Innovation in China:
The Promise and The Challenge
in A Transition Economy

Inauguraldissertation zur Erlangung des
akademischen Grades eines Doktors der
Wirtschaftswissenschaften
der Universität Mannheim

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Tag der mündlichen Prüfung: 12. Dezember 2018

Acknowledgments

Writing this dissertation has been a lonely task, but it is not the outcome of my efforts alone. I am deeply grateful to a number of people without whom I would not have succeeded.

First and foremost, I am deeply indebted to my supervisor: Michael Woywode for his continuous support and encouragement of my Ph.D study and research, and for his patience and guidance to help me in all the time of writing this thesis. Moreover, I would like to express my deepest gratitude to two professors from China: Shanlang Lin from Tongji University in Shanghai and Shougui Luo from Shanghai Jiaotong University for their hospitality, countless discussion on my thesis as well as the access to the database.

My sincere thanks also goes to colleagues at the University of Mannheim: Aiyong Zhu, Qiang Guo, Annegret Hauer, Niclas Rüffer, Jan Klaus Tänzler, and Steffan for sharing experience and knowledge with me and giving me helpful comments on my work. In addition, I gratefully acknowledge financial support from the Deutsche Forschungsgemeinschaft.

I also wish to thank my best friends Zili Tang, Lin Xue and Lu Wang_Kubert for their numerous help to smooth my life in Germany.

In addition, I would like to take this opportunity to thank doctoral students: Dr. Wei Ye, Yunbin Shen, Xuechen Meng, Jun Cang, Xiaoli Hu, Na Yan at Tongji University and Qiang Luan at Shanghai Jiaotong University for their generous support during my stay in the two universities and their insightful comments on my thesis.

Last, but in this context definitely not least, my deepest gratitude goes to family, Chi, Man and Yan who have been supportive and understanding of an inattentive wife and mother. I am grateful to all the generous support from my father, Qisong Chen, my brother Hui Chen and parents-in-law, Jinlong Zhang and Hongmei Wang.

Finally despite the fact that this is not a one-man job, there is only one to blame for all the errors and omissions: the author.

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List of Acronyms

CAS	Chinese Academy of Science
CCCPC	the Central Committee of the Communist Party of China
EAC countries	East African Community countries
EU	European Union
FDI	foreign direct investment
FIE	foreign invested enterprises
GAC	General Administration of Customs of China
GDP	Gross Domestic Products
GERD	gross domestic expenditure on R&D
GIS	governmental institutional support
GRP	Gross Regional Products
HMT enterprises	Hong Kong, Macau and Taiwan owned enterprises
HTDC	High-tech development zone
IEADS	Industrial Enterprises above Designated Size
IPR	intellectual property right
JV	Joint Venture
"Ke Ji Qiang Guo" strategy	"great power in science and technology" strategy
"Ke Jiao Xing Guo" strategy	"revitalizing the nation through science, technology and education" strategy
MLP	Medium-to-Long-term Plan outline for the Development of National Science and Technology (2006–2020)
MOST	Ministry of Science and Technology
NBS	National Bureau of Statistics of China

NIS	national innovation system
NNSFC	National Natural Science Foundation of China
NTTC	National Technology Transfer Center
PCT	Patent Cooperation Treaty
POE	Private Owned Enterprise
PPC	Productivity Promotion Center
PRI	public research institute
R&D	research and development
"Ren Cai Qiang Guo" strategy	"strengthening the nation through talents" strategy
RIS	regional innovation system
SME	small- and medium-sized enterprise
SIPO	The State Intellectual Property Office
SOE	state-owned enterprises
S&T	science and technology
TBI	Technology Business Incubator
TM	Technology Market
WB	World Bank
WOFE	Wholly-Owned Foreign Enterprises
WTO	World Trade Organization
"Zi Zhu Chuang Xin" strategy	"independent or indigenous innovation" strategy

Chapter 1

General Introduction

China has experienced high rate of economic growth over these decades. Nevertheless China today faces the challenge of sustainable growth in social, economic and ecological aspects. The growth model that China has followed so successfully now needs to change and evolve. Regarding innovation as an effective engine for sustainable growth model, Chinese government has launched a series of policies and regulations with the aim of transforming China into an innovative country by 2020 and a world-leader in innovation by 2050. The Chinese enterprises as potential main innovators are also undergoing a rapid transformation in the process of evolving from backroom producers to the world's leading force of innovation.

However, the unique political and cultural circumstances of China as emerging economy means that the innovation process in China looks very differently than it does in the rest of the world. A number of factors that make China's innovation landscape unique, such as focus on short-term, incremental innovation rather than long-term, radical innovation; close ties between business and local-, provincial- and central-government; the dominance position of state-owned-enterprises (SOEs) in Chinese economy and the political economic climate of structured uncertainty.

Will China be able to becoming a global competitor in innovation? What will it need in terms of institutional changes? Does geographical location advocated in the research field of economic geography really work in China in consideration of its enormous regional imbalance? Are there any other factors besides firm- and region-level ones determining the innovative performance of Chinese enterprises? This thesis sheds light on issues relating to innovation and tries to answer questions like these.

This thesis consists of three chapters that studying diverse determinants of innovation in China qualitatively and quantitatively. Revolving the innovation issues, each chapter discusses the corresponding research topics with different theoretical perspective including regional innovation system (RIS) perspective, economic geographical perspective and also the supply chain concept from management field. Logic exists in the following three chapters. The second chapter overviews the innovation landscape of China and finds the ineffectiveness of RIS in China. It implies that, region in China should have more influence than what we have found. It is consistent with the finding from the empirical study in Chapter 3 that firm's innovation is mainly dependent on its internal resources while sectoral and regional factors only work in specific areas. Therefore, important improvements are required in both the institutional environment and regional innovation system for Chinese enterprises to exploit advantage of location for success in promoting innovation. The fourth chapter is a complementary in discussing the determinants of innovation in China. China as top trading nation in the world have enormous relationship with foreigners while China still have large gap with developed countries in innovation. Therefore, study in Chapter 4 is very necessity to see whether a foreign supplier or customer relationship benefit Chinese enterprise in terms of innovative performance.

Study in chapter 2 applies a regional innovation systems (RIS) viewpoint to observe innovation landscape in China. In recent years china has made advances in innovation capacity such as the high R&D (research and development) intensity, great patent application and top amount of high-tech export. However, the general positive developments in Chinese innovation landscape is challenged by regional and sectoral deficiencies. One of the major challenges accompanying Chinese rapid economic growth is China's high dependency on foreign sources and technology compared with low-level indigenous innovation. Another challenge is China's high patentable activities accompanied with comparable low innovative outputs. Also, deficiency exists in China's large amount of high-tech exports contrary to the low position in global value chain and the extreme sector imbalance. In addition, unbalanced R&D expenditure structure in terms of funding sources, performers and types of R&D expenditures also challenges China's innovation environment.

The second chapter reviews firstly the transition of governmental innovation policies in China and describes the main deficiencies of national and regional innovation situation more deeply and thoroughly with amounts of figures and statistics. Basing on a comparison of the NIS (national innovation system) and RIS concept, this chapter constructs a conceptual explanatory framework for RIS in China. After that, it attempts to analyze and compare imbalance in RIS from three aspects: actors, institutions and relationships. Major statistics of innovation-related indicators are presented and discussed for selected and representative regions. Also, some adjusting strategies are suggested.

The objective of this chapter is to reveal the regional imbalance in terms of innovative indicators and to answer the question: to what extent do RIS constrain or facilitate regions' innovative capacity. Compared to previous innovation studies about China, this chapter presents a comprehensive description of historical innovation policies' development and a from micro (individual level such as firms, universities etc.) to macro (regional level) analysis in terms of innovation input and output progress. Moreover, different from the NIS perspective that previous studies normally use, this paper applies RIS perspective to do within-nation comparison and discuss the RIS effectiveness with each component in a conceptual explanatory framework. In this chapter, I choose 31 administrative provincial-level regions as the unit of analysis. It advances most studies where state is used as spatial scale. Although the data collection is difficult, I use large amount of statistics and official data to reflect the heterogeneity of regions more exactly and benefit more accurate and efficient innovation system analysis results.

The third chapter is an empirical study which questions the role of geographical location in enterprise's innovation in China. Many studies in the field of regional science or economic geography have emphasized the influence of regional characteristics on firm's innovativeness. Their main theoretical arguments are knowledge spillover theory and proximity theory. However, some scholars have questioned the major assumption and mechanism used in these studies and thus the possible overestimated role of firm's geographical position. Meanwhile, scholars from organization and management fields advocate the importance of resources inside the firm on firm's innovativeness. Also, industry characteristics have been argued to influence firm's innovation in some degree. Further, the effect from industry might be region-specific. Therefore, it is necessary to reassess the exact effect from geographical circumstance. To accomplish this purpose, this chapter takes all possible influencing variables into account. After deeply theoretical analysis, I summarize explanatory variables from three levels into an explanatory framework and formulate the different mechanism of knowledge flows from each level to firm. In addition, I use a multi-level econometric approach which goes beyond normal OLS approach frequently applied in previous empirical studies. The advantage of this approach is to avoid the "ecological fallacy" and to disentangle effects from firm, sector and region.

This analysis is based on a sample of Chinese manufacturing firms. Indeed, there are very few studies on firm's innovation in emerging economy. Therefore, it is meaningful to test whether existing theoretical propositions and empirical results still effective in developing areas, especially in China. Moreover, previous studies about Chinese economy generally focus on regional or national innovation system. And most of them conceptualize knowledge spillover effect by using state or metropolitan area as geographic unit. Krugman (1991b: 43) has pointed out that "states aren't really the right geographical units". Similarly, Glaeser et al. (2000) suggest that cities are normally the centers of idea creation and transmission. This chapter therefore uses cities as the level of aggregation to account effects from geographical and sectoral aspect.

As a whole, this study tries to answer the question whether the role of region is more important than that of the others. In other words, it explains how much of the innovation is interpreted by attributes from firm, from sector and from region respectively. This study reviews firstly the main theoretical and empirical arguments relating to the firm's innovation. It describes these arguments from three aspects: relationship between firm and innovation, relationship between sector and innovation and relationship between region and innovation. Basing on the theoretical backgrounds, it then attempts to model the effect from three levels in a comprehensive multilevel framework. After that, the empirical findings from different models are presented and discussed.

The study combines two longitudinal dataset. One is China City Statistical Yearbook (CCSY) and the other is China Annual Survey of Industrial Firms (CASIF survey). The empirical results show that firm's innovation is mainly dependent on its internal resources while sectoral and regional factors only work in specific areas. Although the fact that the regional attributes are weakly linked to the firm's innovation remarkably undermines the generally recognized effect of geography, economic geography still matters for some firms when firms are categorized in three parts. Similarly, industry variety within a geographic region exhibits limited effect.

This chapter contributes to the empirical studies on firm's innovation in some ways. Firstly, this study is one of the very few researches which relate micro level firm's innovation with macro level agglomeration in emerging economy. Secondly, it uses city as spatial scale which advances most of studies about Chinese economy where state is frequently used as unit of observation. Thirdly, it accounts for variables from three levels and thus has a very high data requirement. Finally, the usage of multi-level econometric method makes our results more robust and reliable.

The fourth chapter is also an empirical study which analyzing innovation determinants with a particular attention on the spatial distribution of firm's main customer-supplier relationships. Determinants of firm's innovative performance have been extensively discussed with kinds of theoretical perspectives, including resource based view, network approach, economic geography and proximity theories etc. In this chapter, we consider a specific perspective, the spatial distribution of firm's main customer-supplier relationship, which contributes to explain firm's innovation performance to some degree. Very few researchers have realized the role of the influence from focal firm's upstream or downstream market players, namely the influence from firm's customer or supplier. Furthermore, little empirical evidence is available to support these claims. This study fulfills the gap by including the spatial distribution of a focal firm's customer-supplier relationship into innovation analysis. Deploying the customer-supplier relationship concept from supply chain management literature, I define different types of customer-supplier relationships for a focal firm. Basing on the country where focal firm's main supplier or customer locates, four types of customer-supplier relationships are identified, namely ① domestic supplier-domestic customer relationship, ② domestic supplier-foreign customer relationship, ③ foreign supplier-domestic customer relationship, ④ foreign supplier-foreign customer relationship.

