather representative role. Shanghai, thus, diffuses the technologies originating in the YRD toward other regions. On the other hand, Nanjing seems to be in a more balanced position, showing a similar share of gatekeeper (17%), representative (17%), and liaison (15%). Within the YRD, Nanjing directly imports the external technology into the regions, and then equally exports the internal technologies to the other regions. Shenzhen, a top rank brokerage region in PDS, mainly works as a consultant, then a liaison, similarly with Beijing. The next higher broker region in the BGR, Tianjin, has a tendency to be a liaison, exchanging the technologies regardless of the BGR regions.

In contrast to the brokerage regions within the megalopolises, the highest share of Chengdu and Wuhan demonstrates that the principal role of anchor regions outside of super-regions is a coordinator (42%, 50%, respectively); Chengdu, capital of Sichuan province, and Wuhan, capital of central Hubei province seem to exchange technologies within the non-super regions. Given the different patterns of the top region's role between the super region and non-super region, it is clear that top anchor regions in the super regions have more significant roles both intra-megalopolis and inter-megalopolises as well. The top broker regions located outside of the super-regions including Chongqing, Xian, and Changsha as well, however, do not seem to deliver technology to the super regions. It corroborates the idea that anchor regions in the super regions contribute to the transfer of technologies in the whole national innovation system, not just to the megalopolis.

*Table 36 GF brokerages - Top 20 regions*

| Rank | Regions | Super Regions | Coor. | G.keeper | Rep. | Consult. | Liaison | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Beijing | BGR | 16 | 532 | 473 | 6149 | 3800 | 10970 |
| 2 | Shanghai | YRD | 150 | 650 | 993 | 2206 | 796 | 4795 |
| 3 | Nanjing | YRD | 91 | 506 | 508 | 1410 | 459 | 2974 |
| 4 | Shenzhen | PRD | 12 | 203 | 302 | 1403 | 729 | 2649 |
| 5 | Tianjin | BGR | 10 | 130 | 222 | 775 | 949 | 2086 |
| 6 | Guangzhou | PRD | 12 | 232 | 186 | 817 | 630 | 1877 |
| 7 | Hangzhou | YRD | 104 | 379 | 361 | 770 | 261 | 1875 |
| 8 | Chengdu | Non_Super | 893 | 349 | 431 | 21 | 46 | 1740 |
| 9 | Wuhan | Non_Super | 748 | 528 | 278 | 33 | 70 | 1657 |
| 10 | Suzhou | YRD | 70 | 338 | 221 | 427 | 275 | 1331 |
| 11 | Wuxi | YRD | 66 | 209 | 289 | 396 | 202 | 1162 |
| 12 | Chongqing | Non_Super | 403 | 310 | 174 | 25 | 53 | 965 |
| 13 | Xian | Non_Super | 416 | 203 | 186 | 1 | 25 | 831 |
| 14 | Nanchang | Non_Super | 266 | 154 | 259 | 40 | 47 | 766 |
| 15 | Ningbo | YRD | 24 | 197 | 84 | 317 | 121 | 743 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 | Changsha | Non_Super | 294 | 265 | 106 | 14 | 33 | 712 |
| 17 | Hefei | YRD | 51 | 162 | 149 | 230 | 108 | 700 |
| 18 | Foshan | PRD | 17 | 113 | 106 | 215 | 242 | 693 |
| 19 | Dongguan | PRD | 7 | 91 | 87 | 220 | 222 | 627 |
| 20 | Qingdao | Non_Super | 284 | 167 | 142 | 13 | 17 | 623 |

### 6.3.2. The trend of anchor region's brokerage roles

Figure 33 visualises that two regions, Beijing and Tianjin, connect the BGR with other regions, playing a role of a transmitting hub. The highly concentrated external links might reinforce the hierarchical structure of technology flows.

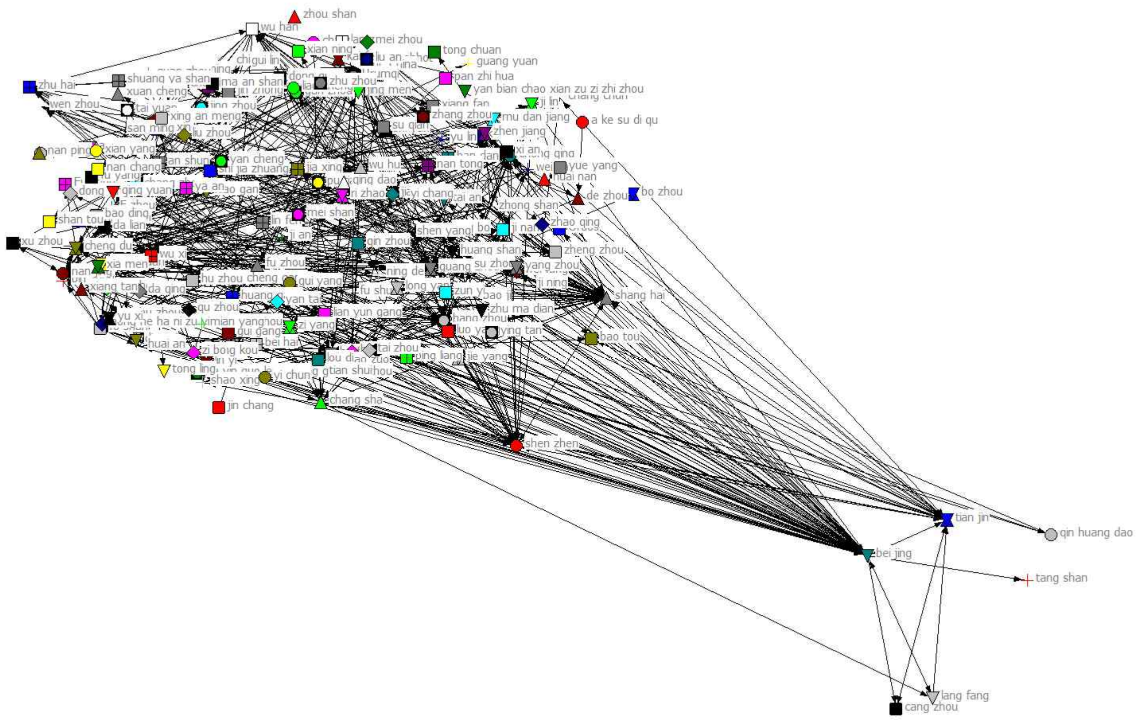



*Figure 33 Interactive links - BGR*

Table 37 reports the counts of brokerage roles of Beijing after 2007: the total frequency from 2001 to 2006 is below 1. The structural property analysis already reveals that foreign technologies originating in overseas countries dominates the technology transfer network, leaving the brokerage role void. The highest number observed is 2369 in 2010, which sharply increased from 9 in 2007, then a slight decline followed.

*Table 37 Annual trend of GF brokerages - Beijing*

| | Coordinator | Gatekeeper | Represen. | Consultant | Liaison | TOTAL |
|---|---|---|---|---|---|---|
| 2001 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2002 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 0 | 0 | 5 | 0 | 4 | 9 |
| 2008 | 0 | 43 | 0 | 139 | 128 | 310 |
| 2009 | 5 | 59 | 163 | 625 | 566 | 1418 |
| 2010 | 2 | 60 | 127 | 993 | 1187 | 2369 |
| 2011 | 17 | 188 | 225 | 893 | 945 | 2268 |
| 2012 | 3 | 111 | 90 | 958 | 784 | 1946 |

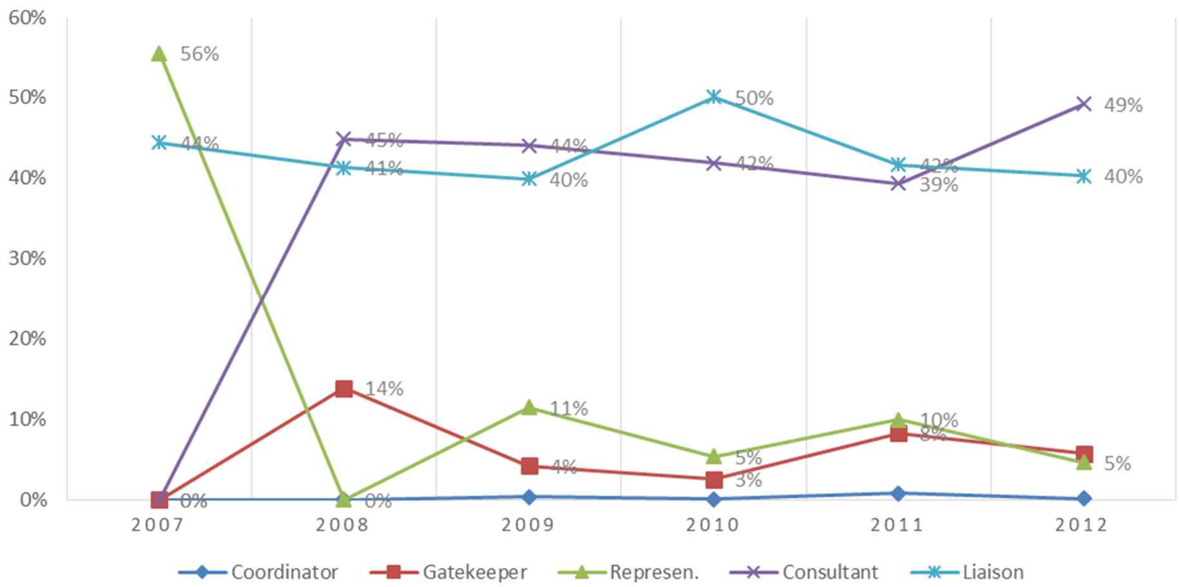



*Figure 34 GF brokerages after 2007- Beijing*

Figure 34 traces the annual trend of the proportion of roles from 2007 to 2012. Despite a sudden fluctuation between 2007 and 2008, the ratio seems to have a stable trend afterwards. The bifurcate trend clearly denotes that Beijing plays a significant role as a liaison and consultant, taking up more than 80% of total shares. The sum of the shares of the other roles, however, remained below 20% through the periods. The annual trend indicates that Beijing has brokered the technologies through the whole regions nationwide, serving as a global hub within the national innovation system, rather than the local connector.

