博士論文

The Role of Universities and Multinational Firms in Knowledge spillover in China: An Empirical Study

中国における知識スピルオーバーに対する大学と多国籍企業の役割に関する実証研究

毛　海宇

The University of Tokyo

The Role of Universities and Multinational Firms in Knowledge spillover in China: An Empirical Study

Ph.D. dissertation submitted to

The Department of Technology Management for Innovation,

The University of Tokyo

By

Haiyu Mao

2017

The Role of Universities and Multinational Firms in Knowledge spillover in China: An Empirical Study

Thesis Chair: Professor Kazuyuki Motohashi

Author: Haiyu Mao

Abstract

This dissertation explores the role of universities and multinational firms in knowledge spillover in China. Promoting university – industry collaboration and internationalization are two important streams throughout the historical development of science and technology (S&T) and innovation policies in China. Therefore, this research is motivated by the belief that local universities and multinational firms' R&D centers are two important knowledge sources of innovation for domestic firms in China. This dissertation aims at answering two fundamental questions (1) how university – industry collaboration networks in China is evolved in different regions in China, and particularly, how university – industry linkages contribute to the innovation and business performance of Chinese ventures? (2) How multinational firms diffuse knowledge, and whether such international knowledge flow generates spillover effects on inventors in China? The net contribution of this dissertation is analyzing the role of universities and multinational firms in knowledge spillover in China by taking the differences of regional innovation systems into account. The dissertation is structured into six parts:

The first part of this dissertation is an introduction of the whole dissertation. It reviews the historical development of university – industry collaboration policies and internationalization policies in China, and demonstrates the differences of regional innovation systems in Beijing, Shenzhen, and Shanghai by China patent statistics.

The second part of this dissertation studies the evolvement patterns of university – industry collaboration (UIC) network in China's four representative regions in terms of technology innovation and local economy: Beijing, Shenzhen, Shanghai, and Wuhan. I found that the UIC network in Shanghai resembles that in Beijing, whereas the UIC network in Wuhan is not as developed as those in Beijing and Shanghai, but followed a similar evolvement pattern. In Shenzhen, which has a long industry tradition but a relatively weak university science sector, even though there is a large number of local high-tech firms, number of firms participated in UIC are much smaller as compared with other three cities.

The third part of this dissertation aims to explore the institutional difference between Tsinghua University Science Park (TusPark) in Beijing, and business incubator of Research Institute of Tsinghua University in Shenzhen (RITS), and to examine how the difference leads to different new product performance for tenants. In doing so, I use survey methodology to investigate the innovation sources, university linkages, and innovation outputs of tenants in TusPark and RITS. I found that tenants in RITS reply more on "market-driven" knowledge sources for innovation: including knowledge from customers, suppliers, and competitors. The empirical findings suggest that the technology support provided by RITS and the high dependency on "market-driven" knowledge sources jointly contribute to the better new product performance for tenants in RITS.

The fourth part of this dissertation selects Shanghai, one of the cities in China that attracted a large number of foreign multinational corporation (MNC) R&D centers, to explore how international knowledge diffusion can be facilitated by foreign direct investment and human mobility. I found that domestic firms are more likely to gain knowledge flow from MNCs through international patent citations when domestic firms' patents are created after MNCs entered Shanghai, and when domestic firms' patents are created by returnee inventors, who moved from MNCs to domestic firms.

The fifth part of this dissertation explores how the geographic proximity and ethnic closeness of U.S. – based inventors to indigenous Chinese inventors affects innovation by the latter inventors within U.S. subsidiaries in China. The issues are analyzed by using patent inventor data for U.S. Fortune 500 Companies and a Chinese ethnic surname database for identifying ethnic Chinese inventors. The results suggest that for MNCs having a cohesive collaboration network between U.S. headquarter Chinese expatriates and local indigenous Chinese inventors, the positive impact of collaboration with headquarters inventors on innovative performance of indigenous Chinese at subsidiaries in China can be strengthened.

The final part of this dissertation summarizes the findings in this thesis, and draws managerial implications for Chinese entrepreneurs, managers at domestic Chinese firms and at foreign MNCs, as well as policy implications for Chinese government and foreign MNCs home country's government.

Table of Contents

List of Figures

List of Tables

1. Chapter 1: Introduction

1.1. Motivation of Research

This dissertation explores the role of universities and multinational firms in knowledge spillover in China. Based on past studies, when I use the term "Knowledge Spillover" in this dissertation, I refer to the process by which inventors gain knowledge flow from knowledge sources, and is able to enhance their own innovation performance and to generate further innovation (Branstetter, 2006). My research is motivated by the belief that local universities and multinational firms' R&D centers are two important knowledge sources of innovation for domestic firms in China. Therefore, the better understanding of how university-industry linkages and knowledge flow from multinational firms generate knowledge spillover effects on domestic Chinese firms would lead to better prescriptions for domestic Chinese firms to formulate their business and technology strategies, and for China's regional and central government to make policies governing university technology transfer and foreign direct investment. Although there is an abundant literatures on university – industry linkages in China (Eun et al. 2006; Hong 2008; Hong & Su 2013; Motohashi 2006; 2008; Motohashi & Yun 2007) and R&D of multinational firms in China (Cheung & Ping 2004; Lin et al. 2009; Motohashi 2010; Motohashi 2014; Motohashi 2015; Motohashi & Yuan 2010; Zhou & Xin 2003), there is little systematic empirical analysis on whether and how universities and multinational firms generate knowledge spillover effects on innovation performance of domestic firms. This dissertation aims at answering two fundamental questions (1) how university – industry collaboration networks in China is evolved in different regions in China, and particularly, how university – industry linkages contribute to the innovation and business performance of Chinese ventures? (2) How multinational firms diffuse knowledge in China, and whether such international knowledge flow generates spillover effects on inventors in China?

1.2. University – Industry Collaboration Policy

Promoting university – industry collaboration and internationalization are two important streams throughout the historical development of science and technology (S&T) and innovation policies in China. Until the early 1980s, because of the long history of centrally planned economy, the science and technology (S&T) sector in China was isolated from industry. In the early 1980s, China Communist Party Central Committee (CCPCC) announced "Decisions on science and technology system reform" to solve the problem of the separation between industry and science (Motohashi 2006). At the same time, driven by the desire to lower the financial costs of supporting universities, the Chinese government dramatically cut the funding. Universities were forced to find alternative sources of funding. Under this background, the Chinese government encouraged greater linkages between universities and industry, by promoting the establishment of university – affiliated enterprises, which were meant to generate profits for universities to finance their operations. Another important initiative of promoting university linkages was the

Torch Program launched in 1988. It encouraged local governments to build high-tech parks and zones, which are in close proximity to universities with the goal of promoting linkages between firms and universities.

From the early 1990s, the Chinese government issued a series of policies for promoting the university – industry collaboration. The government issued “the science and technology progress law of People’s Republic of China” in 1993, which designated S&T developments as one of the most important component in China’s economy development, and “Law on promoting the transfer of scientific and technological achievements” in 1996, which encouraged the technology market transaction (Motohashi 2006). The Ministry of Science and Technology issued the “technology transfer promoting law” in 2014, which was based on the former law of promoting technology transfer in 1996 and which added new sections including the monetary incentives for university researchers. Those laws encouraged the collaboration between firms and universities/research institutes. The government also strengthened the patent laws for better promoting the university – industry collaboration. In 2007, the government issued the law on promoting the transformation of scientific and technological achievements, which was recognized by scholars as the first time to clarify by law that the ownership of intellectual property rights resulted from national science research programs belongs to the undertaker of the programs (Hong 2008). During the transition period of China’s national innovation system, domestic firms’ S&T activities with universities increased significantly (Motohashi & Yun 2007).

1.3. Internationalization Promotion Policy

Another important stream in the historical development of S&T and innovation in China is the promoting of internationalization, which can be dated back to 1992, when the market oriented economy reform was taken seriously based on Deng Xiaoping's South Talk (Motohashi 2006). After the passing away of Chairman Mao Zedong in 1976, Deng Xiaoping became the leader of China. He advocated the "Open Door Policy" with the market economy orientation. Under this policy, the Chinese government spent huge efforts of attracting foreign multinationals to conduct research and development activities in China, and encouraged domestic Chinese firms to improve their research capacity to absorb knowledge flows from foreign multinationals. Beijing and Shanghai are those cities that attracted a large number of MNC R&D centers. The Shanghai municipal government has spent huge efforts to attract MNCs to establish R&D centers in Shanghai. The Shanghai Foreign Investment Commission issued the "circulation on questions of establishing research and development institutions with foreign capital" in 2000, and the "suggestions of Shanghai municipality to encourage foreign capital to establish research and development institutions" in 2003. These two provincial documents are the regulations on establishing R&D institutions with foreign capital in Shanghai, which specified preferential policies in import tax duties, income and corporate tax, land cost and planning expenses, foreign exchange management, intellectual property rights protection, etc.

Another important policy of promoting internationalization in China is the returnee policy, aiming at attracting overseas ethnic Chinese talents who worked at multinationals or universities aboard to innovate at China's domestic firms or universities. Those returnees who worked at foreign multinational firms or at overseas research institutes are potentially important channels of international knowledge flow to domestic innovators. In 2008, the General Office of the Communist Party of China issued "Opinions from Small Group for Coordinating Work on Talent (SGOT) on implementing the Recruitment Program of Global Experts", which specified to use 5-10 years to bring back thousands of returnees to universities and research institutes, companies, or High-tech Science Parks. The implementation of the National Thousand Talents Plan is facilitated by the provincial level returnee policies.

1.4. Indigenous Innovation Policy

Besides the above two important streams in the historical development of S&T and innovation in China, in 2006, the State Council of People's Republic of China announced the "2006-2020 Medium-and-Long-Term National Science and Technology Development Plan", in which clarified the goal of the next 15 years is to let "indigenous innovation" lead the future economic and technology development of China. The Chinese government is promoting indigenous innovation to increase the competitiveness of local firms (Motohashi & Yuan 2010). Therefore, universities and multinational firms would be two important technology spillover sources for enhancing the innovation performance of domestic firms.

1.5. Regional Differences by Patent Statistics

However, the technology landscape in different regions in China varies in terms of political resources, local university and research institutes, internationalization, etc. Previous studies insist that the differences of regional innovation systems should be taken into account when analyzing China's innovation capacity in transition (Li 2009). Since the reform led by the "Open Door Policy", the local governments gained some autonomous power to develop their own trajectory of innovation strategies based on the characteristics of the regions. Beijing, Shanghai, and Shenzhen are three representative regions of the technological and economic development during the transition in China. Beijing is the center of politics and education. It concentrated with intensive long-standing universities and research institutes. On the contrary, Shenzhen was only a fishing village close to Hong Kong and had no local universities. In 1980, Shenzhen was designated as the “special economic zone” to experience the market economic reforms. Shenzhen grew rapidly as the center of low cost assembly and manufacturing exports in China. The municipal government also implemented strategies to encourage high technology entrepreneurship. The innovation strategies successfully nursed many ICT giants such as Huawei Technologies and ZTE. As compared with Beijing, which has a strong educational sector, and Shenzhen, which as a strong industrial base but a weak educational sector, Shanghai has a more balanced educational and industrial base.

Figure 1-1 Trend of Chinese firm and university/research institute patents

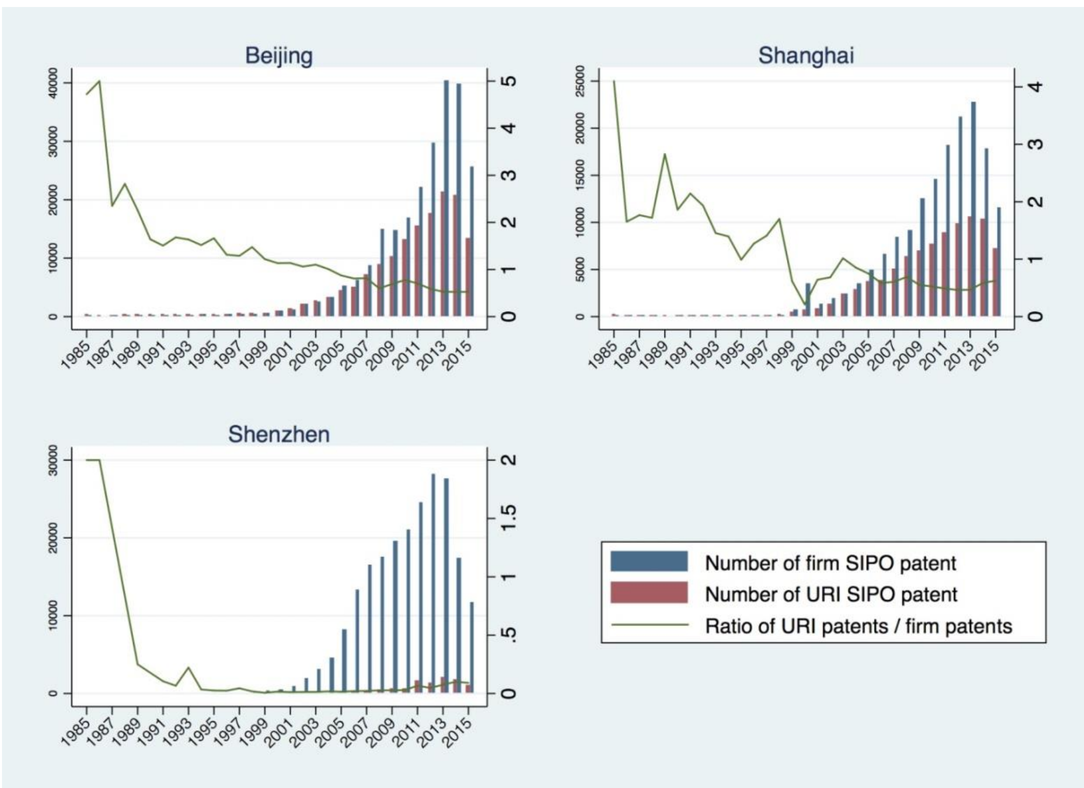


Figure 1-1 shows the trend of China patents applied by firms and universities/research institutes in the three cities. The red bar indicates the number of China patents applied by universities/research institutes, whereas the blue bar indicates the number of China patents applied by firms. The green line shows the trend of the ratio of university/research institute patents to firm patents. The green line shows that in Beijing, the ratio of university/research institute patents to firm patents was above one before 2005, and decreased to 0.5 in the ten years after 2001. This indicates that universities and research institutes were the source of innovation, and the innovation at firms began to rise after 2005. On the contrary, the ration in Shenzhen remained close to zero, indicating that the main source of innovation in Shenzhen is firms. The number of patents applied by firms and universities/research institutes were nearly half of those in Beijing, and the ratio remained around 0.5 from 2005, following a similar pattern in Beijing.

Figure 1-2 Trend of university-industry collaboration patents

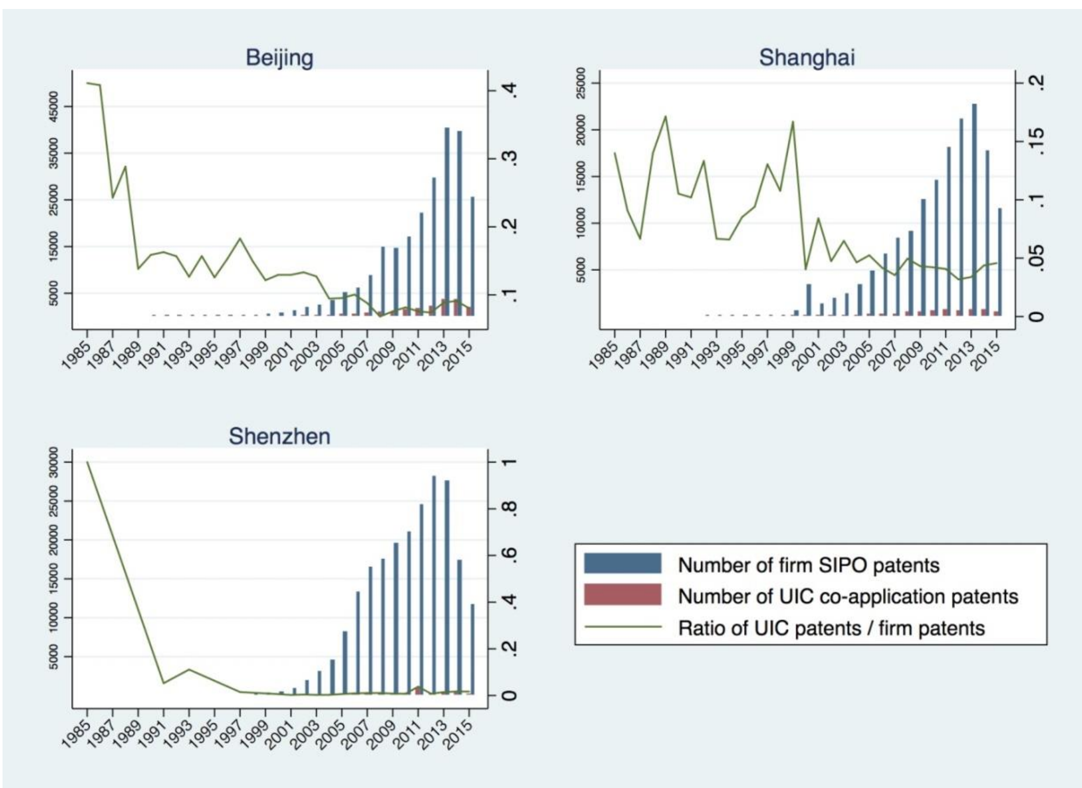
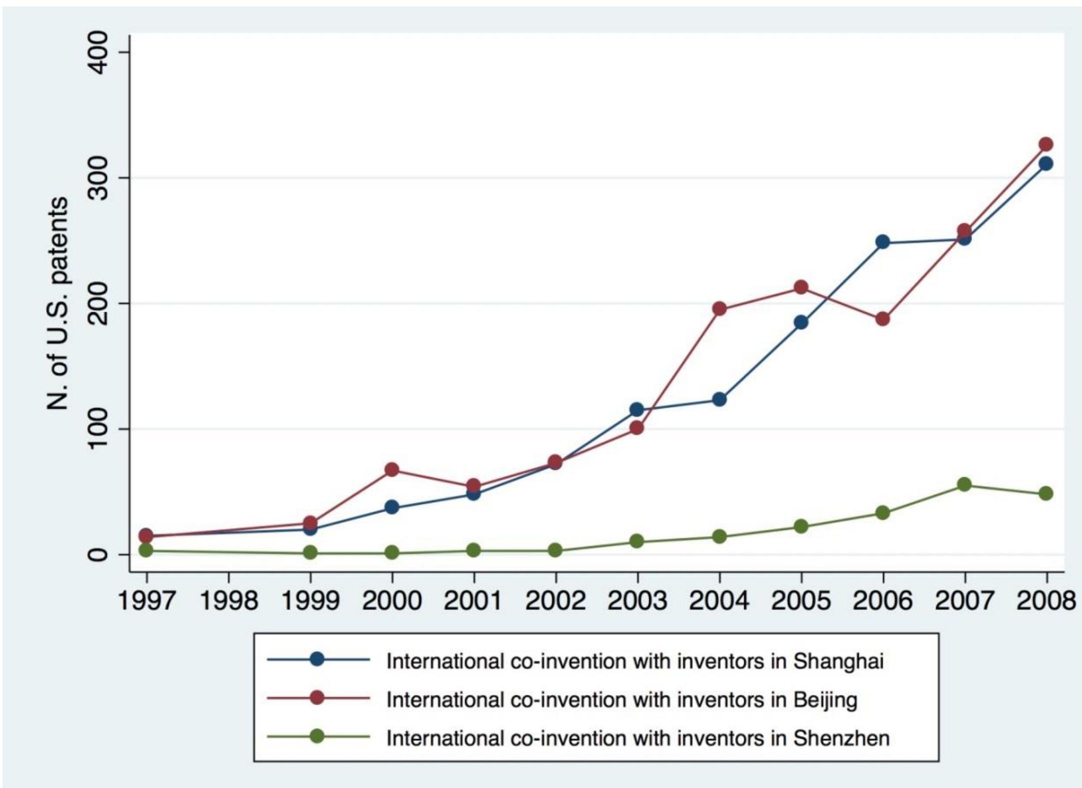


Figure 1-2 shows the trend of number of university-industry collaboration patents in the three regions. The blue bar indicates the number of firm patents, whereas the red bar indicates the number of university-industry co-application (UIC) patents. The green line indicates the ratio of UIC patents to firm patents. Figure 1-2 indicates that Beijing has the largest ratio of UIC patents to firm patents. The ratio remained close to 0.1 from the period 2005 until 2015. The ratio in Shanghai remained close to 0.05 from 2001. However, the ratio of UIC patents to firm patents remained close to zero in Shenzhen. Figure 1-2 indicates that Beijing has the strongest university and industry linkages as compared with Shanghai and Shenzhen.

Figure 1-3 Trend of growth of international co-invention in China (1997 – 2008)



On the other hand, the Shanghai municipal government is aiming to turn the city into a "global innovation hub". Shanghai is growingly becoming the favorite place for foreign MNCs, and is increasingly integrated into the global R&D collaboration network of foreign MNCs (Chen 2006; Sun et al. 2006). By using the Disambiguation and Co-authorship Network of the U.S. Patent

Inventor Database (Fleming et al. 2014), I conducted the analysis on international co-inventions for U.S. patents. Figure 1-3 indicates the trend of growth of international co-invention in Beijing, Shanghai, and Shenzhen. The three lines indicate the number of cross border co-inventions with inventors located outside China and local inventors in the three cities, respectively.

Figure 1-3 indicates that the number of international co-inventions with inventors in Shenzhen remains the smallest. However, the growth trend of international co-invention involving inventors in Shanghai followed a similar pattern of the growth trend of international co-invention involving inventors in Beijing. Because Beijing is the capital city concentrated with abundant beneficial policies, strong local research institutes, and a large pool of science and engineering talents, it would be natural for Beijing to be the leader of international co-inventions with local inventors. However, even though Shanghai does not have so many political resources as in Beijing, it is still able to attract multinational firms and generated a comparable number of international co-inventions with local inventors. The factor indicates that Shanghai must have other unique resources, such as the free trade zone and the foreigner friendly culture, that are more attractive to foreign multinationals. While Beijing and Shenzhen differs in the competitiveness in each science sector and industrial sector, Shanghai's competiveness lies more in the internationalization.

1.6. Chapter by Chapter Introduction

Chapter 2 (titled "Analysis of University – Industry Collaboration Network in China by using Network Analysis Method") gives an overall picture on how university – industry collaboration network is evolved in different regions in China by using Chinese patent data. Motivating my analysis of UIC network in different regions in China is the belief that the roles of universities and research institutes vary in different regional innovation systems in China. Chapter 1 takes the examples of China's four representative regions in terms of technology innovation and local economy development: Beijing, Shenzhen, Shanghai, and Wuhan. I found that the UIC models in Beijing and Shenzhen is very different: Because Beijing has a strong science sector but a relatively weak industrial tradition, university spin-offs are an important player in the UIC network. The UIC model is more towards "university science pushed"; whereas Shenzhen has a long industrial tradition and industrial growth occurred before the development of local universities. Local universities play a role of educational upgrading for local firms. The UIC model is more towards "market needs driven".

The differences of UIC model in Beijing and Shenzhen arose because of the different historical trajectories of university linkages. As mentioned above, in the early 1980s, driven by the desire of lowering the funding cost for universities and research institutes, the Chinese government encouraged the establishing of URI – affiliated enterprises, which could generate profits for universities and research institutes. Universities in Beijing have a long history and accumulated abundant research and technology achievements that were waiting to be commercialized. Tsinghua University is the representative of such universities in Beijing. Under this background, many Tsinghua university spin-offs were established. The Tsinghua University Science Park (TusPark) was established with the initial purpose of establishing an area to manage Tsinghua university spin-off companies (Li & Chen 2014). However, the development of university linkages in Shenzhen followed a very different trajectory. The development of local universities in Shenzhen happened after the local industrial growth. In 1980, followed by the "Open Door Policy", Shenzhen was constructed as a "special economic zone" to experiment China's market reforms, and experienced a rapid growth in manufacturing exports and telecommunication technologies. Unlike Beijing where is concentrated with many long-standing universities, the first university in Shenzhen was only established in 1983. The Shenzhen municipal government realized that the lack of good universities would become an obstacle for the growth of local high-tech firms. In 1998, the Shenzhen municipal government collaborated with Tsinghua University, and jointly established the Research Institute of Tsinghua University in Shenzhen (RITS). Compared with TusPark in Beijing, which has the responsibility of promoting the commercialization of Tsinghua university technology, the RITS in Shenzhen is more focusing on providing technological support and educational upgrading for local high-tech firms.

Chapter 3 (titled “A Comparative Study on Tenants in Beijing Tsinghua University Science Park and Shenzhen Research Institute of Tsinghua University”) explores the institutional differences between Tsinghua University Science Park in Beijing (TusPark) and Research Institute of Tsinghua University Incubator in Shenzhen (RITS), and how the institutional difference leads to better new product market performance for tenant firms at RITS in Shenzhen. The focusing on comparing institutional differences between TusPark in Beijing and RITS in Shenzhen is motivated by the belief that when analyzing the role of universities in knowledge spillover to nearby firms, the institutional characteristics of regional innovation systems should be taken into consideration. I found that the main institutional difference between RITS in Shenzhen and TusPark in Beijing is that sources of new product innovation for tenants in RITS is more based on “market-driven” knowledge sources, including knowledge from customers, suppliers and competitors. The empirical results suggest that while collaborating with universities are beneficial for tenant firms’ new product innovation both in TusPark and RITS, collaborating with university and with a higher focus on “market-driven” knowledge sources partially explained the better new product market performance of tenant firms in Shenzhen RITS.

While universities are an importance knowledge source for China domestic firms, the research and development (R&D) centers of foreign MNCs in China is another important channel for knowledge spillover. Existing literatures on foreign multinationals and knowledge spillover in host countries demonstrated two empirical approaches for measuring MNCs' knowledge spillover on innovation performance of domestic firms in host countries. The first empirical approach is to estimate the effect of foreign direct investment on the productivity of domestic firms in host countries (Haskel et al. 2007; Smarzynska Javorcik 2004). Previous studies have investigated the technology spillover effects from the innovative activities of multinationals to China domestic firms (Motohashi & Yuan 2010). An alternative empirical approach is to measure knowledge spillover from foreign multinationals to domestic firms by using patent citation data (Singh 2003). However, there is a lack of studies on examining MNCs' knowledge diffusion and knowledge spillover in China by using the second empirical approach.

Recent literatures also show that human mobility is an important channel of diffusing MNCs' knowledge to domestic Chinese firms. Returnee inventors who moved from foreign MNCs to Korean and Taiwan firms were found to contribute to the technological catching-up progress for Korean and Taiwan firms in the ICT industry (Song 2000; Song et al. 2001). Human mobility from foreign multinational subsidiaries to Chinese domestic firms in Zhongguancun high-tech cluster in Beijing was found to generate knowledge spillover effects on domestic firms (Dai & Liu 2009; Filatotchev et al. 2011). However, most of the existing literatures used firm level data to examine the role of returnee inventors in knowledge sourcing in China. There are little empirical studies using patent level data and citation data to capture how returnee inventors can facilitate the acquisition of MNCs' knowledge for domestic firms.

Moreover, most of the existing studies on knowledge diffusion from foreign MNCs to domestic Chinese firms took Beijing as an example (Liu & Buck 2007; Zhou & Xin 2003). Shanghai is growingly integrated into the global R&D networks of multinational firms. As indicated by figure 1.3, implies that even though Shanghai is not the policy center in China as Beijing, Shanghai is still able of attracting the multinationals' FDI in R&D. However, there is little empirical evidence on whether and how multinational firms diffuse knowledge to domestic Chinese firms in Shanghai. The analysis of MNCs and knowledge diffusion in Shanghai would give a more complete picture on the role of multinational firms in knowledge spillover in China.

Chapter 4 (titled "Multinational Corporations and Knowledge Diffusion to Domestic Firms in Shanghai: Evidence from Patent Citation Data") aims at closing those gaps by using patent citation data to explore how MNCs diffuse knowledge to domestic Chinese firms in Shanghai. Firstly, I find that the probability of knowledge flow through international patent citations to MNCs with Shanghai inventions is greater when domestic Chinese firms' patents were created after MNCs entered Shanghai. Secondly, I found that the probability of knowledge flow through international patent citations is also greater when domestic Chinese firms' patents involve returnee inventors. Thirdly, I found that the knowledge flow from MNCs with Shanghai invention has a positive impact on domestic Chinese firms' innovation performance, which is measured by using patent quality.

While chapter 3 and chapter 4 focus on inter-organizational knowledge flow from university and foreign MNCs to domestic Chinese firms, chapter 5 (titled "Physically Proximate or Culturally Cohesive? Geography, Ethnic Ties, and Innovation in China) takes the perspective from U.S. MNCs, and focuses on intra-organizational knowledge flow from MNCs' headquarter in the home country to MNCs' subsidiaries in the host country, and studies how U.S MNCs promote the innovation performance of indigenous Chinese inventors employed at U.S.MNCs' subsidiaries in the host country.

Previous literatures found that knowledge spillover tend to be geographically localized because of the tacit nature of knowledge (Feldman & Audretsch 1999; Jaffe et al. 1993), however, MNCs can overcome the geographic constraint on knowledge flow and enable cross border diffusion of knowledge (Singh 2003; 2007). However, facilitating the cross-border knowledge flow within MNCs is not easy. Cultural distances between headquarter inventors in the home country and indigenous inventors in the host country may hinder effective cross-border knowledge transfer. On the other hand, geographical distance between inventors in the home country and indigenous inventors in the host country brings the problems of time zone differences, and less formal or informal interactions, which also affect the effective management of cross-border R&D projects.

Previous literatures show that human mobility and ethnic closeness both promote cross-border knowledge flow (Bartlett & Ghoshal, 1999; Foley & Kerr 2013). MNCs may assign headquarter inventors abroad, or initiate cross-border collaboration between host country inventors and headquarter inventors of the same ethnicity as the host country inventors. These approaches make use of geographical proximity, cultural closeness, or both. Chapter 5 uses a sample of 104 U.S. multinational firms, and explores how the geographic proximity and ethnic closeness of U.S. headquarter-based inventors to indigenous Chinese inventors affects innovation by the latter inventors within U.S. subsidiaries in China. The findings suggest that firstly, China-based co-invention between dispatched and indigenous Chinese raises the latter's innovation performance.

Secondly, a cohesive collaboration network between U.S. expatriate Chinese and indigenous Chinese accrues more benefits of cross-border invention to indigenous Chinese inventors. This paper draws managerial implications that U.S. MNCs should train U.S.-based ethnic Chinese inventors to lead R&D projects in China, and use strategic personnel assignments and virtual teams to promote the innovation performance of indigenous Chinese inventors.

2. Chapter 2: Analysis of University – Industry Collaboration Network in China by using Network Analysis Method

2.1. Introduction

In the early 1980s, the Chinese government faced the problem of a tight national budget. Motivated by the desire of lowering the cost of supporting universities and public research institutes (PRIs), the Chinese government dramatically cut the funding for universities and PRIs. Thus, universities and PRIs had to find alternative funding options. The concept of university technology commercialization in China was first raised under this background, with the aim of commercializing university technology to generate economic impact.

Previous literature suggests that the issuing of "Chinese Bayh-Dole Act", which specify that universities can retain titles to inventions that are derived from government funding, dramatically increased the number of university patents, and also co-application patents owned by university and companies (Hong 2008; Hong & Su 2013). However, there is little research showing the dynamics of changes of university-industry collaboration (UIC) network in China after the issuing of the “Chinese Bayh-Dole Act”, especially by using social network analysis method. Moreover, previous research shows that the role of universities is also different in each regional innovation system in China (Chen & Kenney 2007). Thus the pattern of UIC network in each region is also expected to be different. However, little research showed the difference of UIC network patterns across different regions in China.

In this paper, I try to close this gap by using network analysis method to examine the evolvement patterns of China’s UIC network, and further investigate the different UIC networks in China four main regions: Beijing, Shanghai, Shenzhen, and Wuhan. To do so, I use university-company co-application patents as samples. I use the network visualization tool UCINET to visualize the evolvement patterns of UIC network in China. Then, I calculate bipartite two-mode network indicators for UIC network in China, and examine the changes of network indicators across different time periods.

2.2. History of China’s Science Policy on University – Industry Collaboration

Because of the long period of centrally planned economy, in the early 1980s, most of the research and development resources are concentrated in universities and public research institutes, whereas the corporate sector are relatively weak in innovation capacities. The early university technology commercialization in China took the form of university spin-off ventures firms, instead of university – industry joint research.

In 1988, the Chinese government launched the Torch Program to encourage local governments to build high-tech parks, with the purpose of providing sources for employment and taxes. These high tech parks are built in close proximity to universities and PRIs with the aim of facilitating the spur of university and PRI spin-offs. In 1999, the Ministry of Education and Ministry of Science and Technology formally recognized 15 university science parks as experimental national university science parks.

At the end of 2014, according to *2015 Annual Report on China Torch Program*, there are 115 National University Science Parks in China, a number of 9,972 tenant firms, 7,192 accumulated graduated tenants, and 2,828 new tenants in 2014. A total income of RMB 36.12 billion is generated and 1.63 million persons are employed by the incubatees in the year of 2014. The top three regions in terms of number of National University Science Parks are Beijing (14 national university science parks and 1052 incubatees), Shanghai (13 national university science parks and 1295 incubatees), and Jiangsu (11 national university science parks and 1466 incubatees).

Besides the Torch Program, the Chinese government also implemented a series of policies aiming at promoting collaborations between universities and companies. In 1993, The National People's Congress passed the science and technology progress law of the People's Republic of China, which encouraged the collaboration between corporates and universities or research institutes. In 1996, The National People's Congress passed Law of the PRC on Promoting the Transformation of Scientific and Technological Achievements, which specified that the commercialization of scientific and technology achievements at university and PRIs should be promoted.

The Chinese government also tried to learn from the experience of university – industry collaboration in other countries. The enactment of the Bayh-Dole Act in 1980 in the US allowed universities to appropriate the property rights to inventions that are resulted from university research funded by federal funding. The Bayh-Dole Act gave strong incentives to universities to set up Office of Technology Licensing, and to collaborate with industries. The Bayh-Dole Act sharply increased the number of university patents (Mowery et al. 2001).

Chinese scholars suggested that the university patent applications also sharply increased after the issuing of the "Chinese Bayh-Dole Act" (Hong 2008). The Chinese version of Bayh-Dole Act was first issued by the Ministry of Education in April 1999. The name of the document is "Intellectual property protection management rules for universities", which specified that universities can retain titles to inventions that are resulted from government funding. The document also emphasized the protection and commercialization of university intellectual properties.

In 2008, The National People's Congress issued the Chinese version of Bayh-Dole Act in the format of Law. The name of the law is "The Law of the PRC on Promoting the Transformation of Scientific and Technological Achievements 2007 revised version". The No. 20 Article of the law clarified that the ownership of intellectual property rights resulted from national science research programs or S&T programs belongs to the organization (university) which undertake the programs.

The Chinese patent law was enacted in 1985. The State of Intellectual Property Office (SIPO) provides the Chinese patent dataset. The information of patent includes the name of the invention, patent applicant information, the application and grant year, and inventor information. For the analysis of Chinese patents, I use the Chinese patent dataset version 2015, which includes the data information from patent applicant year 1985 – 2015.

Figure 2-1 shows the trend of growth of patents that are applied by Chinese universities (including UIC patents). From 1985 to 1999, I can see that there is almost no change in the growth of patents. After the issuing of Chinese Bayh-Dole Act in 1999, the number of patents applied by universities each year sharply increased. From 2007, the number of patents applied each year increased from 20,000 to 100,000 in 2014, a 5 time increase in 7 years.