This study argues that spatial difference in customer-supplier relationship influences focal firm's innovative performance. In consideration of knowledge heterogeneity caused by physical and cognitive difference, I propose that a firm possessing either foreign customer or supplier relationship can generate more innovative performance than a firm without foreign customer or supplier relationship. The paper seeks to broaden the theoretical and empirical discussion of the relation between networking, innovation and location. It doesn't intention to undermine the value of existing perspectives mentioned above. The objective of this study is to pursuit a more broad perspective and to advance our understanding of the determinants of innovation through an empirical study.

This chapter firstly review the relevant studies and put forward hypotheses. After that, methodological issues concerning empirical study are discussed and findings are presented. The final section summarizes and discusses the most important findings of the analysis. The basic data used in this study is a longitudinal dataset of all small and medium-sized science and technology firms in Shanghai. The data collection has started in year 2009 and carried out yearly by Science and Technology Commission of Shanghai Municipality (STCSM). Due to its compulsory nature, the data suffers less from unreliable observations and is of higher quality than survey data or questionnaire. Empirical results highlight the importance of internal resource as well as external cooperation for innovation purpose. These results in general are in line with findings from previous studies. The effect of governmental support on innovation issues is also underscored here. This implies an idiographic feature of Chinese business environment: institutional benefit from government might bring firms benefit in improving innovative performance.

The newest insight of the fourth chapter is the significant positive effects from three types of spatial distribution of customer-supplier relationship on firm's innovative performance. Furthermore, the result is robust based on panel data and on different estimation methods. This study also provides several important implications for innovation management, especially in China.

As a whole, this thesis contributes to innovation literature by providing empirical and theoretical lens for improving indigenous innovation in China.

Chapter 2

Innovation Landscape in China -- A Regional Innovation Systems Viewpoint

2.1 Introduction

China has achieved an extraordinary rapid economic growth and social development over nearly four decades since the economic reform and the “open door” policy in 1980s. The Chinese GDP (Gross Domestic Products) has shown remarkable growth over the past years (Figure 2. 1). China is now the second largest economy with a GDP volume of 11191 billion U.S. dollar in the world only after the United States in 2016 (Figure 2. 2). However, China is still a developing country with its GDP per capita far lagged behind average of that of developed countries or OECD countries (Figure 2. 3). To keep high rates of economic growth and to realize nation-wide industrialization and urbanization, it is necessary for China to change its current pattern of growth. Chinese government has recognized innovation as an effective engine for sustainable economic, social and environmental development. The yearly aggressive increasing research and development (R&D) budgets (Figure 2. 4) has shown government’s long-term commitment to science and technology innovation. China’s investment in R&D is from 34.869 billion yuan in 1995 to 1.5676 trillion yuan in 2016, an increase of 10.63% over the previous year. Meanwhile, China’s R&D intensity (ratio of national R&D

expenditure to GDP) also known as GERD (gross domestic expenditure on R&D), has nearly quadrupled from 0.57% of total GDP in 1995 to 2.11% in 2016 (Figure 2. 5). In 2012, China overtook European Union (EU) with R&D intensity of 1.93%, just above EU's average value of 1.92% (Figure 2. 6). It is a milestone for china as a potential innovative nation in global economy. Until 2016, the R&D intensity in China has exceeded the level of 2% for three consecutive years.

Figure 2. 1 GDP growth rate (2000 – 2016)

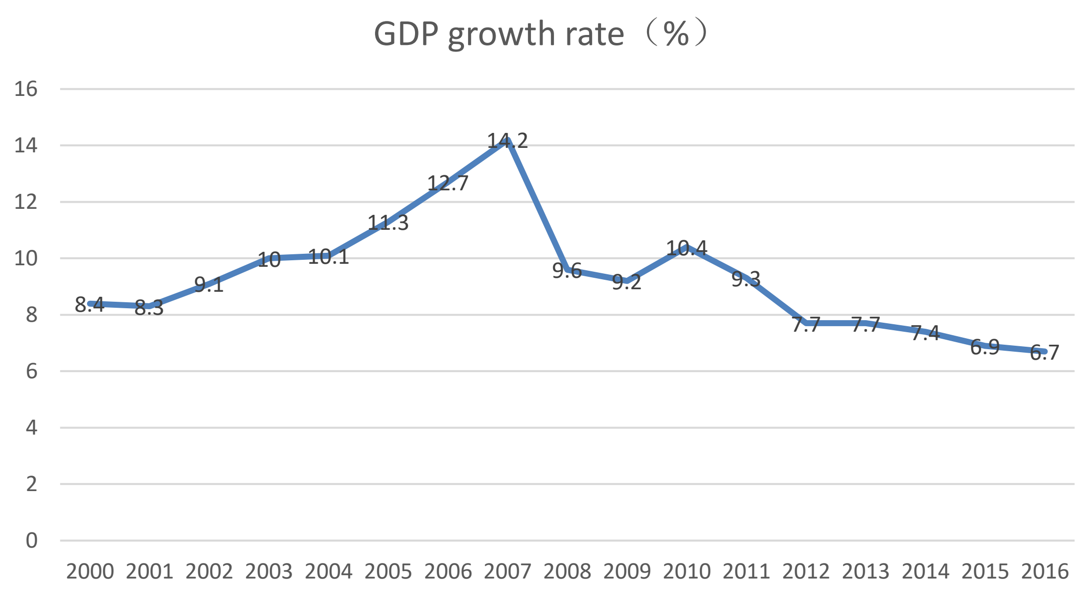


Figure 2. 2 international comparison: GDP ranking, 2016 (in billion U.S. dollars) (source: World Bank)

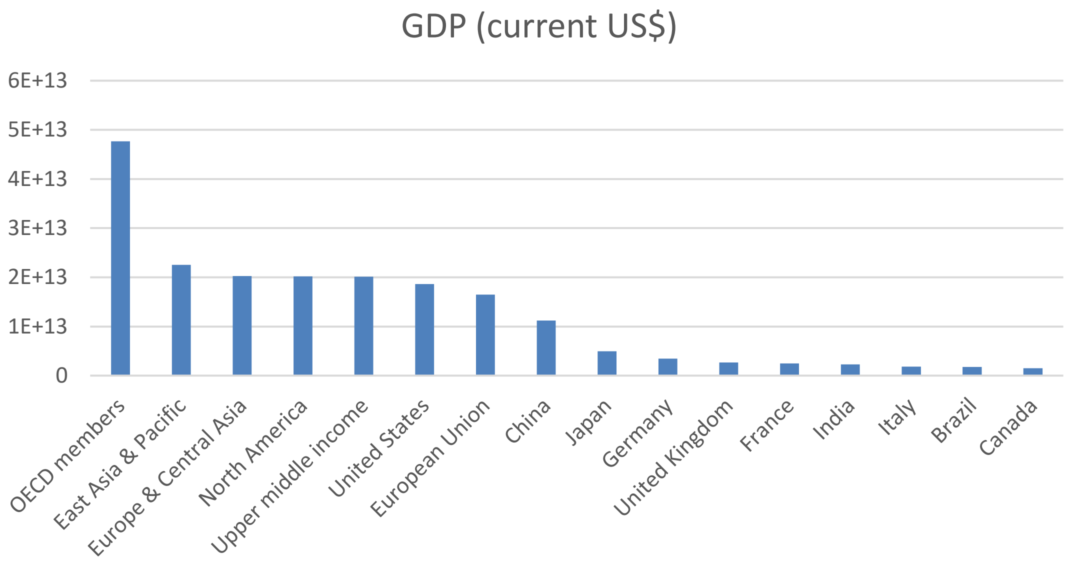


Figure 2. 3 international comparison: GDP per capita, 2016 (source: WB)

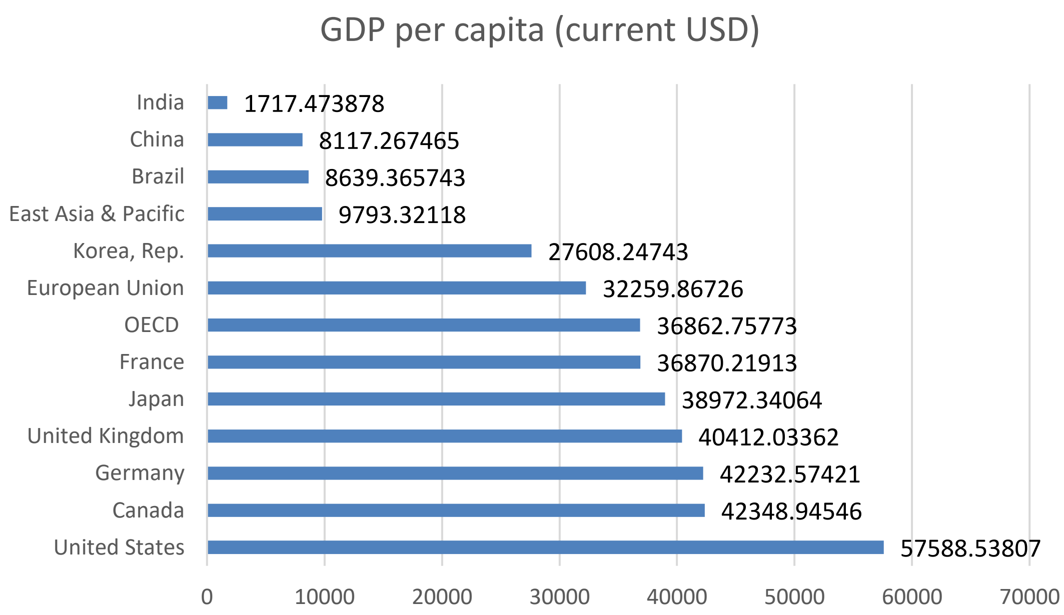


Figure 2. 4 GERD, China, 2007-2016 (source: NBS)

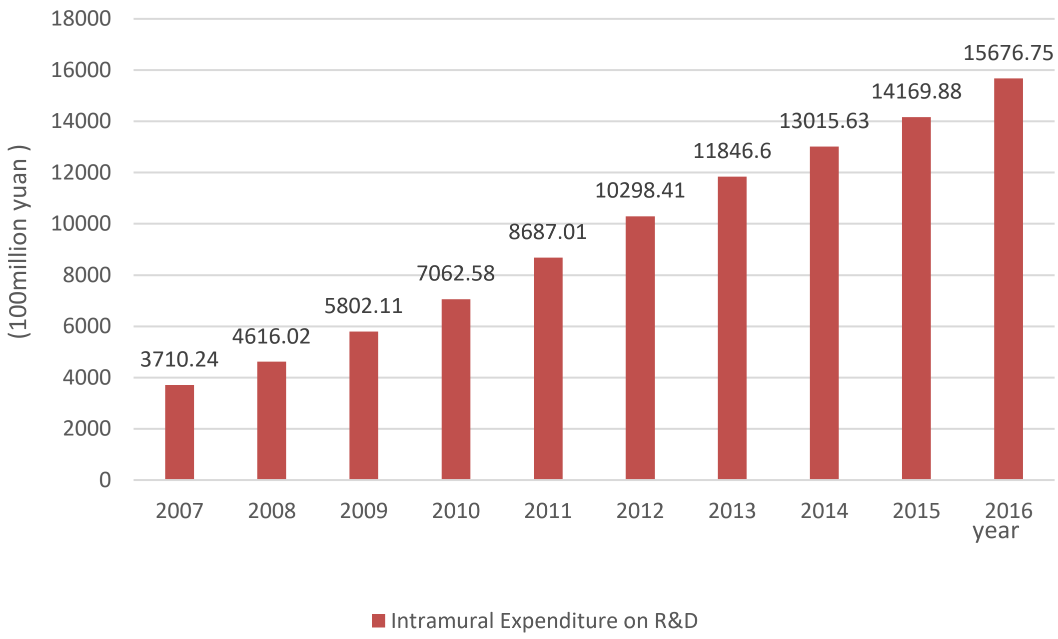


Figure 2. 5 GERD as percentage of GDP (% of GDP), China, 2006-2016, (source: NBS)