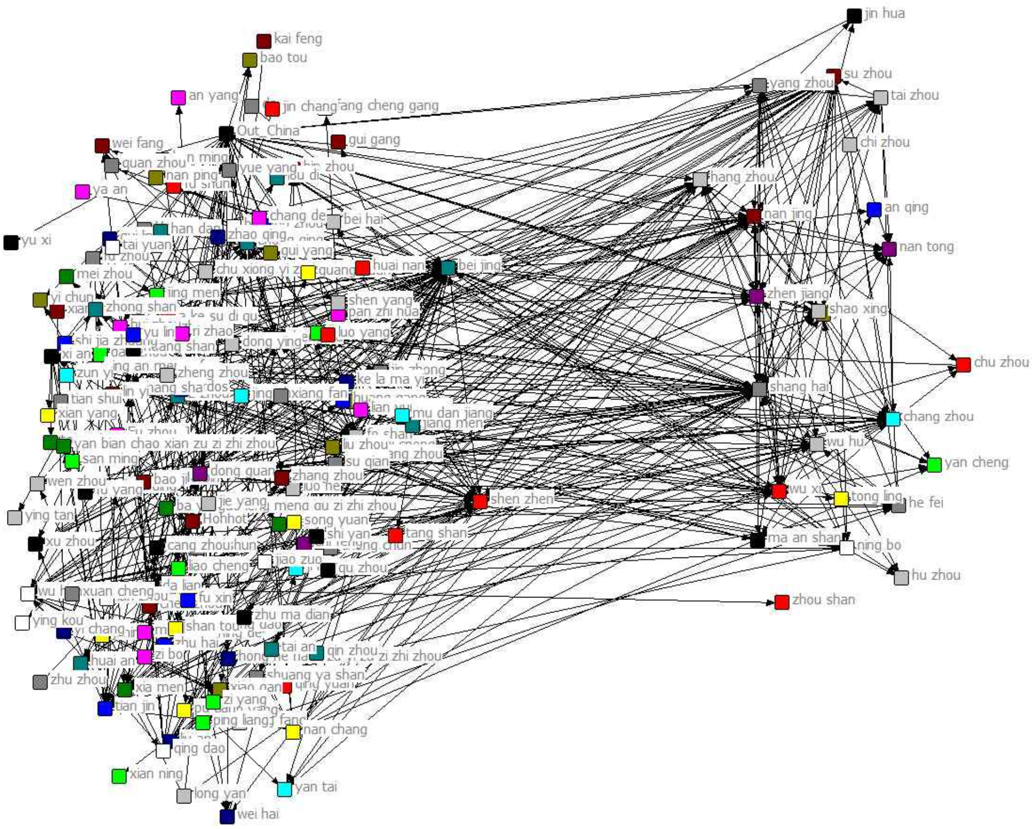



*Figure 35 Interactive links – YRD*

The technology flows of YRD show more complex connections in that several regions have direct links with outside megalopolis. For instance, Shanghai, Nanjing, Suzhou and Hangzhou have diverse neighbour regions, maintaining intra and inter-regional links. The top anchor hub in YRD, Shanghai, brokers as a gatekeeper and liaison in 2007, for the first time. The frequency increases steeply until it reached the peak (1718) in 2011. In 2007 and 2008, when the total number of brokerages is lower than 1000, the highest role of Shanghai is a gatekeeper followed by liaison; however, the two roles gradually decline as the total number increases after 2009. While the gatekeeper line goes downward, the roles of a consultant and representative marked a steep rise during the periods. It denotes that the role of Shanghai as a technology importer to the megalopolis has diminished, on the other hand, it turned to a technology diffuser (representative) and nation-wide hub (consultant) gradually.

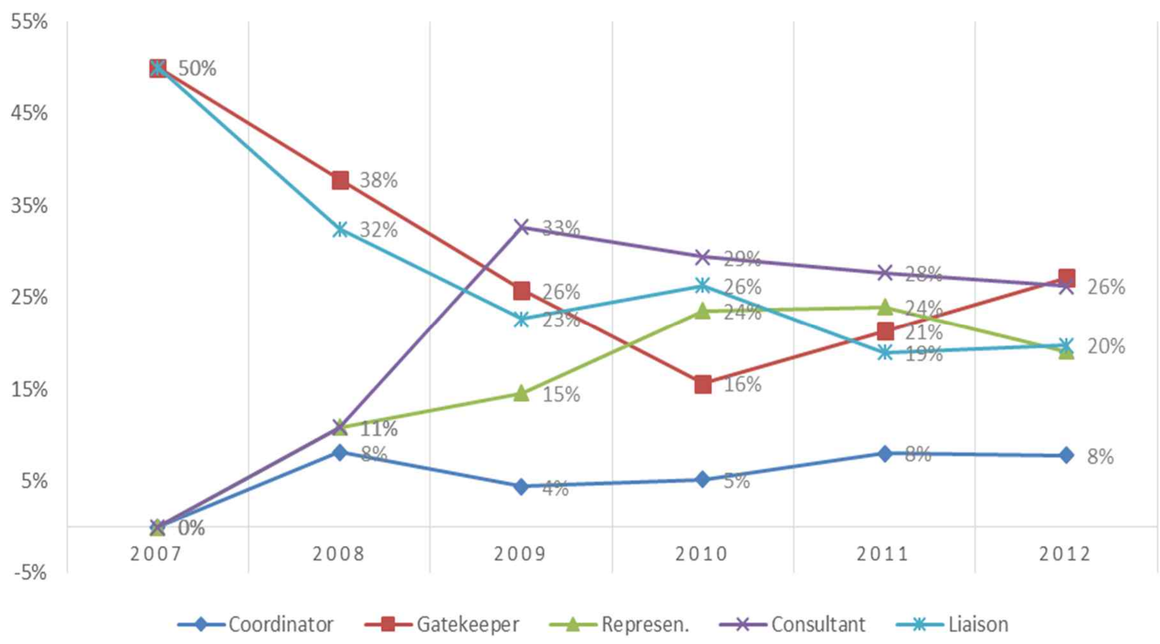



Figure 36 GF brokerages after 2007- Shanghai

An interesting result emerges that the proportion of gatekeeper bounces back while consultant gradually declines after 2010. In 2012, more balanced shares, compared to that of Beijing, are marked: Gatekeeper, and consultant (26%), representative, and liaison (20%), and coordinator (8%). Thus, it is reasonable to define the role of Shanghai as a balanced broker.

*Table 38 Annual trend of GF brokerages - Shanghai*

| Shanghai | COORDINATOR | GATEKEEPER | REPRESEN. | Consultant | LIAISON | TOTAL |
|---|---|---|---|---|---|---|
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 0 | 1 | 0 | 0 | 1 | 2 |
| 2008 | 3 | 14 | 4 | 4 | 12 | 37 |
| 2009 | 53 | 312 | 176 | 395 | 274 | 1210 |
| 2010 | 62 | 188 | 284 | 354 | 317 | 1205 |
| 2011 | 138 | 366 | 412 | 476 | 326 | 1718 |
| 2012 | 59 | 206 | 145 | 199 | 150 | 759 |

Last, PRD also seems to have diverse partners, similar to YRD. The inward connections appear to go to Shenzhen, Dongguan, and Foshan. It is notable that the total number of brokerages is less than those of other megalopolises as shown in Table 39. The largest frequency was 662 in 2009, which is even less than 1000. After its reached peak, the total number shows a gradual decline until 387 in 2012. In 2008, the proportion of gatekeeper is a top role of Shenzhen, the two main roles remaining as liaison and consultant after the total number is saturated.

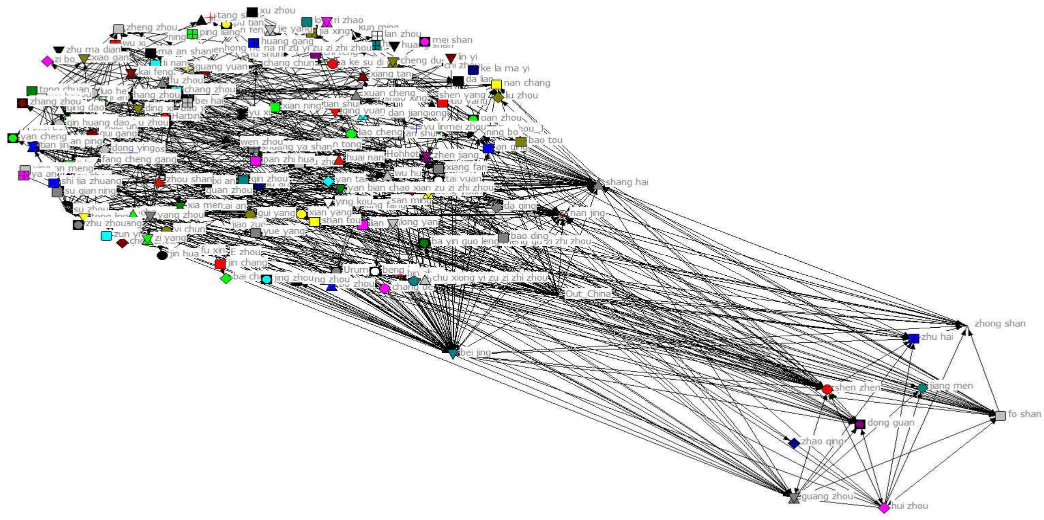



*Figure 37 Interactive links – PRD*

During the last three years, the sum of two main roles (liaison and consultant) was kept over no less than 70%, while the sum of the secondary role (representative and gatekeeper) is around less than 30%. In 2012, similar to Beijing, Shenzhen also has bifurcated brokerage roles, contributing to the exchange of nation-wide technologies rather than within the PRD.