Figure 2-1 Trend of growth of Chinese university patents

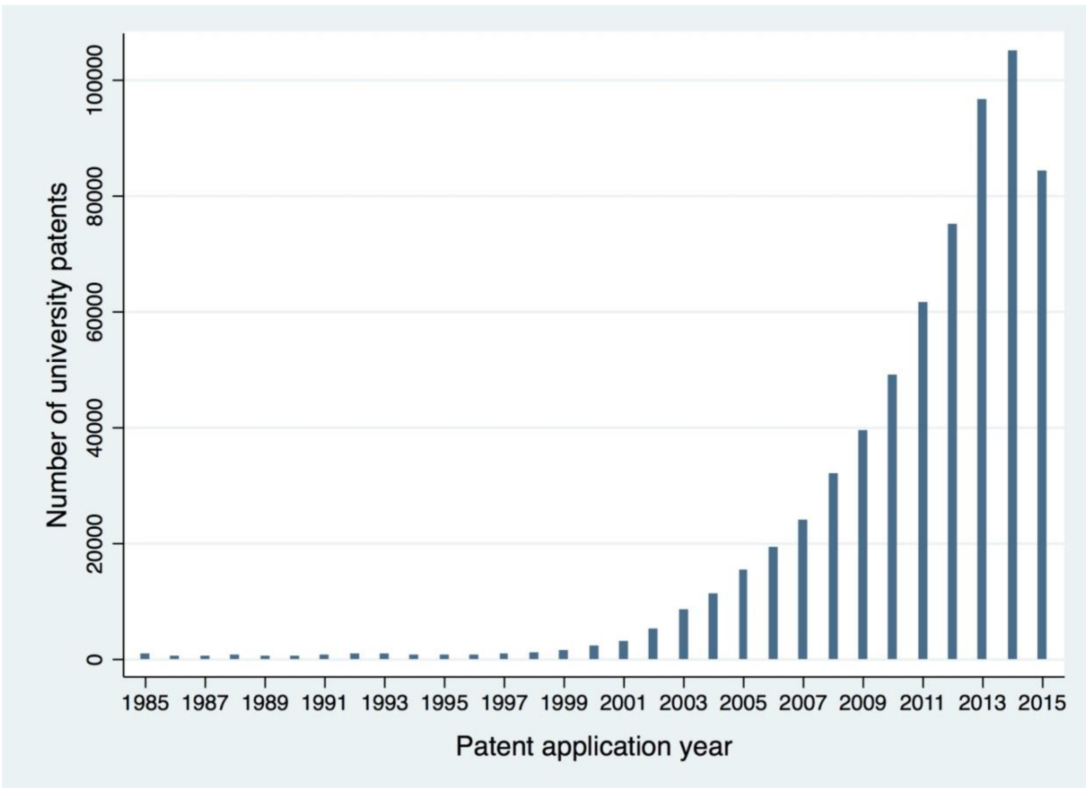
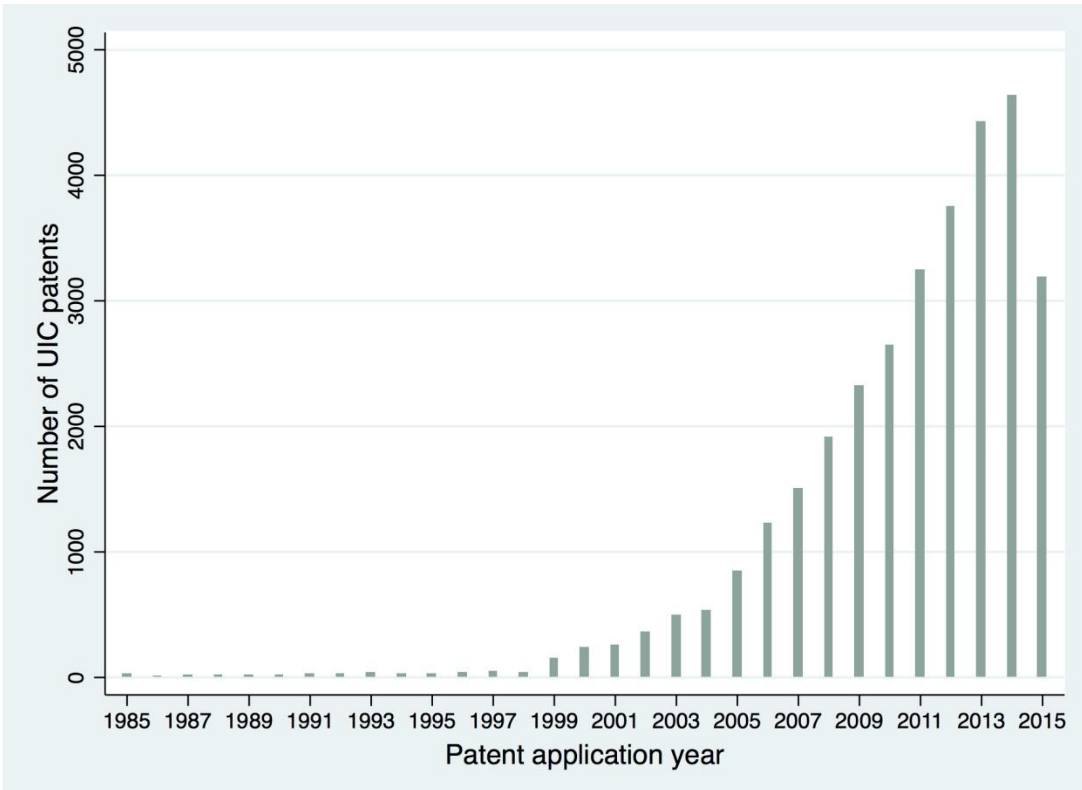


Figure 2-2 shows the trend of growth of number of Chinese university-industry joint application patents from 1985 to 2015. The whole growth trend of number of university-industry joint applications follows a very similar pattern as the growth trend of number of Chinese university patents. The growth in the 7 years period of 2007-2014 is around 3 times as the growth in the 7 years period of 2000-2010.

Figure 2-2 Trend of growth of Chinese university-industry co-application patents



2.3. Visualization of UIC Network in China by using Co – application Patents

In order to study the evolvement of China's university – industry collaboration network, I use the university-company co-application patents for the analysis. The co-application patent means that the patent is jointly applied by a university and a company. In order to have a uniform sample, in my analysis, I only consider the co-application patents that only have two applicants (one university and one company).

Table 2-1 shows the top 25 university in terms of degree, the number of different firms that the university has collaborated with from 1985 – 2015. The first five universities are Tsinghua University in Beijing, Zhejiang University in Zhejiang province, Shanghai Jiao Tong University in Shanghai, South China University of Technology in Guangdong, and East China University of

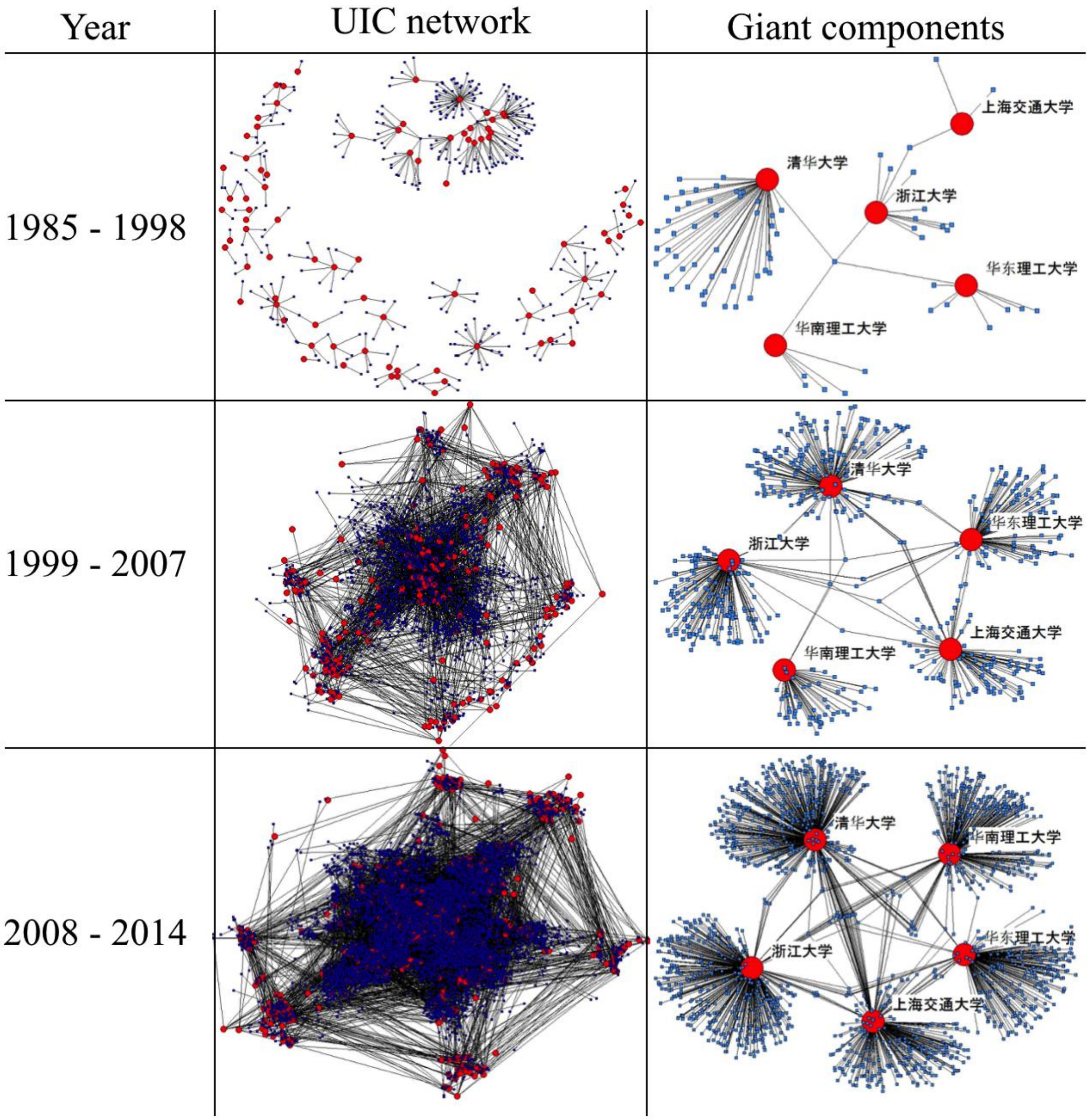
Technology in Shanghai. For example, Tsinghua University has collaborated with 662 different firms from 1985 – 2015.

Table 2-1 University ranking in terms of degree (number of firm ties that a university node has)

rank	university	degree	region
1	清华大学	662	Beijing
2	浙江大学	535	Zhejiang
3	上海交通大学	368	Shanghai
4	华南理工大学	347	Guangdong
5	华东理工大学	318	Shanghai
6	东华大学	250	Shanghai
7	江南大学	244	Jiangsu
8	东南大学	218	Jiangsu
9	天津大学	218	Tianjin
10	华中科技大学	198	Hubei
11	西安交通大学	188	Shanxi
12	中南大学	188	Hu'nan
13	浙江工业大学	182	Zhejiang
14	重庆大学	176	Chongqing
15	四川大学	176	Sichuan
16	北京化工大学	164	Beijing
17	复旦大学	163	Shanghai
18	北京科技大学	161	Beijing
19	中山大学	161	Guangdong
20	同济大学	159	Shanghai
21	大连理工大学	150	Liaoning
22	上海大学	148	Shanghai
23	东北大学	128	Liaoning
24	北京航空航天大学	125	Beijing
25	厦门大学	120	Xia'men

Figure 2-3 shows the evolvement of UIC network in China from 1985 – 2015 by using network visualization method. I use the software UCINET for the visualization analysis. In Figure 3, the red node indicates a university, and the blue node indicates a firm, the link between red node and a blue node indicates that the university and the firm have past collaboration as indicated by co-application patent.

Figure 2-3 Evolvement of university – industry collaboration network in China



I divide the time span into three periods by taking consideration of the two important timing of the start of huge increase in Chinese university patents. I can see that before 1999 that the Chinese Bayh-Dole Act was issued, UIC network in China was not dense from 1985 – 1998. From 1999 to 2007, the UIC network in China becomes much denser within the 9 years. After 2008, the UIC network in China from 2008 – 2015 grows even denser as compared with the UIC network in the period of 1999 – 2007.

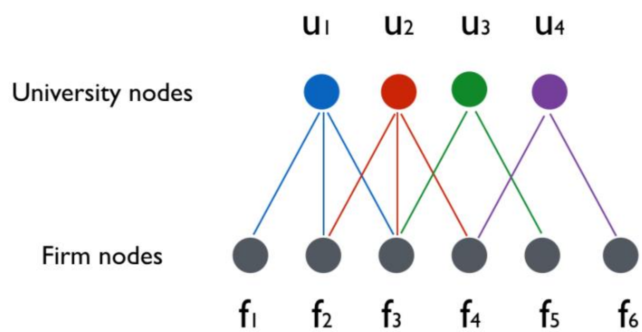
On the right part of figure 2-3, I take the top 5 universities in terms of number of different firm ties possessed as sample for analysis. In the period of 1985 – 1998, Tsinghua University has the largest number of firm ties. There are also a small number of firms that collaborated with different universities, even though the universities are in different regions. In the period of 1999 – 2007 and the period of 2008 – 2015, the UIC networks of these five universities grow much denser. The number of firms that collaborated with different universities also grows along with the three time periods. The figure shows that after the issuing of Chinese Bayh-Dole Act, the university – industry collaboration network in China also experienced a huge growth within the 15 years.

2.4. Bipartite Two Mode Network Indicators of UIC Network in China

In this chapter, I calculate two-mode network indicators for China's university – industry collaboration network, and examine the changes of the network indicators through the three time periods. In social network analysis, two-mode network refers to network ties between two sets of entities (Borgatti 2009). In university – industry collaboration network, the two sets of nodes are university and firm nodes.

Latapy et al. (2008) described the methodology and indicators for analyzing two-mode networks. The two-mode network is also named as bipartite graph, which is $G = (\top, \bot, E)$. The bipartite two-mode network is illustrated as figure 2-4.

Figure 2-4 Bipartite two – mode network



I denote by $n_\top = |\top|$ the number of top nodes, which are university nodes in UIC networks. And $n_\bot = |\bot|$ the number of bottom nodes, which are firm nodes in UIC networks. I denote by $m = |E|$ the number of existing university – industry collaboration links in the bipartite two-mode network. In one mode network, degree is referred as the number of ties of a given type that a node has. In bipartite two mode network, I calculate the top and bottom degree respectively. I denote by $k_\top = (m / n_\top)$ the degree for university nodes. It is the average number of ties that a university node has. Respectively, I denote by $k_\bot = (m / n_\bot)$ the degree for company nodes. It is the average number of ties that a company node has. In one mode network, density is the measure of cohesion. It is the number of existing ties in the network, expressed as a proportion of the number of ties possible. In the bipartite two-mode network, I denote by $\delta(G) = (m / n_\top n_\bot)$ the bipartite density. It is the fraction of existing university – industry collaboration links with respect to possible ones.

Table 2-2 summarizes the changes across the three time periods. The number of universities in the third time period increased around 6 times as compared with the first time period, and increased around 2 times as compared with the second period. The number of unchanged university nodes indicates how many university nodes in the last time period are remained. The number of new university nodes indicates how many new universities joined into the UIC network. For example, there are 70 universities out of 86 in the first time period still participate in the UIC network in the second time period. I can see that most of universities that participate in the last time period still tend to remain in the UIC network in the next time period.

However, for the net changes of number of company nodes across the three time periods, I can see that only 4% (14/325) of company nodes in the first time period still remain in the UIC network in the second time period, and 24% (484/1,976) of company nodes that participated in the UIC network in the second time period still remained in the third time period. On the other hand, there are lots of new companies participated in the UIC network, especially in the third time period, where 8,657 new firms participated in UIC. The changes of UIC links across the three time periods resemble the patterns of changes of firm nodes. I can see that only 9 UIC links out of 348 links in the first time period still remained in the second time period, and 20% (437/2,199) UIC links in the second time period still remained in the third time period.

Table 2-2 Changes of Bipartite Indicators for China's UIC network

Bipartite Indicators	1985 - 1998	1999 - 2007	2008 - 2015
$n_\top$ *(Number of unviersity nodes)*	86	230	491
$n_{\top\_Remained}$ *(Number of unchanged unviersity nodes)*		70	217
$n_{\top\_new}$ *(Number of new unviersity nodes)*		160	274
$n_\perp$ *(Number of company nodes)*	325	1,976	9,141
$n_{\perp\_Remained}$ *(Number of unchanged company nodes)*		14	484
$n_{\perp\_New}$ *(Number of new company nodes)*		1,962	8,657
m *(Number of UIC links)*	348	2,199	10,724
$m_{\_Remained}$ *(Number of old UIC links)*		9	437
$m_{\_New}$ *(Number of new UIC links)*		2,190	10,287
$k_\top$ *(Degree of university nodes)*	4	10	1,762
$k_\perp$ *(Degree of company nodes)*	1	1	1
δ *(Bipartite density)*	0.0125	0.0048	0.0024

Figure 2-5 Degree distribution for university and firm nodes

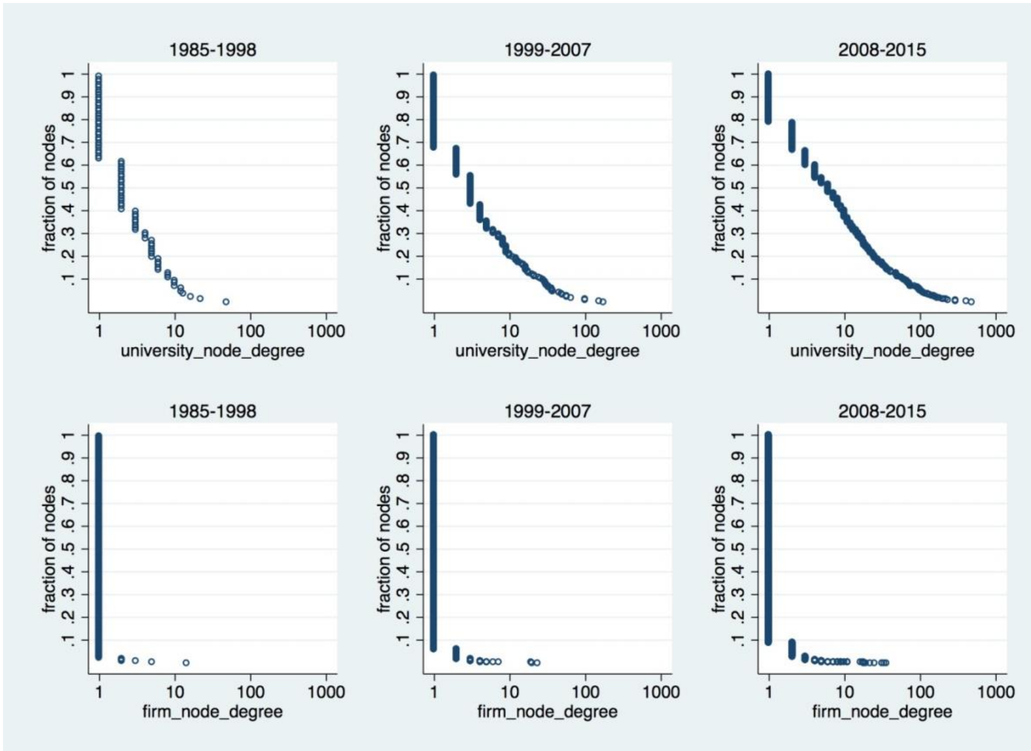
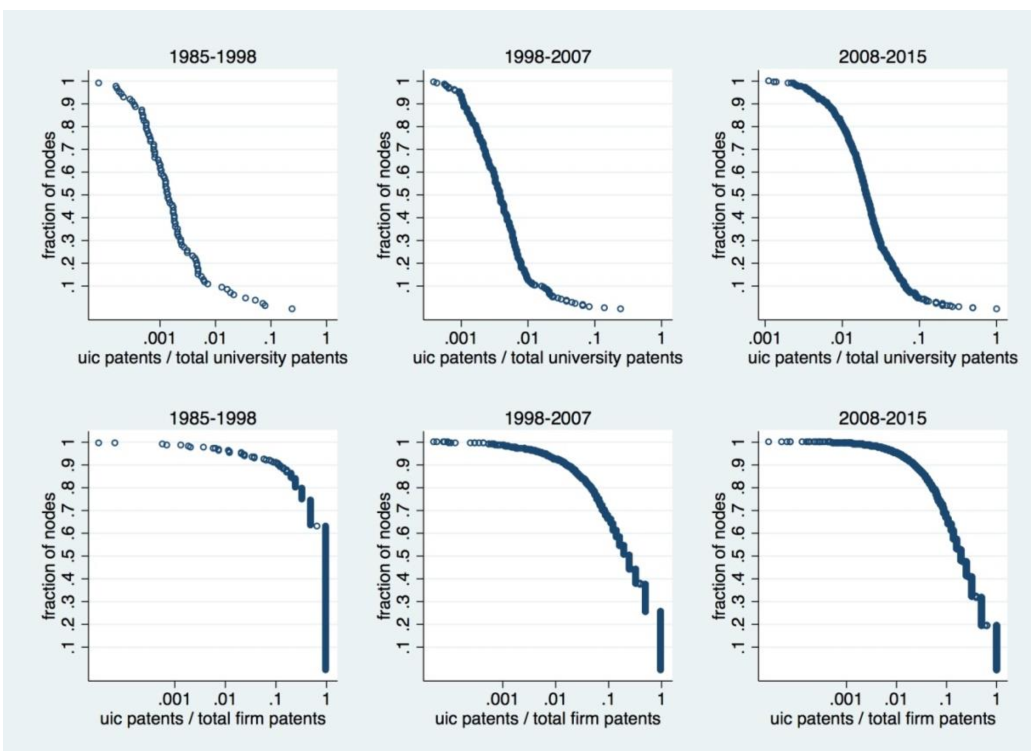


Figure 2-6 Distribution of the percentage of UIC patents



For the degree of university and firm nodes, I see that on average, one university node in the first time period has 4 firm ties, and 10 firm ties in the second time period, but 1,762 firm ties in the third time period. However, the average degree for firms remained as 1 across the three time periods. Figure 2-5 shows the distribution of degrees of university and firm nodes. The vertical axis indicates the fraction of nodes; the horizontal axis indicates the degree. The blue stick indicates the fraction of nodes that have a given degree. The length of the blue stick indicates the percentage of the nodes that at a given degree.

First, for university nodes degree, the fraction of nodes that have one degree is around 40% (0.6 ~1 as showed by the length of blue stick). This fraction reduces to around 30% in the second time period, and 20% in the third time period. On the other hand, the fraction of university nodes that have more than 10 firm ties is below 5% in the first time period. In the second time period, there are around 5% of university nodes that each has more than 100 firm ties. In the third time period, there are around 3% of university nodes that each has nearly 600 firm ties. Second, for the firm degree, I can see that there are around 90% of firm nodes that has only one university tie, and this fraction is nearly unchanged across the three time periods. Figure 2-6 indicates that in the first time period, around 60% of firm nodes only had one patent, which was the UIC patent. This indicates that university spin-offs made up a large portion of firm nodes.

2.5. Regional Comparative Analysis of UIC Network in China

Previous studies on China's regional innovation system suggest that the role of universities and PRIs differ in each regional innovation system. For example, in Beijing, universities and PRIs contributed to the economic growth through the spurring of university and PRI spin-offs. In contrast, in Shenzhen, the industrial growth occurred before the development of local higher education institutions. The main function of local universities in Shenzhen is providing educational upgrading for local high tech companies (Chen & Kenney 2007). In this Chapter, I take the four regions: Beijing, Shanghai, Shenzhen, and Wuhan, which are representative of high technology and industrial growth in China as samples, and study the different patterns of UIC networks in each region. In each region, I take the top 5 universities in terms of degree as samples for the analysis.

2.5.1. Beijing

Beijing is the capital city that concentrated with large number of prestige universities and research institutes in China. According to the *2015 Statistic Yearbook of China's Higher Education*, in 2014, 18% of total S&T funding from government and 17% of total S&T funding from industry are allocated to Beijing. 18% of university and research institute R&D spending took place in Beijing. One of the characteristics of regional innovation system in Beijing is the strong science sector. Because Beijing is a government city that has a relatively little industrial and commercial tradition, the "science push" model of university technology commercialization in the format of university spin-offs contributed significantly to the regional economic development. One of the important elements in Beijing's innovation system is the Zhongguancun Science Park (ZSP), which is referred as the "Silicon Valley" in China. The ZSP is located in Haidian district, where concentrated with the most famous universities and research institutes in China, such as Tsinghua University, Peking University, and China Academy of Science. ZSP is the earlies and largest IT-related cluster in China. The local high-tech firms located in ZSP are in a close proximity to those famous universities and PRIs. The ZSP and university science parks provide the physical place for university spin-offs, local high tech firms, and universities and PRIs to interact with each other.

Figure 2-7 shows the evolvement of UIC network in Beijing. Through the three time periods, Tsinghua University has the largest number of different firm ties. Most of these firms are university spin-off in the first time period.

Table 2-3 shows the changes of network indicators for UIC network in Beijing. First, I can see that even before 1999, there were 100 university links. I further looked into how many firm patents that these firm has, and found that most of the firms only have one patent, and such patent is the UIC patent. I can infer that these firms were spin-off companies from the universities. However, the percentage of old UIC ties that were remained in the next time period is very low, there is only 4% of UIC ties in the first time period still remained in the second time period, and there is 19% of UIC ties in the second time period still remained in the third time period. Overall, table 2-2 illustrates that the UIC network mode in Beijing is characterized as "science push", because of the large number of UIC links to university spin-off companies.

Figure 2-8 indicates the degree distribution for university and firm nodes. First, for university degree, I can see that the fraction of universities that only have one firm tie is decreasing across the three time periods; on the other hand, the fraction of university nodes that have around 100 firm ties is increasing. This indicates the fact that there are more universities that collaborate with multiple firms. Second, from the firm side, I can see that the fraction of firms that only have one university tie is nearly unchanged across the three time periods. It indicates that firms tend to only collaborate with one university.

Figure 2-9 shows the distribution of percentage of UIC patents to total patents. In the first time period, around 40% of firms only had one patent, which was the UIC patent. Large portion of university spin-offs suggests that the UIC model in Beijing is led by “university science”.

Figure 2-7 Evolvement of university – industry collaboration network in Beijing

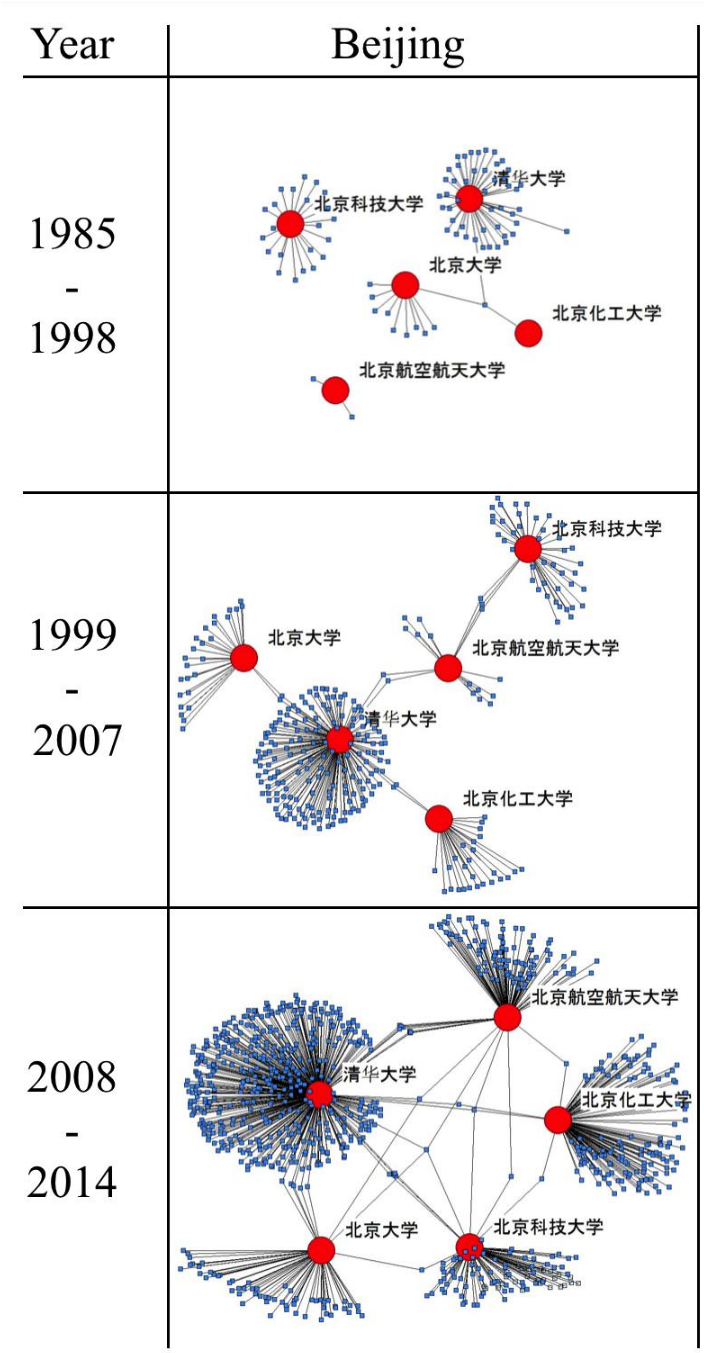


Table 2-3 Changes of Bipartite Indicators for UIC network in Beijing

Bipartite Indicators	1985 - 1998	1999 - 2007	2008 - 2015
$n_\top$ *(Number of unviersity nodes)*	11	22	31
$n_{\top\_Remained}$ *(Number of unchanged unviersity nodes)*		11	10
$n_{\top\_new}$ *(Number of new unviersity nodes)*		11	21
$n_\perp$ *(Number of company nodes)*	97	345	1,301
$n_{\perp\_Remained}$ *(Number of unchanged company nodes)*		6	1,233
$n_{\perp\_New}$ *(Number of new company nodes)*		339	68
m *(Number of UIC links)*	100	367	1,400
$m_{\_Remained}$ *(Number of old UIC links)*		363	1,329
$m_{\_New}$ *(Number of new UIC links)*		4	71
$k_\top$ *(Degree of university nodes)*	9	17	45
$k_\perp$ *(Degree of company nodes)*	1	1	1
δ *(Bipartite density)*	0.0937	0.0484	0.0347

Figure 2-8 Degree distribution for university and firm nodes

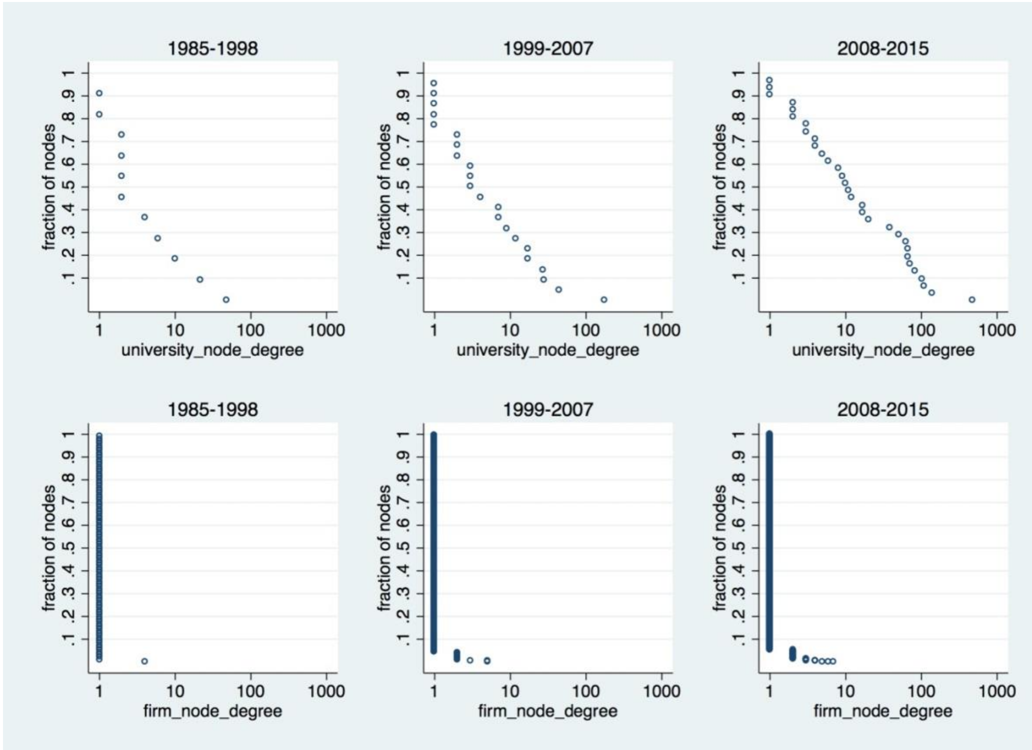
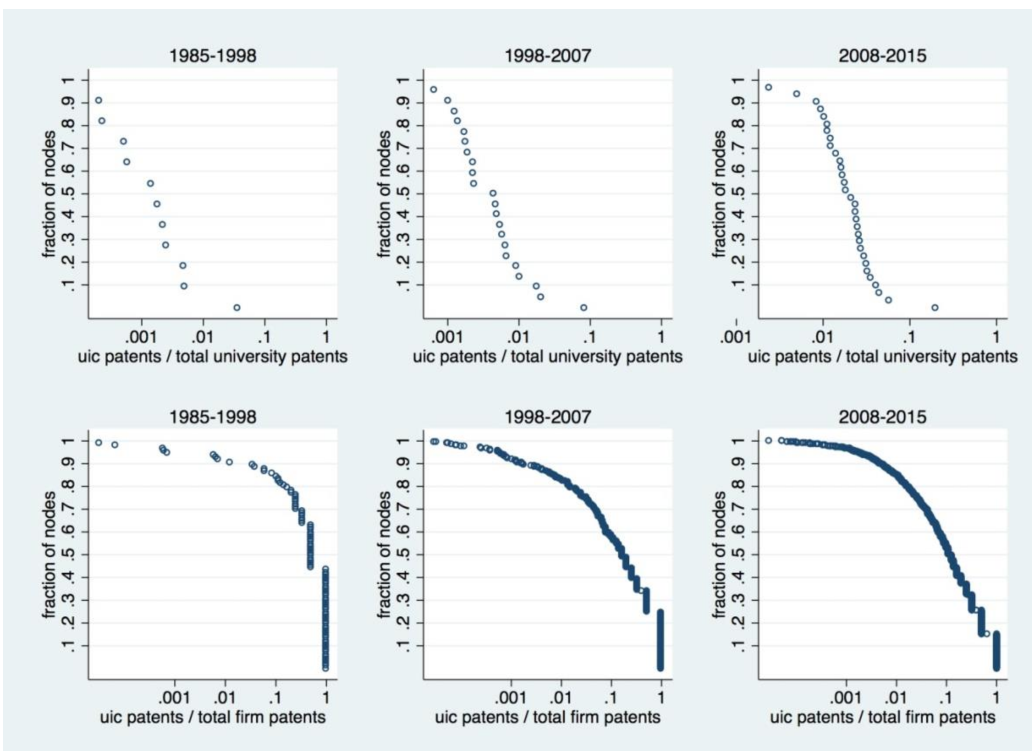


Figure 2-9 Distribution of ratio of UIC patents in Beijing



2.5.2. Shanghai

Shanghai has relatively more industrial and commercial tradition as compared with Beijing. In the 1960s, the Yangpu district in shanghai was one of the major industrial center in China that accommodated more than half a million works (Leng & Wang 2013). Shanghai has a strong industrial base. According to the *2015 China Statistics Yearbook on High Technology Industry*, in 2014, 6% of total intramural expenditure on R&D in China took place in Shanghai. Shanghai is also one of the top cities in China that attracts a large number of foreign funded enterprises in high-tech industry. 9% of foreign funded enterprises in China are concentrated in Shanghai. In terms of R&D activities of foreign funded enterprises, 14% of total intramural expenditures on R&D spent by foreign funded enterprises in China took place in Shanghai.

Similar to the Zhongguancun Science Park (ZSP) in Beijing, the Zhangjiang High-tech Park in Shanghai is also the important IT cluster in China. Zhangjiang High-tech Park is surrounded by many famous Chinese universities and national research institutes, such as branched of Fudan University, Shanghai Jiao tong University, and the research institute branch of Chinese Academy of Science. The Zhangjiang High-tech Park provides the physical place for high-tech firms and universities and PRIS to interact with each other.

Figure 2-10 shows the evolvement patters of university – industry model in Shanghai. The evolvement pattern resembles the pattern in Beijing. The number of firm ties attached to each university grows fast through the three periods. However, I can see that in the third period of 2008 – 2015, the number of firm ties attached to each university is denser than that in Beijing. The common firm ties among those universities in Shanghai are also denser than in Beijing.

Table 2-4 shows the changes of network indicators for the UIC network in Shanghai. As compared with Beijing, I can see that although there are fewer universities in the UIC network as compared with Beijing, all universities that participated in the UIC network in the first time period were still remained in the second time period, and all universities that participated in the UIC network in the second period still participated in the third time period. However, as in the case of Beijing, the percentage of UIC links remained is very small. For example, only one UIC tie that in the first time period was remained in the second time period, and 20% of UIC ties in the second time period was still remained in the third time period.

Figure 2-11 indicates the degree distribution for university and firm nodes in Shanghai. As compared with Beijing, the percentage of universities that have only one firm ties is also decreasing. However, in the third time period, there are no universities that only have one single firm ties. On the other hand, the fraction of universities that have around 100 firm ties is increasing. It indicates that even though Shanghai has fewer universities that participated in UIC as compared with Beijing, these universities effectively play the role in UIC as indicated by the large university node degree.

Figure 2-12 shows the distribution of percentage of UIC patents to total patents. As compared with the distribution of ratio of UIC patents to firms' total patents in Beijing, the distribution of ratio of UIC patents to firms' total patents in Shanghai is particularly different in the first time period: there are more university spin-offs (firms with only UIC patents) in Beijing in the first time period than in Shanghai.