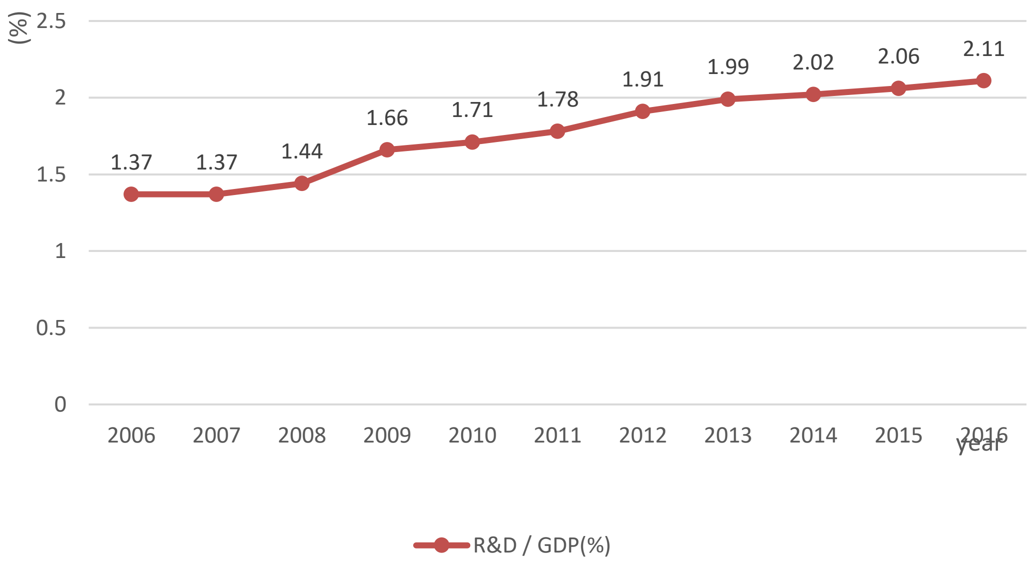
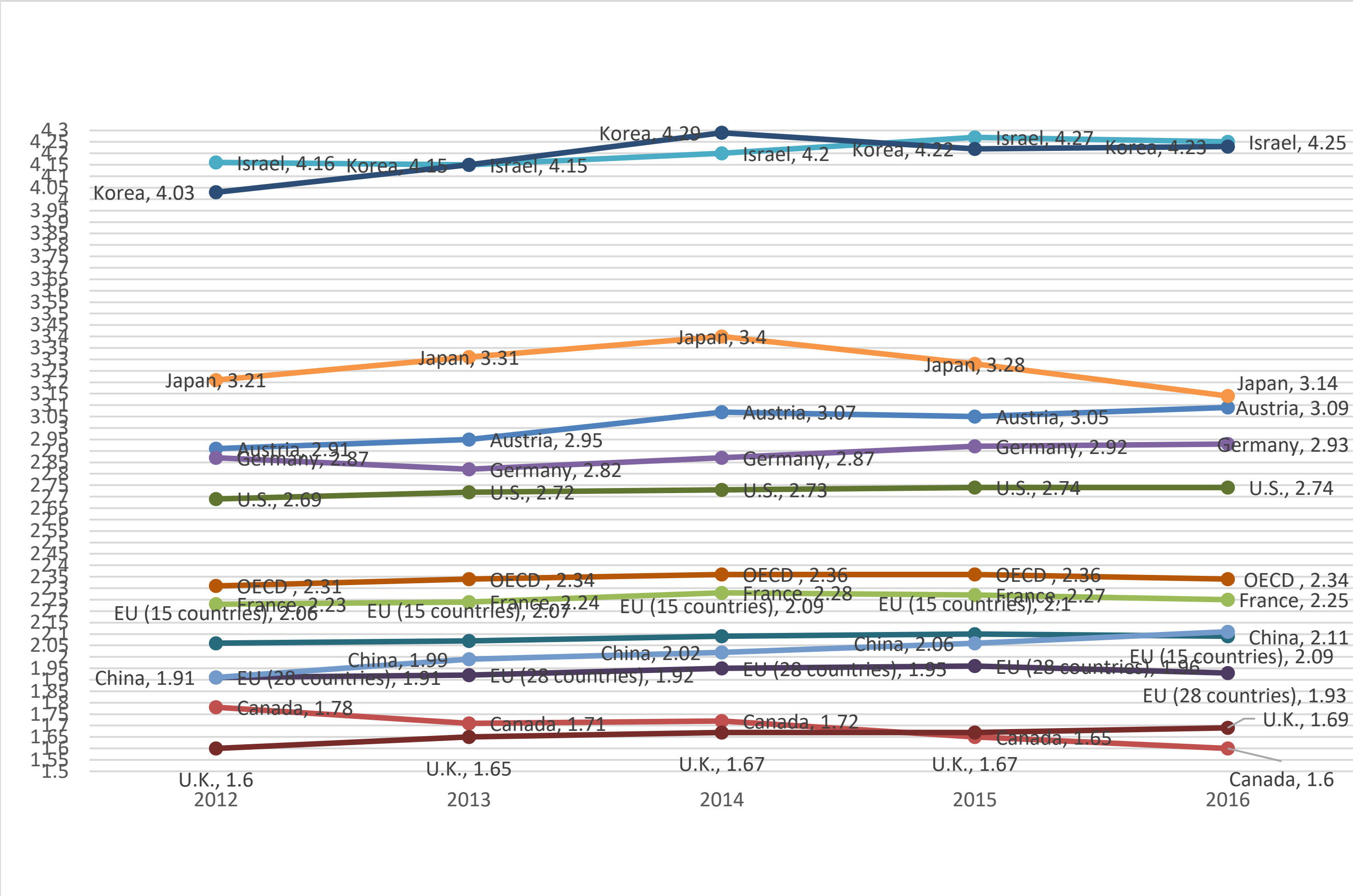


Figure 2. 6 GERD international comparison (source: OECD)



However, high R&D spending statistics as innovative input do not necessarily guarantee successful innovative performance. Regarding to innovation phenomenon, several paradoxes exist in Chinese economy. One paradox is that the significant economic growth is accompanied with low sustainability. As Grimes and Du (2013) claims, china's economic development is highly dependent on low-cost and low value-added manufacturing model while this kind of growth model has unsustainability nature. For example, nowadays increasingly discussion about the damage of the "hazy weather" or other environmental pollution on Chinese populations' quality of life has urged the government to reconsider its economic growth model and innovation system from a long-term perspective. Another paradox is that China's comparable high R&D intensity does not lead to significantly superior indigenous innovation by local firms or not-foreign enterprises. The Chinese enterprises engage mainly not in novel-product innovation[1], but rather in incremental and second generation innovation[2] imitation (Murphree & Breznitz, 2013). Although the Chinese government has emphasized "Zi Zhu Chuang Xin" (independent or indigenous innovation) strategy since year 2006, the dependency on foreign sources of technology is still dominant in china, particularly in Chinese high-tech sectors (Grimes & Du, 2013; Grimes & Sun, 2014). For example, although China has been the primary global exporter of high-tech products for many years (Figure 2. 7), most of these exports were derived from foreign invested enterprises (FIE)[3] rather than domestic firms (Figure 2. 8). Moreover, a focus on the economic and innovation situation at the provincial scale indicates the contradictory phenomenon of high level of overall national growth versus unbalanced regional development. A within-nation comparison reflects remarkable regional variations existing in various aspects, such as GRP (Gross Regional Product) share of GDP (Figure 2. 9), GRP per capita (Figure 2. 10), regional policies and strategies, public-private partnerships, innovation efforts and performance including R&D personal (Figure 2. 11) and new

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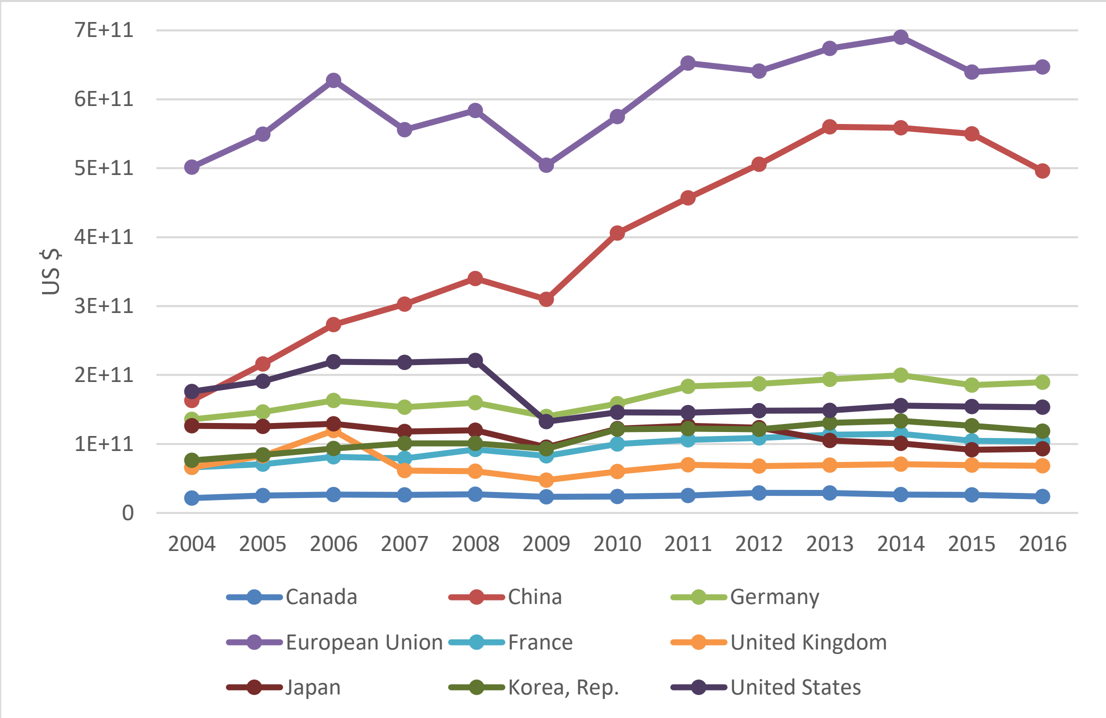
[1] Novel-product innovation means the creation of wholly new goods and services (Murphree & Breznitz, 2013: 198)

[2] Definition of incremental and second generation innovation: innovation around existing inventions, goods, and services. This includes improvements, simplifications, new applications and uses, new processes, and new ways of producing existing products (Murphree & Breznitz, 2013: 198).

[3] Companies in China are diversity. According to the registration status, there are domestic funded enterprises (including state-owned enterprises (SOE), collectively-owned enterprises, cooperative enterprise, joint ownership and POEs (Private Owned Enterprise)), Hong Kong, Macau and Taiwan owned (HMT) enterprises and enterprises with foreign investment. HMT enterprises are sometimes categorized into FIEs (Foreign Invested Enterprise) if they are not listed explicitly. FIEs operates as Sino-foreign cooperative, Joint Venture (JV) or Wholly-Owned Foreign Enterprises (WOFE).

products value of industrial enterprises above designated size[4] (IEADS) (Figure 2. 12) and so on (Wang & Lin, 2013a; Lin et al., 2011). While there is regional imbalance in terms of innovative indicators among provinces, significant difference exists between coastal and inland regions. Coastal regions account for most of the proportion of some innovative measures, such as patent applications, sales of new products and R&D expenditures. Moreover, even among coastal provinces the values of some measures are uneven. For example, innovation activity in terms of granted patents (Figure 2. 13) is concentrated in several provinces including Guangdong, Shanghai, Jiangsu, Shandong and Zhejiang (Fu, 2008).

Figure 2. 7 High-tech Exports: international comparison (2004 – 2016) (Source: WB)



[4] Since 2011, the National Bureau of Statistics have defined the "Industrial Enterprises above Designated Size" (IEADS) as the enterprises with annual income of the main business of and above 20 million yuan.