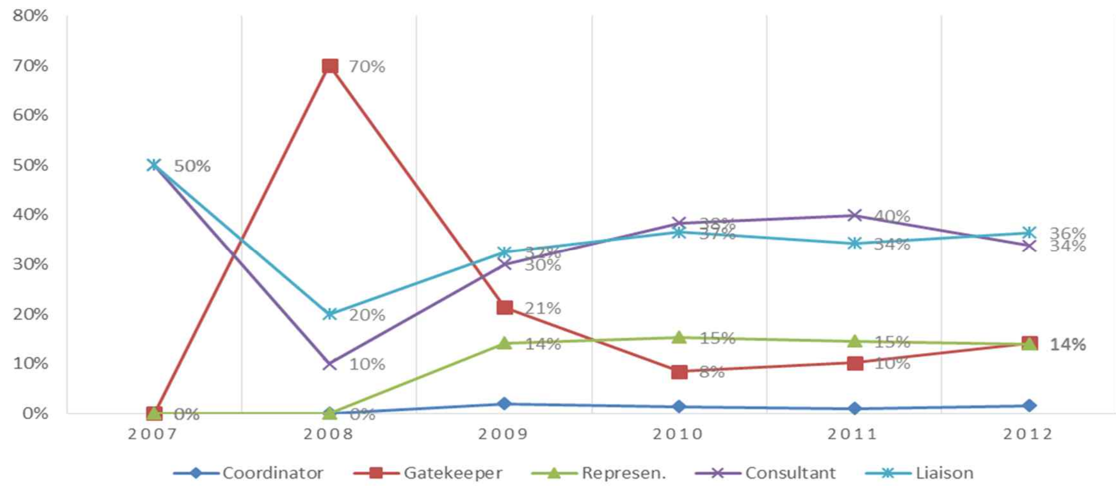



*Figure 38 GF brokerages after 2007- Shenzhen*

*Table 39 Annual trend of GF brokerages - Shenzhen*

| | COORDINATOR | GATEKEEPER | REPRESEN. | Consultant | LIAISON | TOTAL |
|---|---|---|---|---|---|---|
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 0 | 0 | 0 | 0 | 1 | 1 |
| 2007 | 0 | 0 | 0 | 1 | 1 | 2 |
| 2008 | 0 | 14 | 0 | 2 | 4 | 20 |
| 2009 | 13 | 141 | 94 | 199 | 215 | 662 |
| 2010 | 9 | 55 | 100 | 250 | 238 | 652 |
| 2011 | 5 | 54 | 77 | 211 | 181 | 528 |
| 2012 | 6 | 55 | 54 | 131 | 141 | 387 |

### 6.3.3. Contribution of Anchor's brokerage role to the evolution of network

Consistent with the former analytic model, the contribution effect is estimated by the conditional method of moments in SIENA. Table 40 compares two models. The basic model examines two contradictory roles – gatekeeper and representative - to find which of the propensity of technology flow contributes to the evolution of nation-wide technology network (Breschi and Lenzi 2017). Traditionally, 'gatekeeper' and 'representative' referred to scientists whose social influence placed them in positions to act as principal brokers of technological knowledge (Allen 1977). The full model adds two roles – Consultant and Liaison – as the expansion of heterogeneous roles. The role as a coordinator, however, is not counted in the model due to its low frequency.

*Table 40 Anchor role estimation results*

| | Basic model (n=130) | | Full model (n=130). | |
|---|---|---|---|---|
| | Estimation value | Standard error | Estimation value | Standard error |
| *Rate function* | | | | |
| Rate $\lambda_{2009-2010}$ | 5.515 | $0.168^{***}$ | 27.11 | $0.984^{***}$ |
| Rate $\lambda_{2010-2011}$ | 0.001 | $0.001^{***}$ | 0.007 | $0.008^{***}$ |

| | | | | |
|---|---|---|---|---|
| Rate $\lambda_{2011-2012}$ | 0.001 | $0.001^{***}$ | 0.009 | $0.009^{***}$ |
| Density | 0.032 | $0.005^{***}$ | -1.416 | $0.009^{***}$ |
| Reciprocity | 0.047 | $0.015^{***}$ | 1.098 | $0.055^{***}$ |
| *Objective function* | | | | |
| Gatekeeper | -0.0159 | $0.003^{***}$ | -0.012 | $0.005^{**}$ |
| Representative | 0.0219 | $0.005^{***}$ | 0.025 | $0.008^{***}$ |
| Consultant | | | 0.008 | $0.004^{**}$ |
| Liaison | | | -0.012 | $0.004^{***}$ |

$^{**}P<0.05$, $^{***}P<0.001$.

The basic model shows a consistent pattern of the structural effects with that of the previous analysis. The rate of changing its status drops between 2010 and 2011, implying a strong path-dependency also emerges. Looking at the positive and significant value of density and reciprocity, the overall structural effect seems to have a significant influence on the development of the network. All the two variables of the roles reported the significant effect, while the signs are contrary. The role as a representative (0.0219) has a positive effect on the development of the network, nonetheless, the gatekeeper seems to have not contributed the evolutionary process.

In the full model, the rate coefficient dropped more sharply than the basic model. Although the sign of density has changed from positive to negative, it is generally expected that the nodes maintains it original position after the density reaches to the point. The interest result is the different signs of the objective function variables in that former two basic variables maintain the tendency (-0.012, 0.025, respectively). The consultant has a small but positive effect (0.008), nevertheless, liaison was estimated to have a negative effect (-0.012).

A fundamental implication of all the significant values of the brokerage roles is that the brokerage roles played by the anchor regions influenced the network evolution in either positive or negative way. Reflecting the types of the brokerage on the basis of the social network theory, the brokerage role as liaison appear to have opportunity to benefit from intermediating between heterogeneous groups (Boari, Molina-Morales et al. 2017). The empirical estimation, however, demonstrates the contradictory effect.

The common feature of the two positive estimation values (representative and consultant) is that an anchor region have more influences to the regions outside of its own super-region. The representative, that acquires technology knowledge from other co-located region, acts as the technology source for other regions in the outside. In the case of the consultant, an anchor region connects only with regions located outside of the super-region, thus connecting other regions. Contrary, the gatekeeper, acquiring from the regions outside of the super-region, acts as a technology source for the regions inside of its own super-regions. Liaison connects different regions in different super-regions. To sum up, the main contribution of anchor regions, in the perspective of the national innovative system is directed to the external regions outside rather than inside of the super-regions.

## 6.4. Conclusion

This section employs social network metrics to capture the technology flow patterns in region-to-region level, demonstrating which regions play roles in creating, transmitting and consuming roles in the network, which leads to an emergence of a pattern. The analysis argues that the growth of technology transfer is partly a function of a few leading principal regions through flows of patent.

What the current study challenges is the mechanism of the brokerage role of an anchor region in the network evolution. Reflecting the importance of an anchor node in the development of the network, there is obviously an increasing interest in the specific type of brokerage role of the anchor node. The current chapter examines the structural changes of the network, capturing the functional characteristics of the brokering function of the three major anchor regions. Next, section 3 examines the contribution effect of the roles in the development of the network and the last section summarizes the results.

The GF framework found that Beijing and Shenzhen tend to transmit technology as a nation-wide hub in the national innovation system, rather than a local hub in the megalopolis. Shanghai seems to serve as a more balanced broker region both as a local diffuser and a nation-wide hub. This result shows that the Chinese anchor regions have two different patterns—nationwide hub and local megalopolis hub. This finding has a practical implication for regional policy makers in that some anchor regions in the megalopolis might be evolved into national technology sources, while the other brokerage type might remain as a local hub. This issue motivates a discussion of the strategic allocation of limited resources in the sense of whether well-established brokerage regions (geographical clusters as well) are effective in enhancing the innovative capacity of a nation, calling for attention to be given to fast-growing economy countries.

While the canonical studies of a brokerage position in the network have remained constant in identifying the positive association with performance, this research contributes to this literature further by disentangling the positive and negative effect of brokerage activities. It is worth noting that the quantitative analysis supports that a liaison among brokerage types contributes to the evolution of the network. The identification of different patterns in the analysis provides practical implications to regional policymakers in addressing innovation policy, in that the brokerage role as a representative is more effective to economic development based on technology innovation. The quantitative analysis makes it plausible to say that anchor regions are required to serve as a conduit for domestic anchor regions rather than a local region anchor in order to lead the national innovation system.

# Chapter 7. The anchor regions in the hierarchical structure of national innovation system

## 7.1. Introduction

How a region acquires exogenous knowledge, and utilizes it to re-create new knowledge is critical in regional economic growth (Coe and Helpman 1995, Cooke 2004, Audretsch and Keilbach 2008, Capello, Caragliu et al. 2010, Sonn and Park 2011, Choi and Cho 2015, Park 2016, Choi and Choi 2017). In a fast-growing economy, in particular, such knowledge acquisition process is even more important as means of extending the knowledge base (Chatterji 1996, Jonash 1996, Kim 1997), and acquiring informal channels of tacit knowledge (Cohen and Levinthal 1989, Huber 1991). The utilization of exogenous knowledge as opposed to domestic R&D is advantageous because it can reduce the uncertainty of the latter and facilitates connections with the creators of advanced knowledge across national borders (Capon and Glazer 1987, Chatterji and Manuel 1993, Bathelt and Henn 2014).