Figure 2-10 Evolvement of university – industry collaboration network in Shanghai

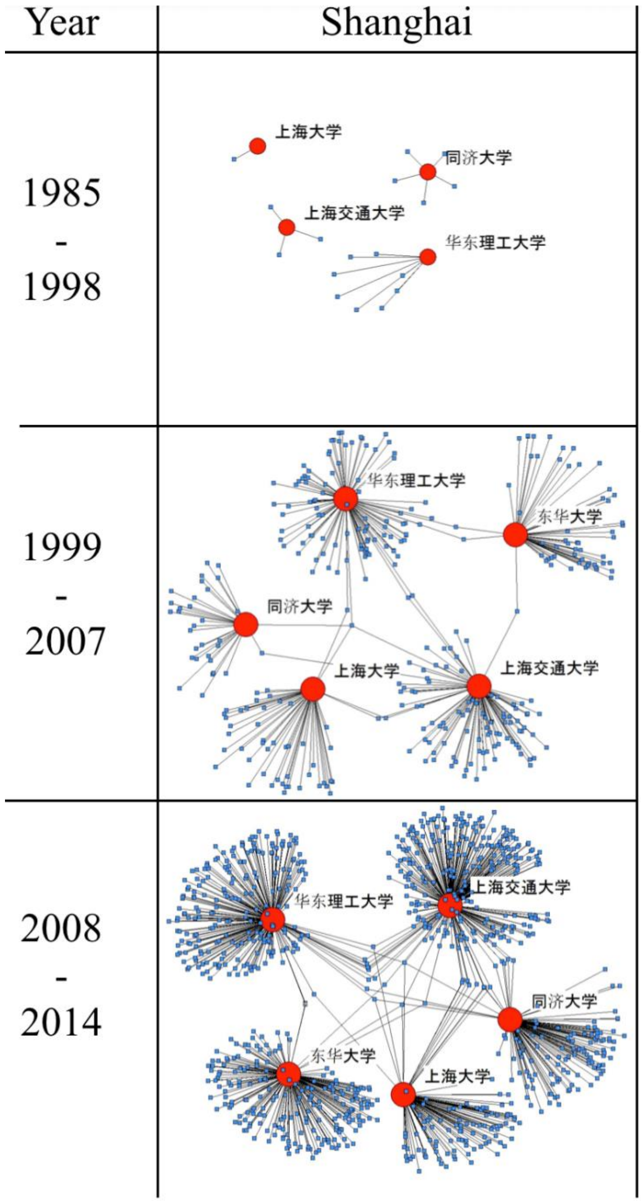


Table 2-4 Changes of Bipartite Indicators for UIC network in Shanghai

Bipartite Indicators	1985 - 1998	1999 - 2007	2008 - 2015
$n_{\top}$ *(Number of unviersity nodes)*	6	15	15
$n_{\top\_Remained}$ *(Number of unchanged unviersity nodes)*		6	15
$n_{\top\_new}$ *(Number of new unviersity nodes)*		9	0
$n_{\perp}$ *(Number of company nodes)*	26	427	1.189
$n_{\perp\_Remained}$ *(Number of unchanged company nodes)*		1	94
$n_{\perp\_New}$ *(Number of new company nodes)*		426	1,095
m *(Number of UIC links)*	28	458	1,268
$m_{\_Remained}$ *(Number of old UIC links)*		1	93
$m_{\_New}$ *(Number of new UIC links)*		457	1,175
$k_{\top}$ *(Degree of university nodes)*	5	31	85
$k_{\perp}$ *(Degree of company nodes)*	1	1	1
δ *(Bipartite density)*	0.1795	0.0715	0.0711

Figure 2-11 Degree distribution for university and firm nodes

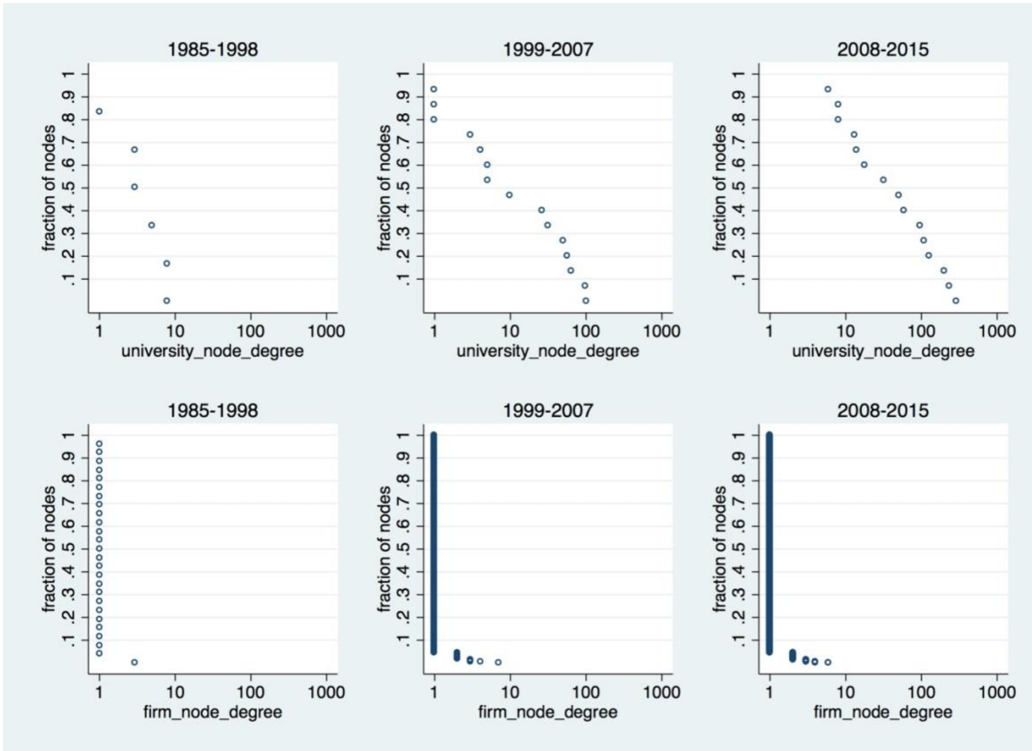
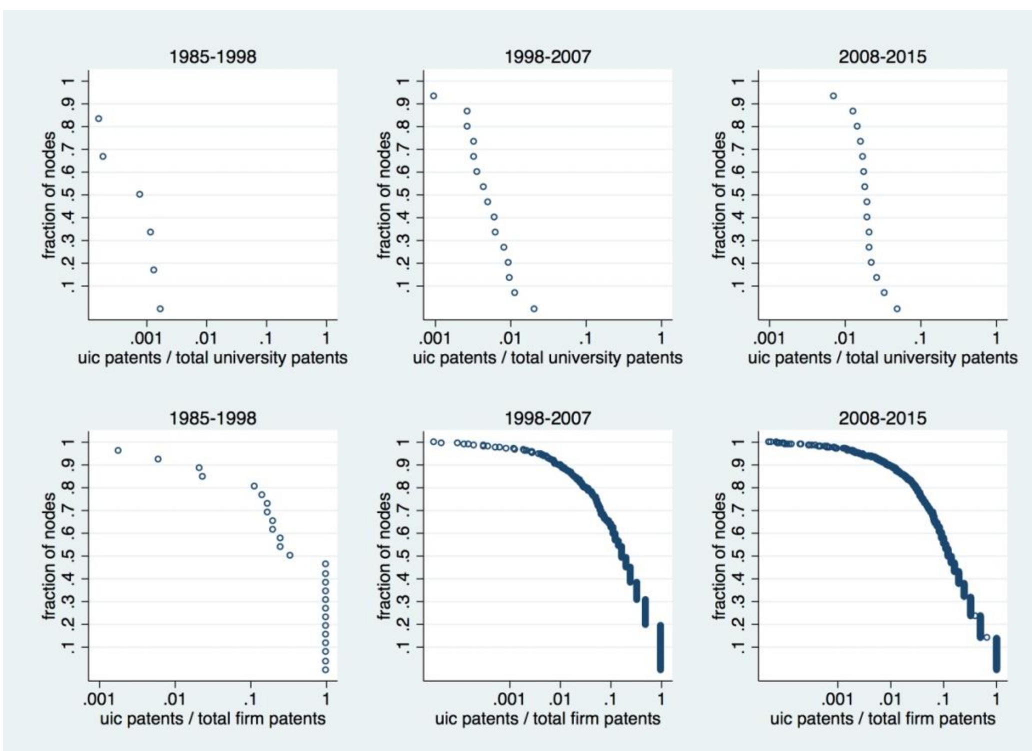


Figure 2-12 Distribution of ratio of UIC patents in Shanghai



2.5.3. Shenzhen

While for Beijing, University Science Parks initially originated from the government needs of facilitating university technology commercialization and generating regional economic impact, for Shenzhen, the emergence and growth of university science parks followed a different trajectory. Until 1979, Shenzhen was a fishing village which is located closely to Hong Kong. In 1980, Shenzhen was designated as a “special economic zone” to experiment China’s market reforms and to act as the base for relocation of manufacturing from Hong Kong. After experienced the rapid growth as a center for manufacturing exports, Shenzhen transferred from a fishing village to a low cost assembly center, and further turned into a high-tech center, when telecommunication technology firms such as Huawei and ZTE had appeared in the early 1990s.

In the early 1980s, Shenzhen municipal government had realized that the lack of higher education institutions would become an obstacle for local high-tech firms industrial upgrading. In 1983, the first university in Shenzhen, Shenzhen University was established. In 1993, Shenzhen municipal government decided to attract leading universities in other cities to establish branches in Shenzhen, famous branches including the Research Institute of Tsinghua University and Research Institute of Harbin Technology University. In 2000, the municipal government established the Shenzhen Virtual University Park (SZVUP) with the aim of encouraging collaboration between local high-tech firms and branches of universities.

Figure 2-13 shows the evolvement of UIC network in Shenzhen. In the first period of 1985-1998, only Shenzhen University has firm ties. In the second and third period, the Research Institute of Tsinghua University and Research Institute of Harbin Technology University developed more firm ties. However, the UIC network is much less developed as compared with Beijing and Shanghai.

Table 2-5 shows the changes of network indicators for UIC network in Shenzhen. I can see that in the first time period, only one university was in the UIC network, and this UIC link is not remained in the second time period. There are much fewer universities and firms that participated in UIC in Shenzhen as compared with Beijing and Shanghai.

Figure 2-14 shows the degree distribution for university and firm nodes in Shenzhen. I can see that most of firms collaborate with only one university. As compared with the UIC model in Beijing, I can infer that the UIC model is very different from the "science push" model in Beijing. In the contrast, because the industrial growth and regional economy development in Shenzhen occurred prior to the development of local universities and PRIs, I can infer that the UIC model in Shenzhen is more "market driven", as local universities play the role of providing educational upgrading for local high-tech firms through university-industry collaboration.

Figure 2-15 shows the distribution of percentage of UIC patents to total patents for universities and firms in Shenzhen. As compared with the case in Beijing and Shanghai, the fraction of firms that large ratio of UIC patents to total firm patents is smaller. Even in the third time period, only around 20% of firm nodes which have more than 50% UIC patents. This suggests that the UIC model in Shenzhen is not "university sciences push", but is more driven by firms current R&D needs.

Figure 2-13 Evolvement of university – industry collaboration network in Shenzhen

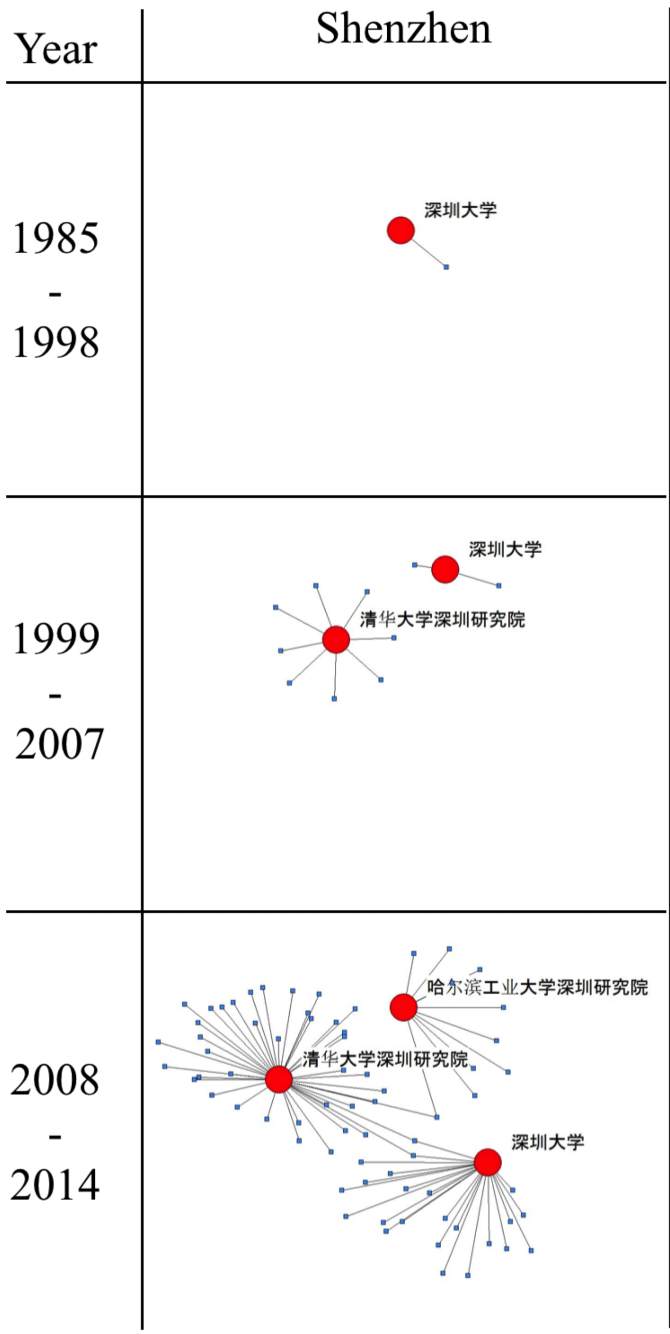


Table 2-5 Changes of Bipartite Indicators for UIC network in Shenzhen

Bipartite Indicators	1985 - 1998	1999 - 2007	2008 - 2015
$n_{\top}$ *(Number of unviersity nodes)*	1	3	4
$n_{\top\_Remained}$ *(Number of unchanged unviersity nodes)*		1	3
$n_{\top\_new}$ *(Number of new unviersity nodes)*		2	1
$n_{\perp}$ *(Number of company nodes)*	1	11	79
$n_{\perp\_Remained}$ *(Number of unchanged company nodes)*		0	4
$n_{\perp\_New}$ *(Number of new company nodes)*		11	75
m (Number of UIC links)	1	11	82
$m_{\_Remained}$ *(Number of old UIC links)*	1	0	4
$m_{\_New}$ *(Number of new UIC links)*		11	78
$k_{\top}$ *(Degree of university nodes)*	1	4	21
$k_{\perp}$ *(Degree of company nodes)*	1	1	1
δ *(Bipartite density)*	1	0.3333	0.2595

Figure 2-14 Degree distribution for university and firm nodes

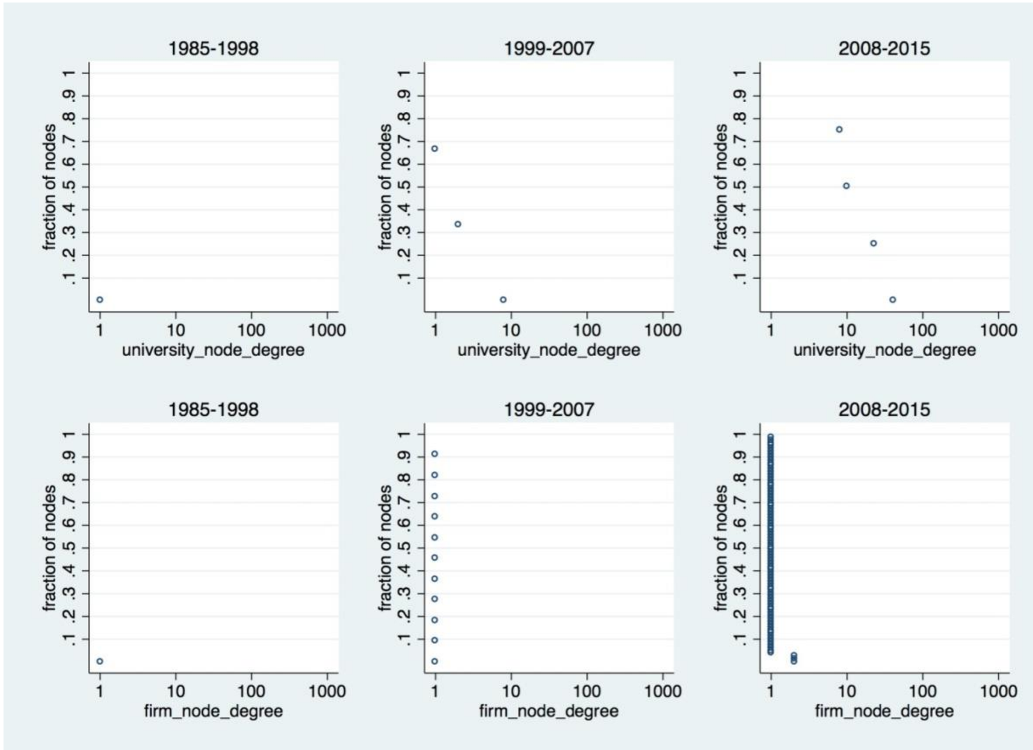
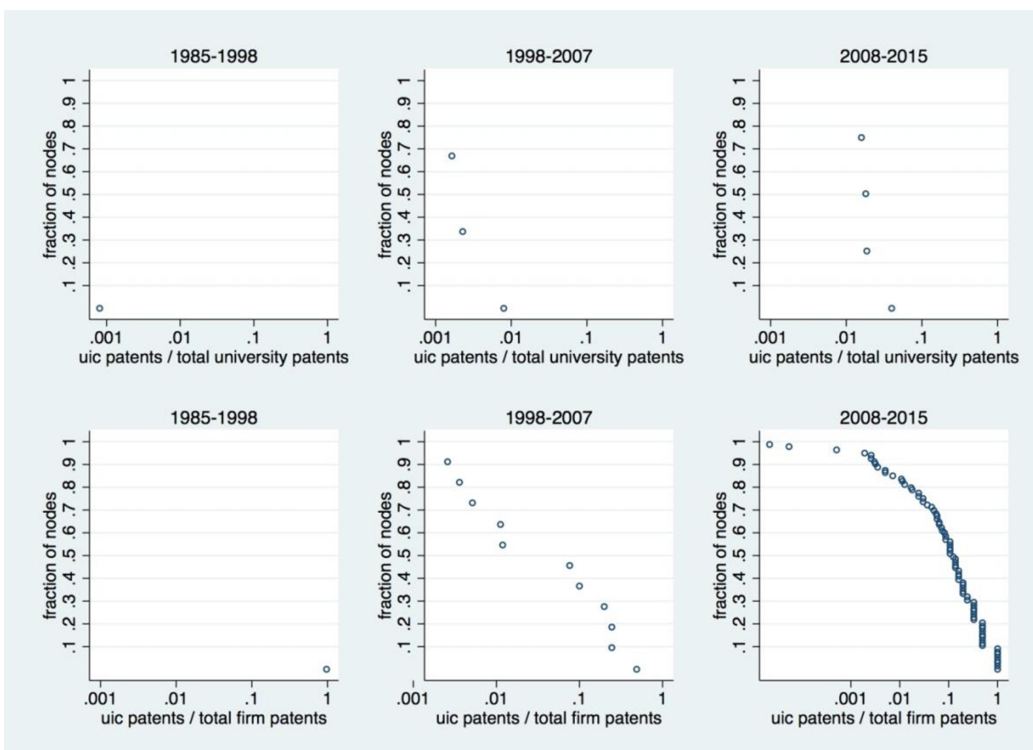


Figure 2-15 Distribution of ratio of UIC patents in Shenzhen



2.5.4. Wuhan

Because the "market oriented" economy was first initiated in southern and eastern coastal cities, the farther the inland city is from the coastal area, the less developed is the inland city's economy. For research on comparing the regional innovation system between coastal and inland cities, Wuhan, the capital city of Hubei province, is often chosen as the representative city due to its economic and industrial growth (Hong & Su 2013).

The high-tech firms are a primary driver of Wuhan's economy. According to *2015 Wuhan Statistic Yearbook*, in 2014, the new and high tech industry in Wuhan accounted for 58% of total industrial value added in Wuhan. Among the high tech industries, the Electronic Information sector contributed the largest amount of industrial value added. Until 2014, Wuhan has 80 institutions of Higher Education. The famous universities including Wuhan University (武汉大学), Wuhan University of Science and Technology (武汉科技大学), and Wuhan University of Technology (武汉理工大学).

Figure 2-16 shows the evolvement pattern of UIC network in Wuhan. Overall, the UIC network in Wuhan is less developed as compared with that in Beijing and Shanghai, but is relatively more developed as compared with that in Shenzhen. In the first period of 1985-1998, only Wuhan University has three firm ties. In the second period, each of the five universities developed some firm ties, but the firms only attach to one university. There was no firms collaborated with multiple universities as indicated in the graph. In the third period of 2008-2015, more firms participated into university industry collaboration, and the number of firms that collaborate with multiple universities also increased.

Table 2-6 shows the changes of network indicators for the UIC network in Wuhan. As compared with Beijing and Shanghai, there are fewer universities and firms in the UIC network. However, the number of firms that participated in UIC network grows very fast. The number of firms in the UIC network in the third time period is nearly 6 times as in the second time period.

Figure 2-17 shows the degree distribution for university and firm nodes in Wuhan. I can see that the fraction of universities that have large firm ties also grow very fast. In the second time period, there were no universities that have 100 firm ties, and there were only 10% of universities that have around 50 firm ties. However, in the third time period, there were around 40% of universities that have around 50 firm ties, and 10% of universities have around 100 firm ties.

Figure 2-18 shows the distribution of percentage of UIC patents to total patents for universities and firms in Wuhan. The distribution follows a similar pattern as in Beijing and Shanghai: in the first time period, all firms have only UIC patents and no single firm patents. The fraction of firms that only have UIC patents but no single firm patents decrease over the three time periods.

Figure 2-16 Evolvement of university – industry collaboration network in Shenzhen

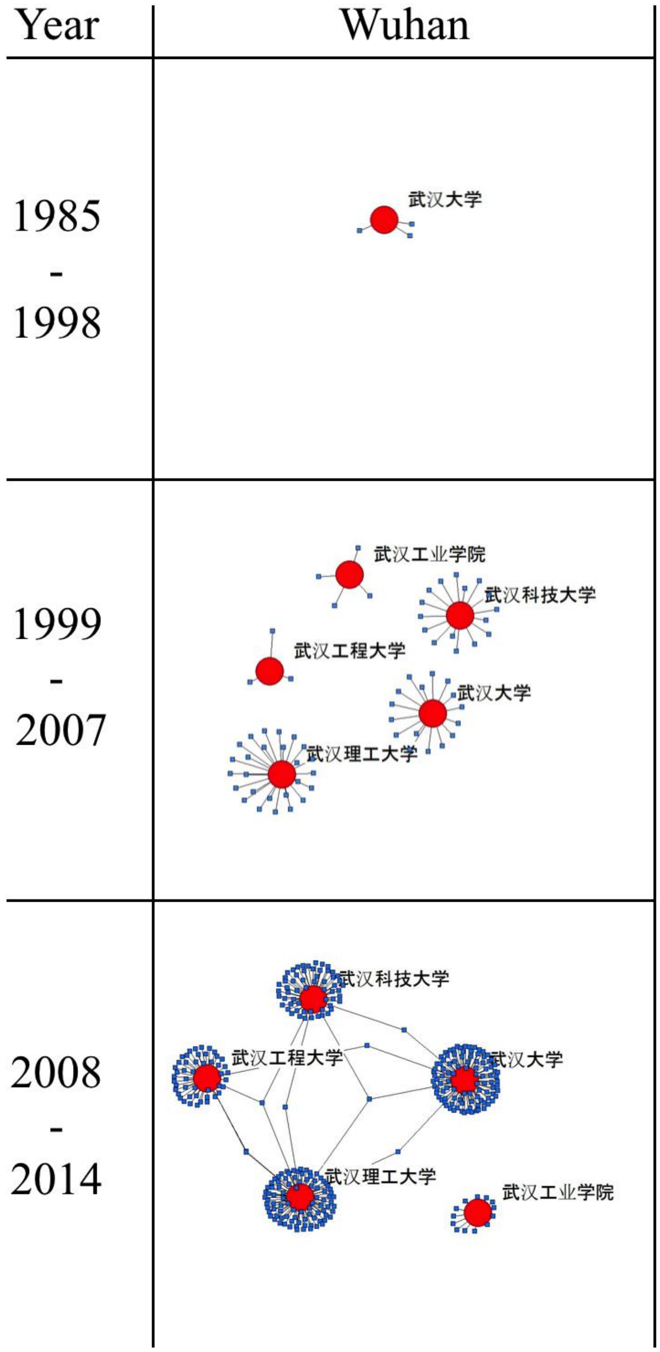


Table 2-6 Changes of Bipartite Indicators for UIC network in Wuhan

Bipartite Indicators	1985 - 1998	1999 - 2007	2008 - 2015
$n_{\top}$ *(Number of unviersity nodes)*	3	9	15
$n_{\top\_Remained}$ *(Number of unchanged unviersity nodes)*		2	9
$n_{\top\_new}$ *(Number of new unviersity nodes)*		7	6
$n_{\perp}$ *(Number of company nodes)*	6	103	599
$n_{\perp\_Remained}$ *(Number of unchanged company nodes)*		0	23
$n_{\perp\_New}$ *(Number of new company nodes)*		103	576
m *(Number of UIC links)*	6	104	639
$m_{\_Remained}$ *(Number of old UIC links)*		0	21
$m_{\_New}$ *(Number of new UIC links)*		104	618
$k_{\top}$ *(Degree of university nodes)*	2	12	43
$k_{\perp}$ *(Degree of company nodes)*	1	1	1
δ *(Bipartite density)*	0.3333	0.1122	0.0712

Figure 2-17 Degree distribution for university and firm nodes

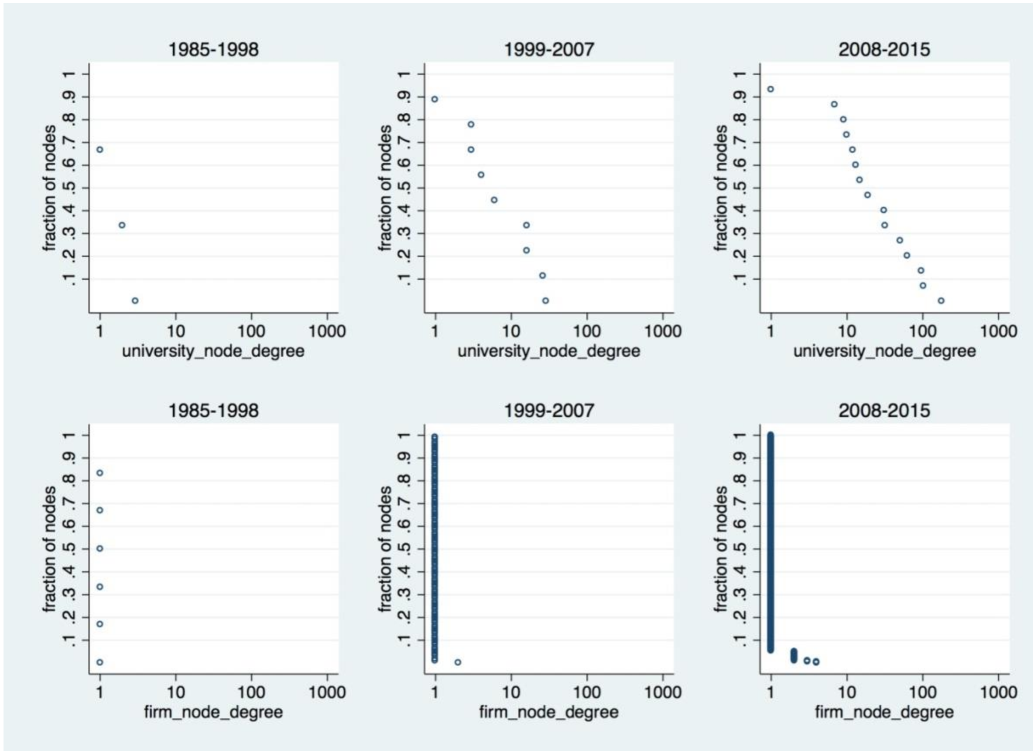
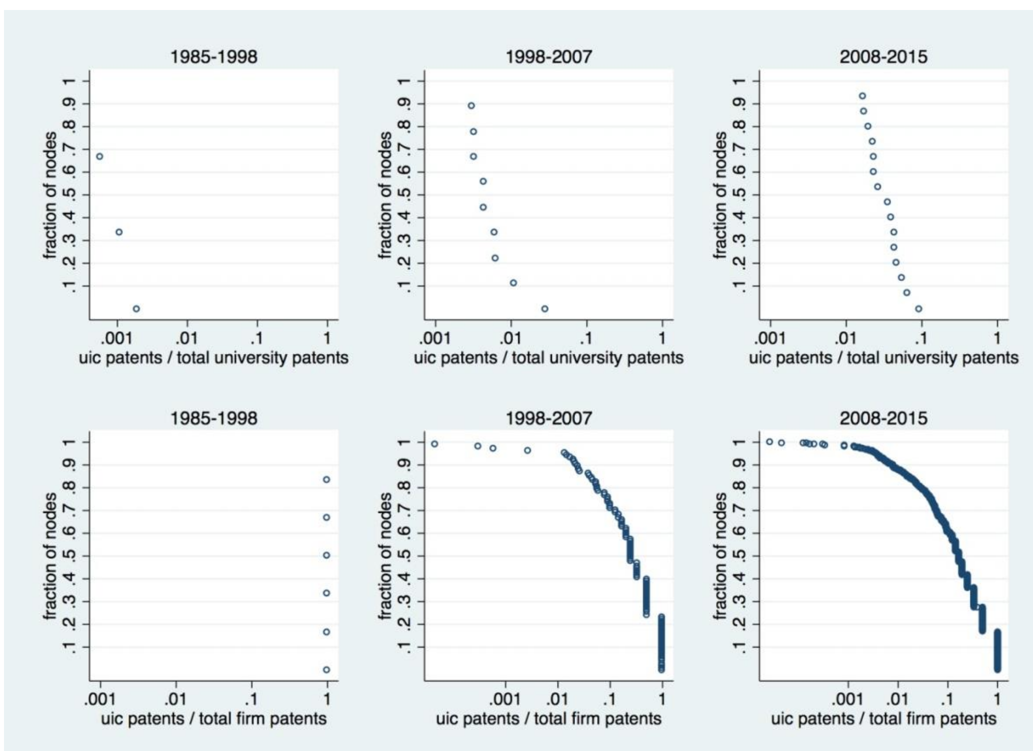


Figure 2-18 Distribution of ratio of UIC patents in Wuhan



2.6. Conclusion and discussions

This paper focuses on the dynamic changes of UIC network in China, and different patterns of UIC network in China's four main regions: Beijing, Shanghai, Shenzhen, and Wuhan. I divided the time span into three periods. The first period is 1985-1998 by taking consideration of the issuing of "Chinese Bayh-Dole Act" in 1999. The second period is from 1999-2007, and the third period is from 2008-2015. I do this split because of the surge of Chinese university patents from 2008, as suggested by figure 2-1. 2008 is also the year that the "Chinese Bayh-Dole Act" was enforced in the format of law that was implemented by the national congress. However, previous research suggests that the huge increase in Chinese university patents is induced by multiple reasons and cannot be simply attributed to the issuing of "Chinese Bayh-Dole Act". Li (2012, showed that by the end of 2007, 29 out of 30 provinces in mainland China had launched a patent subsidy program, and found that the surge of university patents can be partially explained by the impact of patent subsidy program.

My findings also suggested that the evolvement patterns of UIC network have their own characteristics across different regions. The evolvement patterns of UIC network in Beijing and Shanghai are similar. New firm ties attached to each university grow fast through the second and third time period. In the case of Wuhan, although the UIC network are not as intensive as those in Beijing and Shanghai, new firm ties clustered intensively around each university through the three time periods. In Shenzhen, however, even though there is large number of local high-tech firms, number of firms participated in UIC network are much smaller as compared with other three cities.

The UIC network in Shanghai is led by both the strong industrial base and science sector. The UIC network in the inland city Wuhan is not as developed as those in Beijing and Shanghai, but the evolvement pattern of the UIC network in Wuhan followed a similar pattern as in Beijing and Shanghai.

After reviewing the historical role of university in each regional innovation system, I concluded that in Beijing, universities contribute to the industrial development and regional economy through the university spin-offs, the UIC network is more “sciences push”; whereas in Shenzhen, industrial development occurred prior to the development of local universities. I found that there is limited number of universities and small number of firms participated in UIC network as indicated by co-application patents, and I can infer the UIC model in Shenzhen is not a “university science push”. Because universities play the role of providing educational upgrading for local high-tech firms (Chen & Kenney 2007), I can infer that the UIC network in Shenzhen is more “market driven”, that the UIC in Shenzhen is more towards contributing to the firms current product development needs.

3. Chapter 3: A Comparative Study on Tenants in Beijing Tsinghua University Science Park and Shenzhen Research Institute of Tsinghua University

3.1. Introduction

This paper examines the role of University Science Park and Business Incubator on the innovation performance and business performance of tenants. I use survey data from two institutions affiliated to China's top university – Tsinghua University. One is Tsinghua University Science Park (TusPark), the other one is the business incubator of Research Institute of Tsinghua University in Shenzhen (RITS). This paper explores the following research questions: (1) what are the institutional difference between TusPark and RITS? (2) How this difference leads to different new product market performance for tenant firms in TusPark and RITS?

University Science Park and Business Incubator were created with the objective of transferring university knowledge to nearby firms in the mechanisms of formal and informal collaborations, interfirm human mobility, and spin-off of universities. Such exchange of tacit and explicit knowledge between firms and universities may contribute to firms' innovation in the form of new products, new services, or new processes (Díez-Vial & Montoro-Sánchez 2016; Löfsten &

Lindelöf 2005). Recent literatures suggested that roles of universities / research institutes (URIs) in regional innovation systems (RIS) might be different across regions (Chen & Kenney 2007). Therefore, it is imperative to take the institutional differences of RIS into account when analyzing the roles of University Science Park and Business Incubator across regions.

Previous studies explored the mechanisms of TusPark and RITS respectively. Studies on TusPark found that firms having internal innovations grounded in their own competitive advantages showed better innovation performance, and formal research and development collaboration with Tsinghua University only played a marginal role (Motohashi 2013). Some Chinese scholars studied the innovation system of RITS by using case study method. They found that the joint collaborations between RITS's laboratories and tenants are more market-oriented: RITS provides more upper stream applied research, and partner tenants are responsible for development and manufacture process; RITS also provide pilot experiment platform to encourage firms to conduct intermediary test for their products with their customers (He et al. 2013; Sun et al. 2009). However, there is little empirical research on comparing the institutional differences between TusPark and RITS, and on how such institutional differences lead to different new product market performance for tenant firms.

In this paper, I close this gap by conducting a comparison study on tenants in TusPark and RITS. I found that firms in RITS have better new product market performance than firms in TusPark. I demonstrated that the main institutional difference between TusPark and RITS lies in that tenants in RITS rely more on "market-driven" knowledge sources for innovation, such as knowledge from customers, suppliers, and competitors. I found that the technology support provided by RITS and the high dependency on "market-driven" knowledge sources jointly contribute to the better new product performance for tenants in RITS.

3.2. Literature Review

3.2.1. Science Parks and Business Incubators

There is no unformal definition of Science Park or Business Incubator. There are several similar terms that describe these institutions, such as *Technology Park, High-tech Park, Research Park*, *Innovation Center* and so on (Löfsten & Lindelöf 2002). Previous studies defined these institutions as property-based organizations with identifiable administrative centers focused on the mission of business incubating through incubation services, resources sharing, and knowledge agglomeration (Chan & Lau 2005; Löfsten & Lindelöf 2005; Phan et al. 2005). Many universities established science parks to foster the creation of university spin-offs (Link & Scott 2003; 2005).

Previous studies on science parks and business incubators demonstrated that university linkages may foster tenant firms' innovation (Löfsten & Lindelöf 2002; Quintas et al. 1992; Rothaermel & Thursby 2005). Scholars also explored the role of science parks by comparing the performance of firms locating inside and outside parks, and found that firms located on parks tend to be more innovative. Scholars attributed the reasons to the fact that science parks offer a clustering effect and establish links among firms and universities (Lindelöf & Löfsten 2003; Yang et al. 2009).

The first national high-tech parks in China appeared in 1988, when the Chinese government launched the *Torch Program*, an initiative aiming at promoting university-industry collaboration and stimulating regional economic growth. The Tsinghua University Science Park (TusPark) in

Beijing was among the first national level university science parks in China. In 1998, Tsinghua University and Shenzhen municipal government jointly established the Research Institute of Tsinghua University in Shenzhen (RITS). Previous studies explored the university linkages and innovation in TusPark (Motohashi 2013), and the mechanisms of RITS (Wang Luhao 2013). However, there is a lack of comparative studies on university linkages and firms' innovation in TusPark and RITS. There are also few studies exploring how the institutional differences between TusPark and RITS contribute to the differences of firms' performance.