Figure 2. 8 High-tech exports in China by ownership (2016, 100 million yuan)

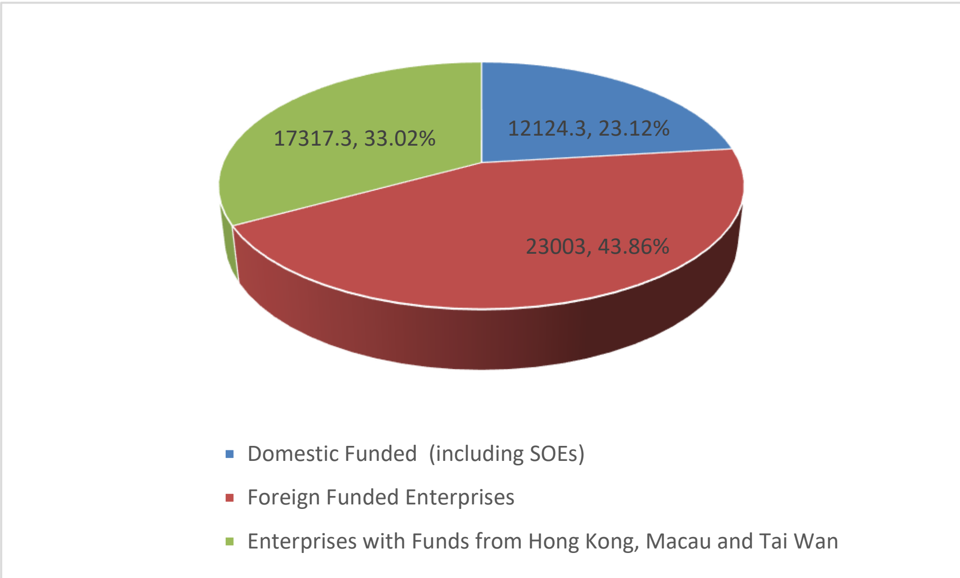


Figure 2. 9 within-nation comparison: GRP share (% of GDP) (2016)

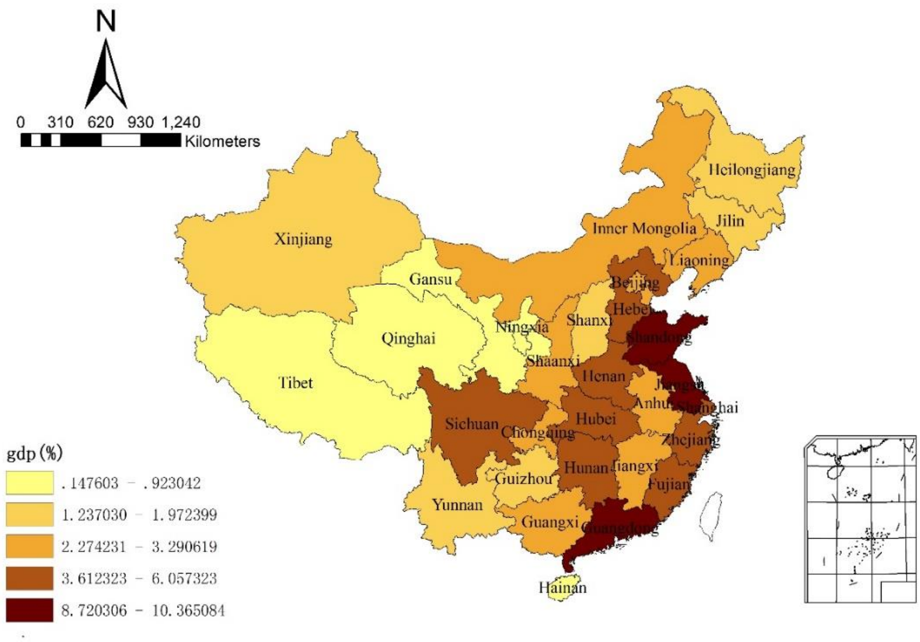


Figure 2. 10 within-nation comparison: GRP per capita (2016)

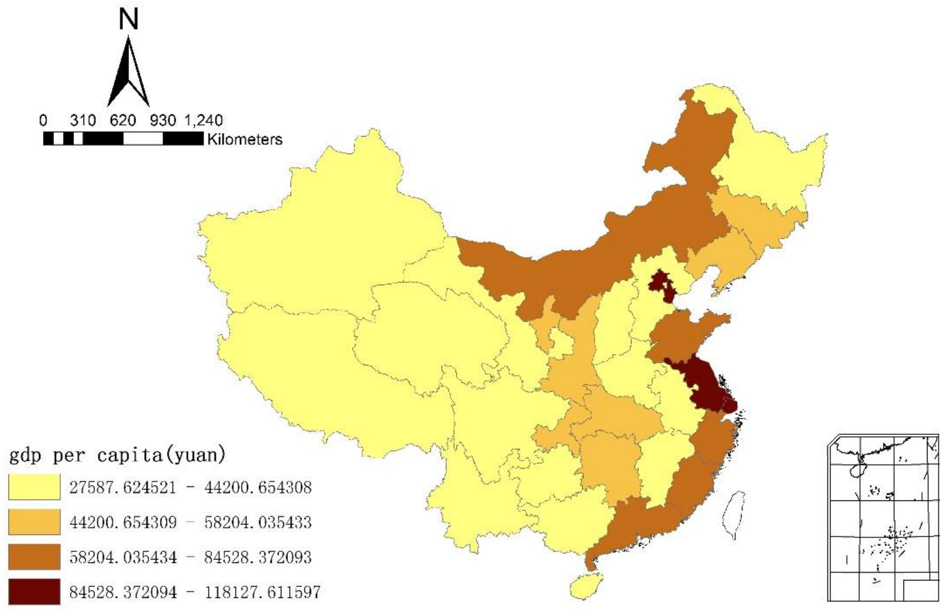


Figure 2. 11 within-nation comparison: R&D personal (% of national level) (2016)

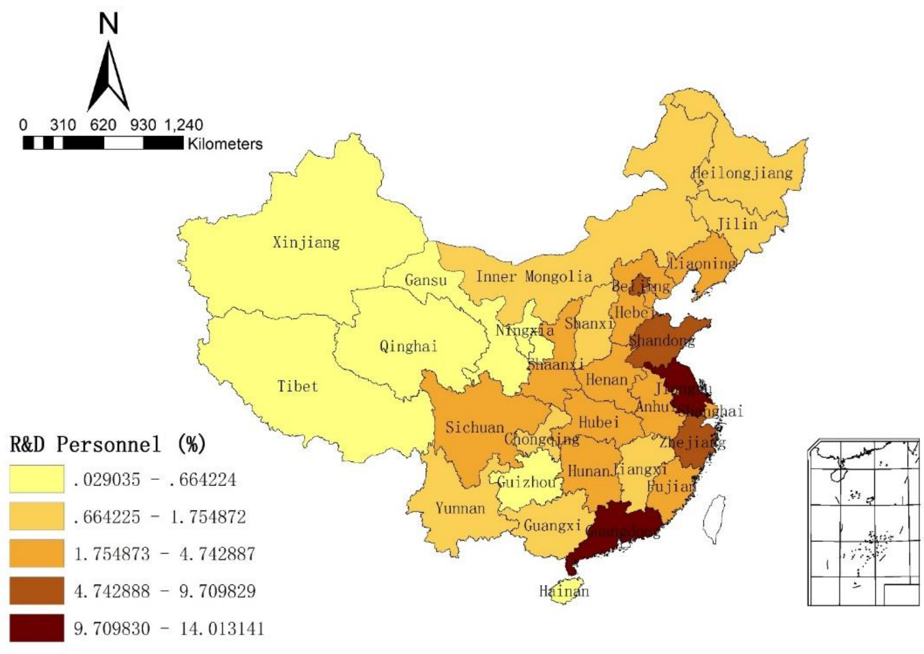


Figure 2. 12 within-nation comparison: new products value from IEADS (% of national level) (2016)

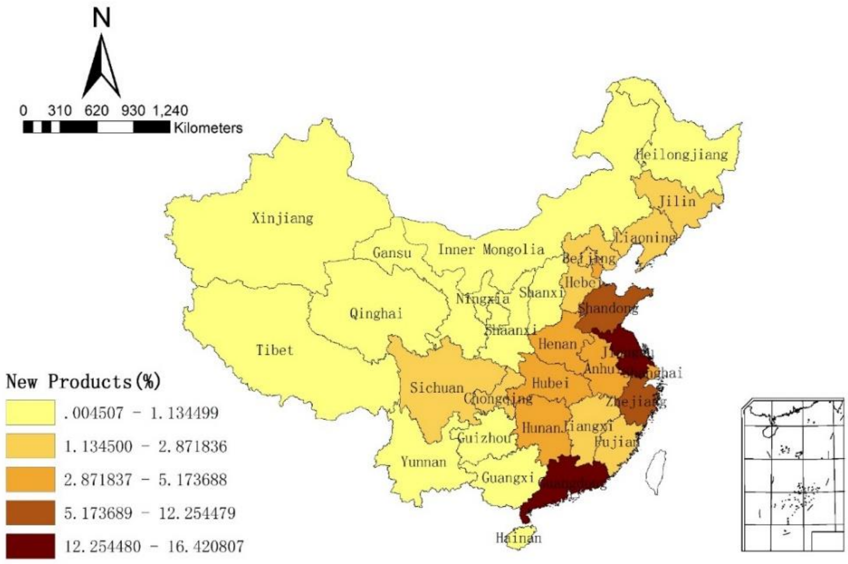
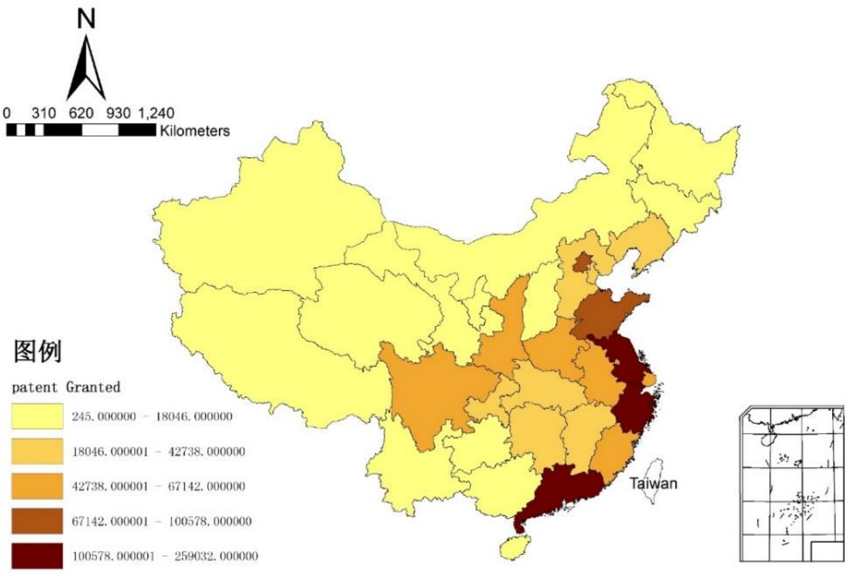


Figure 2. 13 within-nation comparison: amount of granted patents (2016)



The existence of above mentioned paradoxes has challenged "the traditional understanding of the role of government in industrial innovation" (Shu et al., 2015: 290). Also, the recognition of these paradoxes has required researchers and innovation-involved actors to address them and then to realize balanced indigenous innovation in China. In consideration that innovation performance is a joint effect of various factors including related policies, social capital, enterprises' resources, institution, infrastructure, some structural components and their relations such as interaction among market participants, and that china is now in an transition economy, it is necessary to apply a systematic approach to analyze the innovation landscape in China (Li, 2009; Shu et al., 2015). Traditionally, researchers use the theory of the national innovation system (NIS) (Freeman, 1987; Lundvall, 1992; Nelson, 1993) for understanding innovation activities in a country. NIS is "an analytic framework for innovation which a country can sue to analyze its national innovation activity" (Sun & Liu, 2010: 1314). It is a framework bringing all actors and institutions and relationships within and between actors and institutions into one system (Lundvall, 2007). Therefore, NISs in different countries have different structures, actors and relationships and thus different innovative performance. However, to analyze innovation issues at the national level might overlook the huge disparity among sub-nations. NIS is frequently criticized for its inability to capture some distinctive and systematic characteristics relating to regions as a localized phenomenon (Fu, 2008). Especially when taking the great variation among Chinese cities and regions into account, to analyze innovation phenomenon through NIS might be inefficient and incomplete. As Breznitz and Murphree (2011) argues, China's NIS consists of regional subsystems with very different set-ups. Furthermore, innovation is essentially influenced by knowledge spillover while knowledge spillover decays with increased distance. Therefore, a relatively accurate geographical scale needs to be fixed for the observed region to achieve a critical mass of agglomeration and thus to realize innovation (Varga, 2000). Empirical researchers have argued for geographical unit as small as possible (Fritsch& Franke, 2004; Raspe & Van Oort, 2008; Mukim, 2012).