Although previous studies have revealed the importance of externally acquired knowledge to a region's innovative capacity, few have asked how the inter-regional interaction in. Externally acquired knowledge is an important part of the catching-up process because one of the most effective ways to enhance a region's technological capabilities is by importing, assimilating, and improving exogenous technologies across regions (Kim 1998, Liu and White 2001). One critical facture in stimulating technology flows over geographical distance is regional hierarchy (Storper and Walker 1989, Verspagen 2010). The basic idea here is that traditionally influencing region in the hierarchical economic activities, or core regions, due to the variety and convergence of their economic activities, generate a wider range of innovative outputs than peripheral regions (Verspagen 2010). Given such a hierarchy in the national system of innovation (NSI), some regions specialize in providing technologies to other regions. Some relational approaches to urban and regional economic development tend to emphasize the direct connection between global flow and local processes of technology production. For example, authors from the global production network (GPN) claim that a regional economy is usually "coupled" with a multi-national company (MNC) (Ernst and Kim 2002, Yeung 2016). Compared to earlier approaches focusing on the external dependency of regions, their contribution in revealing the relationship between external input and region's development lies in the non-passivity of local actors (Liu and Yeung 2008, Yeung 2009). It is, however, not clear whether or not the domestic core-periphery relations in technology production persist, where this paper tackles that lack of clarity.

One approach to the linkages between regional roles and structures is to track the flow (source and destination) of the technologies underpinning economic activities. But it is not easy to trace those invisible pathways, mainly due to their tacit and intangible nature (Asheim and Gertler 2005). Patent licensing information provides robust evidence that enables us to track codified technology flows between regions, since the information clearly reveals both the source and target of the technology. In recent years, many researchers have applied social network analysis techniques to technology diffusion across space (Cantner and Graf 2006, Ter Wal and Boschma 2009, Boschma, Balland et al. 2014). Social network analysis allows us to understand not only the structural characteristics of the total nodes at a macro level, but also the individual roles of those nodes. This approach has been used to examine regions' functional classifications when transmitting technology between domestic technology transfer networks (Hong 2008, Wang, Pan et al. 2015). This study tackles a further, as yet unanswered, question: what are the core regions' internal roles in technology flow at the inter-region level? The current analysis looks at China to answer this question. China offers a perfect ground because 1) its territory is vast, which makes regional dynamics of innovation more visible (Jiang and Kim 2016) and 2) its technological capacity grew over the last few decades, after global flow of information became natural part of technology development.

The remainder of the paper is organized as follows. The next section, Section 2, will review the literature on technology flows in the network and the roles of leading actors in innovation systems. Section 3 will describe the data and metrics. Section 4 will analyze the structural properties of technology licensing networks. Section 5 will explore anchor regions by investigating knowledge exchange patterns and examining whether a hierarchy in technology persists. Section 6 will sum up the major findings and implications.

## 7.2. The role of anchor region in the hierarchy of innovative system

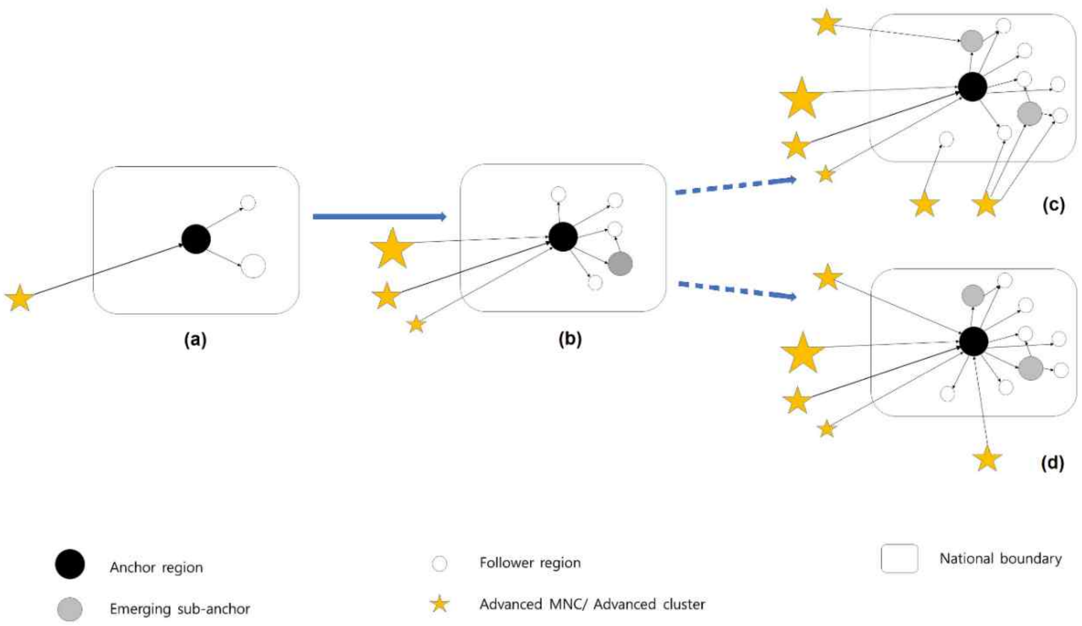
The literature on the NSI focuses on networks that link institutions. The building blocks of the system are institutions such as firms, universities, and governments, among others. From a regional development point of view, such an approach is characterized by what geographers call “methodological statism”, in which the national boundary is treated as the single divider of societies and economies (Dalby and Tuathail 1998). In this approach, little consideration is paid to spatial differences within the national boundary. On the other hand, geographical approaches to innovation tend to focus on the region as spatial unit of analysis and downplay the importance of a NSI. This paper attempts to vines of approaches by locating the region and its innovation system as the spatial building blocks of a national innovation system.

To better explain this idea, the current research proposes a new concept: the anchor region. An anchor region is a region that imports advanced technology from overseas, assimilates and improves that technology, and produces its own technology for other regions within the country. As such, the anchor region is the leading actor within NSI. This idea was inspired by the “anchor firm” concept employed by Feldman (2003) and others. Within an industrial cluster, the “anchor firm” might increase the innovative activities of other firms through externalities (Von Hippel 1994, Feldman 2003). The critical roles of anchor firms in a cluster or industry include assimilating external technologies, reproducing them within a region, and facilitating the growth of innovative activities among neighbors (Peri 2005).

If the anchor firm plays such important role in a regional economy, can a region play a similar role in a national economy? Powell (2003) argues that a firm is not a hierarchy in the sense of a Weberian ideal bureaucracy, within which decisions are made at the top, relayed to the bottom without any loss of information, and always obeyed without resistance or modification. In fact, a firm is a collection of relatively strong, dense networks between divisions and employees, layered on top of each other. If this description is accurate, dense, geographically proximate networks within a region will allow us to treat a regional economy like a structure in a firm, to a certain degree. In fact, researchers have accumulated ample evidence to suggest this, drawn from their approaches to topics ranging from 1980s’ industrial districts to today’s evolutionary economic geography (Russo 1985, Pyke and Sengenberger 1992, Boschma and Ter Wal 2007, Capello and Varga 2013). It therefore seems plausible that a region might play a critical role in assimilating and diffusing exogenous knowledge, within a NSI, which this research calls as “anchor region”.

Firms and other organizations in an anchor region import, assimilate, and improve upon foreign technology. The various local channels of knowledge spillovers, such as informal industry talks, formal partnerships between organizations, and shared labour markets, help other organizations in the same region take advantage of important technology. An anchor firm’s assimilation of foreign technology can therefore trigger that of an entire region. The anchor region will then pass on its technology – a combination of imported and homegrown technology developed in house, to other regions with lower rankings within the nation’s technological hierarchy.

This mechanism of technology diffusion/learning within a national system of innovation may be due to the spatially uneven nature of absorptive capacity. Different regions have different regional environments, with different levels of absorptive capacity, leading to overall disparities in absorptive capacity (Verspagen 2010). An organization with limited absorptive capacity is likely to source technology from within its immediate cultural and geographical environs (Caniëls and Verspagen 2001). This implies that a region which is ranked lower in a nation's technological hierarchy is more likely to learn from the nation's anchor region than from elsewhere. This process is self-reinforcing. Once a link has been established, that link can be exploited repeatedly, due to the path dependency derived from the potential risks of sunk costs and uncertainty (Hong 2008, Sun and Liu 2016).




(a) Dependent NSI, (b) Emerging NSI, (c) Glocalised RIS (d) NSI as Hierarchy of RIS

Figure 39 Two scenarios for changes in inter-regional networks

Let's consider two scenarios involving changes in interregional networks, within a NSI. Initially, as most regional economic literature predicts, an anchor region would emerge. This region would be topologically similar to a transportation network structure in a colonial economy, as described by dependency theorist (Slater, 1975) and can therefore be called "dependent NSI (a)." In this phase, advanced technology comes from outside the NSI, and the anchor region within the NSI can assimilate foreign technology and produce less advanced technology and supply it to other parts of the country. At this stage, the national economy is highly dependent on foreign technology. Successful industrialization and technological development will transform dependent NSI (*a* in *Figure 39*) to what it calls emerging NSI (*b* in *Figure 39*). At this stage, the anchor region has more connections with advanced MNCs, or advanced industrial clusters receiving technology from multiple sources. At the same time, the anchor region's capacity to serve as a regional innovation system increases, and the region can provide a considerable amount of more advanced technology to its follower regions. Thus far, there is little to debate.

*Figure 39* (c) and (d) present different scenarios of evolution, involving topological changes in technology transfer networks. Both scenarios show, that, alongside economic growth and industrial upgrading, new regions will need to use more advanced technology, thereby joining networks. The way in which regions join networks is, however, different in each scenario. If the national boundary and NSI is only one of multiple scales on which knowledge is produced, see a structure like (c), which the analysis call the porous boundary networks. The national boundary is visible, but extremely porous. New entrants to the system form networks with foreign regions and with the original anchor region of the NSI. In the transition from emerging NSI (b) to glocalised RIS (c), the capacity of the anchor region as the importer and producer of technology might increase in absolute terms. However, as many other regions form networks with overseas sources of technology, the anchor region's relative importance within NSI will decrease.

This viewpoint is implicit within the major branches of economic geography.