3.2.2. Innovative Clusters and Regional Innovation Systems

An innovative cluster can be defined as a geographically proximate group of interconnected companies and associated institutions linked by commonalities and complementarities (Porter 2000). Previous studies suggested that learning through networking and interacting, such as formal and informal collaborations, interfirm human mobility, and spin-off of new firms from existing firms, universities and research institutes, are crucial forces pulling new firms into clusters and the essentials for the on-going success of an innovative cluster (Breschi & Malerba 2001). Previous studies demonstrated the success of Silicon Valley as an innovative cluster (Angel 1991; Bresnahan et al. 2001; Saxenian 1990). Recent studies also examined innovative clusters in China, such as the Beijing Zhongguancun Science Park, which is called the "Chinese Silicon Valley" (Tan 2006; Zhou 2005).

On the other hand, the concept of regional innovation system (RIS) focuses on wider geographical regions at the sub-national level. Scholars suggested that RIS plays critical role in creating the appropriate context for knowledge creation and transfer within innovative clusters (Cooke 2001; Cooke et al. 1997). Although embedded in the same national innovation system, the RIS in China may have completely different evolutionary trajectories. Recent studies explored the differences of RIS in China, and found that China's competitiveness depends upon institutional differences among regions (Zhao et al. 2015).

3.2.3. The Role of Universities / Research Institutes in Innovative Clusters and Regional Innovation Systems

Academic literatures suggested that universities / research institutes (URIs) are critical knowledge sources in innovative clusters and regional innovation systems (RIS). Beyond generating commercializable knowledge, they produce other means of knowledge transfers, such as generating and attracting high quality talents to the RIS, and collaborating with local industries through formal and informal technology support (Bramwell & Wolfe 2008; Sohn & Kenney 2007).

Recent literatures on the comparison between RIS suggested that the university-based innovation support in the RIS can either be science-based or applied research oriented (Coenen 2007), and demonstrated that the overall institutional context of the regional innovation system is also imperative for the varying role of URIs institutes across regions (Trippl et al. 2015).

Previous study explored the different roles of URIs in China's RIS through a comparison of the development of the Beijing and Shenzhen technology clusters, and found that URIs in Beijing play extremely important role in the formation of local high-technology clusters, whereas URIs in Shenzhen are more important in providing for technology support and industrial upgrading (Chen & Kenney 2007).

3.3. Comparative Study Framework for Tsinghua University Science Park (TusPark) and Business Incubator of Shenzhen Research Institute of Tsinghua University (RITS)

3.3.1. Differences of Regional Innovation Systems in Beijing and Shenzhen

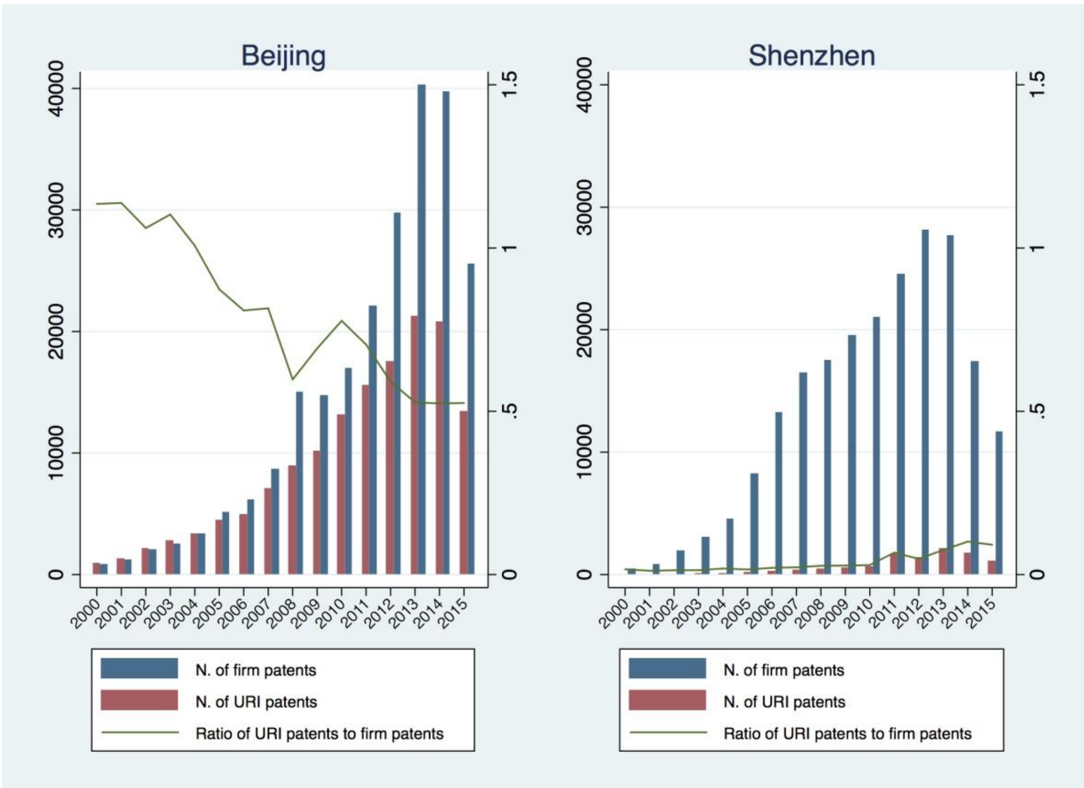
Beijing is the capital city which has the most intensive concentration of universities and research institutes in China. The Haidian district, where TusPark is located, is the heart of the innovative cluster Zhongguancun Science Park. The District is concentrated with long-standing universities and research institutes, including Tsinghua University, which was established in 1911; and Chinese Academy of Sciences (CAS), which was founded in 1949. On the contrary, Shenzhen was a fishing village which is located closely to Hong Kong. In 1980, Shenzhen was designated as a "special economic zone" to experiment China's market reform. Shenzhen successfully transferred from a fishing village to the center of manufacturing exports in China, and further turned into a high-tech center, when telecommunication technology firms such as Huawei and ZTE had appeared in the early 1990s. However, the municipal government realized that the lack of famous institutions of higher education and research would be an obstacle for industrial upgrading. In 1998, the municipal government and Tsinghua University in Beijing jointly established the Research Institute of Tsinghua University in Shenzhen (RITS). In 2000, the municipal government constructed the "University Virtual Campus" (UVC) to attract URIs in other regions to establish branches.

Figure 3-1 shows the differences of RIS between Beijing and Shenzhen by China patent statistics. In Beijing, the ratio of number of URI patents to number of firm patents decreased to 0.5 from 2000 to 2015. However, in Shenzhen, the ratio remained close to 0 during the same period. It demonstrated that the RIS in Beijing and Shenzhen followed very different evolutionary trajectories: while in Beijing the URIs could be a primary force for industrial growth; in Shenzhen the emergence of URIs happened after the industrial growth, and played a role in providing technology and educational support for industrial upgrading.

Because the survey of tenant firms in TusPark in Beijing was conducted in December 2008, and firms were asked to answer the questionnaires according to their performance in the time period from 2006 to 2008, whereas the survey of tenant firms in RITS in Shenzhen was conducted in 2011, and firms were asked to respond to the survey according to their performance in the time period from 2008 to 2010, only the year 2008 is overlapped for the two surveys. Therefore, questions would be raised on whether the time period of 2006-2008 and the time period of 2008-2010 are comparable. For example, whether there were any significant changes of innovation and economic situation in China for the two time periods that would affect the analysis results.

I calculate the three years average growth rate of firm patents for the two time periods in Beijing and Shenzhen based on figure 3-1 to see whether there were any significant changes of innovation across the two time periods. For example, the growth rate for 2008 if calculated as *(number of patents in 2008 / number of patents in 2007) – 1*, then the average growth rate for the time period 2008-2010 is calculated as *(growth rate in 2008 + growth rate in 2009 + growth rate in 2010) / 3*. The average growth rate of firm patents for 2006-2008 and for 2008-2010 in Beijing is 71% and 82%, respectively. The average growth rate of firm patents for 2006-2008 and for 2008-2010 in Shenzhen is 79% and 92%, respectively. For both Beijing and Shenzhen, the average growth rate for firm patents in 2008-2010 is around 10% larger than that in 2006-2008. For both Beijing and Shenzhen, there is no significant increase of the average growth rate of firm patents across the two time periods. Therefore, although this study suffers the limitation of different survey timing, the two time periods are still comparable.

Figure 3-1 RIS differences between Beijing and Shenzhen by patent statistics



3.3.2. Tsinghua University Science Park (TusPark): an overview

In 1994, Tsinghua University proposed the concept of establishing Tsinghua University Science Park, and obtained substantial support from Beijing government. The initial goals of constructing Tsinghua University Science Park were: (1) Promoting Tsinghua University technology commercialization; (2) Establishing an area to manage Tsinghua University spin-off companies (Li & Chen 2014). In 1998, the construction of TusPark was completed. In 1999, the Entrepreneurship Park, which is especially for young venture start-ups, was established within the TusPark. In 2000, the Development Center of TusPark, Beijing Zhongguancun technology and development Co., Ltd, Beijing national asset management Co., Ltd, and other two famous Tsinghua spin-off companies: Tsinghua Tong fang Co., Ltd and Tsinghua Unisplendour Co., Ltd, jointly established the Tsinghua University Science Park Construction Co., Ltd (the name was later changed to "TusPark Holding Co., Ltd in 2004). This company is responsible for the management, construction and development of TusPark.

3.3.3. Research Institute of Tsinghua University in Shenzhen (RITS): an overview

In 1998, the Research Institute of Tsinghua University in Shenzhen (RITS) was jointly established by Tsinghua University and Shenzhen municipal government. RITS has established 6 research centers, under which there are 14 laboratories. As Tsinghua University has established Tsinghua University Science Park, RITS also has its affiliated Business Incubator. However, compared with Tsinghua University which had an accumulation of nearly 90 years of scientific research, RITS has established a different technological innovation system, which has a short history but a market – oriented research focus. In 2000, RITS built its first laboratory. Until 2012, RITS has established 14 laboratories. These 14 laboratories conduct abundant applied research with tenant firms in RITS's business incubator, and these laboratories are the main university technological resources that offered by RITS (Sun et al. 2009).

3.4. Data

The survey on tenants in TusPark was conducted by Motohashi (2013) in 2008, and the survey on tenants in RITS was conducted by Dr. Luhao Wang in 2011. The questionnaires were distributed to tenants in the Tsinghua University Science Park in Beijing (TusPark, surveyed in 2008, valid response: 68/80) and the Research Institute of Tsinghua University in Shenzhen

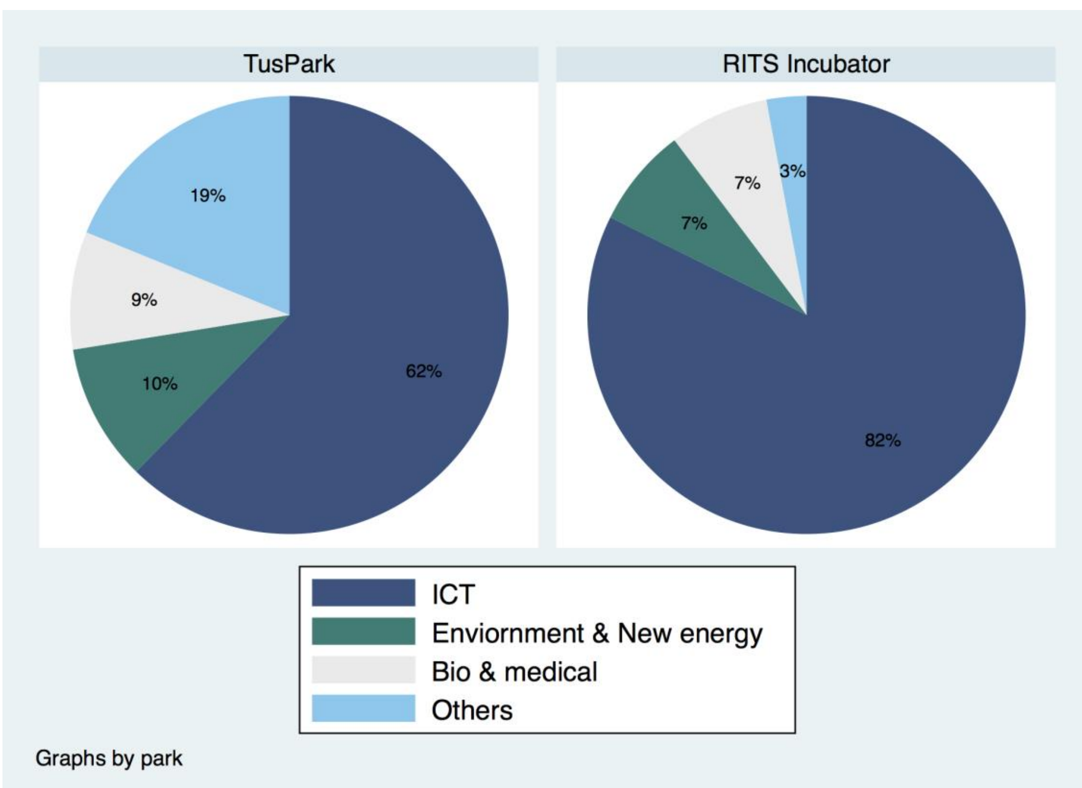
(RITS, surveyed in 2011, valid response: 68/68). In TusPark, the targets of the survey were 80 tenant venture companies at the "Innovation Square". Motohashi (2013, provided a detailed analysis of this survey. In RITS, the targets of the survey were 68 tenant ventures in the business incubator. I use the above survey data for the analysis.

3.5. Preliminary Analysis

3.5.1. Basic Conditions for Tenants

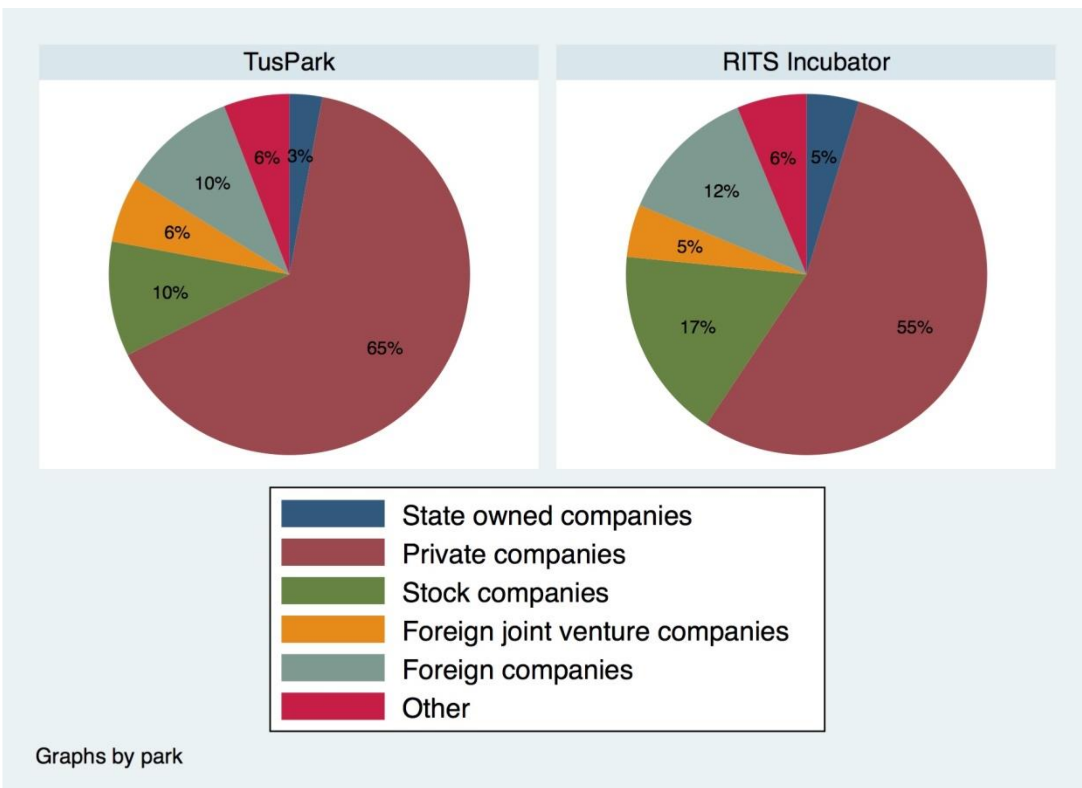
Figure 3-2 describes the industry types of surveyed tenants. Internet and communication technology (ICT) related businesses are the majority of surveyed tenants in TusPark and RITS incubator.

Figure 3-2 Industry Types in TusPark and RITS



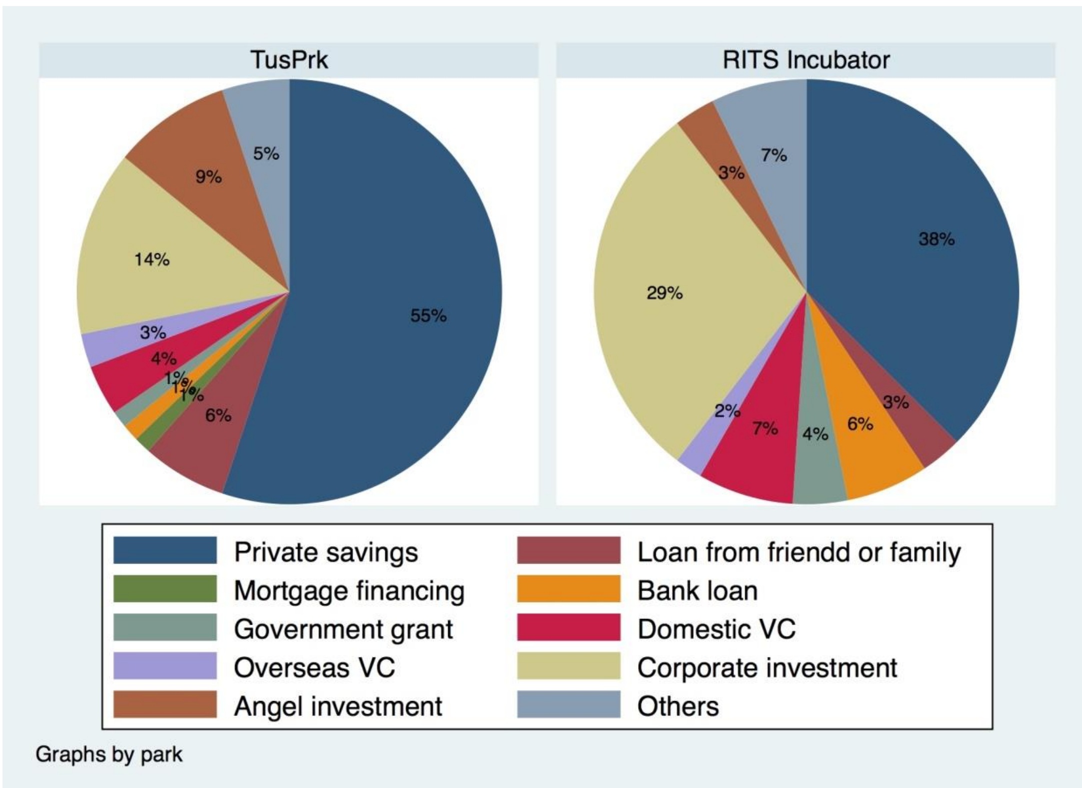
Next, I look at the ownership status of surveyed businesses in TusPark and RITS incubator. As shown in figure 3-3, private companies are the majority of surveyed companies in both TusPark and RITS incubator. There are more stock companies (companies which have other corporations as stakeholders) in my sample from RITS incubator than from TusPark. In my sample, there are 5-6% foreign companies and 10-12% foreign joint ventures from both TusPark and RITS incubator. There are also a small percentage of ventures which are invested and controlled by the Chinese government.

Figure 3-3 Types of venture companies



For venture companies, the source of financing is extremely important for overcoming the "death valley". As indicated in figure 3-4, in TusPark and RITS Incubator, private saving is the major financing source for surveyed companies and account for 38% - 55% of all finance sources. The second largest financial source is corporate investment from other companies. However, in my sample there are more than half of the tenants from TusPark whose major financing source is private saving, whereas the percentage of tenants whose major financing source come from corporate investment is much higher in RITS than in TusPark.

Figure 3-4 Major sources of funding for venture companies



Next, I examine the profile of tenant business owners. The majority of entrepreneurs in TusPark and RITS incubator are 30-44 years old. However, the percentage of 45-59 elder entrepreneurs is two times higher in RITS incubator than in TusPark, suggesting that in my sample there more elder entrepreneurs with more accumulated social experiences from RITS incubator than from TusPark. In terms of gender of the business owner, male entrepreneurs are around 86-92% in TusPark and RITS incubator.

Table 3-1 Age and gender distribution of venture business owners and managers

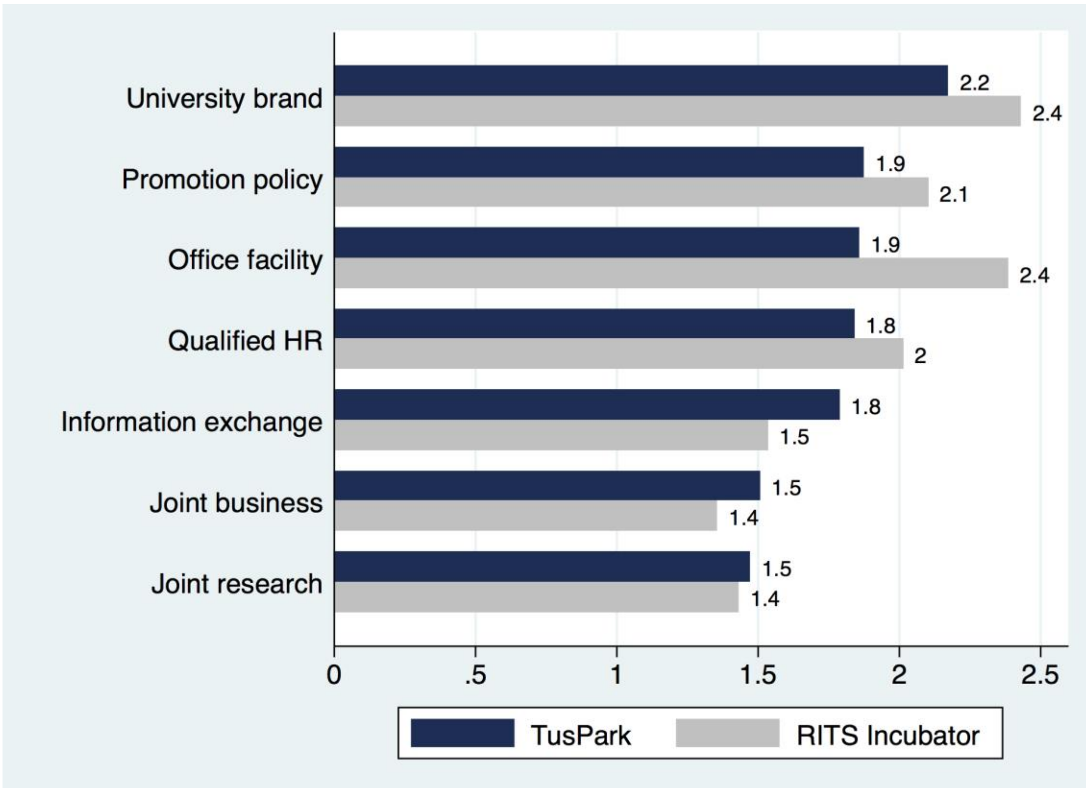
Share	TusPark Share (%) (N=60)	RITS Incubator Share (%) (N=59)
<29	5.00	8.47
30 – 44	65.00	50.85
45 – 59	25.00	40.68
>60	5.00	0
Total	100.00	100.00
	Share (%) (N=65)	Share (%) (N=64)
Male	86.15	89.06
Female	13.85	10.94
Total	100.00	100.00

In terms of education of entrepreneurs, the majority are master degree holders in all the two parks, as shown in Table 3-2. The percentage of PhD holders is more than one third in TusPark, and is around 3 times higher than in RITS incubator. Because PhD entrepreneurs are very likely to bring their university technologies in university laboratories to their start-ups, I infer that such tenants in TusPark are more "university science based" as compared with tenants in the RITS.

Table 3-2 Education distribution of venture business owners and managers

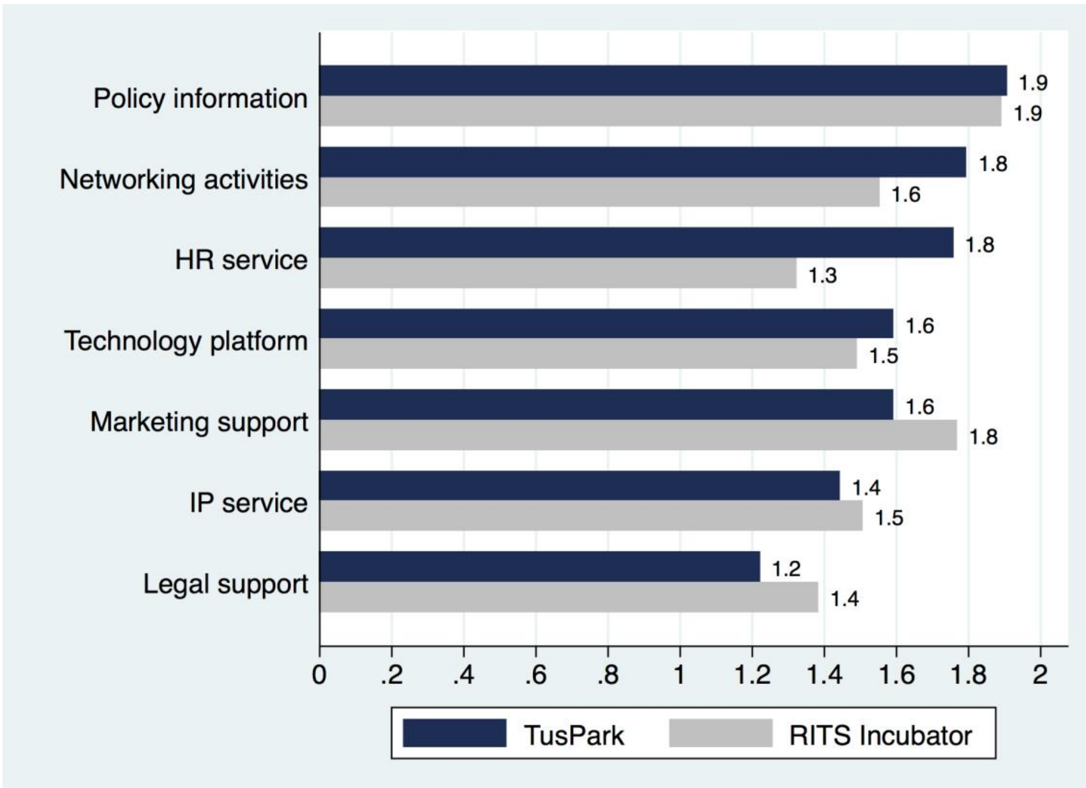
Share	TusPark Share (%) (N=60)	RITS Share (%) (N=59)
PhD	36.67	13.56
Masters	40.00	44.07
Bachelor	20.00	38.98
Vocational School	0	3.39
Others	3.33	0
Total	100.00	100.00

Figure 3-5 Advantages of Science Park tenancy



Tenant businesses are also asked to evaluate the impact of entering Science Park on the success of business. Figure 3-5 shows the comparison of wide-ranging merits for establishing businesses in TusPark and RITS Incubator. In both parks, "University brand" ranks first as the most important advantage locating in science parks, whereas networking activities rank at the bottom. However, tenants in TusPark on average give more importance to networking activities such as "joint business" and "joint research" than tenants in RITS Incubator. It suggests that because tenants in TusPark are more at the early stage than tenants in RITS, they have more incentives to exchange information with other firms on sharing general start-up experiences; because tenants in RITS are more at a matured stage, I tend to see other firms as potential competitors and become reluctant to share information.

Figure 3-6 Evaluation of Science Park services



Tenant businesses are asked to give evaluation of the impact of various science park services on their business success. As indicated by Figure 3-6, tenants in both TusPark and RITS Incubator evaluate "Policy information" as the most important science park service. It suggests that science park has the important function of distributing government policies to tenants. Tenants in TusPark evaluate the importance of "networking activities" higher than tenants in RITS Incubator, but rate the importance of "marketing support" less than tenants in RIST Incubator.

3.5.2. Innovation and Financial Performance

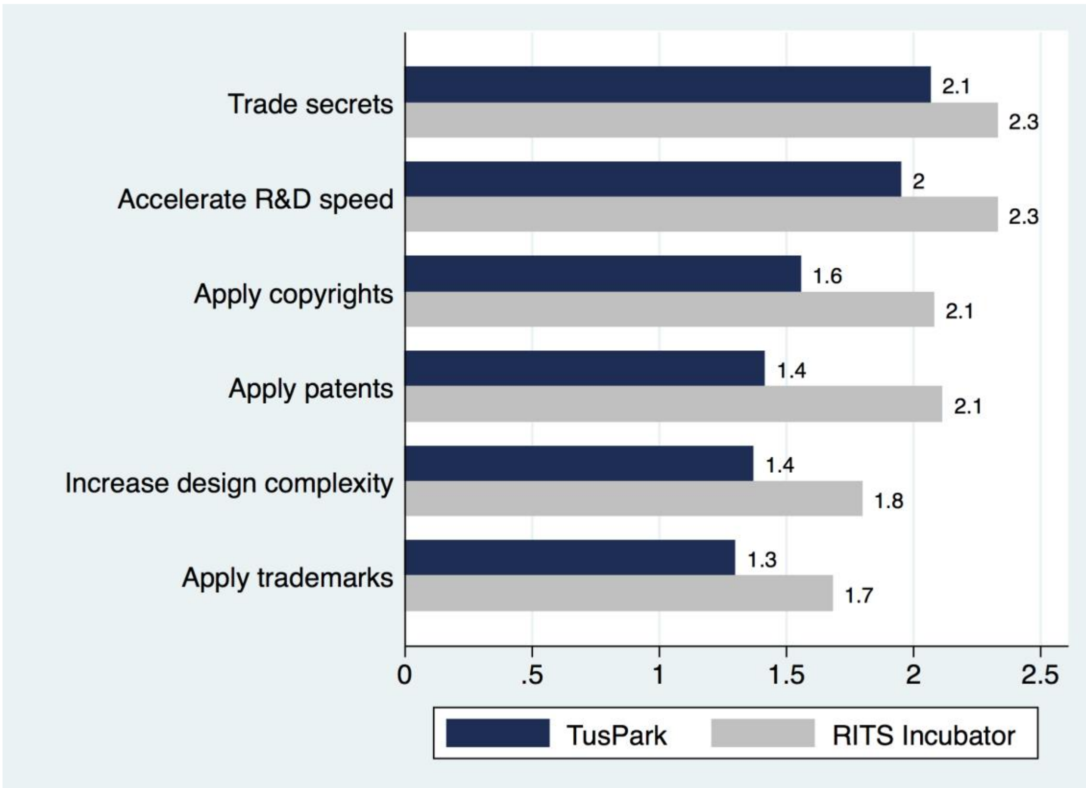
The survey examined whether there is new product development (product innovation) or the evolution of major production processes (process innovation) that are resulted from R&D activities. I find that the percentage of surveyed businesses that have product innovation is higher in RITS Incubator than in TusPark, where 83.58% of surveyed businesses have product innovation. In TusPark, the percentage of surveyed firms that have process innovation is slightly higher than that in RITS Incubator. For the status of intellectual property related activities of surveyed companies, surveyed firms in RITS are more likely to apply patents, trademark, and copyrights (see Table 3-3).

Table 3-3 Innovation outputs of tenants

Share	TusPark Share (%) (N=57)	RITS Incubator Share (%) (N=65)
Product Innovation	76.27	83.58
Process Innovation	69.49	68.66
	Share (%) (N=49)	Share (%) (N=61)
Patent	53.06	77.05
Trademark	30.61	57.38
Copyrights	38.78	65.57

Figure 3-7 further shows the method that tenant businesses used to protect the intellectual property rights, and how do they evaluate the importance of each method. I excluded tenant firms that had neither product innovation nor process innovation in the past three years, and I focus on knowing how tenant firms that have new product or new process will protect their intellectual property rights. For protecting their intellectual property rights, tenant businesses in both TusPark and RITS Incubator tend to give higher priority on "internal protection of trade secrets" and "increasing R&D speed", rather than on "applying patents, trademarks, or copyrights".

Figure 3-7 Methods and importance of intellectual property rights protection



This finding reflects that tenant businesses are aware of the importance of intellectual property rights protection. However, tenants tend to prefer using alternative intellectual property protection methods, rather than applying patents. Nagaoka et al. (2010) summarized the mechanisms to appropriate returns from innovations and reasons for not to patent for unpatented innovations. "The ease of inventing around" ranks in the first. Because the majority of tenants in the two parks are in IT-related industries, their products face the risk of being easily copied and invented around.

Moreover, the intellectual property rights protection system in China is still not mature, small firms may not be able to win the lawsuit if their patents are infringed by large companies, and they are also reluctant to incur the high costs of lawsuits for infringements. Thus, they choose keeping trade secrets, speedy product development, and increasing complexity of product design as more effective mechanism of appropriating returns from innovation than applying patents and copyrights.

Figure 3-8 Share by customers of new products

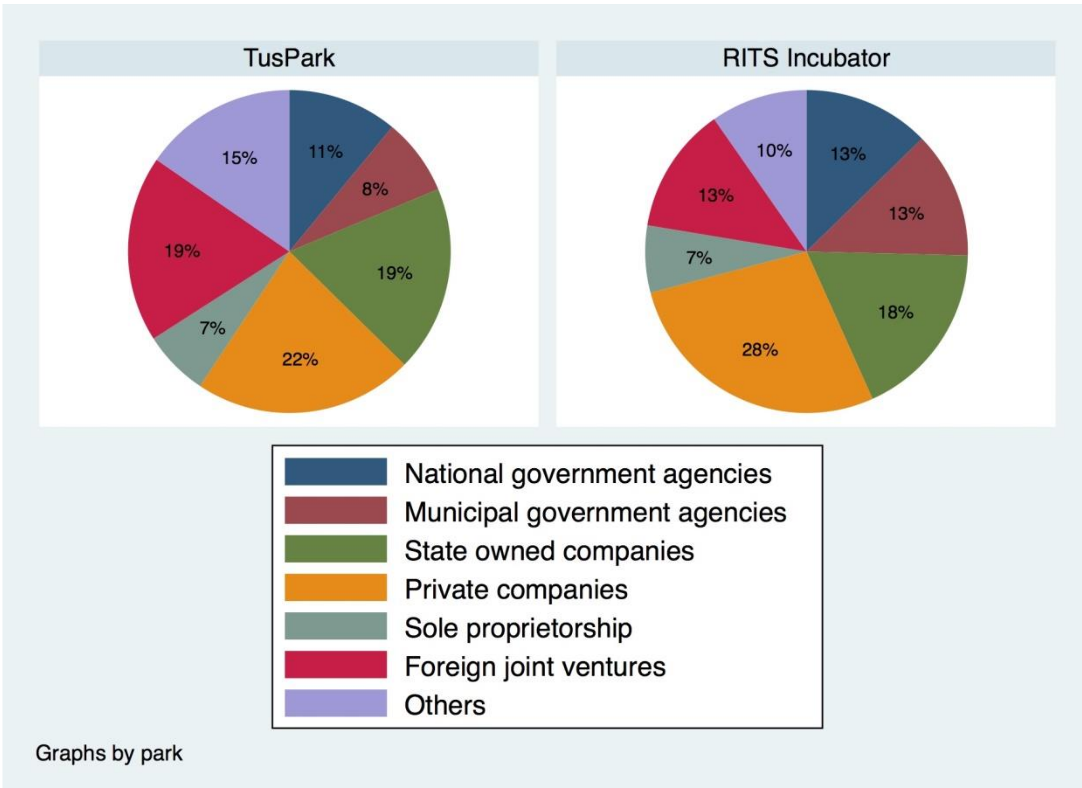


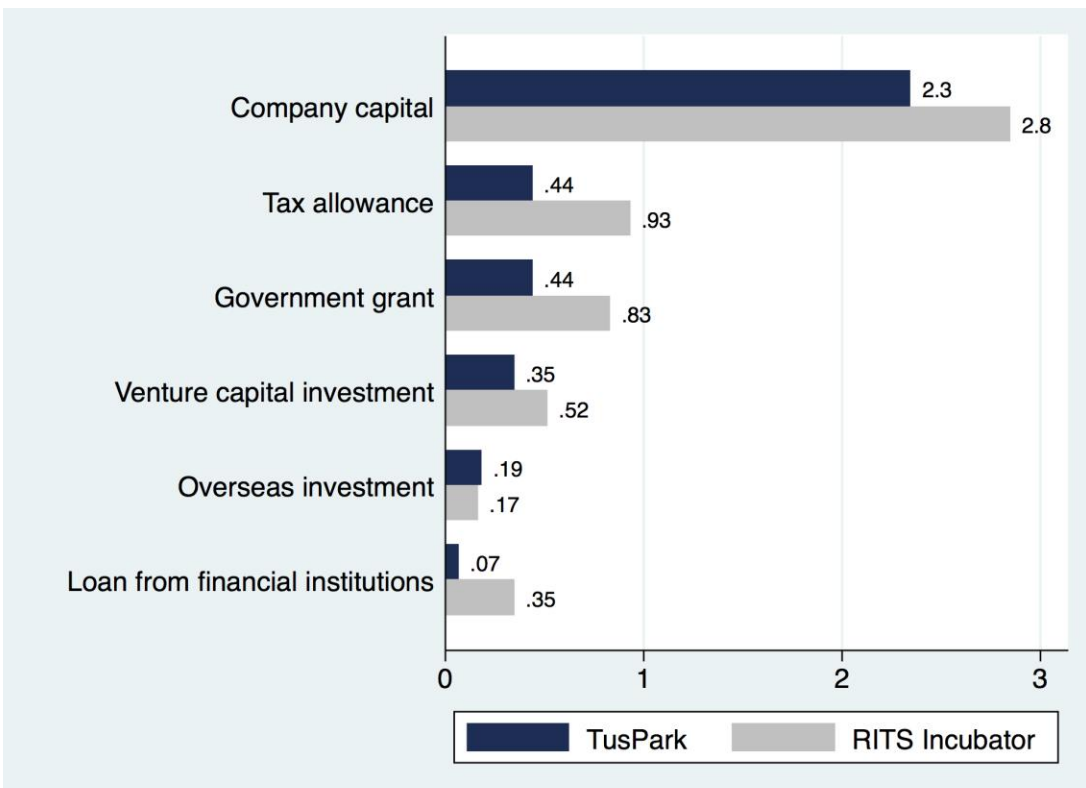
Figure 3-8 shows the shares of customers of new products developed by tenant businesses. In both TusPark and RITS Incubator, "private companies" are the main customers of new products. The percentage of tenants answering "private companies" as the main customers of new products are 5% higher than that in TusPark. On the contrary, the percentage of tenants regarding "foreign joint ventures" as major customers of new products is higher in TusPark than in RITS Incubator.