Taking above consideration into account, this chapter adopts regional innovation system (RIS) perspective to analyze innovation situation in China. In comparison to NIS viewpoint, RIS treats region as relatively independent innovation system and pays close attention on large diversity of this lower scale of economy (Li, 2009). NIS is probably less sufficient for large countries especially china (Edquist, 2005). Therefore, RIS viewpoint is an more appropriate perspective in analyzing innovation in China.

The objective of this essay is to reveal the regional imbalance in terms of innovative indicators and to answer the question: to what extent does RIS constrain or facilitate regions' innovative capacity. Compared to previous innovation studies about China, this paper presents a comprehensive description of historical innovation policies' development and a from micro (individual level such as firms, universities etc.) to macro (regional level) analysis in terms of innovation input and output progress. Moreover, different from the NIS perspective that previous studies normally use, this paper applies RIS perspective to do within-nation comparison and discusses the RIS effectiveness with each component in a conceptual explanatory framework. The paper contributes to innovation literature by providing empirical and theoretical lens for improving indigenous innovation in China. In this paper, I choose 31 administrative provincial-level regions as the unit of analysis[5]. This paper advances most studies where state is used as spatial scale. Although the data collection is difficult, the provincial-level data can reflect the heterogeneity of regions more exactly and benefit more accurate and efficient innovation system analysis results.

This chapter uses four major data sets. The first is the China statistical Yearbook on Science and Technology which provides the annual scientific and technical statistics of 31 provinces, autonomous regions and municipalities and is coedited by the National Bureau of Statistics of China (NBS) and the Ministry of Science and Technology of China (MOST). The second is the China City Statistical Yearbook which comprehensively reflects the annual social and economic development of more than 280 prefecture-level Chinese cities. The third is the statistical materials that have been used in formulation of China's S&T policy including China Science and Technology Development Report, Government reports and resolutions on technology development and others by governmental agencies at different level. The fourth is the statistics from

[5] Here the 31 administrative regions include 22 provinces, 5 autonomous regions and 4 municipalities. Since Hong Kong, Macao and Taiwan differ in their economic and political background from most of the other regions, and since information from these regions is not available, they are excluded from this analysis. This paper refers to the 31 administrative units as regions and do not make distinctions between provinces, municipalities, and autonomous regions.

international organizations such as OECD and World Bank used for international comparison. Detailed sources will be provided when they are used.

This chapter is organized as follows. In following section I review the transition of governmental innovation policies in China. Then I describe main features of national and regional innovation situation. The third section is an analysis part. Basing on a comparison of the NIS and RIS concept, I try to construct a conceptual framework for RIS in China. After that, I attempt to analyze and compare imbalance in RIS from three aspects: actors, institutions and relationships. Major statistics of innovation-related indicators are presented and discussed for selected and representative regions. Also, some adjusting strategies are suggested. The last section is a summary and discussion.

2.2 Background

This section reviews the historical development of governmental policies relating to innovation and then summarizes major challenges in current national and regional innovation situation. This section provides the background for the RIS analysis in the following section.

2.2.1 Evolution of governmental policies in innovation (from 1949 to now)

It is necessary to review the general national policies[6] in innovation before applying RIS to compare regional disparity. Although each region in China has gained certain autonomy in developing economy and social issues, it is still under the guidance of the

[6] In the context of china's development, S&T systems are equivalent to innovation systems, so the term "S&T" and "innovation' is exchangeable within this article.

central politics and institutions by central government (Li, 2009). The national innovation policies, more accurately to say, science and technology (S&T) policy in China, have undoubtedly constrained or facilitated region's innovative capacity to some extent. China's innovation policies are largely formulated and issued by MOST. MOST is one of the leading government agencies in china's innovation drive, especially on the policy side. A review shows that Chinese S&T policy has evolved through five periods (Table 2. 1)

The initial establishment phase is from year 1949 to 1965. In 1949, the Chinese Academy of Science (CAS) was established in Peking. Until now, CAS has developed to an entity with multiple functions in research, high-tech development, technology transfer, and training talents. It has played a significant advisory role in making S&T policy in China. In January 1956, the Central Committee of the Communist Party of China (CCCPC) issued a call for "March to Science". In the same year, the National Science Planning Commission was established to formulate the first long-term science and technology development plan of New China, namely "the National Science and Technology Development Vision Plan from 1956 to 1967".

From 1966 to 1976 is the severe devastation phase where China experienced an unprecedented cultural revolution and there is a major distortion in science and technology policies.

The third phase is from 1978 to 1984. It is the important reconstruction period in the history of S&T policies' development. The national science conference in March 1978 symbolized that China's S&T development has begun to enter a brand-new period. Deng Xiaoping, the political Leadership after Chairman Mao, made an important speech at the conference and putted out the famous thesis that S&T is productive force and that the key to China's "Four Modernizations" is the modernization of S&T (Liu et al., 2011). In 1979 Chinese economic reform was initiated and the Chinese economy began to open to international trade. It is the famous open-door reform in China. Since then, foreign capital has begun to participate in the Chinese economy (Fu, 2008).

Table 2. 1 Evolution of governmental policies in innovation (1949 – now)

Phase	Major Events
(1) establishment phase (1949 - 1965)	In 1949, the CAS was established in Peking.
	In January 1956, CCCPC issued a call for "March to Science".
	In 1956, "the National S&T Development Vision Plan from 1956 to 1967" was formulated.
(2) devastation phase (1966 - 1976)	cultural revolution
(3) reconstruction phase (1978 - 1984)	In 1978, at the national science conference Deng Xiaoping made an important speech and putted out the famous thesis.
(4) S&T system initial construction (1985 - 1998)	
1985 - 1992 initial construction	In 1985, Deng Xiaoping made speech "Reform S&T to Liberate Productivity" at the National S&T Working Conference.
	In 1985, CCCPC issued the "Decision on the Reform of the S&T System".
1992 - 1998 adjustments and innovations	the 1992 "South Talk" symbolized the new stage of Chinese socialist market economy.
	In 1993, the "S&T progress law of the People's Republic of China" was passed.
	In 1995, ex-president Jiang put forward the strategy of "revitalizing the nation through "Ke Jiao Xing Guo" at the national
	S&T conference. Meanwhile, CCCPC issued the "Decision on Accelerating the Progress of S&T".
	In 1997, CAS submitted report "welcoming the era of a knowledge-based economy with the construction of a NIS".
	In 1998, the State Council decided to start the "knowledge innovation project" by the CAS.
(5) innovation & development (1999 - now)	
1999 - 2005, implementing "Ke Jiao Xing Guo" strategy	In 1999, the "decision on strengthening the technological innovation, developing the high
	technology and realizing industrialization" issued at national technology innovation conference.
	In 2001, tthe "10th Five-Year (2001-2005) Plan for National Economic and Social Development" was approved.
	In 2001, the special program for the S&T Education development plan of the 10^{th} five-year plan was released.
	In 2005, ex-present Hu Jintao put forward an important strategic idea for building an innovative country.

2006 - now, following "Zi Zhu Chuang Xin" strategy	In 2006, at the national S&T conference the State Council presented "MLP".
	In 2007, adoption of the "Law of the People's Republic of China on the Advancement of S&T".
	In 2008, "Policies on Promoting the Industrialization of Independent Innovation Achievements" was formulated.
	In 2010 "Decision on Accelerating the Cultivation and Development of Emerging Industries of strategic importance" issued.
	In 2012 Ex-president Hu gave the speech at National S&T innovation Conference requiring implementing the
	"Ke Jiao Xing Guo" strategy and "Ren Cai Qiang Guo" strategy.
	In 2012, "Opinions on deepening the reform of the S&T system and accelerating the construction of NIS" was released.
	In 2015 "CPCCC's Proposal on Formulating the 13th Five-Year (2016-2020) Plan for National Economic and Social
	Development" was adopted
	In 2015, the "Implementation Plan for Deepening the Reform of the S&T System" was issued.
	In May 2016 the "National Outline for Innovation-Driven Development Strategy" was issued.
	On 30th May 2016 National S&T innovation Conference was held.
	On 28th May 2018 President Xi Jinping delivered a keynote speech at the 19th meeting of the Academicians of the CAS
	and the 14th meeting of the academicians of the Chinese Academy of Engineering.

The fourth phase is from 1985 to 1998 when China's S&T policy system was initially established. Furthermore, depending on the different focuses of the S&T policy reform, I divide this phase into two stages with the 1992 “South Talk” by Deng Xiaoping as a symbol that China’s economy has begun to step into a new stage of the socialist market economy. On March 7, 1985, Deng Xiaoping attended the National Science and Technology Working Conference and made a speech entitled "Reform Science and Technology to Liberate Productivity." On March 13, 1985, the CCCPC issued the "Decision on the Reform of the Science and Technology System", emphasizing that economic construction must rely on S&T and that S&T activities must be oriented toward economic development. Since then, a resolute and step-by-step reform of the science and technology system has begun. The resolution is as a cornerstone for the departure of Chinese economy from Soviet model of innovation since 1950s where S&T activities and the industrial activities are completely separated (Motohashi & Yun, 2007; Tang & Hussler, 2011). The reform in 1980s has several distinct attributes. Firstly, the implementation of open policies for FDI (foreign direct investment) in the 1980s is only for special regimes. Moreover, the source of inward FDI is mainly from overseas Chinese in Hongkong, Macao and Taiwan (Fu, 2008). Although the strategy is “technology in exchange to market access”, with the purpose of technology transfer to Chinese companies through establishment of joint ventures (JVs), the results is poor (Zhou et al., 2010; Grimes & Du, 2013). Therefore, In 1992 the government decided to change the implementation of open-policy from special regimes to nation-wide (Fu, 2008). Secondly, since the 1980s the government has launched several main funding programs including National Natural Science Foundation of China (NNSFC)[7] established in year 1986, High-tech Research and Development Programs namely Plan 863 in year 1986 and Torch program in year 1987 (Murphree & Breznitz, 2013). After that, “an array of centrally, regionally, and locally directed programs” (Murphree & Breznitz, 2013: 199) are carried out to encourage the development of S&T. Thirdly, reform in the period between 1985 and 1992 is distinctive from later reform by its focus that it encourages “universities and research institutes (URI) to strengthen their links with industry” (Tang & Hussler, 2011: 24).

[7] NNSFC: the National Natural Science Foundation of China (http://www.nsfc.gov.cn) is now the largest government funding agency in China with a primary aim to promote basic and applied research.