Evolutionary economic geographers, for example, do not explicitly deny the importance of NSI, but pay little attention to. In their theoretical framework, exogenous factors are important, but whether these factors come from within or outside the national economy has attracted little attention (Trippl, Grillitsch et al. 2017). In relational approaches to economic geography, it is often assumed that a region acquires technology directly from overseas sources. Global production networks, for example, tend to regard the source of the new knowledge as an MNC, when, for example, they discuss strategic coupling between the MNC and the hosting region (Yeung 2009). Similarly, Bathelt, Malmberg et al. (2004)'s conceptualization of a global pipeline does not take national boundaries into account, either.

The second scenario is the transition from (b) to (d), shown in Figure 39, or from emerging NSI to closed NSI. In a closed NSI, the relative importance of an anchor region does not decrease. The anchor region forms networks with more sources of foreign technology, produces more technology itself, and sells more technology to other regions within the NSI. Some of the regions that are at first completely dependent on the anchor region later evolve into sub-anchors, which continue to be dependent on the anchor region but, at the same time, can offer technology to other regions. Since most regional actors rely on the anchor region, the efficiency of information diffusion is, in large part, determined by the anchor region.

## 7.3. Data and methods

### 7.3.1. Patent licensing as a measure of technology flow

The study uses patent licensing as a measure of knowledge flow and chooses patent licensing records rather than often-used measures such as patent citation and co-authorship for various reasons. Many of the existing studies on technology flows, including learning and diffusion, are based on the analysis of patent citation records (Jaffe, Trajtenberg et al. 1993, Maruseth and Verspagen 2002, Hu and Jaffe 2003). The introduction of patent citation data certainly marked a significant development in the relevant areas of research, as it provides one of the rare paper trails for knowledge flow. The fact that citations show the direction of technology flow (since the cited patent is the origin of the technology and the citing patent its destination) is also important. However, the value of citations is limited by the fact that citing is a low-cost activity. An inventor and her agent might add citations just to make their application comprehensive, just as an academic might add citations to show his wide reading. In addition, patent examiners from patent granting authorities may add citations if they discover uncited but related patents. Patent citations, then, cannot differentiate important flows of knowledge from related precedent patents that may or may not have affected the invention of the citing patent (Vernon Henderson 2007).

Another widely-used measure of technology flow is the co-authorship of scientific papers and patents (Jaffe, Trajtenberg et al. 1993, Hu and Jaffe 2003, Peri 2005, Park and Lee 2006, Sorenson, Rivkin et al. 2006, Park 2011, Zhang, Guan et al. 2014, Kim and Park 2015, Choe, Lee et al. 2016). Unlike patent citations, co-authorship is highly likely to reflect real interactions among authors and inventors. However, with co-authorship data, it is difficult to see the direction of information flow. Co-authorship data presents complementary information to that of patents, but does not make as significant a contribution to my knowledge here. In technology transfer research, in which the direction of the technology flow is of prime importance, co-authorship data is not fully useful.

In addition, neither citation nor co-authorship show the economic value of the technology. A patent is granted if the idea is new and its economic impacts are not guaranteed. Many patents never even result in actual production. Citation and co-authorship can therefore show the flow of knowledge, but not that of economically valuable technology. There have been attempts to find a variable within patent records that correlates with the economic value of the patent (Tong and Frame 1994, Reitzig 2003). Diverse variables have been tested, including, among many others, the number of claims, the number of renewals, the sectorial diversity of cited patents, the sectorial diversity of citing patents and the number of citations. Most of these have some positive correlation with the economic value of patents. However, these are indirect measures at best (Hall, Jaffe et al. 2005, Gambardella, Harhoff et al. 2008, Van Zeebroeck 2011).

The use of patent licensing data overcomes all of these problems. First, a licensee makes the conscious decision to use a patent because she understands the economic value of that patent: this solves the economic value problem. Secondly, patent licensing data combines the merits of citation records and those of co-authorship. Like patent citations, patent licensing clearly references the source and destination of technology flows. At the same time, like co-authorship data, the licensing records show real exchange of information. Licensing contract requires complex decision making by both parties, as to the availability, quality, usefulness, and price of the patents concerned, each of which requires intensive interactions between the two parties.

Despite these clear advantages, patent licensing has not been much utilized to date, mainly due to its unavailability. A regulatory body cannot require businesses to report their licensing of patents because the use of patents is directly related to a firm’s production technology, revelation of which might damage the firm’s competitiveness. That is why databases of patent licensing almost never cover a country’s full licensing activities. Partial records that are collected by management consulting firms are occasionally available but rarely comprehensive. This paper acquired the licensing records database of China’s State Intellectual Property Office (SIPO). Combined with the address information available in each patent record, this database allowed us to track spatial technology flows.

### 7.3.2. Data

The region-to-region technology flow network between the licensor (patent owner) and licensee (purchaser) is estimated from the Chinese patent licensing database obtained from SIPO. Under the regulations of the Patent Licensing Contract Recording Procedures (PLCRP), patent contract information – detailing the two parties, their addresses and the patent numbers – is submitted and examined by the authorities. I collected the annually updated data set from 1999 to 2013 containing 32,551 cases of patent licensing information including patent title, the address of the licensee, application number, the assignee and date of filing, and license type.

As a unit of analysis, the analysis combines the prefecture-level city and municipality. In Chinese regional analysis, some use province but the provinces in China are simply too big to contain a regional economy. For example, the biggest one, Xinjiang is roughly the size of Saudi Arabia that is bigger than any of Western European countries. There is huge difference in sizes among provinces, too. Xinjiang is 262 times as big as Shanghai that is municipality or provincial-level city. As such, for most of provinces, the boundaries do not always correspond with the boundaries of economic activities. The desirable unit is the US's metropolitan statistical areas and consolidated metropolitan statistical areas but China does not have such geography. The closest Chinese equivalent I could find was the prefecture-level city. There are 177 of them if I include Inner Mongolian leagues and various ethnic minority groups' autonomous prefectures. I also count together the four municipalities, i.e., Beijing, Shanghai, Tianjin, and Chongqing, because their physical sizes are comparable to that of prefecture-level regions even if their administrative status is equal to provinces.

The licensor's locations could be identified by the address information, using China's patent search system. Patents with unidentifiable addresses or those licensed by individuals were removed in order to focus on inter-organizational transactions. This analysis therefore selected 25,773 Chinese-owned patents transferred between domestic regions and 6,778 non-Chinese-owned patents.

### 7.3.3. The index of technology transfer networks

Because of the way the database is organized, I could use a small-world network structure to test the hypothesis. The concept of a "small-world network structure" is drawn from Watts and Strogatz (1998) who explains the presence of a small-world structure in various natural and social systems. Small-world networks occur when a randomly selected node is connected to another randomly selected node, without going through too many intermediary nodes. Numerous empirical studies have drawn on this work (Kogut and Walker 2001, Balconi, Breschi et al. 2004, Uzzi and Spiro 2005, Chen and Guan 2010), and researchers in innovation studies have used this research to explain knowledge exchange among individuals, organizations, and countries (Watts and Strogatz 1998, Kogut and Walker 2001, Newman 2001, Reitzig 2003, Cowan and Jonard 2004, Van Zeebroeck 2011).

The network dataset comprises both domestic flows among the domestic regions (region-to-region) and foreign flows from other countries (foreign country-to-region). If many Chinese cities are connected with foreign sources, this will cause the network structure to appear more fragmented. On the other hand, if only one anchor region is connected to an overseas source of technology, then the networks will appear much less fragmented.

This analysis tested this using the small world quotient (SWQ) (Everton 2012, Gulati, Sytch et al. 2012). The index is calculated by first estimating both the clustering coefficient (CC) and average path distance (AP). Then, for these are normalised by the ratio of each to the respective CC and AP distance of a random network.

$$SW\ Q = \left[\frac{CC_{actual}}{CC_{random}}\right] / \left[\frac{AP_{actual}}{AP_{random}}\right] \tag{14}$$

Section 5 uses role-equivalence analysis, drawn from network structure analysis, to identify the anchors and their roles, in accordance with social network analysis (Borgatti, Everett et al. 2013). Nodes occupying the same roles are defined as "equivalent nodes" in a network, even if they are not directly connected with each other (Hanneman and Riddle 2005). For instance, two highly equivalent nodes can be substituted for each other because they share the same connections. A node occupying a specific position is highly likely to be embedded in a similar type of relations as others in that same position, and will thus exhibit similar behaviors (Everton, 2012). If I rephrase this concept in terms of the regional technology flow network, equivalent cities are expected to play similar functions in creating, transmitting, and consuming technology across the whole country.

To measure the equivalence of two nodes, I apply a "regular equivalence method," to identify similar role-based patterns. This approach to empirical data processing has the advantage of categorizing the characteristics of the individual nodes into several groups without sacrificing their separate features (White and Reitz 1983, Doreian 1987, De Nooy, Mrvar et al. 2011). According to Faust (1988) and White and Reitz (1983), the equivalence level between two nodes $\boldsymbol{i}$ and $\boldsymbol{j}$ at iteration $\boldsymbol{t+1}$ is given by:

$$M_{ij}^{t+1} = \frac{\sum_{k=1}^{N} \max_{m=1}^{N} \sum_{q=1}^{Q} M_{km}^{t}\left[{}_{ijq}MATCH^{t}_{km} + {}_{jiq}MATCH^{t}_{km}\right]}{\sum_{k=1}^{N} \max_{m} \sum_{q=1}^{Q}\left[{}_{ijq}MAX_{km} + {}_{jiq}MAX_{km}\right]}, \tag{15}$$

where $N$ is the number of actors, $Q$ is the number of relations, ${}_{ijq}MAX_{km} = \max(x_{ikq}, x_{jmq}) + \max(x_{kiq}, x_{mjq})$, ${}_{ijq}MATCH_{km} = \min(x_{ikq}, x_{jmq}) + \min(x_{kiq}, x_{mjq})$, and $x_{ikq}$ is the value of the tie from $i$ to $j$ on relation $q$. This index measures the weighted match of how well $i$'s ties are matched by $j$'s ties, and vice versa. If $i$ and $j$ are perfectly matched (i.e. equivalent), then it equals the maximum value of the sum of the degrees of $i$ and $j$.