However, government agencies including "national governmental agencies", "municipal governmental agencies" and "state-owned companies" together account for 38% of responses in

TusPark, and 44% of responses in RITS Incubator. This indicates that linkages with governmental agencies are treated as important marketing channels for start-up businesses in science parks. Moreover, the percentage of government agency customers is higher in RITS Incubator (26%) than in TusPark (19%)

Figure 3-9 shows how innovation related expenses are financed. For tenants in both TusPark and RITS Incubator, company's own capital is regarded as the major source for covering innovation related expenses. Tax allowance and government grant are evaluated as the second and the third source for financing innovation related expenses.

Figure 3-9 Sources for financing innovation expenses



For those tenants that launched new products in the past three years, the survey asked them to evaluate their degree of satisfaction about the new product market performance. Figure 3-10 shows the difference. Overall, tenants in RITS have more satisfied new product sales as compared with tenants in TusPark. In TusPark, 25% of firms evaluate the new product sales as "unsatisfied". However, only 9% of firms in RITS evaluate the new product sales as "unsatisfied", the rest of firms evaluate the new product sales as relatively success or very success.

Figure 3-10 Evaluation of new product sales in TusPark and RITS

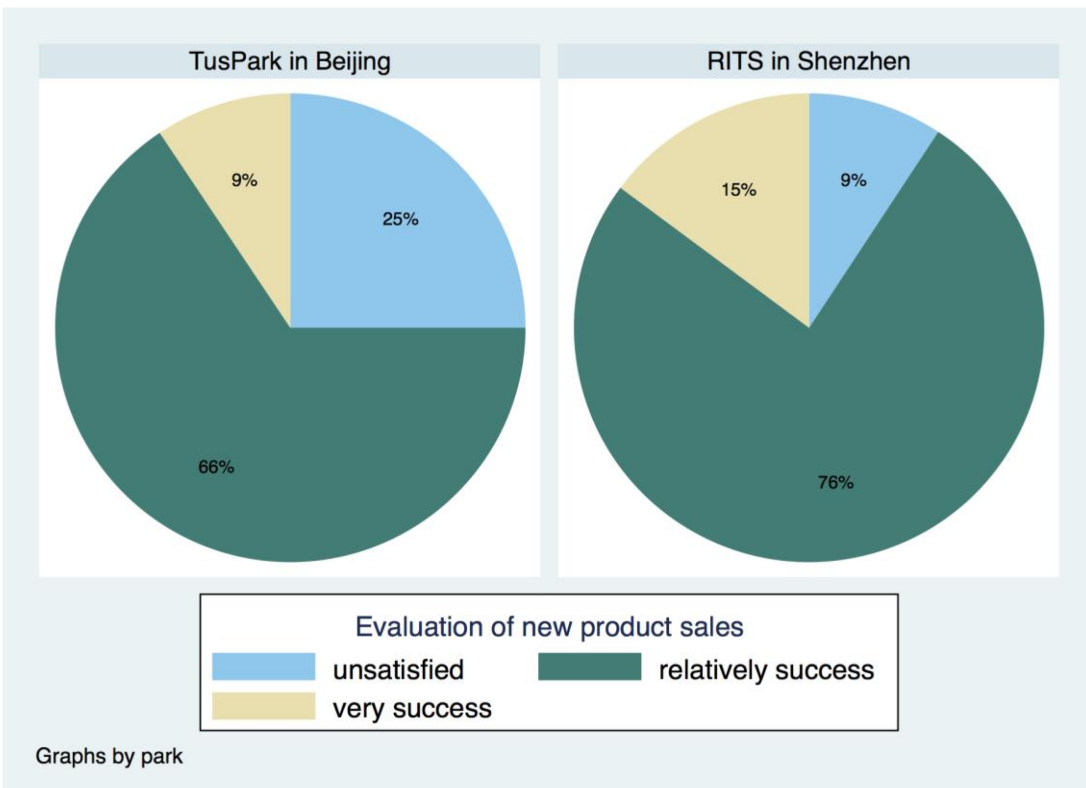
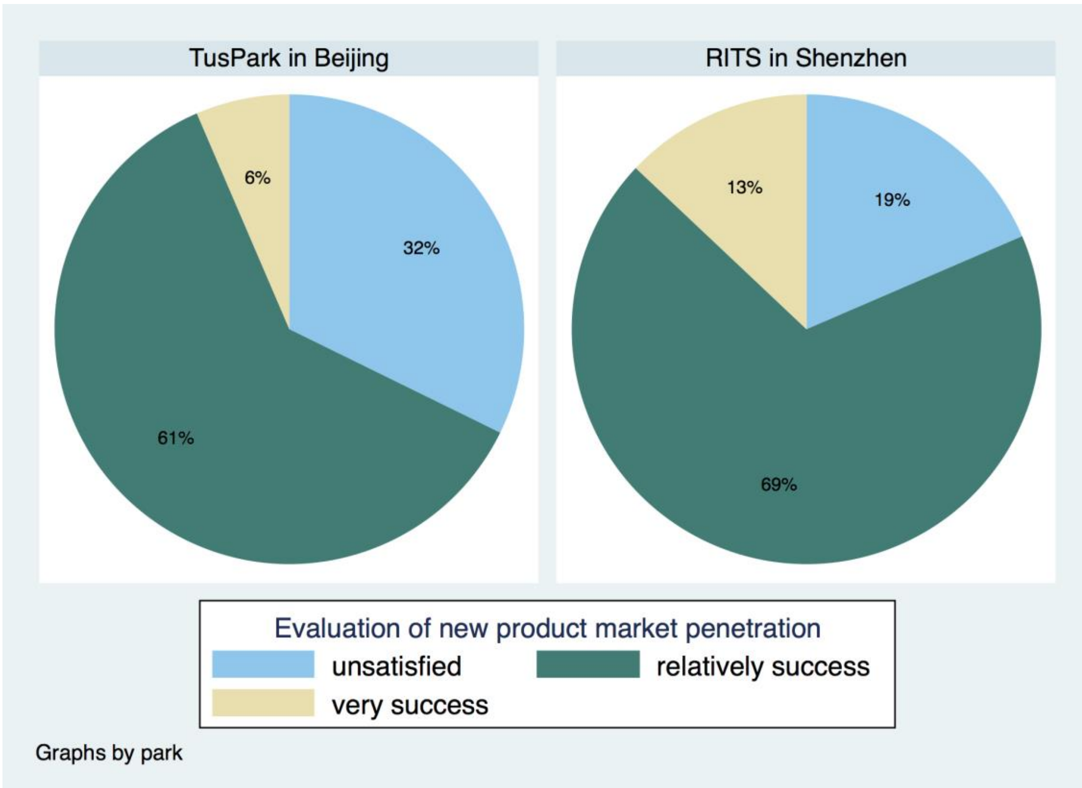


Figure 3-11 shows the difference of new product market penetration. Similar to the difference of new product sales, I found that firms in RITS are also more satisfied with the new product market penetration as compared with firms in TusPark. In TusPark, around 30% of firms think that the new product market penetration as "unsatisfied".

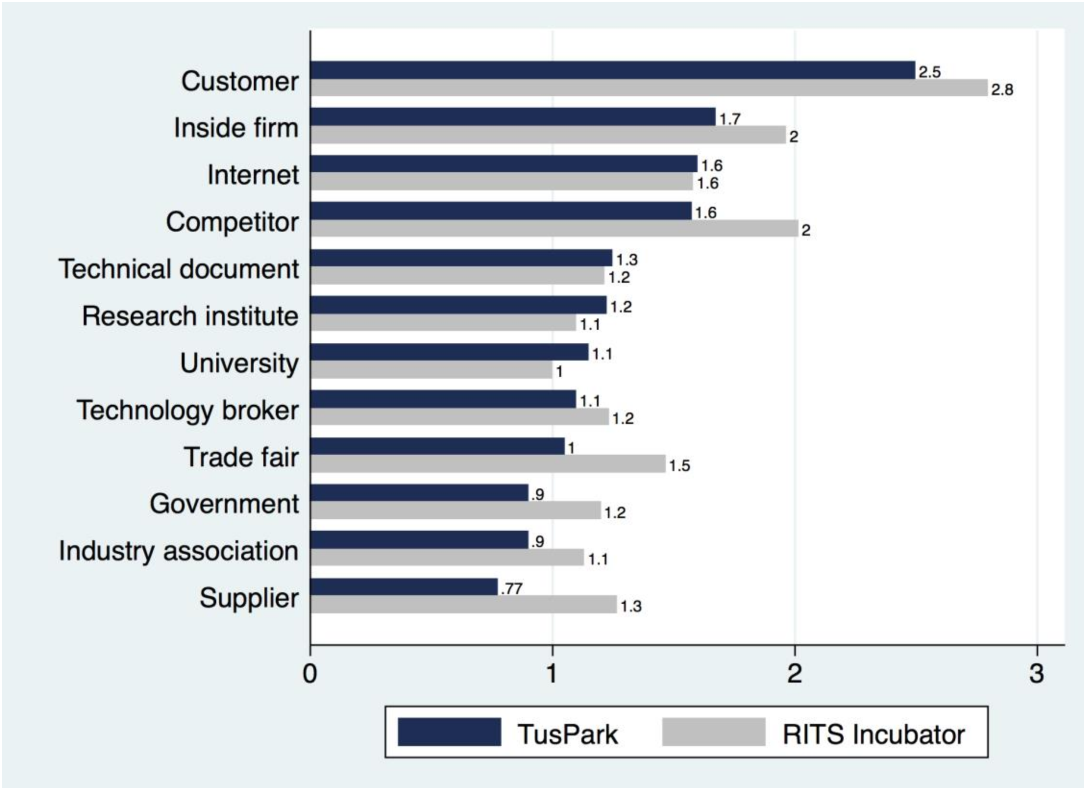
Figure 3-11 Evaluation of new product market penetration in TusPark and RITS



3.5.3. Innovation Sources Used in Firms' R&D

The survey asked the tenants to evaluate the importance of a broad range of knowledge sources of innovation ideas. Figure 3-12 shows that, in both TusPark and RITS Incubator, the importance of "Customers" as knowledge source is evaluated as "from medium to high", and is ranked as the most important knowledge source. On the other hand, in terms of importance of "Technical documents", "University" and "Research Institute" as knowledge sources, tenants in TusPark give slightly higher evaluation than tenants in RITS Incubator. It suggests that tenants in TusPark focus more on basic scientific knowledge-based sources for innovation.

Figure 3-12 Importance of various sources of innovation information



In order to examine in which knowledge sources tenants in the two parks have significantly different evaluation of importance, I conducted pairwise comparisons. The results are summarized in table 3-4. I found that tenants in TusPark have significant higher evaluation than tenants in RITS Incubator in terms of the importance of “Customers”, “Suppliers”, and “Competitors”. This indicates that tenants in RITS Incubator focus more on “business partnership” based knowledge source. On the other hand, table 3-4 shows that, in terms of importance of “Technical documents”, “University” and “Research Institute” as knowledge sources, tenants in TusPark gives slightly higher evaluation than tenants in RITS Incubator. It suggests that tenants in TusPark focus more on basic scientific knowledge based sources for innovation.

Table 3-4 Results of pairwise comparisons for RITS and TusPark

	i-Variable	j-Variable[a]	Mean Difference (i-j)	Significance levels of ANOVA[b] [c]	Pairwise comparisons[d]
1. Inside firm	1	2	0.292	0.149	
2. Customer	1	2	0.300	0.020	(1, 2)
3. Supplier	1	2	0.492	0.012	(1, 2)
4. Competitor	1	2	0.442	0.039	(1, 2)
5. Technology broker	1	2	0.133	0.547	
6. Industry association	1	2	0.233	0.232	
7. University	1	2	-0.150	0.462	
8. Research institute	1	2	-0.125	0.538	
9. Government	1	2	0.300	0.139	
10. Trade fair	1	2	0.417	0.053	
11. Technical document	1	2	-0.033	0.875	
12. Internet	1	2	-0.017	0.938	

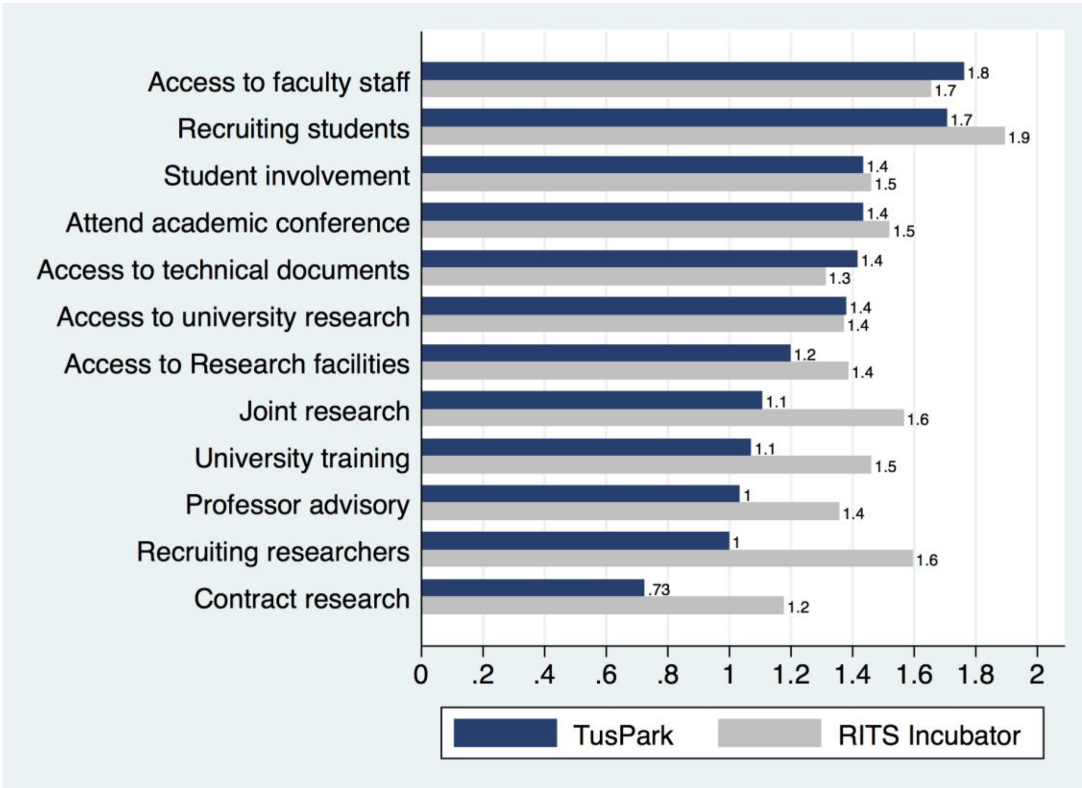
[a] 1: RITS; 2: TusPark.
[b] The mean difference is significant at the 0.05 level.
[c] Adjustment for multiple comparisons: Bonferroni.
[d] (1, 2) means that RITS has significantly higher mean than TSP at 0.05 significant level.

3.5.4. University – Industry Collaboration

The survey asked tenants in TusPark and in RITS Incubator to evaluate the importance of a variety of formal and informal university linkages. Figure 3-13 describes the results. I found that in both TusPark and RITS Incubator, the importance of "accessing to faculty staff" and "recruiting students" rank at the first place, suggesting that for tenants, informal university linkages such as mobility of university researchers and students are important channels of knowledge flow.

Because the rating of the importance of university linkages is highly correlated with each other, I use network analysis software Ucinet's function – Hierarchical clustering method to group highly correlated items into clusters. At each step, the two clusters that are most similar are joined into a single new cluster.

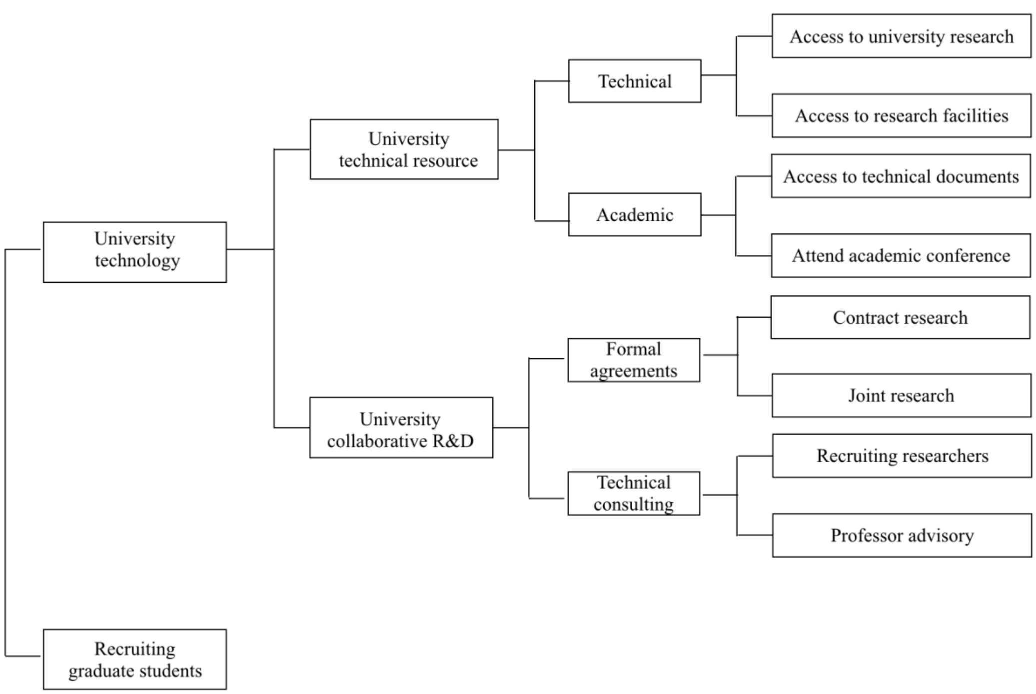
Figure 3-13 Importance of university linkages



Based on the hierarchical clustering results, I construct three new components of university linkages. As shown in table 3-5 and table 3-6, the three main groups of university linkages are: (1) University technical resource, including "Access to university research", "Access to research facilities", "Access to technical documents", and "Attend academic conference". (2) University collaborative R&D, including "Professor advisory", "Contract research", "Joint research", and "Recruiting researchers". (3) Recruiting students. Because "recruiting students" is regarded as an important type of university linkage in terms of university labor input, and it cannot be grouped into another cluster, I use "recruiting students" as a separate variable.

Table 3-5 Hierarchical clustering for university linkages

Table 3-6 Clustering of university linkages



3.5.5. Relationship between University Linkages and Product Innovation

The survey asked firms to answer whether they launched new products or not in the past three years, and whether the innovation sources of making the new product come from university / research institute. Table 3-7 shows the correlation between the ratings of importance of university linkages and whether firm has launched new products that used university knowledge as innovation sources.

Table 3-7 Correlation between importance of URI linkages and product innovation

Types of University Collaboration	New product developed through university collaboration
1. *Access to faculty staff*	0.16
2. *Access to technical documents*	0.21
3. *Access to university research*	0.31***
4. *Attend academic conference*	0.25***
5. *Access to research facilities*	0.28***
6. *University training*	0.08
7. *Student involvement*	0.15
8. *Recruiting students*	0.24***
9. *Recruiting researchers*	0.37***
10. *Professor advisory*	0.24***
11. *Contract research*	0.26***
12. *Joint research*	0.30***

*** *Significant at the 0.01 confidence level*

Table 3-8 Correlation between clusters of university links and product innovation

Types of University Collaboration	New product developed through university collaboration
1. University technical resource (Unitech)	0.29***
a. Access to university research	
b. Access to research facilities	
c. Access to technical documents	
d. Attend to academic conference	
2. University collaborative R&D (Unico)	0.33***
a. Contract research	
b. Joint research	
c. Recruiting researchers	
d. Professor advisory	
3. *Recruiting graduate students*	0.24***

*** *Significant at the 0.01 confidence level*

Table 3-7 and 3-8 show that the importance of the channels of access to university research, access to university research facilities, attend academic conference, recruiting researchers, professor advisory, contract research, joint research, and recruiting students are highly correlated with the product innovation dummy. These types of university linkages are exactly the sub-components of the three main groups of university linkages.

3.6. Empirical Analysis

3.6.1. Theoretical Prediction of Three-way -interaction

As discussed above, I found that compared with tenants in TusPark, tenants in RITS have better new product sales and market penetration. In this empirical analysis part, I empirically investigate the reason why firms in RITS have better new product performance in the market. On one hand, I found that the main difference between RITS and TusPark is that tenant firms in

RITS rely more on “market-driven” sources, such as information from customers, suppliers, and competitors. On the other hand, precious studies on the mechanisms of RITS concluded that one of the unique features of RITS in Shenzhen is the close collaboration between RITS’s laboratories and the tenant firms (He et.al, 2013). These laboratories are the main university technological resources that offered by RITS (Sun et al. 2009). In other words, those laboratories in RITS provide university technological R&D support for tenant firms.

The focus on “market-driven” innovation sources in RITS may contribute to the better new product performance of firms in RITS. On the other hand, because university collaboration may help firms to solve current technological bottle-necks, such new products developed using university technical know-how may be more competitive in the market. In RITS, the collaboration model makes it possible for tenant firms to effectively cater the current market needs with the RITS’s technological support, while such interaction model cannot be found in TusPark in Beijing. Therefore, I hypothesize that market driven innovation sources and new product innovation based on university technology jointly contribute to the new product market performance for tenant firms in RITS.

3.6.2. Methodology

I hypothesize that the positive relationship between better new product performance and locating in RITS may be jointly determined by the interaction between the degree of dependency on market-driven knowledge sources and product innovation through university collaboration. I use the Two-Stage Least Squares Estimation in Simultaneous Equation Models for the empirical analysis. I model **new product sales** as a function of **RITS dummy**, **dependency on market-driven sources**, and **product_uni (new product developed through university collaboration)**, controlling for evaluation of recruiting students, marketing experiences, firm age, firm size, and industries. Where μ is the error term.

$$\textbf{new product sales} = \beta_0 + \beta_1\textbf{product}_{\text{uni}} + \beta_2\textbf{RITS} + \beta_3\textbf{market force} + \beta_4\textbf{recruiting students} + \beta_5\textbf{marketing exp} + \beta_6\textbf{firm age} + \beta_7\textbf{firm size} + \beta_8\textbf{industries} + \mu$$

I hypothesize that university linkages are positively associated with new products developed through university collaboration, I expect that the three groups of university linkages have an impact on whether firms launched new products resulting from university collaboration, and I treat **product_uni** as endogenous. In the first stage of structural estimation, I use the Probit estimation, where v is the error term.

$$\textbf{Product}_{\textbf{uni}} = \pi_0 + \pi_1\textbf{Unitech} + \pi_2\textbf{Unico} + \pi_3\textbf{Recruiting students} + \pi_4\textbf{market force} + \pi_5\textbf{R\&D employee ratio} + \pi_6\textbf{firm age} + \pi_7\textbf{firm size} + \text{v}$$

The reason why I treat **product_uni** as endogenous is because there may be other omitted factors that can both influence the product sales and **product_uni.** In order to test the endogeneity problem, I need additional variables that are correlated with **product_uni**, but uncorrelated withμ. The new additional variables should not affect new product sales directly. Because I assume that the three groups of university linkages have an impact on **product_uni**, and they do not affect new product sales directly, I use the types of university linkages as the new variables. I use the DWH test suggested by Davidson and MacKinnon (1993) to test the endogeneity problem.

$$\textbf{sales} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1\text{Product innovation} + \boldsymbol{\beta}_2\text{RITS} + \boldsymbol{\beta}_3\text{Market force} + \boldsymbol{\beta}_4\text{Industry} + \boldsymbol{\beta}_5\text{Product innovation\_residuals} + \boldsymbol{\varepsilon}$$

The DWH test (Davidson, 1993) is formed by including the residuals of each endogenous right-hand side variables as a function of all exogenous variables. In the above functions, If is significantly different from zero, then OLS is not consistent and I should use the instrumental variables.

I use the following procedures to perform the DWH test in the software STATA. In the first step, the “Unico” (*University collaborative R&D* group of university linkages) and “Recruiting students” are used as additional instrumental variables. The “Unitech” (*University technical resource* group of university linkages) is not added because it is highly correlated with “Unico”. As indicated by table 3-9, the small p-value indicates that OLS is not consistent. Therefore, the DWH test suggests that the two stage structural estimation method should be used.

Table 3-9 Testing endogeneity

prod_uni	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
unico	.5459731	.1679374	3.25	0.001	.2168219	.8751243
Recruiting_students	.0775521	.1630341	0.48	0.634	-.2419889	.3970931
firm_size	.0005301	.0013756	0.39	0.700	-.0021661	.0032263
rd_ratio	.0938706	.6746824	0.14	0.889	-1.228483	1.416224
firmage	-.010735	.0445246	-0.24	0.809	-.0980016	.0765317
ICT	-5.185055	328.5475	-0.02	0.987	-649.1263	638.7561
Enviornment_energy	-5.122895	328.5479	-0.02	0.988	-649.0649	638.8191
Others	-6.176425	328.5487	-0.02	0.985	-650.1201	637.7673
_cons	4.927383	328.5473	0.01	0.988	-639.0135	648.8683

. predict prod_uni_res

sales	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rits_dummy	.3716226	.2332824	1.59	0.115	-.0923668	.8356119
Recruiting_students	-.102361	.1043869	-0.98	0.330	-.3099823	.1052603
prod_uni	.1607032	.2528193	0.64	0.527	-.3421442	.6635505
prod_uni_res	1.392309	.6519785	2.14	0.036	.0955504	2.689069
market_driven_sources	-.0076458	.1398016	-0.05	0.957	-.2857055	.2704139
firmage	.0399647	.0277789	1.44	0.154	-.0152864	.0952158
ICT	.6013135	.4414919	1.36	0.177	-.2767961	1.479423
Enviornment_energy	.4848352	.4927784	0.98	0.328	-.4952812	1.464952
Others	1.662659	.7481705	2.22	0.029	.1745776	3.15074
_cons	.8479578	.6874489	1.23	0.221	-.5193505	2.215266

```
. test prod_uni_res

 ( 1)  prod_uni_res = 0

       F(  1,    83) =    4.56
            Prob > F =    0.0357
```

The samples are 93 firms that launched new products in the past three years (38 firms from TusPark, and 55 firms from RITS). In the first stage of estimation, I use the Probit model and the dependent variable is *Product_uni*; in the second stage of estimation, I use OLS model and the dependent variable is *New product sales* and *New product penetration*. The main independent variables include *RITS dummy, Market driven sources, Unitech, Unico,* and *Recruiting students*. Table 3-10 describes the measurement of the dependent, independent, and control variables.

Table 3-10 Definition of variables

Variables	Definition of variables
Dependent variables	
1. *Product_uni:*	=1 if the new product is developed through university / research institute collaboration; =0 otherwise
2. *New product sales:*	Degree of satisfaction on sales of new products in the past three years
3. *New product penetration:*	Degree of satisfaction on market penetration of new products in the past three years
Independent variables	
1. *RITS dummy:*	=1 if located in RITS; =0 if located in TusPark
2. *Market-driven sources:*	the average score of "Customer, supplier, and competitor"
3. *Unitech:*	the average score of group "university technology resources"
4. *Unico:*	the average score of group "university collaborative R&D"
5. *Recruiting students:*	the score of "Recruiting students"
Control variables	
6. *Marketing experience:*	the year of marketing experience of founder
7. *R&D employee ratio:*	the percentage of R&D personnel
8. *Firm age:*	firm age until the survey year
9. *Firm size:*	the log of firm's number of employees
10. *Industry dummies:*	ICT, biotech, new energy and environment, and others

3.6.3. Research Findings

Firstly, as shown in table 3-11, in the first stage Probit estimation model, I found that the three groups of university linkages: accessing to university technical resources, building university collaborative R&D, and recruiting university students all have positive and significant impact on firm's new product innovation, which resulting from university collaboration.

Table 3-11 Structural estimation first stage

First stage Probit estimators	Product_uni		
	(1)	(2)	(3)
RITS	-0.276	-0.608	-0.458
	(0.395)	(0.390)	(0.356)
Unitech	**0.699*****		
	(0.174)		
Unico		**0.607*****	
		(0.166)	
Recruiting students			**0.261***
			(0.142)
R&D employee ratio	-0.473	-0.633	-0.992*
	(0.561)	(0.542)	(0.509)
log (N. of employees)	0.0940	0.0670	0.152
	(0.152)	(0.147)	(0.135)
Firm age	0.0316	0.0277	0.0370
	(0.0566)	(0.0537)	(0.0500)
Constant	-0.387	0.144	0.0974
	(0.457)	(0.407)	(0.434)
Observations	93	93	93

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Secondly, in the second stage model, I investigate the reason why firms in RITS have better new product sales and market penetration? In table 3-12 and table 3-13, I construct the three way interaction term among RITS dummy, dependency on market-driven sources, and product_uni dummy. I found that the coefficient of the three way interaction term is positive and significant in all the four models. However, the coefficients of the interaction term "RITS × product_uni", "market-driven sources × product_uni", and "RITS × market-driven sources" are negative and significant. Scholars suggest that when interpreting three-way interactions, the lower-order interactions cannot be interpreted in the presence of significant higher-order interactions (Skarlicki et al. 1999), only the highest order of interaction between RITS dummy, dependency on market-driven sources, and product_uni dummy is the interest of this study.

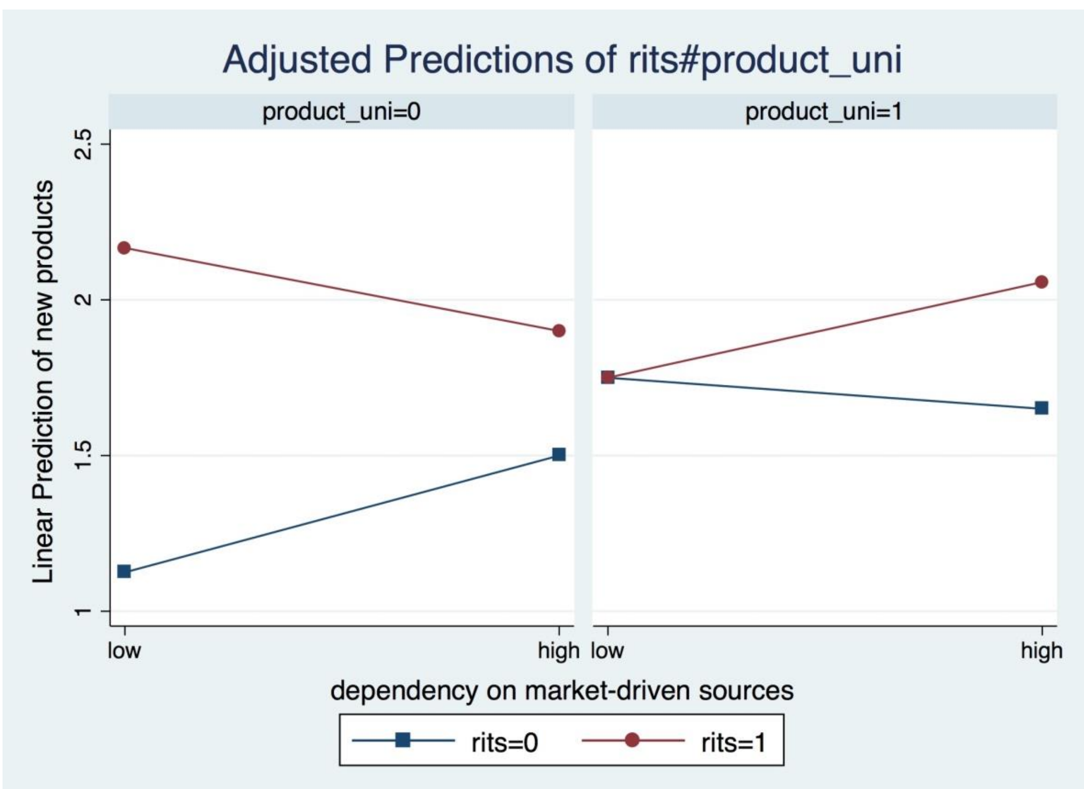
Table 3-12 Structural estimation second stage (Sales)

Second stage linear prediction	New product sales		
	(1)	(2)	(3)
Product_uni	1.219**	1.421**	-0.117
	(0.602)	(0.602)	(1.124)
RITS	1.484***	1.500***	1.484***
	(0.574)	(0.570)	(0.504)
Market-driven sources	0.341	0.363	0.442*
	(0.301)	(0.298)	(0.234)
RITS × Market-driven sources × Product_uni	**1.093****	**1.075****	**1.280*****
	(0.492)	**(0.490)**	**(0.439)**
RITS × Product_uni	-2.055**	-2.004**	-2.316***
	(0.806)	(0.807)	(0.752)
Market-driven sources × Product_uni	-0.586	-0.601*	-0.680**
	(0.359)	(0.356)	(0.309)
RITS × Market-driven sources	-0.762*	-0.766*	-0.901***
	(0.404)	(0.401)	(0.325)
Recruiting students	-0.0115	-0.0202	0.101
	(0.0742)	(0.0733)	(0.128)
Marketing experience	0.0124	0.00940	0.0130
	(0.0155)	(0.0161)	(0.0155)
Firm age	0.0178	0.0168	0.0237
	(0.0215)	(0.0217)	(0.0292)
log (N. of employees)	0.133**	0.130*	0.174*
	(0.0664)	(0.0670)	(0.0910)
Industry dummy	Yes	Yes	Yes
Constant	0.486	0.340	1.094*
	(0.530)	(0.521)	(0.656)
Observations	93	93	93

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

For better interpreting the three-way interaction, I create a graph of new product sales as a function of RITS_dummy, product_uni dummy, and dependency on market-driven sources. The graph in figure 3-14 illustrates how the slope of dependency on market-driven sources varies as a function of RITS_dummy and product_uni dummy. On the right hand part of the graph, I found that in RITS, new products resulting from university collaboration and with more dependency on market-driven sources are associated with better new product sales. This result suggests that in RITS, the new products, which are responding to the latest trend of current market needs and are also combined with university technology, are more competitive in the market. However, in TusPark, the dependency on market-driven sources does not lead to better performance of new product resulting from university collaboration.

Figure 3-14 The effect of three-way-interaction on new product sales



The left hand part of the graph shows that in TusPark, new products which are not resulting from university collaboration but with more dependency on market driven sources are associated with better product sales. However, left part of the graph shows that in RITS, new products which are not resulting from university collaboration but with low dependency on market driven sources are associated with better new products. I infer that those firms in RITS with low dependency on market driven sources but have better new product sales may be the ones that already have established and matured market channels.