The S&T policies in the second stage from 1992 to 1998 can be characterized as “adjustments and innovations”. As mentioned above, the 1992 “South Talk” symbolized the new stage of Chinese socialist market economy. In July 1993, China's first basic science and technology law, the " Science and technology progress law of the People's Republic of China” was passed. In May 1995, ex-president Jiang put forward the famous strategy of "revitalizing the nation through science, technology and education (Ke Jiao Xing Guo)” in his speech at the national science and technology conference. Meanwhile, the CCCPC issued the “Decision on Accelerating the Progress of Science and Technology” and emphasized that economic development should rely on the progress of S&T. The “Ke Jiao Xing Guo” strategy is regarded as the third milestone in the process of China’s S&T development following the party’s call “March for Science” in 1956 as the first milestone and the holding of the National Science Conference in 1978 as the second one. What needs to be explained here is that the implementation of the “Ke Jiao Xing Guo” strategy is after year 1998. In December 1997, the CAS submitted a research report entitled “welcoming the era of a knowledge-based economy with the construction of a national innovation system”. The report conceptualizes the NIS into four sub-system namely knowledge innovation system, technology innovation system, knowledge dissemination system and knowledge application system. It’s the first time that the concept of NIS is officially proposed. Since then, creation of a national innovation system in China has been put on the agenda. In June 1998, the State Council decided to start the “knowledge innovation project” by the CAS as a pilot NIS-program.

In general, the objective of most programs in the period between 1992 and 1998 is to promote basic research and thus public research institutes (PRI) and universities have greater operational autonomy in doing research work (Tang & Hussler, 2011).

Since 1999 the S&T policies has entered the fifth phase as innovation and development phase. This phase can also be divided into two stages where the first stage between 1999 and 2005 implementing “Ke Jiao Xing Guo” strategy and the second stage from 2006 until now following “Zi Zhu Chuang Xin” strategy. In August 1999, at national technology innovation conference the government issued the “decision on strengthening the technological innovation, developing the high technology and realizing industrialization” which required the further implementation of the “Ke Jiao

Xing Guo" strategy, the construction of national knowledge innovation system and the accelerated transformation of S&T achievements into productivity etc. With accession to the WTO (World Trade Organization) in 2001, China has been obligated to relax various policy-related "barriers" gradually and to open up its economy to foreigners to an increasing extent. However, the stronger presence of FDI did not bring effective knowledge spillover to Chinese firms and the dependency of China's economy on foreign investments kept stronger (Buckow, 2013). In March 2001, the 4th Meeting of the 9th National people's Congress of China approved the "10th Five-Year (2001-2005) Plan for National Economic and Social Development" and called for the construction of NIS. Also, the special program for the Science and Technology Education development plan of the 10th five-year plan was formulated and released. In October 2005, at the Fifth Plenary Session of the Sixteenth Central Committee, ex-present Hu Jintao clearly put forward an important strategic idea for building an innovative country.

Afterwards, the national science and technology conference held in January 2006 is a milestone in the evolution of china's innovation policy. At the conference the State Council presented "Medium-to-Long-term Plan outline for the Development of National Science and Technology (2006–2020)" (MLP) with the aim of transforming China into an innovative country by 2020 and a world-leader in innovation by 2050 (Wu, 2009; Shu et al., 2015). One of the goal of the MLP is to "push forward the comprehensive establishment of a national innovation system with Chinese characteristics" (Sun & Liu, 2010: 1312). In December 2007, the adoption of the "Law of the People's Republic of China on the Advancement of Science and Technology" provides an important legal guarantee for the implementation of the MLP, for the improvement of national independent innovation capabilities, and for building an innovative country. In December 2008, "Policies on Promoting the Industrialization of Independent Innovation Achievements" was formulated to accelerate the industrialization process of innovative achievements, to improve industry's core competitiveness and to promote the development of high-tech industries. In 2010, the State Council also issued the "Decision on Accelerating the Cultivation and Development of Emerging Industries of strategic importance". In July 2012 National S&T innovation Conference was held. Ex-president Hu gave the speech requiring implementing thoroughly the "Ke Jiao Xing Guo" strategy and "Ren Cai Qiang Guo" (strengthening the nation through talents) strategy, and following the guiding principles of “Zi Zhu Chuang Xin”, key leapfrogging, supportive development and future-leading. In September 2012, the CPCCC and the State Council released a document of “Opinions on deepening the reform of the S&T system and accelerating the construction of national innovation system”. The document set the goal for the country to be "in the ranks of innovative nations" by 2020. The goal is to fully implement the MLP and to lay a foundation for the country to become a technological power when celebrating the centennial anniversary of New China in 2049. In March 2015 "CPCCC’s Proposal on Formulating the 13th Five-Year (2016-2020) Plan for National Economic and Social Development" was adopted, which placed innovation at the core of the country’s overall development. It required the implementation of theoretical innovation, institutional innovation, scientific innovation, technological and cultural innovation.

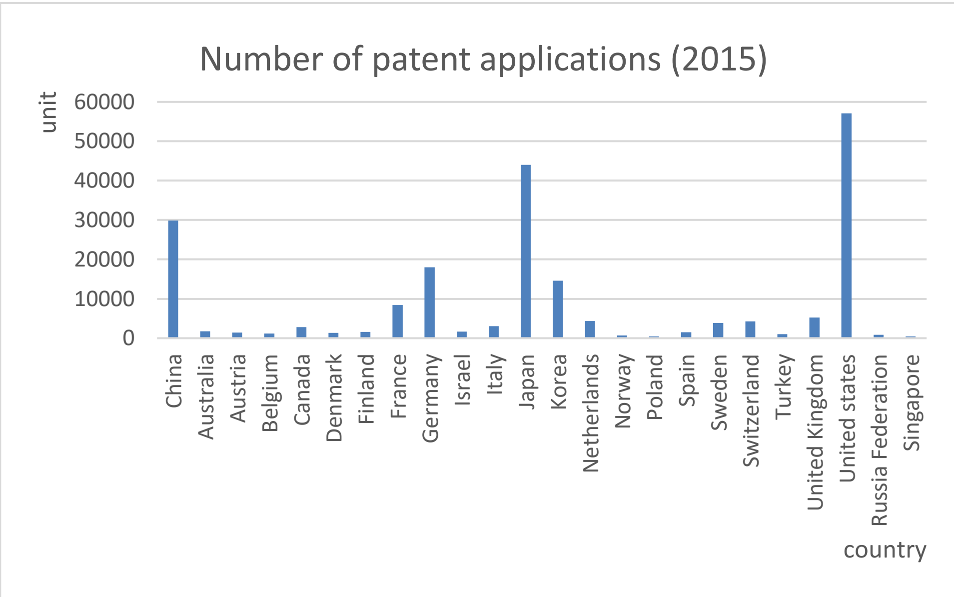
In August 2015, the Party Central Committee CPCCC and the State Council issued the “Implementation Plan for Deepening the Reform of the Science and Technology System” which deployed 143 reform tasks to be completed by 2020. Until now (May 2018), more than 110 tasks have been completed. In May 2016 the “National Outline for Innovation-Driven Development Strategy” was issued. On 30th May 2016 National S&T innovation Conference was held again. President Xi Jinping delivered an important speech emphasizing that we must place scientific and technological innovation in more important position and insist the path of independent innovation (Zi Zhu Chuang Xin) with Chinese characteristics to build a powerful S&T country in the world. It’s the first time that the strategy of “Ke Ji Qiang Guo” (Great power in science and technology) is presented. On 28th May 2018 at the 19th meeting of the Academicians of the Chinese Academy of Sciences and the 14th meeting of the academicians of the Chinese Academy of Engineering, President Xi Jinping delivered a keynote speech in which he emphasized that China must continue to make progress in science and technology and endeavor to become the world's innovation highland if it wants to achieve prosperity and rejuvenation.

With government’s long-term insistence on the goal of building a world scientific and technological power, China’s science and technology has achieved great progress in these years. As Xi’s speech on 28th May 2018, “in the past five years, the contribution rate of technological progress increased from 52.2 percent to 57.5 percent, and China's innovation capacity was ranked No 17 worldwide up from No 20 in 2012"[8]. However, there are still challenges in advancing its science and technology. One of the major challenges is the regional imbalance in innovations, especially in indigenous innovation.

2.2.2 Challenges in innovation landscape in china

In recent years china has made advances in innovation capacity such as the increasing R&D input and intensity (Figure 2. 4, Figure 2. 5), great patent application (Figure 2. 14) and top amount of high-tech export (Figure 2. 7). However, the general positive developments in Chinese innovation capacity is contrasted by regional and sectoral deficiencies. This part details major challenges in innovation landscape at national and regional level.

Figure 2. 14 International comparison of number of patent applications under the PCT system



[8] http://usa.chinadaily.com.cn/a/201805/30/WS5b0dd7a0a31001b82571d05f.html

2.2.2.1 High dependency on FDI vs. low-level indigenous innovation

One of the major challenges accompanying Chinese rapid economic growth is China's high dependency on foreign sources and technology compared with low-level indigenous innovation (Grimes & Sun, 2014). Although China has been the largest exporter in the world, almost half of the exports comes from FIEs (Figure 2. 15). In 2017 only three of the top ten exporting firms are domestic funded (Table 2. 2). The same as in the field of high-tech exports where the majority of these exports are produced by FIEs rather than domestic Chinese firms (Buckow, 2013; Grimes & Sun, 2014)**.** Take year 2016 as an example, almost 77% of high-tech exports are from foreign- and HMT-funded enterprises and while only 33% of that are from domestic funded firms **(**Figure 2. 8). It indicates the ongoing high level of dependence of china's economy on foreign resources. Following that the initial policy aiming at FDI-induced innovation has not been particularly successful (Grimes & Sun, 2014)**,** current S&T policy focusing on indigenous innovation since 2006 doesn't significantly reduce the dominant role of foreign companies in Chinese economy and improves the innovative performance of local firms.

Figure 2. 15 Exports value by enterprise ownership (2016)

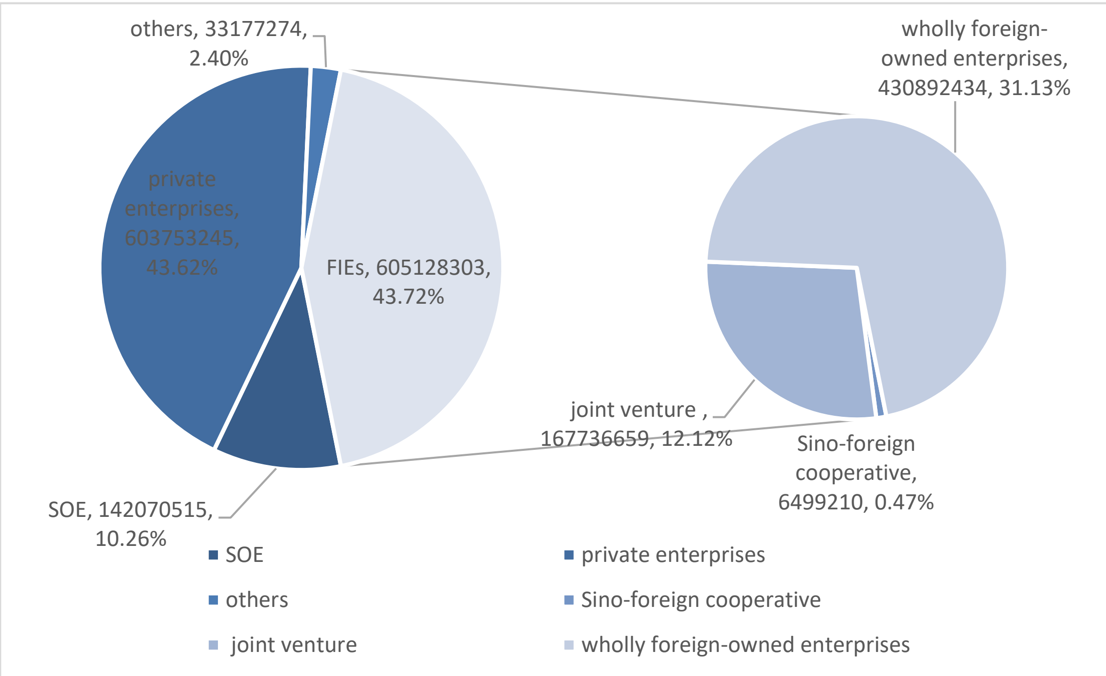


Table 2. 2 top ten exporting firms in China (2017)