I also apply other familiar metrics in social network analysis, such as inter-node level centralities, degree centrality, betweenness centrality, and O-I index. The former two indices are generally acknowledged to capture the in/out flow degree of nodes, and their "brokering" roles, respectively (Borgatti, Everett et al. 2013). The O-I index shows whether a particular node is a provider or a consumer in the network, by calculating the ratio of the difference and total degree index. When the value of a node is close to 1, the number of patents exported is greater than that of those imported, implying that the nodes have higher knowledge quality levels (Choe, Lee et al. 2016).

In the following section, I presented the structural characteristics of network by employing topography metrics and small world index. Then, Section 5 identifies the anchor cities, by employing the role-equivalence method, followed by a node-level centralities analysis. Lastly, the presence of technology production hierarchies, and the dynamics of anchor firms are demonstrated. In Section 4, I measure the whole network's network-level structural characteristics, using topography metrics: diameter, centralization, density, centrality, and connectedness.

## 7.4. The hierarchical structure of technology flows: *a small-world network*

The structure of the technology transfer network, calculated using multiple metrics, is illustrated in Table 41. The first noteworthy observation is that the centralization value tends to decrease over time, with increasing de-centralization as the network diameter expands. More specifically, the connections became concentrated in a few central cities, until 2006, well before the centralization score plunged to 0.22 in 2012. There are consistent structural changes: until 2007, the network diameter remains below 3, but its size increases to 7 after 2007. This implies that, while a surge of new cities caused a sharp increase in the network diameter, the accompanying decrease in centralization shows that the entrants were all connected to the anchor cities.

The direction of centrality shows whether the linkages are inward (in-centrality) or outward (out-centrality) to/from the region. The out-centrality value reaches its maximum (1) in 2004, and continuously decreases thereafter. The in-centrality value, on the other hand, shows a rising trend, despite some fluctuations. The intersectional trend between the two indices represents a distinctive change. As more cities are involved in the technology transfer, the prevailing outflows are reduced, along with increases in the in-centrality level. The density and connectedness indices also reflect the changes which happened in 2007: the density continues to decline with a steep increase of connectedness level after 2008.

In sum, a small number of cities dominate the entire system as sources of technology. In the later part of the period under consideration, more cities joined the network, expanding its size as indicated in the increase of diameter from 2 in 2002 to 7 in 2012. This was accompanied by decreasing density, while connectedness continued to increase. In other words, while the new linkages from the new cities contributed to the expansion of the network, the influence of central nodes remained as strong as ever or grew even stronger. In order to perform a more robust analysis of these results, I examined the small-world network structure.

Table 41 Network-level topography analysis result in year

| Year | Diameter | Centralization | Out-Central | In-Central | Density | Connectedness |
|---|---|---|---|---|---|---|
| 2001 | 2 | 0.93 | 0.87 | 0.07 | 0.06 | 0.06 |
| 2002 | 2 | 0.89 | 0.85 | 0.09 | 0.05 | 0.05 |
| 2003 | 1 | 0.91 | 0.87 | 0.01 | 0.04 | 0.04 |
| 2004 | 1 | 1.00 | 1.00 | 0.07 | 0.06 | 0.06 |
| 2005 | 1 | 1.00 | 0.95 | 0.05 | 0.04 | 0.04 |
| 2006 | 2 | 1.00 | 0.96 | 0.07 | 0.04 | 0.04 |
| 2007 | 3 | 0.76 | 0.73 | 0.06 | 0.03 | 0.04 |
| 2008 | 6 | 0.46 | 0.45 | 0.19 | 0.02 | 0.21 |
| 2009 | 7 | 0.30 | 0.30 | 0.12 | 0.02 | 0.45 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2010 | 7 | 0.32 | 0.32 | 0.15 | 0.02 | 0.44 |
| 2011 | 7 | 0.28 | 0.28 | 0.15 | 0.02 | 0.49 |
| 2012 | 7 | 0.22 | 0.22 | 0.17 | 0.01 | 0.42 |

*Figure 40* shows the SWQ of the technology diffusion network over time. The initial rise in the earlier period supports my argument for the emergence of a small-world network structure. The coefficient reached over 500 in 2008. However, it then dropped below 100, but showed a gradual increase afterwards. Together, these results are likely to confirm the emergence of the small world structure across cities and time periods. Although there are some fluctuations due to the influx of new cities in the technology transfer network around 2008, the structure seems to remain as a small world. The trend is consistent with Zhang, Guan et al. (2014), whose SWQ value from co-authorship also shows an uprising trend. The presence of a small-world network is highly correlated with a combination of "high connectivity within regions" and "inter-cluster bridging ties." Dense connections within the regions emerge mainly due to risk aversion and information bias, embedded in licensing contracts. Intangible factors such as reliability, reputation, and informal cliques might reduce the risks involved in technology exploration and the trade costs that dictate preferences for neighboring partners (Gulati and Gargiulo 1999, Zaheer, Gözübüyük et al. 2010).

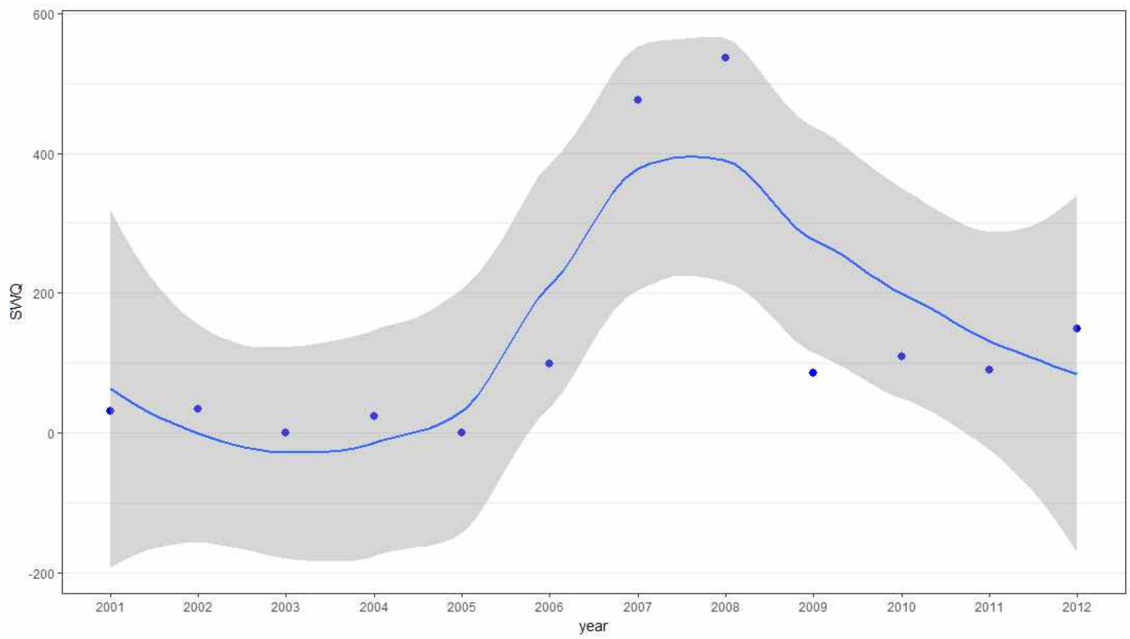


Figure 40 Annual trend of SWQ (small-world quotient)

The bridging ties serve as effective conduits through which a region can access new resources that are typically unavailable through ties with neighbors (Burt 2005). The motivation for an institution within the non-principal region to seek new technology from outside provides a further incentive for that institution to connect with a bridging region (McEvily and Zaheer 1999, Zaheer and Bell 2005). Within such settings, the existence of a small-world network structure reinforces the importance of anchor cities, and plays an influential role in diffusion/learning technologies within the innovation system (Watts and Strogatz 1998, Zhang, Guan et al. 2014).

This macro-analysis highlights the structural transformation of the technology transfer network over time. In the earlier stage, until 2006, the technology seems to have been exchanged unidirectionally, between few cities, within a centralized overall structure. In the next period, from 2007 to 2008, an increasing number of cities participate in the networks. In part, this sharp expansion may reflect Chinese government-led policy to promote the market mechanism in technology transfer around the early 2000s, consistent with Zhang, Guan et al. (2014)'s work. In 1999, China government established Shanghai Technology Property Rights Exchange to enhance the integration of financial market and the property rights market. The Chinese State Council, consequently, set up the Outline of the Program for the State Long-term Science and Technology Development (2006–2020) supporting over 60 policy measures to encourage technology transfer such as the fiscal system, taxation, banking, industries, government purchases, and protection of intellectual property rights in 2005 (Yülek and Taylor 2011). These state-led policy led more firms and public sector institutions into the technology transfer market, expanding the network size. This transition process follows a small-world model, with power and influence concentrated in a small number of cities. The balanced in/out centralities hint at interactive transactions, rather than unilateral ones. After 2009, the network appears to be saturated in size, highly connected, and more "small world."

## 7.5. Exploring the patterns of anchor's roles

The analyses of technology transfer networks in the previous section shows (1) expansion of networks and (2) enduring existence of hierarchy. Building upon these structural level findings, this section looks into micro details. More specifically, I ask the following two questions: (1) which cities are the anchor cities at the top of the hierarchy? And (2) what are the other cities like?