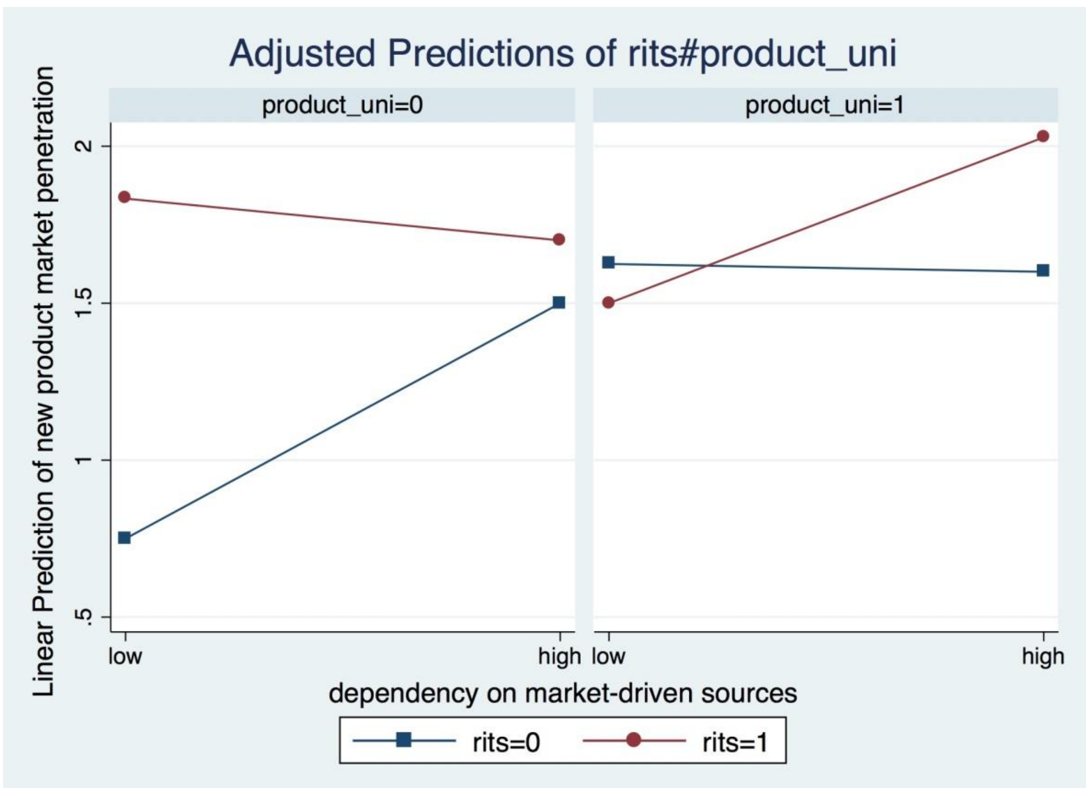
Table 3-13 Structural estimation second stage (market penetration):

Second stage linear prediction	New product market penetration		
	(1)	(2)	(3)
Product_uni	1.489**	1.476**	0.454
	(0.594)	(0.595)	(0.917)
RITS	1.622***	1.609***	1.592***
	(0.567)	(0.566)	(0.539)
Market-driven sources	0.401	0.398	0.441
	(0.296)	(0.296)	(0.273)
RITS × Market-driven sources × Product_uni	**1.071****	**1.048****	**1.190****
	(0.486)	**(0.487)**	**(0.472)**
RITS × Product_uni	-1.967**	-1.905**	-2.129***
	(0.797)	(0.801)	(0.784)
Market-driven sources × Product_uni	-0.545	-0.535	-0.581*
	(0.354)	(0.353)	(0.336)
RITS × Market-driven sources	-0.856**	-0.853**	-0.940**
	(0.398)	(0.398)	(0.373)
Recruiting students	-0.0210	-0.0186	0.0608
	(0.0735)	(0.0729)	(0.106)
Marketing experience	-0.000118	-0.00127	0.00227
	(0.0154)	(0.0159)	(0.0152)
Firm age	0.0180	0.0180	0.0230
	(0.0216)	(0.0216)	(0.0251)
log (N. of employees)	0.155**	0.156**	0.186**
	(0.0665)	(0.0666)	(0.0792)
Industry dummy	Yes	Yes	Yes
Constant	0.0272	0.0495	0.601
	(0.526)	(0.517)	(0.603)
Observations	93	93	93

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3-13 and figure 3-15 shows the result for new product market penetration. The right part of figure 3-18 shows that in RITS, new products resulting from university collaboration and with more dependency on market-driven sources are also associated with better market penetration. However, in TusPark, the dependency on market-driven sources is not associated with better market penetration. The results suggest that the institutional differences between firms in RITS and TusPark lead to the different market performance.

Figure 3-15 The effect of three-way-interaction on new product market penetration



The left part of figure 3-18 shows that in TusPark, new products which are not resulting from university collaboration but with more dependency on market driven sources are associated with better market penetration. However, in RITS, for firms with new products which are not resulting from university collaboration, the dependency on market driven sources has little effect on market penetration. The results suggest that in RITS, products resulting from university collaboration and the high dependency on market-driven innovation sources lead to better market penetration.

3.6.4. Implications

This paper explores what factors contribute to the more successful new product sales and market penetration for tenants in RITS. I found that the high dependency on market-driven innovation sources and developing new products through university collaboration lead to higher market performance of new products for firms in RITS in Shenzhen, but not for firms in TusPark in Beijing. One of the possible reasons is that RITS particularly provide market-oriented university technology support for tenant firms, whereas such support is not in place in TusPark.

One of the main differences between RITS and TusPark is that RITS provide very applied-research oriented and market focused technical support to tenant firms, for example, one of university technical support is providing pilot scale experiment platform for tenant firms. RITS provide the space, facilities, and researchers for tenant firms to conduct intermediary pilot experiments with the customers of tenant firms (He et al. 2013). However, such university technology supporting system is not in place in TusPark. Therefore, in RITS, the university collaboration through university technology support can help tenant firms to effectively respond to the information collected from customers, suppliers, and competitors, and coming up with new products which are in current market needs. However, because such market-oriented university technology support is not in place in TusPark, the university collaboration may not help firms to best respond to the information collected from market-driven sources. Thus high dependency on market-driven innovation sources and developing new products through university collaboration lead to higher market performance of new products for firms in RITS in Shenzhen, but not for firms in TusPark in Beijing.

The research findings draw managerial implications for domestic Chinese firms as well as policy implications for Chinese government. Firstly, when making the decision of choosing which university science park to locate on, firms may consider their objective of university collaboration and the institutional differences between university science parks. Scholars suggested that firms' objective of university collaboration is either seeking university technology seeds for new project development, or seeking university technology support for firms' current R&D project completion (Cohen et al. 2002). If firms' aim of university collaboration is more towards seeking new product ideas and opening new markets, locating in TusPark in Beijing is beneficial for finding more university technology seeds; If firms' aim of university collaboration is more towards seeking university technology support for accelerating development of current products, which are highly responding to current market needs, then firms may consider to locate in RITS in Shenzhen.

Secondly, this paper suggests that Beijing and Shenzhen both have their own unique regional innovation characteristic. University science parks are embedded in the city's own regional innovation system, and institutional differences between university science parks in Beijing and Shenzhen are raised. One of the policy implications for the municipal government is to make use of the city's own comparative advantage, which is embedded in its regional innovation system. For example, Beijing has a long history of universities and research institutes, top universities such as Tsinghua University has accumulated abundant university technologies waiting for commercialization. Thus, the Beijing city government could consider giving preferential policies on commercializing university technology and on helping firms to expand the new market.

On the other hand, Shenzhen has a long history of industrial development, but a short history of universities and research institutes. Local universities in Shenzhen play a role in technology supporting for local high-tech firms. The findings in my research suggest that the institutional difference between TusPark in Beijing and RITS in Shenzhen lies in that tenants in RITS rely more on market-driven sources. Such market-driven knowledge sources and the market-oriented university R&D support together give a positive impact on the new product market performance for tenants in RITS. Thus, the Shenzhen city government could consider giving preferential policies on encouraging company sponsored university industry collaboration projects, and university R&D support for firms' development of those new products that are highly responding to current market needs.

3.7. Conclusions

This paper explores the role of University Science Park on tenant firms' innovation and business performance by conducting quantitative analysis of tenants in Tsinghua University Science Park (TusPark) and Incubator of Research Institute of Tsinghua University in Shenzhen (RITS). In terms of innovation performance, 86% of firms in RITS have new products in the past three years, and 77% of them have patents. Whereas 77% of firms in TusPark have new products in the past three years, and 53% of them have patents. In terms of business performance, firms in RITS also have better new product sales and new product market penetration as compared with firms in TusPark: 91% of firms in RITS evaluated their new product sale was successful, whereas 75% of firms in TusPark evaluated their new product sale was a success in the market.

I found that the main institutional difference lies in that the innovation sources for firms in RITS are more “market-driven”. Firms in RITS rely more on market-driven innovation sources: such as information from customers, suppliers, and competitors. In the empirical analysis part, I found that the dependency on market-driven knowledge sources (information from customers, suppliers, and competitors) and developing new products through university collaboration jointly contribute to the better performance of new products of firms in RITS.

This paper makes three contributions to the current literatures on University Science Park in China. Firstly, by using Chinese university science park survey data, I provide empirical evidence that inside Chinese university science parks, the three types of university collaboration contribute to tenant firms’ new product innovation. Secondly, I found that the main institutional difference between RITS and TusPark is that the innovation in RITS is more based on “market-driven” knowledge sources, including knowledge from customers, suppliers and competitors. Thirdly, I empirically found that in RITS, collaborating with university and with a market driven focus partially explained the better new product performance of firms in RITS.

This paper examines the role of university science parks, and draws important implications for the domestic Chinese firms as well as municipal government in China. Firstly, when choosing which University Science Park to locate on, domestic firms may consider their type of R&D activities, their aim of university collaboration, and the institutional context of the regional innovation system that the University Science Park is embedded in. Secondly, the municipal government in China should make use of the city’s own competitive advantages, which are embedded in the regional innovation systems, and accordingly issue preferential innovation policies for local University Science Parks.

3.8. Limitations and Further Research

One of the limitations of this research is the different timing of the survey. The survey for tenants in TusPark was conducted in 2008, whereas the survey for tenants in RITS was conducted in 2011. Therefore, the time span for the survey in TusPark is 2006-2008, whereas the time span for survey in RITS is 2008-2010. Only the year 2008 is overlapped. However, as shown in figure 3-1, from patent statistics I didn't find any significant changes for university and firm innovation before and after 2008. Therefore, the survey data in TusPark and in RITS is still comparable. This paper focused on the comparison between Tsinghua University Science Park in Beijing and the Research Institute of Tsinghua University in Shenzhen. In future research, international comparison is worthwhile. For example, recently studies show the difference of entrepreneurial process and performance for MIT and Tsinghua University alumni entrepreneurship (Eesley et al. 2016). The cross-national comparison on University Science Park of MIT and Tsinghua will give more insights on the strengths and weaknesses of each University Science Park.

4. Chapter 4: Multinational Corporations and Knowledge Diffusion to Domestic Firms in Shanghai: Evidence from Patent Citation Data

4.1. Introduction

The Chinese government has been keen on attracting multinational corporations (MNCs) to set up research and development (R&D) centers in China, with the hope of gaining knowledge flow and externalities from MNCs to domestic Chinese firms. Shanghai is one of the cities that attracted a large number of MNC R&D centers. The Shanghai municipal government has spent huge efforts to attract MNCs to establish R&D centers in Shanghai. The Shanghai Foreign Investment Commission is responsible for the approval of establishment of MNC R&D centers in Shanghai. Shanghai Foreign Investment Commission issued the “circulation on questions of establishing research and development institutions with foreign capital” in 2000, and the “suggestions of Shanghai municipality to encourage foreign capital to establish research and development institutions” in 2003. These two provincial documents are the regulations on establishing R&D institutions with foreign capital in Shanghai, which specified preferential policies in import tax duties, income and corporate tax, land cost and planning expenses, foreign exchange management, intellectual property rights protection, etc. The Shanghai municipal government issues the preferential policies for MNC R&D centers in Shanghai at least in the hope of positive externalities from foreign MNCs on domestic Chinese firms. As one of the important core carrier of developing Shanghai into Innovation Hub with global influence, Zhangjiang Science Park management committee drafted the "2015 Zhangjiang Science Park Action Plan of Establishing Global Innovation Hub.", which emphasized the connection between Shanghai free trade experimental zone and Zhangjiang National Science Park, and aimed at accelerating the establishment of technology innovation hub with global influence.

Innovation is well-known to be geographically concentrated (Jaffe et al. 1993). Previous studies on MNCs suggests that MNCs excel at transferring and developing knowledge across borders, and can overcome the geographical constraint on international diffusion (Kogut & Zander 1993). Moreover, the globalization of MNC's R&D is regarded as an important channel of knowledge diffusion to local firms in host countries. There is an abundant empirical literature on productivity and technology spillovers effects of foreign direct invest (FDI) on innovation performance of local firms in host countries. Previous studies largely focused on the "North-North" pattern of international knowledge sourcing with FDI in R&D departing from developed countries and targeting other developed countries (Branstetter 2006; Jaffe & Trajtenberg 1999), and analyzed the knowledge spillover effects on local firms in host countries (Branstetter 2006; Singh 2007).

Recent studies show that international knowledge sourcing may also follow a "North-South" pattern with FDI in R&D departing from developed countries and targeting emerging economies, and the knowledge spillover effects on local firms in developed countries as host countries, such as China and India (Branstetter et al. 2013; Feinberg & Majumdar 2001; Mrinalini & Wakdikar 2008). Recent literatures show that the R&D activities of MNCs in China may also generate knowledge and productivity spillover effects on domestic Chinese firms (Cheung & Ping 2004; Filatotchev et al. 2011; Liu & Buck 2007; Motohashi & Yuan 2010).

Previous studies long recognized that inter-firm human mobility as a key driver of knowledge diffusion between firms (Almeida & Kogut 1999; Ganco 2013). Scholars named the knowledge sourcing through employee mobility as "learning-by-hiring" (Almeida et al. 2003). Human mobility also facilitates knowledge transfer across borders (Johnson & Regets 1998; Saxenian 2006). Recent studies show that cross border human mobility is an important channel of knowledge diffusion in technological catching-up countries. Returnee inventors who had working experiences at foreign MNCs and who later moved to Korean and Taiwan firms are found to cite more patents of their former MNC employers when innovating at Korean and Taiwan firms (Song et al. 2001). Chinese returnees who moved from foreign MNCs to domestic Chinese firms are also found to play important roles in knowledge spillover to domestic firms (Filatotchev et al. 2011).

Literatures on multinationals and international knowledge diffusion demonstrated two empirical methodologies to measure knowledge diffusion in host countries. The first empirical approach is to estimate the effect of foreign direct investment on the productivity of domestic firms in host countries (Haskel et al. 2007; Smarzynska Javorcik 2004). An alternative empirical approach is to measure knowledge diffusion from foreign multinationals to domestic firms by using patent citation data. By using patent citations as an indicator of knowledge spillover, scholars found that

Japan's FDI in the U.S. acted as a channel of knowledge spillover to domestic firms in the U.S. (Branstetter 2006). Knowledge diffusion from U.S. and Japan MNCs are found to play an important role in the technology catching-up processes for Korean and Taiwan local firms (Hu & Jaffe 2003). Recent studies also explored the impact of Indian returnee inventors who are hired aboard on the value of Indian patents (Alnuaimi et al. 2012). However, most studies on foreign multinationals and knowledge diffusion in China used the first empirical approach to analyze knowledge spillover effects on the productivity of Chinese domestic firms. There is little empirical studies use the second empirical approach – using patent citation data to measure knowledge diffusion in China. Also, there is limit empirical study on analyzing the impact of returnee inventor on knowledge diffusion in China at the patent level.

Literature has emphasized that foreign direct investment and human mobility are two important channels of knowledge flows to domestic firms in China. However, literature on how foreign direct investment and human mobility together contribute to knowledge diffusion to domestic firms in China still remains inconclusive. This paper takes the methodology of measuring knowledge diffusion by using patent citation data, and aims to contribute to the current literatures by addressing the following questions: (1) how actively do foreign MNCs leverage domestic inventors and conduct innovation in Shanghai in China? (2) Whether domestic Chinese firms' patents that are created after MNCs entered Shanghai tend to make more citations to MNCs? (3) Whether domestic Chinese firms' patents involving returnee inventors are more likely to make more citations to MNCs?

I use U.S. patent data for the analysis. I started from extracting all U.S. patents with inventor addresses in Shanghai city, and distinguish the applicants as domestic Chinese firms or foreign

MNCs. Using patent citation data, this paper suggests that the probability of knowledge flow is greater when domestic Chinese firms' patents are created after MNCs entered Shanghai, the probability of knowledge flow is also greater when domestic Chinese firms' patents involve returnee inventors who moved from foreign MNCs to domestic Chinese firms.

4.2. Hypotheses

Knowledge flows from MNCs and host country firms has long been a hot topic in the international management literatures. The host country governments continuously spend huge efforts in attracting foreign direct investment, at least with the purpose of gaining knowledge flow from them. Particularly, for developing country governments, attracting foreign direct investment from advanced countries is an important way of gaining knowledge flow. However, literature on how domestic firms in developing countries as host countries could gain knowledge flow from foreign direct investment is limited (Singh 2003).

Previous studies largely focus on the "North-North" pattern of international knowledge diffusion with foreign direct investment departing from developed countries and targeting on other developed countries (Keller 2002; 2004). Scholars have been focusing on developed countries as host countries and show that foreign multinationals in developed countries contribute to local knowledge spillover. The foreign subsidiaries of European firms were found to result in productivity gains to the host countries (Kokko 1992). Foreign MNCs in the U.S. were found to contribute to local technological progress (Almeida 1996). Scholars also examined knowledge spillover between MNCs and host countries, and found that foreign MNCs contribute less to host country knowledge than they gain from it (Singh 2003; 2007).

However, recent literatures show that international knowledge spillover may also follow a "North – South" pattern with foreign direct investment departing from developed countries and targeting on emerging economies as host countries. Empirical evidence suggests that Chinese domestic firms benefit from foreign MNCs (Lin et al. 2009). Foreign MNCs in China are found to generate knowledge spillover effects on innovation performance of domestic firms only when domestic firms' absorptive ability is taken into account (Liu & Buck 2007).

Most literatures on knowledge flow from foreign MNCs to Chinese domestic firms take Beijing city as an example (Liu & Buck 2007; Zhou & Xin 2003). China had a history of centrally planned economy. Beijing has been the center of policy and education, and is concentrated with the most political and educational resources. Therefore, Beijing has been attracting a lot of foreign MNCs to benefit from the policies and a large availability of local talents.

However, the technology landscape in developing countries such as China is highly uneven. Among innovation regions in China, there are considerable differences in local industrial and institutional resources, as well as their positions in MNCs' and China's strategies (Zhou & Xin 2003). As one of the important core carrier of developing city Shanghai into Innovation Hub with global influence, Zhangjiang Science Park management committee drafted the "2015 Zhangjiang Science Park Action Plan of Establishing Global Innovation Hub", which focuses on accelerating the establishment of technology innovation hub with global influence. Shanghai has a long tradition of both industrial and educational development, and has a global environment which is open to foreigners. The analysis of knowledge flow from MNCs to Chinese domestic firms in Shanghai will give us a more complete understanding of foreign multinationals and international knowledge diffusion in China.

Before MNCs enter the host country, local firms have limited interaction chances with MNCs and are less likely to get knowledge flow from MNCs. However, after MNCs entered the host country through FDI in R&D, the close geographically proximity to MNC R&D facilities provides chances for domestic firms' inventors to interact with MNCs inventors that are employed at MNC subsidiaries, and may facilitate the knowledge transfer from MNCs to local firms. Thus my first hypothesis suggests that if domestic firms' inventions are made after MNCs entered in Shanghai, the domestic firms' inventions are more likely to make citations to MNCs' patents:

HYPOTHESIS 1. *The probability of knowledge flow through international patent citation is greater when Chinese domestic firms' inventions are created after MNCs entered Shanghai*

Literatures on knowledge diffusion show that human mobility plays an important role in knowledge diffusion between firms (Almeida & Kogut 1999; Almeida et al. 2003; Choudhury 2010). Recent studies show that inventor mobility provides a channel of international knowledge flow from foreign multinationals to domestic firms. Returnee inventors who moved from foreign MNCs to Korean and Taiwan firms were found to contribute to the technological catching-up progress for Korean and Taiwan firms in the ICT industry (Song et al. 2001). Human mobility from foreign multinational subsidiaries to Chinese domestic firms in Zhongguancun high-tech cluster in Beijing were found to generate knowledge spillover effects on domestic firms (Filatotchev et al. 2011).

Tacit knowledge which is imperative for making new inventions is "sticky" and will not move unless the inventor who processes that knowledge also move (Szulanski 1996; 2000). Nelson and Winters (1982) claim that frequent face-to-face formal or informal interactions and learning-by-observing are imperative for transferring tacit knowledge. Returnee inventors who had working experience at multinationals and who later moved to domestic Chinese firms are expected to contribute to the international knowledge diffusion. Because returnee inventors are expected to have their global innovation networks that were accumulated when they worked at foreign multinationals, the inventions created by returnee inventors at domestic Chinese firms are more likely to obtain the knowledge flow from foreign multinationals. My second hypothesis suggests that besides foreign direct investment, human mobility is another channel of gaining knowledge flow from foreign MNCs for domestic Chinese firms.

HYPOTHESIS 2. *The probability of knowledge flow through international patent citation is greater when Chinese domestic firms' inventions are created by returnee inventors*

4.3. Data on Firm Ownership and Patent Citation

4.3.1. Data on U.S. patents with Inventor Address in Shanghai

I use the Disambiguation and Co-authorship Network of the U.S. Patent Inventor Database (Fleming et al. 2014) and PATSTAT 2015 version for the data construction. The Disambiguation and Co-authorship Network of the U.S. Patent Inventor Database (which will be abbreviated as The U.S. Patent Inventor Database below) includes detailed inventor address for each inventors of a patent, and assigns each inventor a unique inventor ID, which is useful to identify inventor mobility.

First, in order to identify the innovation activities of firms in Shanghai, I extract all U.S. patents with at least one inventor whose address is in Shanghai. Second, because I focus on firm applicants, I only keep the patents that are applied by firms as single applicants, and exclude patents that are applied by other type of applicants, such as universities, research institutes, and individuals, by screening the name of applicants. Finally, I standardize all applicant names by removing unnecessary spaces, correcting misspelled names, etc.

However, because the patent grant year in the U.S. Patent Inventor Database is 1975 – 2013, and because it will take more than one year and a half for a patent application to be published, the number of patent applications in this database is not complete in the years close to 2013. Because the patent grant year in PATSTAT 2015 is until 2015, it includes more complete patent applications until 2013. Because PATSTAT 2015 also includes the inventor address for each inventors of a patent, I link the firm names in the U.S. Patent Inventor Database to PATSTAT 2015 and update the U.S patent applications with Shanghai inventors until the patent application year of 2013.

4.3.2. Data on Firm Ownership

I use the firm applicant names to identify whether the firm is a domestic Chinese firm or a multinational corporation. Because all the firms have Shanghai inventors in my dataset (and all firms are the single applicants of the patents), thus all firms should have branches or headquarters in Shanghai. Therefore, all the firms in my dataset should have registered at the Shanghai Admission of Industry & Commerce.

The Official Webpage of Shanghai Admission of Industry & Commerce discloses the firm's ownership, indicating whether (1) the firm is a "sole foreign corporation", which is classified as a foreign MNC, or (2) the firm is a "Hong Kong – Macaw – Taiwan owned corporation", which is classified as a HMT multinational corporation or (3) the firm is a "local firm", which is further classified as a foreign joint venture, a HMT joint venture, or a pure domestic Chinese firm.

One way to identify firm's ownership is to manually check the firm names on the official webpage of Shanghai Admission of Industry & Commerce. Firstly, I narrow the searching scope by starting from the firms that applied U.S. patents with Shanghai inventors, and applied China priority patents. This is because when applying U.S. patents, it is natural for domestic Chinese firms to apply the U.S. patents with China priority (first apply the patents in China, and then apply the patents in the U.S.). In this paper, I focus on examining the knowledge flow from MNCs outside mainland China to pure domestic Chinese firms. I identify whether the firm is a pure domestic Chinese firms by manually searching patent applicant names on the official webpage of Shanghai Admission of Industry & Commerce, and I identified 173 pure domestic Chinese firms which made citations to multinational corporations with Shanghai inventors, and 117 multinational corporations which have Shanghai inventors. Secondly, based on the patent data extracted from U.S. Patent Inventor Database, for those firms that applied U.S. patents with Shanghai inventors, there are 354 firms that didn't apply any China priority patents. I treat these firms as multinational corporations. I finally have 173 pure domestic Chinese firms and 471 multinational corporations (MNCs) in my dataset.

4.4. Preliminary Analysis

4.4.1. Patenting Activities of MNCs in Shanghai

Figure 4-1 shows the trend of number of MNCs entered Shanghai. I define "the year entering Shanghai" as the year that a MNC first applied its U.S. patents with Shanghai inventors.

I identify MNCs entering Shanghai by using the information of U.S. patents with Shanghai inventions applied by MNCs. If the MNC applied its first U.S. patents with Shanghai inventors, then I treat the earliest applicant year of the patent as the entering year in Shanghai. In figure 4-1, the horizontal axis indicates the year when MNC applied the first U.S. patents with Shanghai inventors, whereas the vertical axis indicates the accumulated number of MNCs entered Shanghai. Figure 4-1 shows that from 2002 until 2012, the accumulated number of MNCs entered Shanghai nearly increased 3 times.

Figure 4-1 Year and number of MNCs entered Shanghai

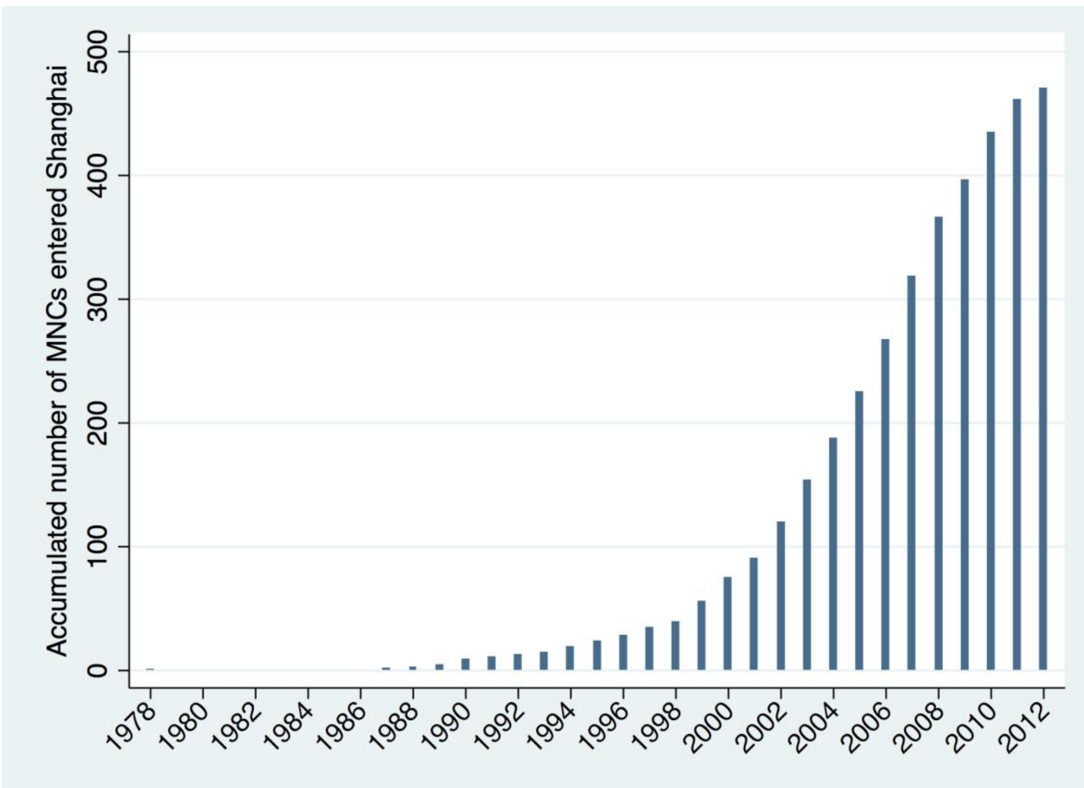
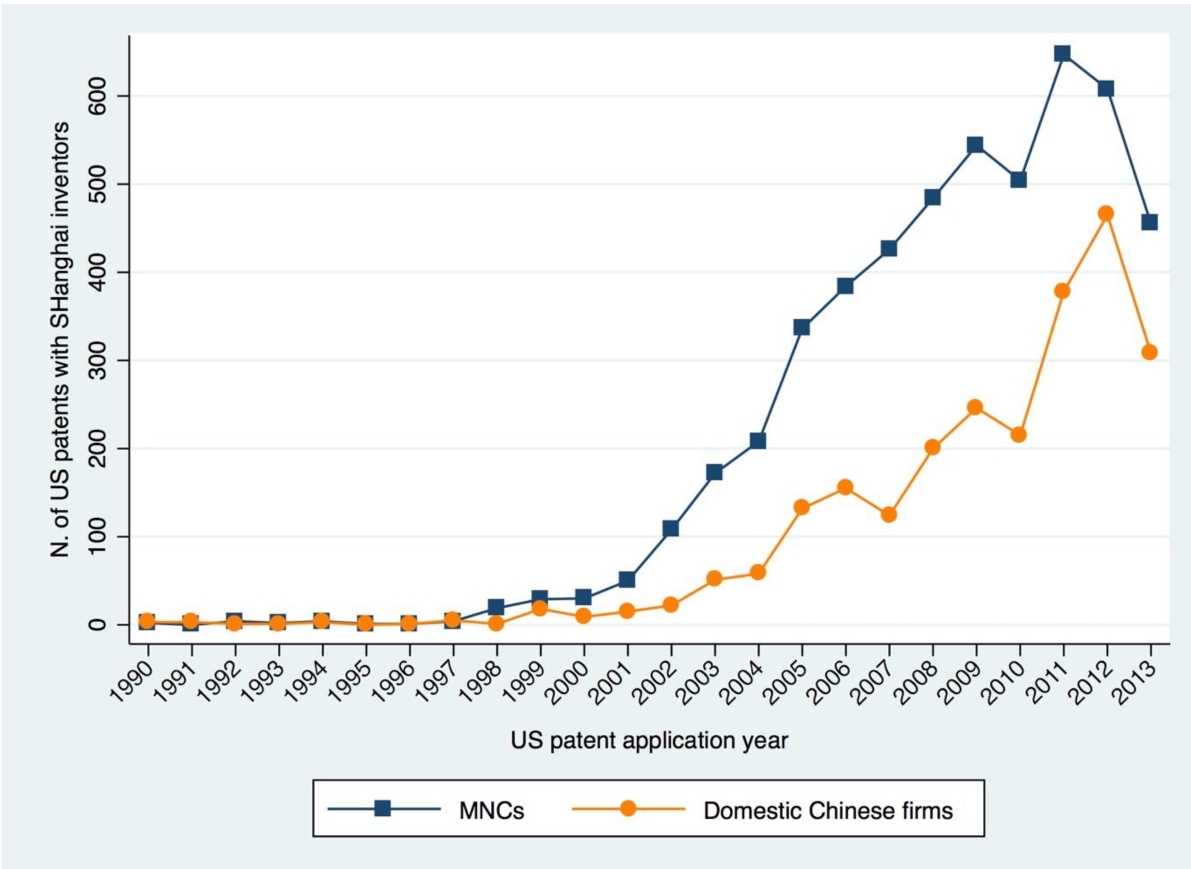


Figure 4-2 shows the trend of number of U.S. patents with Shanghai inventors applied by pure domestic Chinese firms, and by MNCs whose patents were cited by those pure domestic Chinese firms. The horizontal axis indicates the applicant year of the patent, whereas the vertical axis indicates the number of U.S. patents with Shanghai inventors. The blue line indicates the trend for MNCs, whereas the yellow line indicates the trend for domestic firms.

Figure 4-2 Trend of U.S. patents with Shanghai inventors



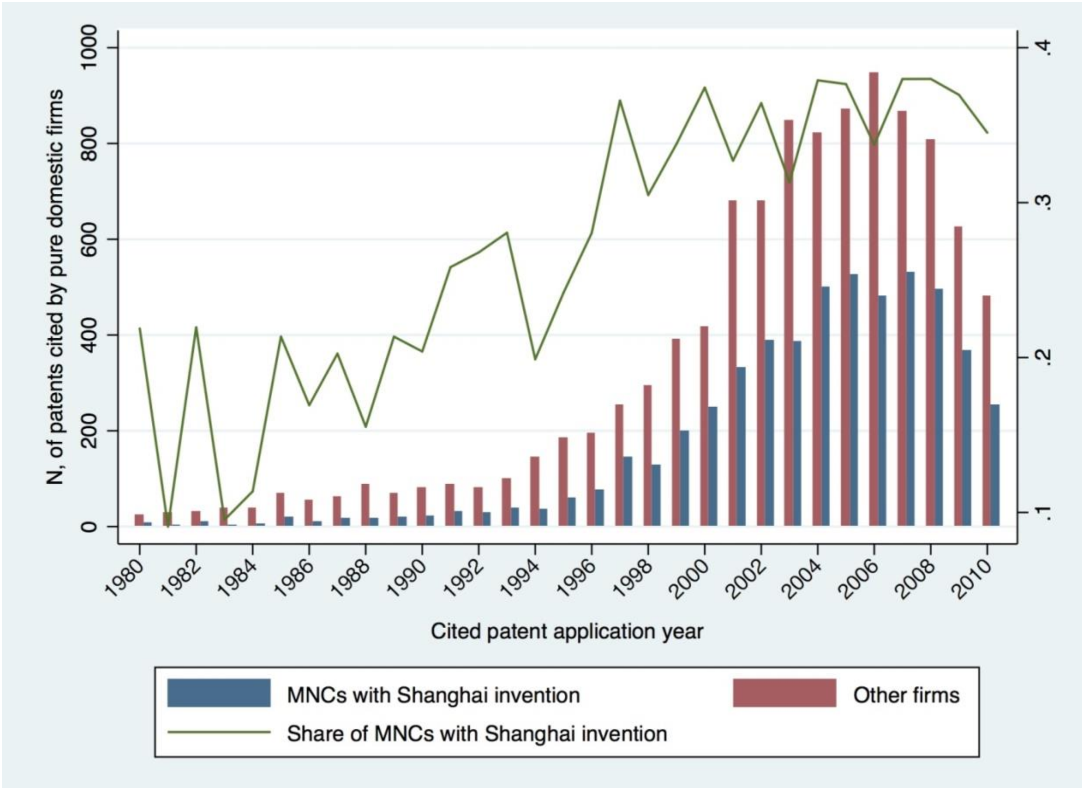
4.4.2. Patent Citations to MNCs' Patents

The U.S. patents are required to disclose the citations to prior arts. The citation information indicates to what extent new inventions are built upon existing knowledges. Patent citation data has long been used as a measurement of international knowledge flow (Almeida 1996). However, there are two factors that may add noise to such a measurement of knowledge flow. Firstly, patent citations may be added for strategic reasons (Lampe 2012). Secondly, patent examiner citations may also influence the effectiveness of using patent citation as measure of knowledge flow (Alcacer & Gittelman 2006).

For understanding how well do patent citations measure knowledge flow, scholars used survey data and found that patent citation is highly correlated with knowledge flow (Duguet & MacGarvie 2005). Therefore, in this paper I use patent citation to measure the international knowledge flow obtained by pure domestic Chinese firms from MNCs. I extract the patent citations made by the U.S. patents with Shanghai inventors that are applied by pure domestic Chinese firms, and I match the names of MNCs which applied U.S. patents with Shanghai inventors with the patent applicants of the patents that are cited by pure domestic Chinese firms.

Figure 4-3 shows the cited patents by patent application year. The horizontal axis indicates the earliest applicant year of the cited patents. The green line shows that the share of cited patents applied by MNCs with Shanghai inventions increased from 1994 and became stable after 2000. It also indicates that the number of patents cited by pure domestic Chinese firms continue to increase until year 2008. Because in my dataset, the patent grant year is until year 2013. There might be some patents that are still not granted in 2013, and the patent citation of such not granted patents is not available yet. In order words, there might be more cited patents after year 2008, however, because those citing patents are not granted yet, the number of cited patents after 2008 in figure 4-3 might be under estimated.

Figure 4-3 Trend of patents cited by pure domestic Chinese firms



4.5. Empirical Analysis

4.5.1. Patent Citation as an Indicator of Knowledge Flow

The U.S. patents filed to USPTO are required to include citations of prior inventions on which the new patents are built on. Patent citation thus serves as an indicator of knowledge flow among patent inventors. Although patent citation is not a perfect measure of knowledge flow, because citations are sometimes added by patent examiners and may also be added for strategic purposes, however, scholars suggested that patent citation can still be an effective indicator of knowledge flow (Alcácer et al. 2009; Alcacer & Gittelman 2006).

Singh (2003) studied the knowledge flows from MNC subsidiaries to domestic entities by analyzing the citation patterns of U.S. domestic players and subsidiaries of foreign MNCs in the

U.S. He used patent citation data and estimated the probability of citation between two patents. Thus, for the analysis on knowledge diffusion to local firms, I use the same binary dependent variable that equals one if the citation actually take place, and zero otherwise. My interest lies in what characteristics of the citing and cited patents have an effect on the likelihood of citation from domestic firm's citing patents to MNC's cited patents.