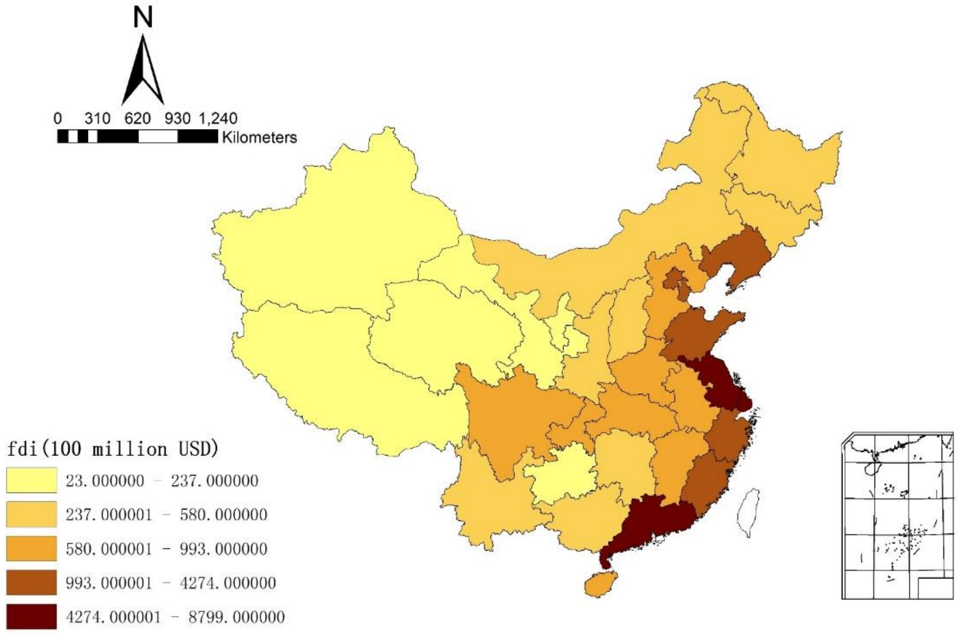
Rank	Firm Name	Export Amount(100 million USD)	Registration Status
1	Hongfujin Precision Electronics (Zhengzhou) Co., Ltd.	281	HMT enterprise
2	Tech-Com (Shanghai)Computer Co.,Ltd.	176	HMT enterprise
3	Protek (Shanghai) Co.,Ltd.	145	Foreign-owned
4	Futaihua Industrial (Shenzhen) Co.,Ltd.	128	HMT enterprise
5	Huawei Technologies Co. Ltd.	117	Private enterprise
6	Maintek computer (suzhou) Co., Ltd	116	Foreign-owned
7	Suzhou Delta International Logistics Co., Ltd.	115	SOE
8	Micron Semiconductor (Xian) Co., Ltd	107	Foreign-owned
9	Sansung Electronics (Huizhou) Co.,Ltd.	96	Sino_foreign joint venture
10	Huawei Device Co.,Ltd.	95	Private enterprise

Empirical studies have gained similar conclusions. A firm-level survey conducted in China's three most important mega urban regions (Beijing, Shanghai-Suzhou as the high-tech core of the Yangtze River Delta and Shenzhen-Dongguan as the industrial core of the pearl River Delta)) by Lin et al. (2011) indicates, majority firms don't regard knowledge exchange with FIEs as important factor of firm-level innovation. Also, study from Zhou et al. (2010) compares above three regions found that Beijing as the least foreign oriented region outperformed others in all measures of technological dynamism. It indicates that in China a stronger foreign-oriented region does not necessarily lead to a higher level of technological innovation and there exist other region-level factors such as local governance structure which is highly supportive of high-tech industry and thus positively associated with regional innovation performance.

Taking knowledge spillover theory into account, the comparable low innovative capacity of Chinese firms indicates partly that the expected knowledge spillover resulting from the co-existence of FIE and local firms doesn't been realized successfully. "Inter-firm knowledge exchange played a much less important role than what I have expected in the process of technological innovation" (Wang & Lin, 2013a: 41). The reasons are various. One lies in the low level of Chinese companies' internal resource including the study ability and absorption capability (Lundvall, 2011; Grimes &Du, 2013). Another is that FIE are reluctant to introduce advanced technologies due to the weak intellectual protection regime in China (Lin, et al., 2011; Grimes &Du, 2013). Therefore, the role of FDI has been overemphasized in Chinese setting. High presence of FDI in a region does not help local firm's innovation improvement and thus a region's innovation capacity in a higher degree (Lin, et al., 2011). For example, provinces with high FDI such as Fujian do not have high amount of granted patents correspondingly (Figure 2. 13 vs. Figure 2. 16). It is consistent with the empirical result that the innovative performance of firms or regions in China depends much on relationship among the strategic positions held by the firm and the state rather than the relationship between firms (Wang & Lin, 2013: 41). Researches have revealed the importance of the political and institutional environment around the firms rather than the external technology transfer among firms. Developing countries could achieve catch-up in technology if they adopt policies relating to human capital and industrial development (Lin, et al., 2011).

Furthermore, as mentioned above, the innovation effort and performance of provinces are imbalanced and increasingly diverging (Buckow, 2013). There are significant regional differences in "industrial structure, ownership, export-orientation and technological investment" (Zhou et al., 2010: 119), and in public-private partnership and linkages with kinds of foreign investors. For example, benefiting from certain regional autonomy some coastal provinces have developed their own local innovation and technological strategies beyond the national planning (Buckow, 2013). As a result, each region has been placed with its specific industry at the different positions of the global value-added chain (Lin et al., 2011). However, most are locked into the downstream of global value chains. Therefore, it is necessary to underline the construction of an efficient RIS in developing indigenous innovation.

Figure 2. 16 Within-nation comparison: FDI investment (2016)



2.2.2.2 Intensive patenting activity vs. comparable low innovative outputs

The second challenge is China's increasing intensive patentable activities accompanied with comparable low innovative outputs. The patenting activity in China has increased progressively in all three indicators including patents application accepted, patents granted and patents in force (Figure 2. 17). Also, international comparison shows that China was ranked third in patent applications filed under the PCT by region of origin in 2015 (Figure 2. 14). However, patent statistics should not be regarded as equivalent to innovations (Shu et al., 2015). Patent represents normally firm's purely technological endeavor. Findings from Shu et al.(2015) show that applied or granted should be conceptualized as the "potential innovation competence of a firm while product and process innovations are realized innovation outputs" (Shu et al., 2015: 302).Patents and innovations are distinct activities. Patents might not be easily transformed into new products while new products represent the demands of the market and meets the general conception of the market introduction of innovation (Knoben, 2009; Shu et al., 2015). This kind of argument is consistent with the statistics about new products output from China. Also, observation on the patents and outputs performance of high-tech industry at regional level gains similar results (Figure 2. 18). Studies in related field also verify this phenomenon. As Murphree and Breznitz (2013) point out, frequent patenting activities in China are companied not by novel-product innovation, but rather by incremental and second generation innovation. China relies still largely on its low-cost manufacturing export processing model in spite of significant economic progress in recent years (Grimes and Du, 2013).

Figure 2. 17 Domestic patents (2007 – 2016)

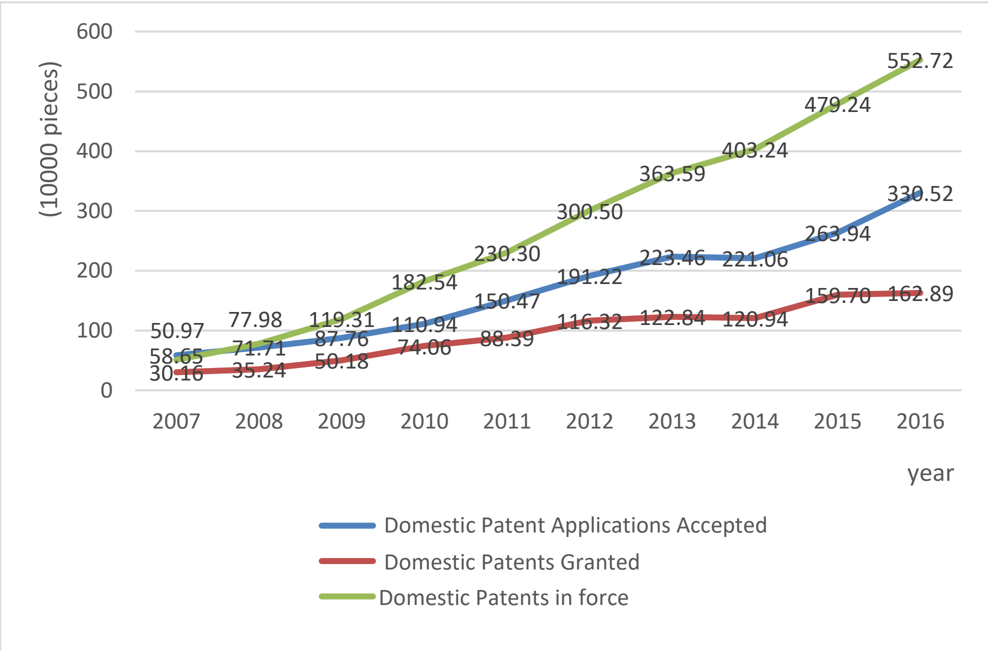
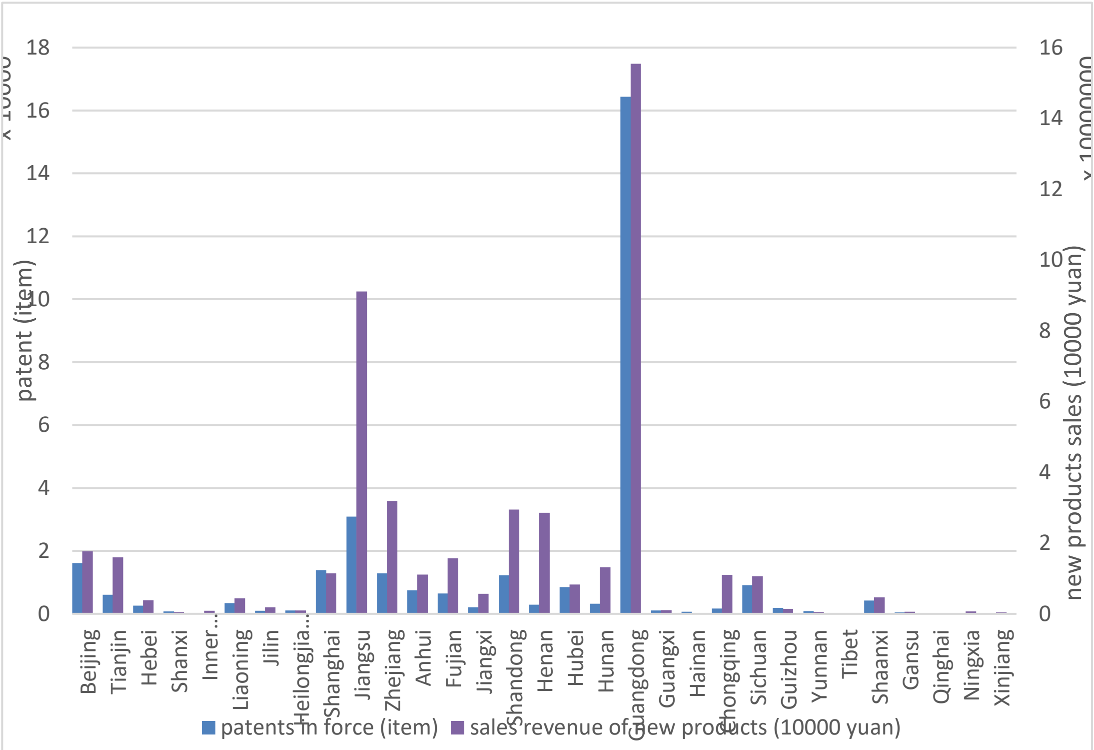