### 7.5.1. The identification of anchor regions

*Table 42* summarizes the results of the equivalence analysis, divides all 181 cities into eight groups, and displays the averaged values of innovative activities. For clarity, *Figure 41* presents four quadrants, plotting the patent growth rate (CAGR) on the y-axis against the in-flow/out-flow (O-I index) levels, and displaying them against a territorial map.

Table 42 Network centralities and (avg.) knowledge activities indices by patterns

| Group | Sub-Group | No. of regions | Centralities | | | O-I Index | Local patents purchase | | Patents Growth Ratio | License Contracts | | Total Patent | Overseas Patent Adopted |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Out-Degree | In-Degree | Between-ness | | Total | Ratio | | Licensor | Licensee | | |
| Anchor | 1 | 5 | 38 | 27 | 2503 | 0.1 | 720 | 0.44 | 0.42 | 1502 | 1305 | 39.1 | 782 |
| Fast - Follower | 4 | 42 | 10 | 11 | 347 | -0.1 | 168 | 0.37 | 0.36 | 338 | 339 | 10.9 | 62 |
| | 6 | 24 | 4 | 4 | 118 | 0.02 | 45 | 0.24 | 0.29 | 92 | 82 | 5.90 | 1 |
| Self-sustain starter | 2 | 10 | 2 | 0.9 | 6 | 0.5 | 19 | 0.41 | 0.24 | 38 | 27 | 2.30 | 0.1 |
| | 8 | 11 | 2 | 0.5 | 0 | 0.6 | 15 | 0.00 | 0.28 | 28 | 20 | 2.25 | 0 |
| Depender | 3 | 11 | 1 | 3 | 6 | -0.7 | 10 | 0.36 | 0.28 | 19 | 41 | 1.84 | 20 |
| | 5 | 73 | 0.6 | 2 | 9 | -0.7 | 8 | 0.34 | 0.27 | 13 | 26 | 1.64 | 0.2 |
| | 7 | 5 | 0.5 | 2 | 0 | -0.7 | 7 | 0.14 | 0.28 | 8 | 22 | 0.68 | 0 |

The region's patent applications growth rate was plotted on the y-axis to capture that region's basic innovative capacity. The x-axis charts the tendency of the technology activities (i.e. whether the region is importing or exporting patents). The direction of a region's technology flow signifies its receptivity to explore external technology and authority power for its internal knowledge stocks (Capello and Lenzi 2013). The top right quadrant consists of fast-growing cities, which are actively exporting knowledge, while the bottom left quadrant consists of cities lagging in knowledge growth and technologically reliant on others.

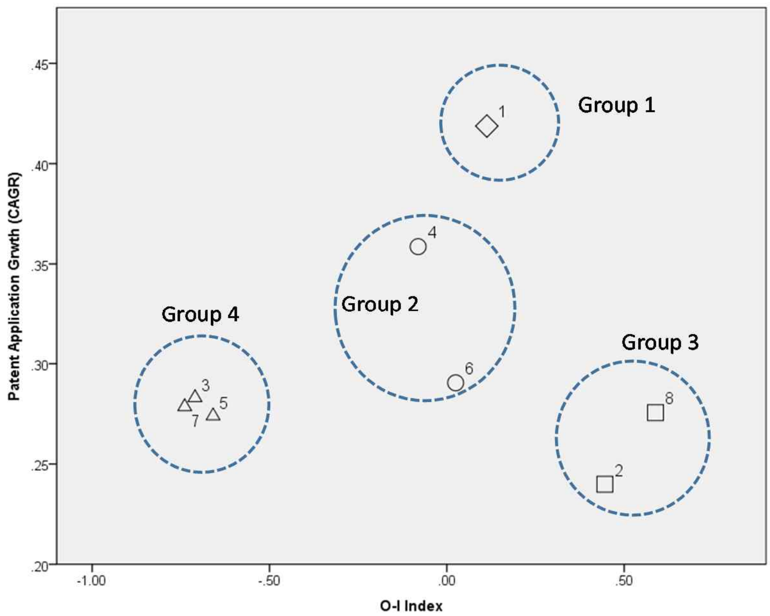



Figure 41 Patterns by equivalent groups

Group 1, the anchor group, consists of five cities: Beijing, Shenzhen, Dongguan, Suzhou, and Shanghai. Beijing centers on the Bohai Gulf Region (BGR), the capital of China. Shenzhen and Dongguan are both located in the Pearl River Delta (PRD) and Suzhou and Shanghai in the Yangtze River Delta (YRD). These three metropolitan areas, the super regions, are the three main drivers of the Chinese economy. The analysis corroborated the primary role of the three traditional core regions, Beijing, Shenzhen, and Shanghai, but also found that Dongguan and Suzhou played a pivotal role in their respective super-regions. Both regions display similar patterns in their interactions with neighbor regions. For instance, Dongguan shares a border with Shenzhen and Suzhou with Shanghai. Both import a lot of overseas patents and reproduce local patents.

Table 42 demonstrates that the anchor group's innovative capacities are well above those of other regions across almost all dimensions (i.e. betweenness centrality, patent growth rate, patent production and consumption, total patents, and overseas patents). These regions import a large number of foreign technologies (782), are nodes that connect other regions (with a high betweenness centrality of 2503), and display a high rate of intra-regional technology licensing (720). They also have fast-growing patent applications (0.42) and the highest ratio of local patent consumption (0.44).

Group 2 includes two subgroups of 66 regions, with similar but lagging patterns, compared with those of the anchor group. Subgroup 4, however, is more similar to the anchor group than the others: with higher centralities (347), overseas technology imports (62), and active technology exchange transactions. Group 4 appears to be at an early stage of development, with higher values of patent production (338) and consumption (339). It seems to be a "fast follower," while Subgroup 6 is a "follower."

Pattern 3, at the bottom right, consists of 21 regions in two groups (2, 8). Their pattern is quite distinctive: with a higher O-I index (0.5, 0.6), and lower betweenness centrality (6, 0), and overseas patent adoption (0.1, 0). These two subgroups also have the lowest patent growth rate (0.24, 0.28) and more licensor than licensee contracts. This indicates that these regions are specialized in technology creation, without the influx of exogenous technologies. They do not appear to be associated with strong technology importers, but show higher values in out-degree centrality. Given that out-degree centrality is an alternative index for the level of innovative technology capacity, these regions are clearly outperforming the others in their authority power to produce knowledge for other regions.


Figure 42 Anchor regions by equivalent roles

Most of the regions fall into Group 4, in the bottom left quadrant. Overall, these regions display lower levels across almost every dimension. This suggests that these regions are at the earliest stage of knowledge exchange and therefore tend to rely on external sources. Strong evidence for this exogenous pattern is shown in the highest negative O-I index and the lowest betweenness centrality value.

### 7.5.2. The hierarchies of technology flow and the dynamics of anchor regions

In this section, it discusses whether the presence of anchor regions influences the hierarchies of technology production structures and how anchor regions facilitate these dynamics. Figure 43 displays the changes in the regression slope of rank-size distribution over a time series. The rank-size distribution provides information on the extent of the hierarchy between the actors (Parr 2004, Meijers and Burger 2010). The analysis calculated the slope of the rank's regression line according to the region's patent size. The steeply decreasing slope implies that the distribution of the patent size of regions has become more hierarchical in structure. The gap between anchor and other regions continues to gradually increase.

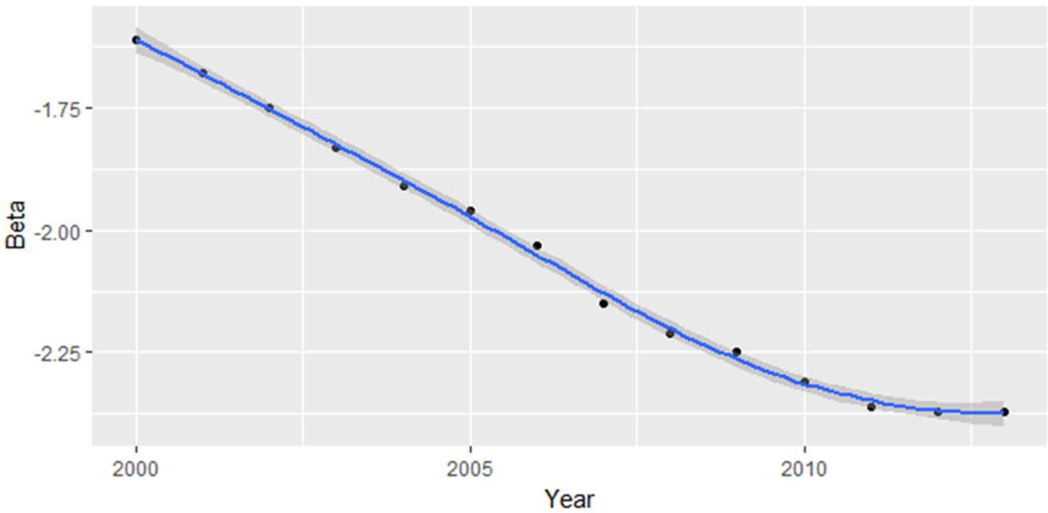



*Figure 43 Slope change of rank-size regression*

Table 43 presents the transition intervals at which licensees turn into licensors, according to my patent data sources. The interval between a technology consumer importing patents from overseas countries and transforming into a provider might be interpreted as evidence of innovative capacity elevation (Chung and Lee 2015). It also shows how a region that serves a leading role, initiated by exogenous technology, can support other domestic regions (Trippl, Grillitsch et al. 2017). As Kim (1997) suggested, a shorter interval provides one of the mechanisms by which catching-up countries can accelerate their developmental processes, by absorbing high-level technologies from other countries.

The total overseas patent/technology inflows are 6,778. As expected, the majority (51%) were imported by the anchor regions. Group 2 has the second largest inflows, at 44%. The initial year of foreign technology adoption took place in 2008, but the average interval period year for role transitions from buyer to provider differs across groups. The anchor group took one year for the transition, with a small standard deviation (1). Meanwhile, Group 2 took two years, with higher variances, and Group 4 exhibits a four-year transition period. Group 3 has few cases of total overseas technology adoption and no record of transition experiences. This suggests that the Group 4 regions have little to do with exogenous development.