4.5.2. *Data*

I use the citation pairs between U.S. patents applied by domestic Chinese firms and U.S. patents applied by MNCs in the U.S. for the analysis. I identify MNCs in the U.S. by using inventor address. The term "MNCs in the U.S." refers to MNCs that applied U.S. patents with all inventors located in the U.S. Because if the MNC applied U.S. patents with all inventors located in the U.S., the MNC should have subsidiary or headquarter in the U.S. For the citation pair, I only consider cited MNC's patents with all inventors located in the U.S.

In my dataset, there are 925 domestic Chinese firms' U.S. patents which made citations to 1876 U.S. patents applied by MNCs in the U.S. Therefore, the possible citation pairs are 1735300 (925 × 1876). The data are cut in two ways to form a uniform sample. First, the application year of domestic firm's U.S. patent does not come before the application year of MNC's U.S. patent. For example, the citation pair between the domestic firm's U.S. patent applied in 1997 and MNC's U.S. patent applied in 2000 is excluded because it is not a possible citation pair; Second, the application year of the cited MNC's patent is within ten years of the application year of the citing domestic firm's patent (Kerr, 2008).

4.5.3. Dependent Variable

International knowledge flow: The dependent variable equals 1 if the citation between citing patent filed by domestic firms and cited patent filed by MNCs actually take place, 0 otherwise.

4.5.4. Independent Variables & Control Variables

Citing patent created after MNC entered Shanghai: This independent variable equals one if the domestic Chinese firm's citing patent is created after MNC entered Shanghai, and zero otherwise. If the application year of domestic firm's citing patent is after the year that the MNC of the cited patent entered Shanghai, in such case the domestic Chinese firm's citing patent is treated as a patent created after the MNC entered Shanghai.

Citing patent including returnee inventor: This independent variable equals one if the domestic Chinese firm's citing patent includes at least one returnee inventor, and zero otherwise. The returnee inventor is defined as the inventor whose earliest patent was invented at "MNCs in the U.S.", and whose subsequent patent was invented at domestic Chinese firm. Because the U.S. Inventor Database (Fleming et al. 2014) assigned each inventor a unique inventor ID, I could track the patenting records of each inventor. I identify returnee inventors by checking the inventor address and the patent applicant during the patent grant period 1975-2013.

Ratio of CN priority patent for MNC: measures the ratio of U.S. patents with China priority to all U.S. patents applied by MNC. China priority means that the MNC filed its U.S. patent application first in China, and then in the America. A higher ratio of the U.S. patents with China priority to the total U.S. patents implies that the MNC may focus more the China market, because the MNC choose to apply the patent first in China.

Scale of domestic firm: This control variable is the number of U.S. patents applied by domestic Chinese firms in each patent application year. It measures the firm size of the domestic Chinese firm.

Scale of MNC: This control variable is the number of U.S. patents applied by MNCs in each patent application year. It measures the firm size of the MNC.

MNC entered Shanghai year: This control variable is the earliest application year of MNCs' first patents that were invented in Shanghai. It controls the time lag that domestic Chinese firms' patents are created after MNCs entered Shanghai.

Citing patent application year: This control variable is the application year of China priority of domestic firms' U.S. patents. I add the citing year fixed effects in order to remove citation rate differences originated from different citing patent application year.

Cited patent application year: This control variable is the earliest application year of MNCs' U.S. patents. Together with the above control variable, I control the citation time lag between the citing and cited patent.

Citing patent technology field: Because patents in some technology field may tend to make more citations, this variable controls the technology field of the domestic firms' patents. I use the first three of the four digits of the IPC code, which indicates the main class of the patent, as a measure of the technology field. This variable is the dummy of technology fields of the domestic firms' patents.

Cited patent technology field: Similar as the above control variable, it is the dummy of technology fields of MNCs' patents. I use the first three of the four digits of the IPC code as the technology field. Because some patents in particular technology fields may receive more citations, this variable controls the technology fields of MNCs' patents.

Table 4-1 Descriptive Statistics

Variable	Mean	SD	Min	Max
1. International Knowledge Flow	0.002	0.040	0.000	1.000
2. Citing patent created after MNC enter Shanghai	0.761	0.426	0.000	1.000
3. Returnee inventor	0.212	0.409	0.000	1.000
4. Ratio of CN priority patents for MNCs	0.002	0.007	0.000	0.117
5. Log(Domestic firm's all U.S. patents)	4.634	2.074	0.000	7.434
6. Log (MNC's all U.S. patents)	6.889	1.687	0.000	9.534

4.6. Results

Table 4.1 shows the descriptive statistics. The average of ratio of CN priority patents for MNC is very small, and with a largest ratio of 11.7%. Table 4.2 and 4.3 shows the regression results. Because the dependent variable is a binary variable, probit regression model is used for all the regressions. The main independent variables are *Citing patent created after MNC enter Shanghai*, which equals one if the domestic Chinese firm's U.S. patent is created after the year that the MNC entered Shanghai, and zero otherwise; and *Citing patent including returnee inventor*, which equals one if the domestic Chinese firm's U.S. patent includes returnee inventor, and zero otherwise. The two main independent variables are added separately in model 1 and model 2, and are added together in the last model.

The *Citing patent created after MNC enter Shanghai* is significant and positive in model 1 and model 3-6. The results suggest those domestic Chinese firms' patents which are created after MNCs entered Shanghai are more likely to make citations to MNCs patents. After MNCs entered Shanghai, local firms have more chances of interacting with MNC R&D centers due to geographic closeness. Such geographic proximity facilitates the knowledge diffusion from MNCs to local firms. Thus the first hypothesis is supported.

The *Citing patent including returnee inventor* is significant and positive in model 2-6. The results suggest that if the domestic Chinese firms' patents include returnee inventor who moved from MNCs to domestic Chinese firms, those patents are more likely to cite the patents of MNCs. Because inventor networks and prior direct / indirect collaborative ties are found to have a positive impact on patent citations (Singh 2005). Returnee inventors who had been working aboard are expected to have the accumulated overseas inventor networks, when returnee inventors innovate at domestic Chinese firms, they are likely to make citations to MNCs' patents.

On the other hand, because returnee inventors have participated in the invention process of foreign MNCs, they are expected to have more tacit knowledge and better understanding regarding MNCs' inventions. Thus after coming to domestic Chinese firms to innovate, returnee inventors are more likely to make citations to MNCs' patents, and gain knowledge flow from them. The results support the second hypothesis that the returnee inventors, who worked at MNCs and who moved to domestic Chinese firms can help the domestic firms to gain knowledge flow from MNCs.

Table 4-2 Knowledge Diffusion from MNCs to Domestic Firms

	International Knowledge Flow		
	(1)	(2)	(3)
Citing patent created after MNC enter SH	0.173***		0.174***
	(0.0239)		(0.0239)
Returnee inventor		0.0452**	0.0474**
		(0.0191)	(0.0191)
Ratio of CN priority patents for MNCs	0.463	0.342	0.461
	(1.263)	(1.265)	(1.262)
Scale of domestic firms	0.0144**	0.0114*	0.0129**
	(0.00641)	(0.00644)	(0.00646)
Scale of MNCs	0.00497	0.00722	0.00509
	(0.00720)	(0.00721)	(0.00720)
MNC entered Shanghai year fixed effect	Yes	Yes	Yes
Citing patent application year fixed effect	Yes	Yes	Yes
Cited patent application year fixed effect	Yes	Yes	Yes
Citing patent technology field fixed effect	Yes	Yes	Yes
Cited patent technology field fixed effect	Yes	Yes	Yes
Constant	-9.047	-8.868	-9.013
	(876.9)	(884.2)	(878.9)
Observations	1083266	1083266	1083266

***indicates significant at 1%

In model 4-6, I added the interaction term of "*Citing patent after MNC entered Shanghai × Ratio of CN priority for MNCs* in model 4, and the interaction term of "*Citing patent after MNC entered Shanghai × Domestic firm scale*" in model 5, and the two interaction terms together in model 6. In model 4 and 6, the variable "*Citing patent after MNC entered Shanghai*", "*Ratio of CN priority for MNCs*", and the interaction term are all significant. The interaction term is positive and significant, with a coefficient of a higher absolute value than that of "*Ratio of CN priority for MNCs*". It indicates that those citing domestic firms' patents created after MNC entered Shanghai are more likely to cite those MNCs with a higher ratio of China priority patents. Because MNCs with a higher ratio of China priority patents may tend to focus more on China market, the results imply that the knowledge diffusion from those MNCs which are more committed to China market is more likely to happen.

In model 5 and 6, the variable "*Citing patent after MNC entered Shanghai*", "*Scale of domestic firms*", and the interaction terms are all significant. The coefficient of "*Citing patent after MNC entered Shanghai*" is positive. The coefficient of "*Scale of domestic firms*" is positive, and the interaction term is negative and with a coefficient smaller than the absolute value of the coefficient of "*Scale of domestic firms*". The results indicate that generally domestic firms' patents created after MNCs entered Shanghai are more likely to cite MNCs' patents. However, domestic firms with large firm size are comparatively more likely to cite MNCs' patents. For other control variables, the "*Scale of MNCs*" is positive but not significant.

Table 4-3 Knowledge Diffusion from MNCs to Domestic Firms (Continue)

	International Knowledge Flow		
	(4)	(5)	(6)
Citing patent created after MNC enter SH	0.159***	0.253***	0.247***
	(0.0246)	(0.0499)	(0.0501)
Returnee inventor	0.0481**	0.0467**	0.0474**
	(0.0191)	(0.0191)	(0.0191)
Ratio of CN priority patents for MNCs	-6.045*	0.503	-6.396*
	(3.388)	(1.261)	(3.450)
Scale of domestic firms	0.0130**	0.0270***	0.0289***
	(0.00646)	(0.0102)	(0.0102)
Scale of MNCs	0.00521	0.00474	0.00481
	(0.00721)	(0.00720)	(0.00722)
Citing patent after MNC enter SH × Ratio of CN priority	8.403**		8.918**
	(3.543)		(3.606)
Citing patent after MNC enter SH × Domestic firm scale		-0.0177*	-0.0199**
		(0.00972)	(0.00977)
MNC entered Shanghai year fixed effect	Yes	Yes	Yes
Citing patent application year fixed effect	Yes	Yes	Yes
Cited patent application year fixed effect	Yes	Yes	Yes
Citing patent technology field fixed effect	Yes	Yes	Yes
Cited patent technology field fixed effect	Yes	Yes	Yes
Constant	-8.996	-9.084	-9.073
	(879.7)	(873.5)	(873.7)
Observations	1083266	1083266	1083266

***indicates significant at 1%

4.7. Conclusion and Implications

Recent literature has shown that domestic firms in technological catching-up countries could gain knowledge flow from foreign direct investment and from human mobility. However, current literatures studied the two mechanisms of gaining knowledge flow separately. This paper takes Shanghai, one of the top cities attracting foreign direct investment in China, as an example, and empirically examines how domestic firms in China could gain knowledge flow from foreign direct investment and returnee inventors.

The results of empirical tests generally support my hypotheses. The empirical results show that domestic Chinese firms' patents are more likely to gain knowledge flow through international patent citations when (1) domestic Chinese firms' patents are created after MNCs entered Shanghai, (2) when domestic Chinese firms' patents involve returnee inventors who moved from MNCs to domestic Chinese firms.

By introducing the interaction terms, I found that those domestic Chinese firms' patents created after MNCs entered Shanghai are more likely to gain knowledge flow through international citations when (1) cited MNCs are more committed to China market as indicated by a relatively higher ratio of China priority patents; (2) domestic Chinese firms have a relatively larger firm size.

The intended contribution of this study is to examine whether attracting MNCs to Shanghai facilitate the international knowledge flow to domestic Chinese firms, and the role of returnee inventors in international knowledge sourcing in Shanghai. This study suggests that domestic Chinese firms' patents that are created after MNCs entered Shanghai are more likely to cite

MNCs with Shanghai inventions. Because after the establishment of R&D facilities of MNCs in Shanghai, domestic Chinese firms which have R&D activities in Shanghai have more chances of face-to-face interaction with inventors at R&D centers of MNCs in Shanghai, those interactions with R&D facilities of MNCs in Shanghai may facilitate the international knowledge sourcing to domestic Chinese firms.

On the other hand, this study also suggests that when domestic Chinese firms' patents involve returnee inventors who moved from MNCs' overseas R&D centers to domestic Chinese firms are also likely to make more citations to inventions of MNCs. Because returnee inventors had overseas working experience at MNCs, they are expected to have accumulated global inventor networks and are expected to better understand the technologies of MNCs. Thus the returnee inventors may act as another channel of international knowledge sourcing to domestic Chinese firms.

Furthermore, this study explores for those domestic firms' patents created after MNCs entered Shanghai, what kind of characteristics of cited MNCs and citing domestic firms are likely to influence the knowledge diffusion. I found that the knowledge diffusion is more likely to happen when those MNCs more committed to China market, as indicated by the higher ratio of China priority patents. On the other hand, I found that domestic firms with larger firm size are also more likely to gain knowledge flow when MNCs entered Shanghai. Previous literatures explored knowledge flow from foreign direct investment and the absorptive capacity of domestic firms (Liu & Buck 2007), and large firms with higher absorptive capacity tend to gain more knowledge flow from MNCs.

The results could be of interest to Chinese policy makers, who focus on attracting foreign direct investment and returnee inventors. This paper provides empirical evidence for Chinese policy makers that attracting MNCs to Shanghai enhance the international knowledge flow to domestic Chinese firms. Policies of encouraging the interactions between domestic Chinese firms and MNCs' R&D facilities in Shanghai could be considered. Moreover, this study suggests that knowledge diffusion is more likely to happen from those MNCs that are more committed to China market, therefore Chinese policy makers could consider to encourage foreign direct investment from those MNCs with more commitments to China market, and issue incentives for the interactions between MNCs and domestic Chinese firms.

However, MNCs are also cautious about positive knowledge spillover on domestic firms, who are their competitors in the China market. This paper also suggests that returnee inventors play an important role in gaining knowledge flow from MNCs. The Chinese government recognized that overseas Chinese talents could be a key drive of international knowledge sourcing in China. In 2008, the General Office of the Communist Party of China issued "Opinions from Small Group for Coordinating Work on Talent (SGOT) on implementing the Recruitment Program of Global Experts", which specified to use 5-10 years to bring back thousands of returnees to universities and research institutes, companies, or High-tech Science Parks. The implementation of the National Thousand Talents Plan is facilitated by the provincial level returnee policies. The results in this paper provide empirical evidence that returnee inventors who come back to domestic firms play important role in gaining international knowledge flow, thus more returnee policies targeting at bring returnee inventors who had working experiences at foreign MNCs aboard to domestic Chinese firms could be implemented.

This paper also provides important implications for management for domestic Chinese firms. The results in this paper emphasize that returnee inventors are crucial for gaining knowledge flow from foreign MNCs. Thus, domestic Chinese firms may consider hiring more returnees who had been innovating at foreign MNCs aboard, and making use of the overseas inventor networks of returnee inventors to gain knowledge flow from foreign MNCs in advanced countries.

4.8. Limitations and Future Research

Because the U.S. Inventor Database (Fleming et al. 2014) has data truncation problem after 2008, therefore returnee inventors may not be completely identified after 2008. In future research, the returnee database could be updated by using more updated U.S. Inventor Database. This paper takes Shanghai as an example to explore how domestic Chinese firms could gain knowledge flow from MNCs through foreign direct investment and human mobility. However, the technology landscape in different regions in China varies in terms of political resources, local university and research institutes, internationalization, etc. Beijing is the educational and policy center in China, the political resources and human resources attracted large number of MNCs. On the other hand, Shenzhen was the manufacturing center that also attracted large number of MNCs, especially MNCs from Hong Kong, Macaw, and Taiwan due to the close geographic proximity. For future research, a comparative study among Beijing, Shanghai, and Shenzhen will give a more complete picture of MNCs and knowledge diffusion in China.

5. Chapter 5: Geographically Proximate or Culturally Cohesive? Geography, Ethnic Ties, and Innovation in China

5.1. Introduction

U.S. multinational corporations (MNCs) are increasingly conducting research and development (R&D) in China to benefit from its scientific and engineering talent (Lewin et al. 2009). Moreover, China is transforming from "the worlds factory" into "the worlds market." Catering to the needs of the local Chinese market, U.S. MNCs increasingly employ international co-invention to leverage their indigenous Chinese manpower to create innovations in China.

In this paper, I define "U.S. expatriate Chinese" as those Chinese inventors who have working experiences at the U.S. headquarters. I define "Indigenous Chinese" as those Chinese inventors who are employed at U.S. firms subsidiaries in China and don't have working experiences in the U.S. headquarters. I distinguish "China invention" from "Chinese invention." A China invention is one that is created entirely in China by indigenous Chinese inventors. A Chinese invention is one created solely by inventors who are ethnically Chinese, including U.S. expatriate Chinese inventors and indigenous Chinese inventors.

I define "collaboration network" as a network consisting of a variety of inventors that are geographically distributed, and heterogeneous in terms of their operating environment and/or culture, but that collaborate to better achieve common goals. After accumulating skills by collaborating with U.S. counterparts, including western and Chinese expatriate inventors, indigenous Chinese innovators are expected to create innovations without intellectual input from headquarter inventors (Branstetter et al. 2014).

The ability of MNCs to generate knowledge spillovers among indigenous inventors depends on whether they can transfer knowledge from home base to local recipients (Kogut & Zander 1993). Almeida et al. (2002) identify the tacitness of knowledge as its main impediment to cross-border transfer. Szulanski (1996) and Von Hippel (1994) cite the importance of personnel mobility—i.e., assigning inventors overseas—in transferring tacit knowledge. Foley and Kerr (2011) emphasize how ethnic collaboration networks transmit codified and tacit knowledge to generate inventions.

Notwithstanding the consensus endorsing in-country assignments and collaboration of ethnic networks, little empirical evidence indicates whether collaborating with headquarters inventors generates spillovers among a firm's indigenous inventors. Moreover, little is known about how overseas assignments and ethnic collaboration networks interact to sponsor knowledge spillover in host countries. This study closes this gap by researching three questions with reference to R&D in China by U.S. multinationals.

First, does collaborating with headquarters inventors generate knowledge spillovers among firm's indigenous Chinese inventors? Second, as headquarters inventors' geographical proximity to indigenous inventors is replaced by virtual electronic collaboration, how does a firm's ethnic

Chinese collaboration network facilitate cross-border knowledge transfer and spillovers? Third, as headquarters inventors geographical proximity to indigenous inventors is intensified by assigning personnel to China, do firms with cohesive ethnic Chinese collaboration networks have more knowledge spillovers?

Foley and Kerr (2013) indicate that expatriate inventors at MNCs promote overseas collaboration with indigenous innovators of their own ethnicity. This study advances the literature by examining the role of Chinese expatriate inventors as intermediaries between western and indigenous Chinese inventors. I demonstrate that a cohesive intrafirm network strengthens cross-border collaboration and innovation by firms' indigenous Chinese inventors.

This study samples U.S. Fortune 500 Companies in a firm fixed model to study how headquarters inventors' geographical proximity to indigenous inventors and intrafirm ethnic collaboration networks affect innovation by indigenous Chinese inventors.

5.2. Theory and Hypotheses

5.2.1. Geographical Proximity and Local Knowledge Spillover

Evolutionary theory suggests MNCs excel at transferring and developing knowledge across borders. This knowledge, according to Kogut and Zander (1993), comprises the required information and know-how. Knowledge is information about ***what*** something means, and know-how is ***how*** to do something. Almeida et al. (2002) used "cross-border knowledge building" to describe the process by which MNCs combine transferred knowledge with indigenous partners' knowledge.

Previous studies have analyzed several dimensions of a firm's knowledge. Winter (1998) identified four: *tacit or articulable, observable or not observable in use*, *complex or simple,* and *dependent or independent of a system.* Following winters taxonomy, Zander and Kogut (1995) identify five dimensions: *codifiability*, *teachability, complexity, system dependence,* and *product observability.*

These categorizations imply that not all knowledge is codified easily and transferred within a firm. Polanyi's (1967) well-known discussion of tacit knowledge suggests that people know more than they can convey—a suggestion akin to noncodifiable and complex knowledge—and exporting tacit know-how internationally is more challenging than transferring it intrafirm.

Academic literature long has studied how intrafirm worker mobility—i.e., assigning personnel to foreign subsidiaries—creates and transfers knowledge across borders (Bartlett & Ghoshal, 1999; Edstrom & Galbraith 1977). Tacit knowledge is "sticky" unless people possessing it are mobile (Szulanski 1996). In their study of transmitting U.S. aerospace technology to Japan, Hall and Johnson (1970) insist that transferring technical know-how requires sending U.S. personnel to Japan. Their insistence confirms Nelson and Winters (1982) claim that frequent face-to-face formal or informal interactions and learning-by-observing are imperative for transferring tacit knowledge.

Recently, scholars have researched knowledge spillovers among a firm's indigenous inventor in host countries. Hovhannisyan and Keller (2010) examined how short-term assignments of inventors overseas affect innovation abroad. Choudhury's (2010b) study of U.S. multinationals R&D centers in India found that working with a returnee manager raises the likelihood that indigenous Indian inventors will generate patents.

There are several reasons why geographical proximity helps to transfer knowledge to indigenous inventors. It promotes face-to-face interactions that facilitate transfer of tacit know-how and amplifies trust through social relationships. The possibility of knowledge spillovers rises when work-related topics enter the conversation between mobile inventors and local inventors during their spare times. Moreover, it better informs collaborating teams about local customers and technology frontiers (Stuart & Podolny 1996). Therefore, I hypothesize the following.

HYPOTHESIS 1a. *Assigning headquarter inventors to China enhances innovation by indigenous Chinese inventors.*

5.2.2. Intrafirm Ethnic Collaboration and Knowledge Spillover

Ethnicity is an important channel for transferring codified and tacit knowledge through international networks (Kerr 2008). Understanding the behavior of an ethnic group requires understanding the *context* in which behaviors occur (Edward 1976). Communication in "high-context" cultures relies on implicit knowledge, non-verbal signals, and behavioral clues. "Low-context" cultures emphasize verbal information and explicit knowledge.

In "high-context" China, implicit knowledge is often hidden behind verbal information, whereas in "low-context" cultures such as Germany verbal communication is more direct and avoids ambiguity. Misunderstandings between people from high-context and low-context cultures hamper knowledge transfer. Therefore, I hypothesize that culturally homogenous teams reduce barriers to communication, facilitate transfer of tacit knowledge, and improve innovation among indigenous inventors.

HYPOTHESIS 1b. *Assigning Chinese expatriate inventors to China enhances innovation by indigenous Chinese inventors.*

5.2.3. Geographical Proximity and Intrafirm Ethnic Collaboration

Extensive literature suggests that assigning inventors abroad facilitates cross-border knowledge transfer. However, information and communications technology (ICT) increasingly replaces in-country interaction (Gibson & Cohen 2003). Virtual teams can promote cultural synergies, creativity, and a competitive advantage for MNCs (Zakaria et al. 2004).

However, much of China-based R&D involves projects intended for applications outside China (Branstetter et al. 2014). Indigenous Chinese members of virtual teams are expected to undertake more repetitive and codified tasks, whereas their U.S. counterparts provide intellectual and creative input. After collaborating with colleagues in the U.S., the indigenous Chinese are expected to create innovations for Chinese markets independently. Hence, I hypothesize the following.

HYPOTHESIS 2. *Virtual Collaboration between headquarters inventors in the U.S. and indigenous Chinese inventors increases innovation among the latter.*

Interpersonal trust enhances transfer of tacit knowledge among virtual teams (Jarvenpaa & Leidner 1998), and that knowledge forms the basis for indigenous recipients to create knowledge. However, learning between individuals requires trust that cannot be easily facilitated by ICT (Von Zedtwitz et al., 2004). As defined by Mayer et al. (1995, p. 712), interpersonal trust is "the willingness of a party to be vulnerable to the actions of another party based on the expectations that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party." If geographically dispersed multicultural teams fail to build trust early, when speculative information and free-form discussion dominate collaboration, future collaboration may never get off the ground (Gassmann 2001).

How can virtual teams generate knowledge spillover among indigenous Chinese inventors, and how can they build reciprocal trust? One answer is that virtual teams must cultivate "swift trust" because they lack time to develop trust gradually, and their members are prone to trust persons they are familiar with (Jarvenpaa et al. 1998). Therefore, expatriates are inherent intermediaries between knowledge recipients of their own ethnicity and knowledge senders from other cultures (Kapur 2001). They could comprise the core of collaborative intrafirm networks (Funk 2014) that transfer tacit knowledge and engender knowledge spillovers.

A cohesive network between Chinese expatriates and local Chinese facilitate the trust building between headquarter western inventors and local inventors, because both of the two parties may have mutual trust toward Chinese expatriates, and both parties are more likely to develop interpersonal trust toward each other because of having a common intermediary. As a result, the possibility of tacit knowledge transfer and knowledge spillover will rise because of the mutual trust developed between headquarter and local Chinese inventors. Hence, I offer the following hypothesis.

HYPOTHESIS 3a. *A cohesive collaboration network of expatriate and indigenous Chinese accrues more benefits of cross-border invention to indigenous Chinese inventors.*

Teaching tacit know-how requires frequent small-group interaction and often involves a private language or code (Kogut & Zander 1992; Katz & Kahn 1966). Therefore, I posit that a cohesive ethnic Chinese collaboration network, one that includes assigning expatriate Chinese inventors to China, can facilitate transfer of tacit knowledge to indigenous Chinese inventors, increasing their innovative output.

HYPOTHESIS 3b. *A cohesive collaboration network of expatriate and indigenous Chinese accrues more benefits of China-based co-invention to indigenous Chinese inventors.*

5.3. Data and Method

5.3.1. Data

I use U.S. patent data to examine whether expatriate Chinese innovators promote patents by U.S. multinationals in China. Furthermore, I investigate whether assigning expatriate Chinese innovators to Chinese subsidiaries fosters China inventions as defined earlier. Patent data are common indicators of innovation (Griliches 1990; Hall et al. 2001; Nagaoka et al. 2010). Previous studies used patent data to examine expatriate ethnic innovators and MNCs innovation abroad (Choudhury 2010a; Choudhury 2010b; 2010c; Foley & Kerr 2013).

Patent data contain informative details about the innovation, inventor and owner (assignee), allowing us to identify ethnicity by matching inventors names with a database and to identify specific inventors by examining changes in their addresses. I sampled U.S. Fortune 500 companies because most are multinational and conduct R&D in China. Their activities should produce patents attributable to indigenous Chinese inventors.

My data come from several sources. The first is the 2013 Chinese patent database by the China State Intellectual Patent Office (SIPO). The second is the Disambiguation and Co-authorship Network of the U.S. Patent Inventor Database (Fleming et al. 2014), which contains bibliographic information for U.S. patents granted during 1975–2010. The third is the 2008 listing of Fortune 500 firms from the FORTUNE Datastore. The fourth is the Chinese Ethnic Surname Database by the Institute of Genetic and Developmental Biology of the Chinese Academy of Sciences. It includes 387 pinyin[1] covering 97% of Chinese surnames (Yuan 2009). The fifth is Compustat financial database 2010.

I started with the SIPO patent database to construct the firm-level dataset. First, I extracted all patents granted by SIPO that have a U.S. priority and a related Chinese patent with a U.S. priority application from January 1999 through December 2007—i.e., all Chinese-originating patents first granted in the U.S. and then in China. I used post-1999 samples because almost no Chinese patents list indigenous Chinese inventors until 1999 and I stopped after 2007 to prevent the 2008 financial crisis from affecting the analysis. Second, I use the 2008 list of *Fortune 500 firms* to match patent applicants. I compiled 104 *Fortune 500* firms that sought at least one Chinese patent from 1999 to 2007.

Third, I matched names of the 104 Fortune 500 firms with the U.S. Patent Inventor Database and extracted all U.S. patents sought by these firms during 1999–2007. Further, using Compustat, I obtained the firm's financial information (e.g., sales). Finally, I used the Chinese Ethnic Surname Database to estimate inventor's ethnicity. Some Korean and Chinese surnames share pinyin; thus, I compiled a dataset of first and last Korean names for all U.S. patents created in Korea. I dropped from the sample patents granted to inventors with Chinese surnames and Korean first names. I used changes in addresses to assess inventor's mobility. If an inventor declared a U.S. address for his first patent and a Chinese address subsequently, I defined him as having experience with a U.S. firm.

[1] Pinyin is an official phonetic system for transcribing Mandarin pronunciations of Chinese characters into the Latin alphabet

The procedures created a firm-level panel dataset of 104 Fortune 500 firms spanning 1999–2007 for analysis. Many Fortune 500 companies use both overseas assignment and ICT in transnational R&D projects; However, they weight project phases differently (Von Zedtwitz et al. 2004). For example, initially, IBM assigns headquarters inventors abroad to introduce its corporate culture and to collaborate with indigenous inventors. Later, cross-border collaboration occurs via video conferences and email.

Figure 5-1 Trends of Innovations by Inventor Identity

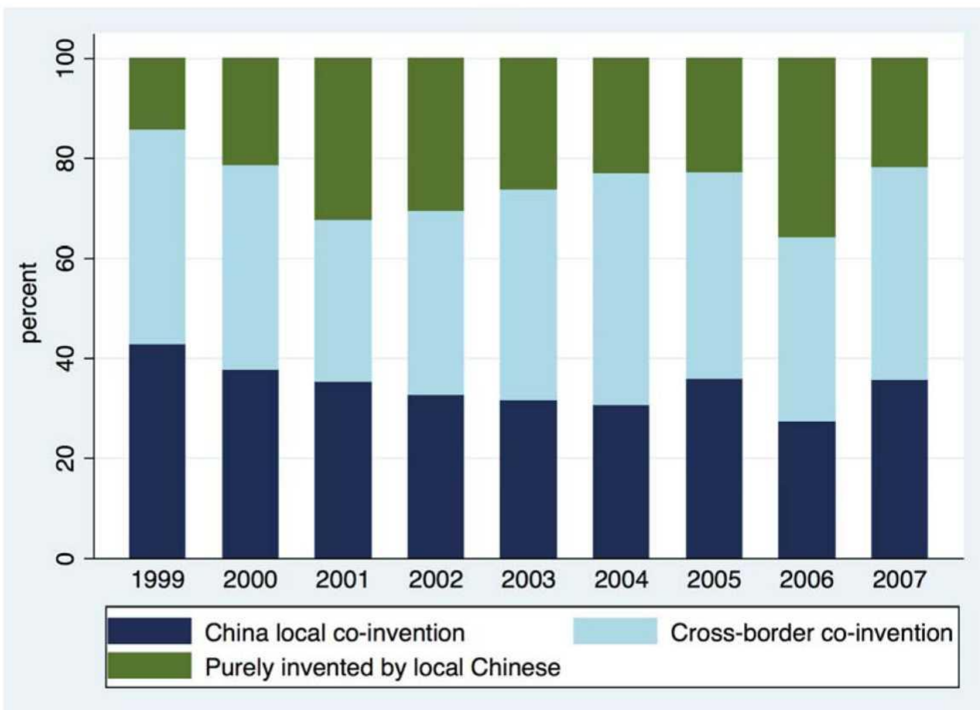


Figure 5-1 indicates trends in inventions by type of collaboration with indigenous Chinese inventors. In the early years, nearly half of all inventions originated through in-country collaboration between headquarters inventors assigned to China and indigenous Chinese inventors. However, as firms accumulate experience in China, in-country collaboration diminishes and ICT-supported collaboration increases. This finding supports Von Zedtwitz et al.s (2004) arguments.

5.3.2. Method

I use an ordinary least squares model that includes firm fixed effects to test my hypotheses. I include fixed effects to control for firm differences and add a year-specific fixed effect to control for increased participation of ethnic Chinese inventors.

Dependent Variables

Log (# Patents on Inventions by Indigenous Chinese): This dependent variable denotes innovative output by sampled firms' indigenous Chinese inventors. It is the log of the number of firms' patents created exclusively by indigenous Chinese inventors. "Indigenous Chinese inventors" refers to Chinese who never worked in the U.S. previously.

Number of patent citations for China inventions: This dependent variable measures the technological impact of inventions created by firms' indigenous Chinese inventors. All patent awards herald innovation (Hall et al. 2000; Nagaoka et al. 2010); However, I use the number of citations (net of self-citations) to indicate the technological impact of China inventions (Trajtenberg 1990), as previously defined, during five years after the patent filing date—the window within which patents receive the most citations (Hall et al. 2001).

Independent Variables

Log (# local co-invention by U.S. expatriate and indigenous Chinese): To test Hypothesis 1a, the independent variable is the log of the number of a firm’s patents awarded to Chinese inventions. As previously defined, those are created in China by Chinese expatriates and/or indigenous Chinese inventors. Addresses from patent filings identified whether Chinese inventors were expatriates or indigenous.

Log (# local co-inventions by U.S. non-Chinese & indigenous Chinese): To test Hypothesis 1a, I introduce an ethnicity variable that differs from the previous variable. It is the log of the number of patents awarded for inventions co-created in China by a firm’s non-Chinese and indigenous Chinese inventors.

Log (# Cross-border co-inventions): My second hypothesis predicts that cross-border collaboration between headquarters inventors in the U.S. and indigenous Chinese inventors generates knowledge spillover among the latter. This independent variable denotes the extent to which a firm sought to patent inventions co-created by U.S. and indigenous Chinese inventors.

Ethnic Chinese collaboration networks – Cohesion: To measure the cohesion of collaboration networks I divided the number of a firms patents awarded to inventions co-created by Chinese expatriates and indigenous Chinese by the total of the firms patents. Values span 0 to 1; a higher value indicates greater network cohesion. Because it measures the portions of patents jointly created by Chinese expatriates and indigenous Chinese out of total firm patents, a higher ratio of Chinese collaborations of a firm should indicate a more cohesive Chinese collaboration network of a firm.

Experience with cross-border co-invention: is a dummy measuring whether a team of indigenous Chinese inventors who secured patents includes members who previously had collaborated with U.S. headquarters inventors of any nationality through virtual teams.

Experience of cross-border co-invention with Chinese expatriates: is a dummy measuring whether a team of Chinese who secured patents includes members who previously had collaborated with Chinese expatriate inventors through virtual teams.

Experience of local co-invention with U.S. experienced inventors: is a dummy. It indicates whether a team of indigenous Chinese who secured patents includes members who previously had collaborated with headquarters inventors of any nationality assigned to China.

Experience of local co-invention with U.S. experienced expatriate Chinese inventors: This dummy indicates whether indigenous Chinese inventors had previously collaborated with headquarters expatriate Chinese inventors assigned to China.

Control Variables

Log (# Firm Sales): It measures the U.S. firms' sales revenues at each year to control for a firm size effect.

Log (# Inventors): The dependent variable and independent variable may be both correlated with the number of inventors of the firm, because firms with larger number of inventors may also have more inventions created by indigenous Chinese inventors and headquarter-based inventors. This control variable measures the number of distinct inventors at each year to control for a firm's innovation capability effect.

5.4. Results

I add firm fixed effects and year fixed effects to control for firm differences and time variance. Tables 1 and 2 present models of quantity of output by indigenous Chinese inventors and the technological impact of their patents, respectively. Hypothesis 1a predicts that assigning headquarters expatriate Chinese inventors to China will boost innovation output by indigenous Chinese inventors.

Models 2–6 in Table 2 test this hypothesis by introducing the two independent variables: number of patents for inventions by Chinese expatriates in China and indigenous Chinese inventors, and number of patents for inventions by non-Chinese headquarters inventors in China and indigenous Chinese inventors. Coefficients for the two independent variables are significant and positive in Models 2–6. Hypothesis 1a is supported.

Hypothesis 2 posits that cross-border collaboration with headquarters inventors enhances innovation by indigenous Chinese inventors. Models 1 and 3–6 test this hypothesis. The coefficient for Log (# Cross-border co-inventions) is significant and positive in all models. Hypothesis 2 is supported.

Hypotheses 3a and 3b address the interdependent effects of a firm's ethnic Chinese collaboration network and headquarters inventors' physical proximity to indigenous Chinese inventors on innovation by the latter. Hypothesis 3a predicts that when headquarters inventors' physical proximity to local Chinese inventors decreases, a cohesive intrafirm Chinese collaboration network strengthens knowledge spillover. Hypothesis 3b predicts that when headquarters inventors are dispatched to work with indigenous Chinese inventors in China, a cohesive intra-firm Chinese network strengthens knowledge spillover.

In Table 2, Models 4–6 test these hypotheses by measuring relations between a firms ethnic Chinese network and types of co-invention. In Model 4, the coefficient for interaction between network cohesion and number of cross-border co-inventions is significant and positive. Innovation by indigenous Chinese increases among firms with cohesive ethnic Chinese collaboration networks. Hypothesis 3a is supported.

In Model 5, interaction between network cohesion and the number of co-inventions involving non-Chinese and indigenous Chinese inventors is positive but not significant. At firms with cohesive Chinese collaboration networks, assigning non-Chinese inventors to China does not enhance innovation by indigenous Chinese inventors.

However, in Model 6 interaction between cohesion and the number of co-inventions created in China by expatriate and indigenous Chinese is significant and positive. At firms with cohesive Chinese collaboration networks, assigning Chinese expatriates to China fosters inventions by indigenous Chinese. Hypothesis 3b is supported.

Table 3 is used to test Hypothesis 1b. Models 1–4 in Table 3 introduce independent variables denoting indigenous inventors’ previous experience with cross-border co-invention and local co-invention. Coefficients for experience in cross-border collaboration are not significant in all models. This finding captures two considerations. First, inventions created via cross-border collaboration are mainly destined for global markets. Second, indigenous Chinese inventors generally perform repetitive and routine tasks.

The finding intimates that indigenous inventors assimilate the U.S. firms' culture of innovation and generate more patents. However, creating high-impact innovations in China requires indigenous inventors to combine the U.S. firm's culture of innovation with local knowledge, a process they did not learn during cross-border collaboration. Therefore, cross-border collaboration might not prepare indigenous Chinese to generate inventions with high technological and economic value.

However, Hypothesis 1b predicts that assigning Chinese expatriates to China helps indigenous inventors to generate high-quality patents eventually. Models 3 and 4 support this hypothesis. In Model 3, the coefficient for experience collaborating in China is significant and positive. In Model 4, after adding all variables, the coefficient for collaborative experience with expatriate Chinese in China is significant and positive. Hypothesis 1b is supported.

Table 5-1 Models of Quantity of Innovation Output

Dependent Variable:	*Log (# Patents on Inventions by Indigenous Chinese)*					
	(1)	(2)	(3)	(4)	(5)	(6)
Log (# local co-invention by U.S. expatriate & indigenous Chinese		0.662*** (0.0541)	0.458*** (0.0555)	0.355*** (0.0578)	0.441*** (0.0570)	0.336*** (0.0609)
Log (# local co-invention by U.S. non-Chinese & indigenous Chinese		0.426*** (0.0734)	0.416*** (0.0694)	0.381*** (0.0685)	0.360*** (0.0812)	0.390*** (0.0687)
Log (# Cross-border co-inventions)	0.359*** (0.0247)		0.230*** (0.0249)	0.215*** (0.0246)	0.234*** (0.0251)	0.243*** (0.0247)
Cohesion			1.480 (2.010)	-10.34*** (2.962)	0.588 (2.117)	-1.767 (2.105)
Cohesion × Log (# Cross-border co-inventions)				11.83*** (2.210)		
Cohesion × Log (# local co-invention by U.S. non-Chinese & indigenous Chinese)					5.195 (3.878)	
Cohesion × Log (# local co-invention by U.S. expatriate & indigenous Chinese)						8.109*** (1.754)
Control Variables						
Log (# Firm Sales)	0.00361 (0.00987)	0.00536 (0.00940)	0.00275 (0.00890)	0.000507 (0.00875)	0.00222 (0.00891)	0.000824 (0.00879)
Log (# Inventors)	0.0121 (0.0104)	0.00918 (0.00994)	0.00691 (0.00942)	0.00897 (0.00926)	0.00736 (0.00942)	0.00822 (0.00930)
Parent Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.0387 (0.0951)	-0.0487 (0.0907)	-0.0273 (0.0858)	-0.0126 (0.0843)	-0.0239 (0.0858)	-0.0130 (0.0847)
N	860	860	860	860	860	860
R^2	0.223	0.295	0.370	0.394	0.372	0.388

"Cross-border co-created patents" are patents awarded to inventions created by indigenous Chinese who never worked in the U.S. and headquarters inventors in the U.S. "Cohesion" assesses the robustness of a firm's Chinese collaboration network. It is the ratio of the number of patents awarded to teams of Chinese expatriates and indigenous Chinese without U.S. experience, divided by the number of total patents. *** indicates significant at 1%.

Table 5-2 Models of Technological Impact

Dependent Variable:	*Number of patent citations for China inventions*			
	(1)	(2)	(3)	(4)
Experience of cross-border co-invention	−1.680 (1.126)	−3.641 (2.428)	−3.625 (2.408)	−3.780 (2.397)
Experience of cross-border co-invention with expatriate Chinese		2.438 (2.675)	2.408 (2.653)	3.454 (2.698)
Experience of local co-invention with U.S. experienced inventors			1.897** (0.816)	−0.130 (1.352)
Experience of local co-invention with U.S. experienced expatriate Chinese inventors				2.387* (1.273)
Control Variables				
Log (# Firm Sales)	−1.492 (5.748)	−1.539 (5.750)	−2.839 (5.729)	−2.704 (5.701)
Parent Firm Dummy	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes
Constant	22.01 (48.55)	22.46 (48.57)	33.86 (48.41)	32.63 (48.18)
N	283	283	283	283
R^2	0.218	0.220	0.236	0.247

The dependent variable sums 5 years of citations for patented inventions created by indigenous Chinese without U.S. work experience. The four independent variables measure whether these Chinese inventors had previously collaborated with headquarters inventors of any ethnicity in the U.S., with Chinese expatriates in the U.S., with non-Chinese inventors in China, or with Chinese expatriates in China. *** indicates significant at 1%.

5.5. Discussion and Conclusion

This study has expanded upon Kogut and Zanders (1993) theory that MNCs enjoy competitive advantage by transferring information and know-how to create cross-border knowledge. This study has demonstrated that R&D at Fortune 500 firms with cohesive networks of ethnic Chinese generates knowledge spillovers among indigenous Chinese inventors.

My empirical results include the following. First, cross-border collaboration between expatriate and indigenous Chinese raises the latter's innovative performance. Second, China-based co-invention between headquarters and indigenous Chinese inventors increases innovation by the latter. Third, a cohesive collaboration network between expatriate and indigenous Chinese accrues more benefits of cross-border invention to indigenous Chinese inventors. Fourth, assigning Chinese expatriate inventors to China enhances innovation among indigenous Chinese inventors.

The intended contribution of this study is to investigate the role of MNCs Chinese expatriate inventors in facilitating cross-border knowledge transfer and knowledge spillover in host countries. U.S. MNCs transnational R&D in China often involves multicultural teams that include Chinese inventors from a high-context culture, and western inventors from a low-context culture. People from high-context cultures relies extensive informal information and a tendency towards close personal relationships. Low-context cultures tend to allow only a minimum of informal information (Gassmann 2001). Therefore, people from different cultures often have difficulty building trust between each other, especially when members are geographically dispersed.

Because Chinese expatriates working in the U.S. generally understand both cultures and can be trained to handle intercultural conflicts, MNCs headquarters ethnic Chinese inventors are an ideal “human bridge” within multicultural teams. The results suggest that for firms with a cohesive collaboration network between Chinese expatriates and firms local Chinese, the positive impact of collaboration with headquarters inventors on innovative performance of local Chinese inventors can be strengthened.

This study expands the literature of personnel development and international knowledge spillover. The results indicate that assigning Chinese expatriates to China yields more effective innovation than collaborating with headquarters inventors in the U.S. Although ICT facilitates international innovation, tacit knowledge is more effectively conveyed face to face.

My study bears implications for enhancing R&D in China. If firms regard Chinese R&D as supplementary, more cross-border collaboration leverages Chinese manpower. If firms wish to maintain autonomous R&D centers in China, assigning Chinese expatriates there leverages indigenous Chinese talent to create localized innovations. In either case, MNCs should train Chinese expatriates to lead R&D projects in China. They are inherent mediators of cultural conflicts and trust-builders on virtual teams. Overall, firms should promote collaboration between expatriate and indigenous Chinese inventors, using strategic personnel assignments and virtual teams to multiply the creativity of indigenous Chinese inventors.

5.6. Limitation and Further Research

First, the U.S. patents in my dataset have the application year from 1999 to 2007. Because I use a 5-year citation window for each application year, the latest application year in my dataset is until 2007. For example, the citation received in 2008-2012 is the 5-year citation window for the patent applied in 2007. Because I extract the citation information from Patstat2015, and the patent data in Patstat begin to have truncation problem after the application year 2012, I extract the citation data for all U.S. patents in my dataset until the citing patent year in 2012. The limitation in this research lies in that the application year of patent data is until 2007. More updated patent data should be used for future research. Second, this study only sampled U.S. firms that conducted R&D activities in China. The findings might not be applicable to other country pairs, such as MNCs in other developing countries as host countries. Therefore, future studies should investigate more country combinations, such as MNCs in India as host country.

6. Chapter 6: Conclusions – Summary, Managerial and Policy Implications

6.1. Summary

Literature on knowledge spillover in China has shown that universities and multinational firms are two important knowledge spillover sources. However, past studies explored the role of universities and multinational firms in knowledge spillover in China separately, the literature on the role of universities and multinational firms in knowledge spillover in China still remained fragmented and inconclusive. This dissertation aims to contribute to the current literature by exploring how universities contribute to innovation performance of domestic Chinese ventures, how multinational firms contribute to the knowledge diffusion to indigenous Chinese inventors not only working at domestic Chinese firms, but also at multinational firms' subsidiaries in China.

Chapter 1 is the introduction of the dissertation, and provides the research backgrounds and structure of the thesis. It highlights the research questions of the dissertation: (1) how university – industry collaboration in China is evolved, and how universities as knowledge source contribute to nearby firms' innovation and business performance? (2) How multinational firms in China diffuse knowledge in China?

Chapter 2 shows dynamic changes of UIC network in China, and different patterns of UIC network in China's four main regions: Beijing, Shanghai, Shenzhen, and Wuhan. I concluded that in Beijing, the UIC network is more "sciences push"; whereas in Shenzhen, because universities play the role of providing educational upgrading for local high-tech firms (Chen & Kenney 2007), I can infer that the UIC network in Shenzhen is more towards "market driven". The UIC network in Shanghai is led by both the strong industrial base and science sector. The UIC network in the inland city Wuhan is not as developed as those in Beijing and Shanghai, but the evolvement pattern of the UIC network in Wuhan followed a similar pattern as in Beijing and Shanghai.

Chapter 3 explores the institutional differences between Tsinghua University Science Park (TusPark) and Incubator of Research Institute of Tsinghua University in Shenzhen (RITS). I found that the innovation sources for tenants in RITS are more based on market-driven innovation sources: such as information from customers, suppliers, and competitors. The empirical analysis part investigated why tenants in RITS are more successful in new product sales and new product market penetration. I found that collaborating with university and with a market driven focus jointly contribute to the better new product market performance of tenants in RITS.

Chapter 4 took Shanghai as an example, and found that foreign direct investment in R&D and human mobility are two important channels for domestic Chinese firms to gain knowledge flow form multinational firms. I found that domestic Chinese firms are more likely to gain knowledge flow from multinational firms through international patent citations when (1) domestic Chinese firms' patents are created after multinational firms entered Shanghai, (2) domestic Chinese firms' patents are created by returnee inventors who moved from multinational firms to domestic Chinese firms.

Chapter 5 explored the role of U.S. MNCs' Chinese expatriate inventors in facilitating cross-border knowledge transfer and knowledge spillover in China. I found that for firms with a cohesive collaboration network between expatriates Chinese and indigenous Chinese, the positive impact of collaboration with headquarters inventors on innovative performance of local Chinese inventors can be strengthened. I also found that assigning Chinese expatriates to China yields more effective innovation than collaborating with headquarters inventors in the U.S. Although ICT facilitates international innovation, tacit knowledge is more effectively conveyed face to face.

6.2. Managerial Implications

6.2.1. Implications for Domestic Chinese Firms

This thesis suggests that universities and local R&D sites of foreign MNCs are two important channels for knowledge spillover to domestic Chinese firms. The findings in this thesis provide managerial implications for domestic firms. Firstly, as Chapter 3 suggests, university collaboration has a positive impact on tenant firms' new product innovation in both the two science parks. Because tacit knowledge of university inventions are embedded in university inventors, the successful completion of university collaboration projects requires frequent face-to-face interaction with university inventors. The close geographical proximity to universities could provide more formal and informal interactions with university inventors, enhancing the tacit knowledge transfer which is important for new product development. I draw implication for those firms who are looking for university collaboration, locating within University Science Park could enhance the interaction chances with university faculties and students.

Secondly, when making the decision of choosing which university science park to locate on, firms may consider their objective of university collaboration and the institutional differences between university science parks. Cohen (2002) suggested that firms' objective of university collaboration is either seeking university technology seeds for new project development, or seeking university technology support for firms' current R&D project completion. Chapter 3 suggests that the institutional difference between RITS and TusPark lies in that: in RITS in Shenzhen, the innovation source for new product development is more market-driven. Those tenants who have high dependency on market-driven innovation source and develop new products through university collaboration are more likely to have better new product market performance. Based on these findings, I can draw implications for high tech firms that: (1) if the firms' aim of university collaboration is more towards seeking new product ideas and opening new markets, locating in TusPark in Beijing is beneficial for finding more university technology seeds; (2) if the firms' aim of university collaboration is more towards seeking university technology support for the development of current products, which are highly responding to current market needs, then firms may consider to locate in RITS in Shenzhen. Because in RITS in Shenzhen, those new products which are highly responding to current market needs and which are developed through university collaboration are more likely to succeed in the market.

Thirdly, as Chapter 4 suggests, domestic Chinese firms' patents which are created after foreign MNCs entered Shanghai are more likely to cite MNCs, and returnee inventors who had working experience at multinational firms aboard and who moved to domestic Chinese firms contribute to the knowledge flow from multinationals to domestic firms. These findings provide important managerial implications that domestic firms may consider enhancing the interaction and collaboration opportunities with inventors at MNCs' China R&D centers, with the objective of monitoring the technology trends of foreign MNCs. Domestic firms may also consider the hiring of returnee inventors who had working experiences at multinational firms aboard, and utilize the overseas inventor networks of returnee inventors to gain knowledge flow from multinational firms through international patent citation.

6.2.2. Implications for Foreign MNCs

The managerial implications for foreign MNCs which have R&D centers in China are straightforward: because Chinese expatriates working in the U.S. are potential "human bridge" between headquarters and China local R&D sites, MNCs should train those ethnic Chinese expatriates to effectively manage cross-border R&D projects. My research suggests that assigning Chinese expatriates to China yields more effective innovation than cross-border collaboration, since tacit knowledge is best conveyed through learning by observing and without language barrier. My research provides implications for MNCs on how to use ethnicity closeness and geographical proximity to enhance the innovation performance of indigenous inventors at MNCs' local R&D centers. Firstly, as suggested by the findings in my fourth paper, when a MNC starts to establish the R&D centers in China, it is important to assign expatriate Chinese to the new R&D sites, and bring the firm's culture and tacit knowledge to the indigenous Chinese inventors. Such personnel assignment can be later replaced by virtual teams and cross-border collaboration.

Secondly, the strategic usage of geographical and cultural proximity can be determined by the functional roles of the local R&D sites. If firms regard R&D sites in China as supplementary, more cross-border collaboration leverages Chinese manpower. If firms wish to maintain decentralized and autonomous R&D centers in China, assigning Chinese expatriates there leverages indigenous Chinese talent to create localized innovations. In either case, MNCs should train Chinese expatriates to lead R&D projects in China, since they are inherent mediators of cultural conflicts and trust-builders on virtual teams.

6.3. Policy Implications

6.3.1. Implications for the Chinese Government

This thesis examines the role of university science parks and foreign R&D centers in knowledge spillover to local firms, and draws important implications for the Chinese government. Firstly, Chapter 2 and Chapter 3 suggest that Beijing and Shenzhen have their own regional innovation characteristics. University science parks are embedded in the city's own regional innovation system, and institutional differences between university science parks in Beijing and Shenzhen are raised. One of the policy implications for the city government in China is to make use of the city's own comparative advantage which is embedded in the regional innovation system. For example, Beijing has a long history of universities and research institutes, top universities such as Tsinghua University in Beijing has accumulated a large number of university technology which is waiting for commercialization. Thus, the Beijing city government could consider giving preferential policies on commercializing university technology and on helping firms to expand the new market. On the other hand, Shenzhen has a long history of industrial development, but a short history of universities and research institutes. Local universities in Shenzhen play a role in technology supporting for local high-tech firms. The findings in my research suggests that the institutional difference between TusPark in Beijing and RITS in Shenzhen lies in that tenants in RITS rely more on market-driven sources. Such market-driven knowledge sources and the market-oriented university R&D support together give a positive impact on the new product market performance for tenants in RITS. Thus, the Shenzhen city government could consider giving preferential policies on encouraging company sponsored university industry collaboration projects, and university R&D support for firms' development of new products, which are highly responding to current market needs.

Secondly, Chapter 4 suggests that domestic Chinese firms' patents which are created after MNCs entered Shanghai are more likely make citations to MNCs. Policy implication for the Chinese government is to continuously attract foreign MNCs to establish R&D centers in China. The Chinese government could consider issuing policies on encouraging the interaction and collaboration between foreign MNCs' inventors and local firms' inventors.

Thirdly, Chapter 4 provides empirical evidence on those returnee inventors who had working experiences at multinational firms aboard play an important role in gaining knowledge flow from multinational firms for domestic Chinese firms. Thus, the Chinese government could consider giving more incentives for returnees who worked at multinationals aboard through returnee related policies, and bring them back to domestic Chinese firms. The Chinese government has recognized that overseas Chinese talents could be a key drive of international knowledge sourcing in China. In 2008, the General Office of the Communist Party of China issued "Opinions from Small Group for Coordinating Work on Talent (SGOT) on implementing the Recruitment Program of Global Experts", which specified to use 5-10 years to bring back thousands of returnees to universities and research institutes, companies, or High-tech Science Parks. The results in this paper provide empirical evidence that returnee inventors who come back to domestic firms play important role in gaining international knowledge flow, thus more returnee policies targeting at bring returnee inventors who had working experiences at foreign MNCs aboard to domestic Chinese firms could be implemented.

6.3.2. Implications for MNCs Home Country Government

Foreign MNCs are increasingly setting up R&D centers in China to benefit from its large scientific and engineering talent pool. The findings in this research suggest that U.S. Chinese expatriates, who worked at U.S. headquarters, play an important role in cross-border knowledge transfer and promoting the innovation performance for indigenous Chinese inventors who are employed at MNCs' R&D centers in China. The findings provide policy implications for MNCs' home country government. Firstly, the findings provide implications for immigration related polices. One of the comparative advantages of United States lies in the large pool of high-skilled immigration (Kerr 2013). Those high-skilled ethnic immigrants are an important human resource at U.S. multinationals, and play an important role in bridging U.S. and ethnic immigrants' home countries. Thus, one of the policy implications for MNCs' home country government is promoting the admissions for high skilled immigrant at multinational corporations. Taking Japan as an example, the immigration bureau of Japan has the points-based preferential immigration treatment for highly skilled foreign professionals. In order to effectively make use of the skilled immigrants as a "bridge" between Japan and immigrant's home country, the immigration bureau of Japan could consider giving addition points to those skilled immigrants who are employed at Japanese multinationals and who are conducting international businesses with immigrants' home countries.

Secondly, the findings in this research also provide implications for education related policies for MNCs' home country government. The foreign students who are studying at the universities in MNCs' home countries are an important labor force for MNCs. Another policy implication for MNCs' home country government is promoting the educational programs which could train foreign students to become future leaders at multinational corporations or international organizations. For example, the University of Tokyo in Japan established The Global Leader Program for Social Design and Management (GSDM), which is a doctoral program to train future leaders, who are expected to play the “bridging role” between Japan and the global society. Such program includes international students and Japanese students. Such programs could help foreign students to enhance their leadership skills in bringing together Japan and foreign students’ home countries.

One of the competencies developed for international students through this program is the cross-cultural communication skills, which is not only about mastering a foreign language. Rather, the cross-cultural communication skill is about a deep understanding of the foreign culture, and the interpersonal skill of handling culture conflicts in a multi-culture team. This thesis provides further implication for how to improve such educational program. Detailed suggestions include (1) providing more multi-culture team works for training foreign students’ leadership skills in handling culture conflicts; (2) providing job or intern opportunities for foreign students to work at Japanese multinational corporations and conduct international business related works.

The thesis provides empirical evidence on that ethnic Chinese inventors play an important role in “bridging” U.S. MNCs headquarter inventors and China subsidiaries’ indigenous Chinese inventors. In conclusion, one of the policy implications for MNCs’ home country government from this thesis is to promote the admission of skilled immigrations and the education for training international students to become future leaders at multinational corporations.

Reference

Alcácer, J., M. Gittelman and B. Sampat (2009), 'Applicant and examiner citations in US patents: An overview and analysis', *Research Policy*, **38** (2): 415-427.

Alcacer, J. and M. Gittelman (2006), 'Patent citations as a measure of knowledge flows: The influence of examiner citations', *The Review of Economics and Statistics*, **88** (4): 774-779.

Almeida, P. (1996), 'Knowledge sourcing by foreign multinationals: patent citation analysis in the US semiconductor industry', *Strategic Management Journal*, **17** (S2): 155-165.

Almeida, P. and B. Kogut (1999), 'Localization of Knowledge and the Mobility of Engineers in Regional Networks', *Management Science*, **45** (7): 905-917.

Almeida, P., J. Song and G. Wu (2003), 'Learning–by–Hiring: When Is Mobility More Likely to Facilitate Interfirm Knowledge Transfer?', *Management Science*, **49** (4): 351-365.

Alnuaimi, T., T. Opsahl and G. George (2012), 'Innovating in the periphery: The impact of local and foreign inventor mobility on the value of Indian patents', *Research Policy*, **41** (9): 1534-1543.

Angel, D. P. (1991), 'High-technology agglomeration and the labor market: the case of Silicon Valley', *Environment and Planning A*, **23** (10): 1501-1516.

Borgatti, S. P. (2009), '2-Mode concepts in social network analysis', *Encyclopedia of complexity and system science*, **6**.

Bramwell, A. and D. A. Wolfe (2008), 'Universities and regional economic development: The entrepreneurial University of Waterloo', *Research Policy*, **37** (8): 1175-1187.

Branstetter, L. (2006), 'Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States', *Journal of international Economics*, **68** (2): 325-344.

Branstetter, L., G. Li and F. Veloso (2013), 'The Globalization of R&D: China, India and the Rise of International Co-invention', *Unpublished working paper*.

Breschi, S. and F. Malerba (2001), 'The geography of innovation and economic clustering: some introductory notes', *Industrial and Corporate Change*, **10** (4): 817-833.

Bresnahan, T., A. Gambardella and A. Saxenian (2001), '‘Old economy’inputs for ‘new economy’outcomes: cluster formation in the new Silicon Valleys', *Industrial and Corporate Change*, **10** (4): 835-860.

Chan, K. F. and T. Lau (2005), 'Assessing technology incubator programs in the science park: the good, the bad and the ugly', *Technovation*, **25** (10): 1215-1228.

Chen, K. and M. Kenney (2007), 'Universities/research institutes and regional innovation systems: the cases of Beijing and Shenzhen', *World development*, **35** (6): 1056-1074.

Chen, Y.-C. (2006), 'Changing the Shanghai Innovation Systems The Role of Multinational Corporations' R&D Centres', *Science Technology & Society*, **11** (1): 67-107.

Cheung, K.-y. and L. Ping (2004), 'Spillover effects of FDI on innovation in China: Evidence from the provincial data', *China Economic Review*, **15** (1): 25-44.

Choudhury, P. (2010), 'Seeking Resources or Seeking Knowledge? A Study of Mobility and Knowledge Creation Using Micro Data', *A Study of Mobility and Knowledge Creation Using Micro Data (August 2010)*.

Coenen, L. (2007), 'The role of universities in the regional innovation systems of the North East of England and Scania, Sweden: providing missing links?', *Environment and Planning C: Government and Policy*, **25** (6): 803-821.

Cohen, W. M., R. R. Nelson and J. P. Walsh (2002), 'Links and impacts: the influence of public research on industrial R&D', *Management Science*, **48** (1): 1-23.

Cooke, P. (2001), 'Regional innovation systems, clusters, and the knowledge economy', *Industrial and Corporate Change*, **10** (4): 945-974.

Cooke, P., M. G. Uranga and G. Etxebarria (1997), 'Regional innovation systems: Institutional and organisational dimensions', *Research Policy*, **26** (4): 475-491.

Díez-Vial, I. and Á. Montoro-Sánchez (2016), 'How knowledge links with universities may foster innovation: The case of a science park', *Technovation*, **50**: 41-52.

Dai, O. and X. Liu (2009), 'Returnee entrepreneurs and firm performance in Chinese high-technology industries', *International Business Review*, **18** (4): 373-386.

Duguet, E. and M. MacGarvie (2005), 'How well do patent citations measure flows of technology? Evidence from French innovation surveys', *Economics of Innovation and New Technology*, **14** (5): 375-393.

Eesley, C. E., D. Yang, T. Li and E. B. Roberts (2016), 'Understanding Entrepreneurial Process and Performance: A Cross-National Comparison of Alumni Entrepreneurship Between MIT and Tsinghua University', *Asian Journal of Innovation & Policy*, **5** (2).

Eun, J.-H., K. Lee and G. Wu (2006), 'Explaining the "University-run enterprises" in China: A theoretical framework for university–industry relationship in developing countries and its application to China', *Research Policy*, **35** (9): 1329-1346.

Feinberg, S. E. and S. K. Majumdar (2001), 'Technology spillovers from foreign direct investment in the Indian pharmaceutical industry', *Journal of International Business Studies*, **32** (3): 421-437.

Feldman, M. P. and D. B. Audretsch (1999), 'Innovation in cities:: Science-based diversity, specialization and localized competition', *European economic review*, **43** (2): 409-429.

Filatotchev, I., X. Liu, J. Lu and M. Wright (2011), 'Knowledge spillovers through human mobility across national borders: Evidence from Zhongguancun Science Park in China', *Research Policy*, **40** (3): 453-462.

Fleming, L., R. Lai, A. D'Amour, D. M. Doolin, Y. Sun, V. I. Torvik, Z. Y. Amy and G.-C. Li (2014), 'Disambiguation and co-authorship networks of the US patent inventor database (1975–2010)', *Research Policy*, **43** (6): 941-955.

Ganco, M. (2013), 'Cutting the Gordian knot: The effect of knowledge complexity on employee mobility and entrepreneurship', *Strategic Management Journal*, **34** (6): 666-686.

Haskel, J. E., S. C. Pereira and M. J. Slaughter (2007), 'Does inward foreign direct investment boost the productivity of domestic firms?', *The Review of Economics and Statistics*, **89** (3): 482-496.

He, J., L. Wang and G. Zeng (2013), 'Commercial exploitation of technical capacity promotes technology commercialization: a case from RITS', *Studies in Science of Science*, **31** (9).

Hong, W. (2008), 'Decline of the center: The decentralizing process of knowledge transfer of Chinese universities from 1985 to 2004', *Research Policy*, **37** (4): 580-595.

Hong, W. and Y.-S. Su (2013), 'The effect of institutional proximity in non-local university–industry collaborations: An analysis based on Chinese patent data', *Research Policy*, **42** (2): 454-464.

Hu, A. G. and A. B. Jaffe (2003), 'Patent citations and international knowledge flow: the cases of Korea and Taiwan', *International journal of industrial organization*, **21** (6): 849-880.

Jaffe, A. B. and M. Trajtenberg (1999), 'International knowledge flows: evidence from patent citations', *Economics of Innovation and New Technology*, **8** (1-2): 105-136.

Jaffe, A. B., M. Trajtenberg and R. Henderson (1993), 'Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations', *The Quarterly Journal of Economics*, **108** (3): 577-598.

Johnson, J. M. and M. C. Regets (1998), 'International Mobility of Scientists and Engineers to the United States--Brain Drain or Brain Circulation?', *SRS Issue Brief*.

Keller, W. (2002), 'Geographic localization of international technology diffusion', *The American Economic Review*, **92** (1): 120-142.

Keller, W. (2004), 'International technology diffusion', *Journal of economic literature*, **42** (3): 752-782.

Kogut, B. and U. Zander (1993), 'Knowledge of the firm and the evolutionary theory of the multinational corporation', *Journal of International Business Studies*: 625-645.

Kokko, A. (1992), 'Foreign direct investment, host country characteristics and spillovers'.

Löfsten, H. and P. Lindelöf (2002), 'Science Parks and the growth of new technology-based firms—academic-industry links, innovation and markets', *Research Policy*, **31** (6): 859-876.

Löfsten, H. and P. Lindelöf (2005), 'R&D networks and product innovation patterns—academic and non-academic new technology-based firms on Science Parks', *Technovation*, **25** (9): 1025-1037.

Lampe, R. (2012), 'Strategic citation', *Review of Economics and statistics*, **94** (1): 320-333.

Latapy, M., C. Magnien and N. Del Vecchio (2008), 'Basic notions for the analysis of large two-mode networks', *Social Networks*, **30** (1): 31-48.

Leng, T.-K. and J.-H. Wang (2013), 'Local states, institutional changes and innovation systems: Beijing and Shanghai compared', *Journal of Contemporary China*, **22** (80): 219-236.

Li, X. (2009), 'China's regional innovation capacity in transition: An empirical approach', *Research Policy*, **38** (2): 338-357.

Li, X. (2012), 'Behind the recent surge of Chinese patenting: An institutional view', *Research Policy*, **41** (1): 236-249.

Li, Z. and H. Chen (2014), 'Tsinghua University Science park', *Tsinghua University Press*.

Lin, P., Z. Liu and Y. Zhang (2009), 'Do Chinese domestic firms benefit from FDI inflow?: Evidence of horizontal and vertical spillovers', *China Economic Review*, **20** (4): 677-691.

Lindelöf, P. and H. Löfsten (2003), 'Science park location and new technology-based firms in Sweden–implications for strategy and performance', *Small business economics*, **20** (3): 245-258.

Link, A. N. and J. T. Scott (2003), 'US science parks: the diffusion of an innovation and its effects on the academic missions of universities', *International journal of industrial organization*, **21** (9): 1323-1356.

Link, A. N. and J. T. Scott (2005), 'Opening the ivory tower's door: An analysis of the determinants of the formation of US university spin-off companies', *Research Policy*, **34** (7): 1106-1112.

Liu, X. and T. Buck (2007), 'Innovation performance and channels for international technology spillovers: Evidence from Chinese high-tech industries', *Research Policy*, **36** (3): 355-366.

Motohashi, K. (2006), 'China's national innovation system reform and growing science industry linkage', *Asian Journal of Technology Innovation*, **14** (2): 49-65.

Motohashi, K. (2008), 'Assessment of technological capability in science industry linkage in China by patent database', *World Patent Information*, **30** (3): 225-232.

Motohashi, K. (2010), 'R&D activities of manufacturing multinationals in China: structure, motivations and regional differences', *China & World Economy*, **18** (6): 56-72.

Motohashi, K. (2013), 'The role of the science park in innovation performance of start-up firms: an empirical analysis of Tsinghua Science Park in Beijing', *Asia Pacific Business Review*, **19** (4): 578-599.

Motohashi, K. (2014), 'Measuring Multinational's R&D Activities in China by Patent Database: Comparison of European, Japanese and US firms', *Working paper*.

Motohashi, K. (2015), 'Measuring Multinationals' R&D Activities in China on the Basis of a Patent Database: Comparing European, Japanese and US Firms', *China & World Economy*, **23** (6): 1-21.

Motohashi, K. and Y. Yuan (2010), 'Productivity impact of technology spillover from multinationals to local firms: Comparing China's automobile and electronics industries', *Research Policy*, **39** (6): 790-798.

Motohashi, K. and X. Yun (2007), 'China's innovation system reform and growing industry and science linkages', *Research Policy*, **36** (8): 1251-1260.

Mowery, D. C., R. R. Nelson, B. N. Sampat and A. A. Ziedonis (2001), 'The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh–Dole act of 1980', *Research Policy*, **30** (1): 99-119.

Mrinalini, N. and S. Wakdikar (2008), 'Foreign R&D centres in India: Is there any positive impact', *Current science*, **94** (4): 452-458.

Phan, P. H., D. S. Siegel and M. Wright (2005), 'Science parks and incubators: observations, synthesis and future research', *Journal of Business Venturing*, **20** (2): 165-182.

Porter, M. E. (2000), 'Location, competition, and economic development: Local clusters in a global economy', *Economic development quarterly*, **14** (1): 15-34.

Quintas, P., D. Wield and D. Massey (1992), 'Academic-industry links and innovation: questioning the science park model', *Technovation*, **12** (3): 161-175.

Rothaermel, F. T. and M. Thursby (2005), 'University–incubator firm knowledge flows: assessing their impact on incubator firm performance', *Research Policy*, **34** (3): 305-320.

Saxenian, A. (1990), 'Regional networks and the resurgence of Silicon Valley', *California Management Review*, **33** (1): 89-112.

Saxenian, A. (2006), *International Mobility of Engineers and the Rise of Entrepreneurship in the Periphery*: Research Paper, UNU-WIDER, United Nations University (UNU).

Singh, J. (2003), 'Multinational firms and international knowledge diffusion: evidence using patent citation data', Citeseer.

Singh, J. (2005), 'Collaborative networks as determinants of knowledge diffusion patterns', *Management Science*, **51** (5): 756-770.

Singh, J. (2007), 'Asymmetry of knowledge spillovers between MNCs and host country firms', *Journal of International Business Studies*, **38** (5): 764-786.

Skarlicki, D. P., R. Folger and P. Tesluk (1999), 'Personality as a moderator in the relationship between fairness and retaliation', *Academy of Management Journal*, **42** (1): 100-108.

Smarzynska Javorcik, B. (2004), 'Does foreign direct investment increase the productivity of domestic firms? In search of spillovers through backward linkages', *The American Economic Review*, **94** (3): 605-627.

Sohn, D.-W. and M. Kenney (2007), 'Universities, clusters, and innovation systems: The case of Seoul, Korea', *World development*, **35** (6): 991-1004.

Song, J. (2000), 'Technological Catching-up of Korea and Taiwan in the Global Semiconductor Industry: A Study of Modes of Technology Sourcing', *APEC Study Center, Columbia University, Discussion Paper Series (December)*.

Song, J., P. Almeida and G. Wu (2001), 'Mobility of engineers and cross-border knowledge building: The technological catching-up case of Korean and Taiwanese semiconductor firms', *Comparative Studies of Technological Evolution*: 59-84.

Sun, W., J. Gao, W. Zhang, D. Wang and G. Feng (2009), 'Insititutional innovation for the industry - university - research institute collaboration: An integrated innovation unit', *Science Research Management*, **30** (5).

Sun, Y., D. Du and L. Huang (2006), 'Foreign R&D in developing countries: empirical evidence from Shanghai, China', *China Review*: 67-91.

Szulanski, G. (1996), 'Exploring internal stickiness: Impediments to the transfer of best practice within the firm', *Strategic Management Journal*, **17** (S2): 27-43.

Szulanski, G. (2000), 'The process of knowledge transfer: A diachronic analysis of stickiness', *Organizational Behavior and Human Decision Processes*, **82** (1): 9-27.

Tan, J. (2006), 'Growth of industry clusters and innovation: Lessons from Beijing Zhongguancun Science Park', *Journal of Business Venturing*, **21** (6): 827-850.

Trippl, M., T. Sinozic and H. Lawton Smith (2015), 'The role of universities in regional development: conceptual models and policy institutions in the UK, Sweden and Austria', *European Planning Studies*, **23** (9): 1722-1740.

Wang Luhao, W. C., Zeng Guoping (2013), 'Study of Stratification Mechanism in Incubatees: Case Research Institute of Tsinghua University in Shenzhen', *Forum on Science and Technology in China*, **9** (9).

Yang, C.-H., K. Motohashi and J.-R. Chen (2009), 'Are new technology-based firms located on science parks really more innovative?: Evidence from Taiwan', *Research Policy*, **38** (1): 77-85.

Zhao, S., L. Cacciolatti, S. Lee and W. Song (2015), 'Regional collaborations and indigenous innovation capabilities in China: A multivariate method for the analysis of regional innovation systems', *Technological Forecasting and Social Change*, **94**: 202-220.

Zhou, Y. (2005), 'The making of an innovative region from a centrally planned economy: institutional evolution in Zhongguancun Science Park in Beijing', *Environment and Planning A*, **37** (6): 1113-1134.

Zhou, Y. and T. Xin (2003), 'An innovative region in China: interaction between multinational corporations and local firms in a high - tech cluster in Beijing', *Economic Geography*, **79** (2): 129-152.

Acknowledgment

I am extremely grateful to my supervisor, Professor Kazuyuki Motohashi. Over the past three years, Professor Motohashi taught me how to establish the intellectual standards that a PhD student should have. His abundant patience and support gave me the strength to move forward and pursue the intellectual standards, which I once thought unachievable. His tremendous creativity and curiosity for economic research inspired me to always ask “why” five times after every matter and to achieve results through continuous improvement. His supervision will inspire me throughout my future career.

I am further grateful to my secondary advisor from GSDM program, Professor Masaru Yarime. I am very thankful to his many very helpful suggestions on my research. I also thank Professor Sotaro Shibayama, Professor Ichiro Sakata, and Professor Kazuro Kageyama and the faculty members at the department of TMI for their persistent support for PhD students through classroom lessons and thesis advising. I also thank my third advisor from GSDM program, Professor Zhang Luyang for his kind help and arrangements on my research about university science parks in China. I am also very thankful to my friends at Motohashi Lab, Dr. Huo, Dr. Dang, Dr. Kang, Dr. Kobayashi, Mr. Suchit, Ms. Yin, Ms. Zhang and Mr. Yu, who gave me many good suggestions on my research.

My parents have been the greatest source of my strength and confidence. This thesis is only possible due to the continuous support from my parents. It is not possible to express my complete thankfulness for my parents.