Table 43 Overseas patents: adoption and transition

| Patterns | Overseas patents adoption | | Year of initial adoption | Transition interval to patents provider | | |
|---|---|---|---|---|---|---|
| | Total Cases | Average | | Cases | Year | St.Dev. |
| Anchor | 3480 | 44.4 | 2008 | 25.6 | 2009 | 1.0 |
| Fast-follower | 2950 | 20.2 | 2008 | 11.8 | 2010 | 1.7 |
| Self-sustain starter | 8 | 8.5 | 2007 | - | - | - |
| Depender | 340 | 12.5 | 2008 | 10.7 | 2012 | 1.5 |

## 7.6. Implications and conclusion

This chapter explores the structure of technology flow and found that the year 2007 marked a clear reversal point, after the high concentrations of earlier periods. After 2007, the network expanded quickly, and the influence of anchor regions became stronger, thereby maintaining the spatial hierarchy of regions with regard to innovation activities. The results of the REGE analysis classified the anchor regions using the ‘role-equivalence’ measure. These anchor regions provide knowledge after assimilating external technology. This analysis argues that the core dynamics of regional externality is to assimilate external knowledge and transform it into localized knowledge. The results corroborates the idea of Sun and Liu (2016) which suggesting that the role of anchor regions is to transform technology from external regions and countries into localized knowledge, thus potentially serving as a conduit for new ideas, technologies, and knowledge for other neighboring regions.

Despite the literature emphasizing the role of ‘weightless technology’ in the development of a region, which might result in the disappearance of the regional hierarchy, the analysis suggests that anchor regions have maintained their positions by reproducing new technology from exogenous technology sources. The small-world network structure provides an effective way for one node to reach any other node in the entire system at the highest possible speed of knowledge transmission, as suggested by Gulati, Sytch et al. (2012) and Cowan and Jonard (2004). From the perspective of a catching-up country, this might result in a “selective choice” policy, for maximum efficiency in fast-growing economies (Branstetter 2001, Camagni and Capello 2013). The efficiency and externality caused by the small-world structure, however, carries the potential risk of excessive homogenization. This potentiality makes the regional innovation system less attractive, which limits the development of new bridging ties to overseas regions (Gulati, Sytch et al. 2012).

# Chapter 8. Conclusion

***Summary and Major findings***

The purpose of this thesis is to explore the mechanism behind the market-mediated technology transfer and the dynamics in the network evolution, mainly addressing the following issues: the characteristics of the market-mediated technology transfer, the geographical incidence of a licensed patent under mutual uncertainties between a licensor and a licensee, the structural properties of market-mediated technology in the domestic regions, the emergence of the specific patterns of the anchor's evolutionary roles and the persistence of the anchor regions in the development of the technology transfer network.

The second chapter draws upon the characteristics of market-mediated technology by looking at the prior studies on the local knowledge spillover, then associating the concept with the mutual uncertainties of the two parties within the bounded space. The fundamental distinction of the market-mediated technology transfer is that it occurs in an interactive way from the knowledge source to the target with the intentional purpose of maximising both their own profits. Combining the uncertainty with the spatial proximity level, the technology provider is highly likely to avert the potential risks by selecting partners located at a further distance. Nevertheless, a licensee party prefers to a more closely located partner to avert the opportunistic behaviour. Moreover, this chapter also reveals that anchor regions play a pivotal role in connecting the local firms in the regional economy with the global market.

Chapter 3 introduces the dataset with some descriptive statistics of the Chinese patents and licensing information. China demonstrates a remarkable growth in patent activities and licensing transactions over the last three decades. Although the licensing market was mainly dominated by foreign countries (U.S. and Japan) in the earlier period, the Chinese domestic patents have led the licensing market after 2007. It is worth noting that three major regions –

Beijing, Shanghai, and Shenzhen – appear to play a key role not only in creating, but also in licensing the patents, reinforcing the influence of the anchor regions. Along with the sharp expansion of these anchors after the mid-2000s, this chapter demonstrates that the domestic technology transfer market reduces the dependency of the foreign technology.

Chapter 4, based on the inter-region technology flow dataset, examines the geographical reach of market-mediated technology transfer. The market-mediated technology flows corroborate that the geographical distance still serves a heavy toll on their transfer across regions. This chapter corroborates the hypothesis in Chapter 2 that the licensors and licensees have a different spatial proximity preference in transferring the market-mediated technology. The estimation result represents the motivation of each other that runs counter to that of the counterpart. The uncertainty in the technology acquisition led a licensee to depend on the informal network within a city-level borderline, while the licensors do not prefer the co-located licensees due to the dissipation effect. It is also interesting that the spatial proximate tendency is even reinforced as they have more experiences in licensing activities. An additional analysis check the robustness of the argument that a private-sector firm's decision is influenced by the competition level in the region.

The two subsequent chapters (Chapter 5 and 6) address the evolution of the network. While the former focuses on the dynamics of network, the latter chapter concentrates on the contribution effect of the specific brokerage roles of the anchors in the longitudinal network growth. According to the dynamic analysis of a network evolution, the probability of changing the relationship sharply dropped if the nodes had already established a partnership. This path-dependency appears to reflect the potential risk of pecuniary-compensated technology transactions, as expected in Chapter 2 and Chapter 7. The reciprocity estimation also confirms that the regions prefer to transfer technology when they set the partnership with the partners. It is also found that the overseas technology inflow influences the decision-making process rather than domestic patents. Despite the sharp surge in the domestic patent number, it might not influence the partnership choice of the region. Then, a region's accumulated records of the licensing-out have a positive effect on the network evolution.

Further to the brokerage roles of the anchor regions, several interesting results are found. Chapter 6 witnesses the different patterns of anchor brokerages in the national technology network. Beijing in BGR and Shenzhen in PRD transmit the technology produced in their super-regions across the whole regions outside, as a 'national anchor', while Shanghai in YRD sits a more balanced brokerage position as a 'regional anchor' that connects the outer and inside of its megalopolis. Another significant result is that the roles as a representative and a consultant, rather than as a gatekeeper and a liaison, contribute to the evolution of the network. It implies that anchor regions serve as a conduit for the whole regions rather than a local region anchor in order to contribute to the growth of a national innovation system.

Chapter 7 explores the patterns of anchor regions in the hierarchical structure of the national innovation system. Confronting the sharp expansion of a market-mediated technology network, this chapter examines two scenarios: the desolation or persistence of the hierarchical structure of anchor regions. A series of analyses supports the latter scenario, claiming that the influence of the traditional core region is even reinforced in the hierarchical network structure as new entrant cities joined the network. The traditional anchor regions have maintained their current positions by reproducing the new technology from the exogenous technology sources.

***Contributions***

This study contributes to the recent upsurge interest in discerning the market-mediated technology from pure knowledge spillovers. The traditional research on the relationship between technology innovation and regional economy has presumed that the regional externality comes from the agglomeration effect within proximate distance, however, this research argues that the technology geared toward economic activity might not occur in geographical proximity. On the other hand, due to the uncertainties embedded in technology transactions, the technology provider might not have motives to transmit its neighbour potential purchaser. The technology demander also has incentives to avoid uncertainty in their pecuniary expenditures by relying on closely located partners. While not denying the significance of the agglomeration economy, the technology diffusion by licensing contract is not always likely to occur in the proximate areas. Nevertheless, the distance between the parties might require the promotion of the transfer of the patents. This empirical result provides significant insights for the policy makers to answer the question: why some innovation clusters are successful, but others are not. Even for one of the most codified types of knowledge for transmission, it is required for a policy to consider the mutual uncertainty to transmit market- mediated technology across the geographical borders.

The analysis also contributes to the theories in economic geography, pointing out the role of the anchor regions in the inter-regional network. Despite the notions of ‘weightless technology’ in the technology diffusion across the regions, which might result in the disappearance of the regional hierarchy, the analysis suggests that anchor regions have maintained their positions by reproducing new technology from exogenous technology sources. The small-world network structure provides an effective way for one node to reach any other node in the entire system at the highest possible speed of knowledge transmission, as suggested by Gulati, Sytch et al. (2012) and Cowan and Jonard (2004). From the perspective of a catching-up country, this might result in a ‘selective choice’ policy, for maximum efficiency in fast-growing economies (Branstetter 2001, Camagni and Capello 2013). The efficiency and externality caused by the small-world structure, however, carries the potential risk of excessive homogenization. This potentiality makes the regional innovation system less attractive, which limits the development of new bridging ties to overseas regions (Gulati, Sytch et al. 2012).

Next, from the perspective of the evolution of the technology transfer network, the series of analyses demonstrates that the anchor regions connect the regions in the megalopolis and the other regions outside. What this research contributes to the array of the studies is that it has found the path-dependency mechanism still works at the regional level and the specific brokerage roles only have a positive influence on the network evolution. The common roles of the two positive contributors (representative and consultant) are summarised as the national broker, rather than a local brokerage role.

Lastly, the series of results commonly implies that the exogenous inflows of technology are essentially considered for facilitating the regional development. Previous studies on a regional innovation system have stressed the inter-relationship of the innovative actors in the region. While the empirical analysis result is based on the case of the Chinese patent licensing market, it provides an insightful strategy for knowledge-driven economic growth for catching-up countries. Given the fragmented innovation system components in developing countries, the exogenous inflows of technology are essential for facilitating technology capabilities. While many researchers argue this point, this empirical study demonstrates the importance of balance between internal and external sources of technology for learning (Bathelt, Malmberg et al. 2004, Wang, Zhou et al. 2013). To reap the benefits of exogenous technology inflows, the catching-up countries are required to establish their internal knowledge base for assimilating them into local knowledge.

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