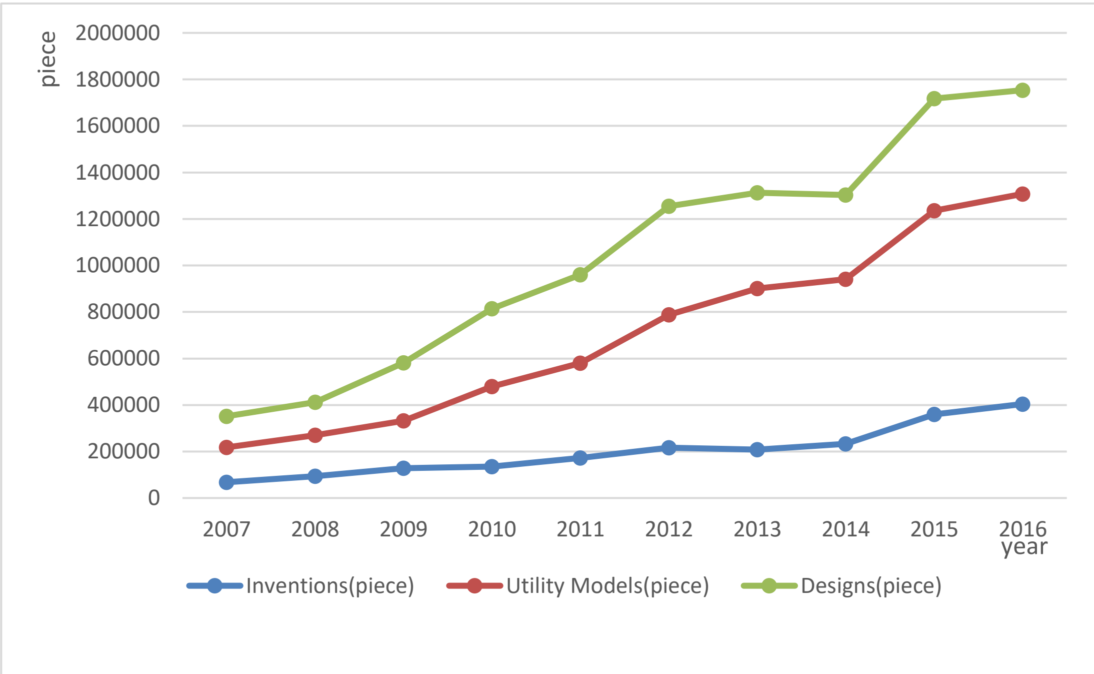
Figure 2. 18 patents vs. new product sales by region: high-tech industry (2016)



The paradox of patenting activity and innovation performance in China challenges our understanding of institutional environment at national and regional scale. On one hand, patent systems is originally created to reduce uncertainty in creating scientific and technological knowledge and thus to motivate the generation and diffusion of innovations (Martin and Scott, 2000). However, due to a weak intellectual property rights (IPRs) regime, "patents in china instead could facilitate local illegal imitation because a patented or trademark-registered product appears profitable and thus gets targeted for imitation in an environment in which social recognition of IPR is weak" (Keupp et al., 2009: 213). On the other hand, the strategic emphasis of recent governmental policies and programs at national and regional level, also summarized as governmental institutional support (GIS), on indigenous innovation might induce firms to apply for patents to maintain their IPRs. The result is that firms' resources and capital are used for patent filing rather than for new product commercialization. In this sense, governmental policies and measures in China might work as a double-edged sword in firm patenting and innovations. They work with patent system to advance science and technology on one hand while distract firms from commercializing patented knowledge into new products on the other hand (Shu et al., 2015).

There are three types of patents in China, respectively invention, utility model and external design[9]. Invention refers to a new technical solution proposed for a product, method or improvement thereof. The utility model is a new technical proposals on the shape, structure or combination of the products which are suitable for practical use. External design is a new design that is aesthetically pleasing and suitable for industrial applications, such as the shape, pattern and color or combination of these. Among them, invention is the most sophisticated technological novelties and normally regarded as major innovation while utility models present only marginal technological improvement and modification. The development situation of the three types of patents granted is showed here (Figure 2. 19, Figure 2. 20, Figure 2. 21). We find that the amount of the granted invention patents each year is far fewer than that of the other two types of patents. Shu et al. (2015) suggest considering firms' patenting motives for market-oriented R&D activities. This situation challenges current S&T policy with emphasis on long-term innovation capacity building in China. Moreover, regional imbalance in patents application accepted, granted and patents in force reveals the difference in the role of regional policies in industrial innovation (Figure 2. 22).

Figure 2. 19 Three types of patents granted (2007 – 2016)



[9] See SIPO (State Intellectual Property Office (China))
http://www.sipo.gov.cn/zsjz/zhzs/201310/t20131024_843493.html

Figure 2. 20 patents in force (three types) by region (piece, 2016)

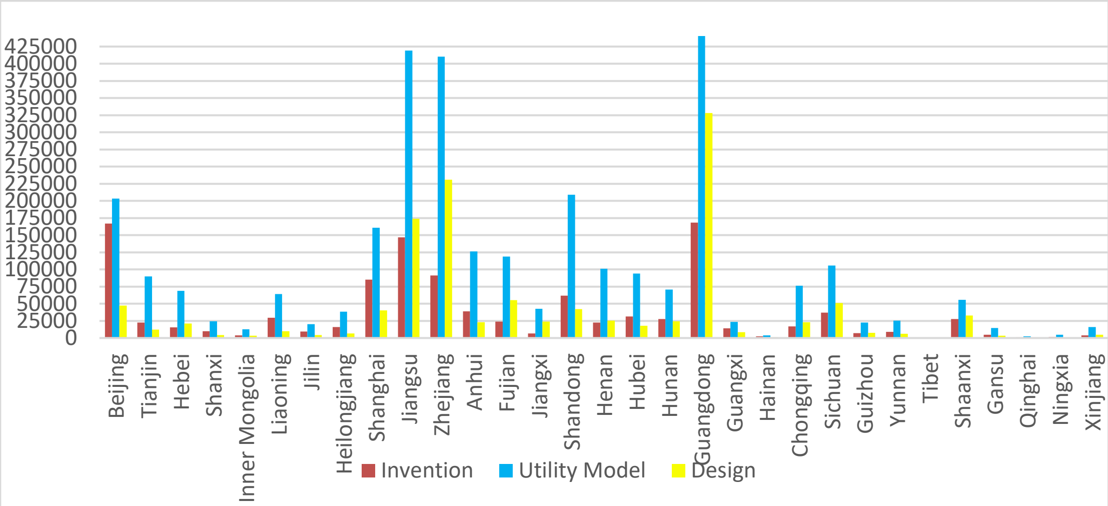


Figure 2. 21 patents application accepted (three types) by region (piece, 2016)

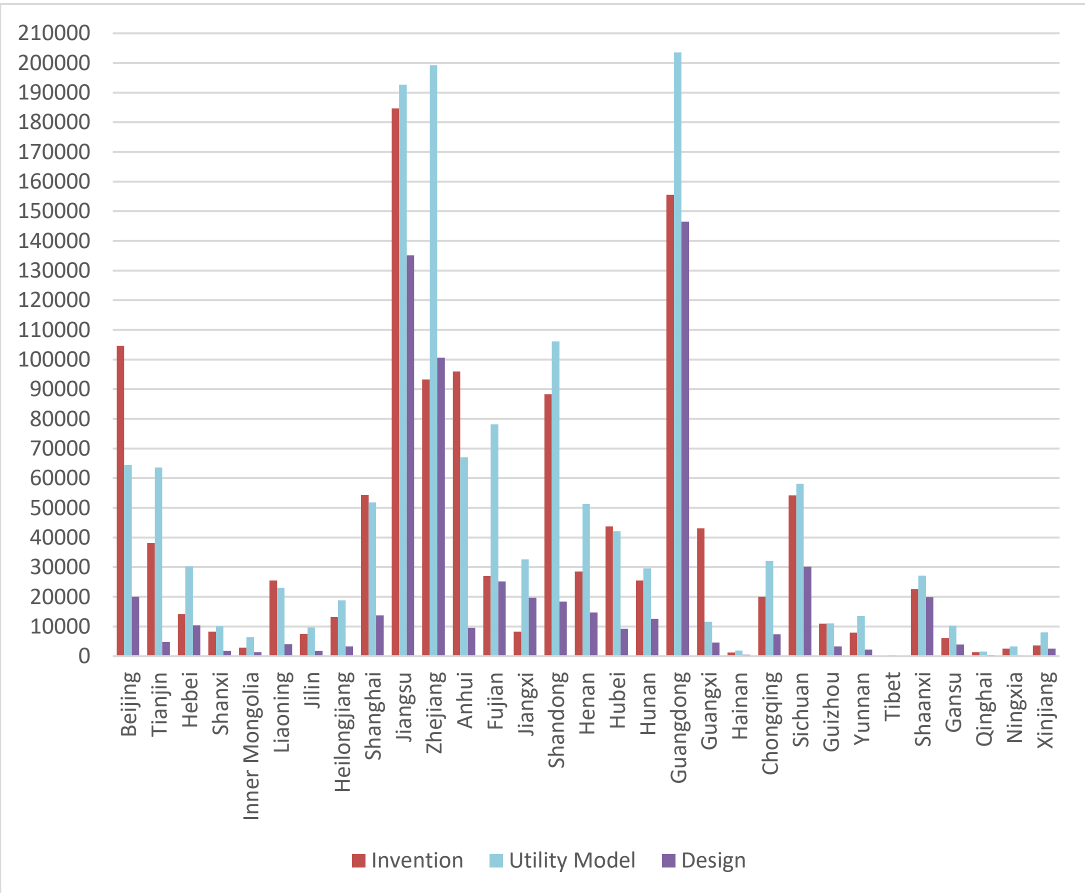
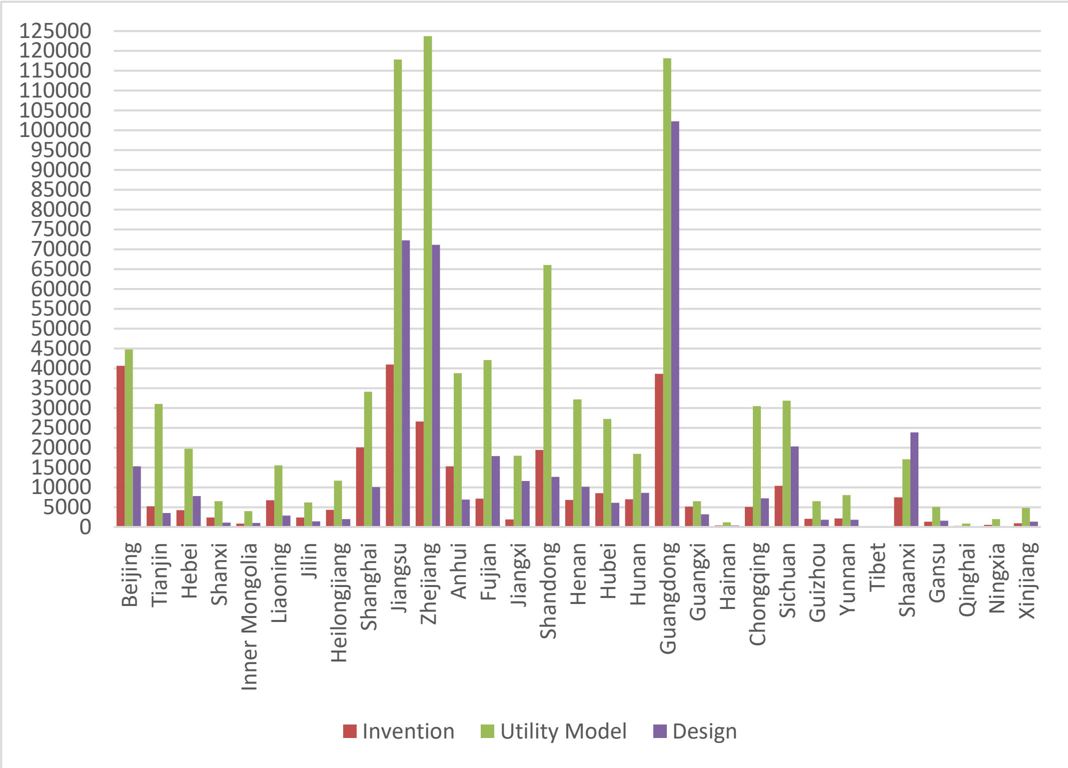


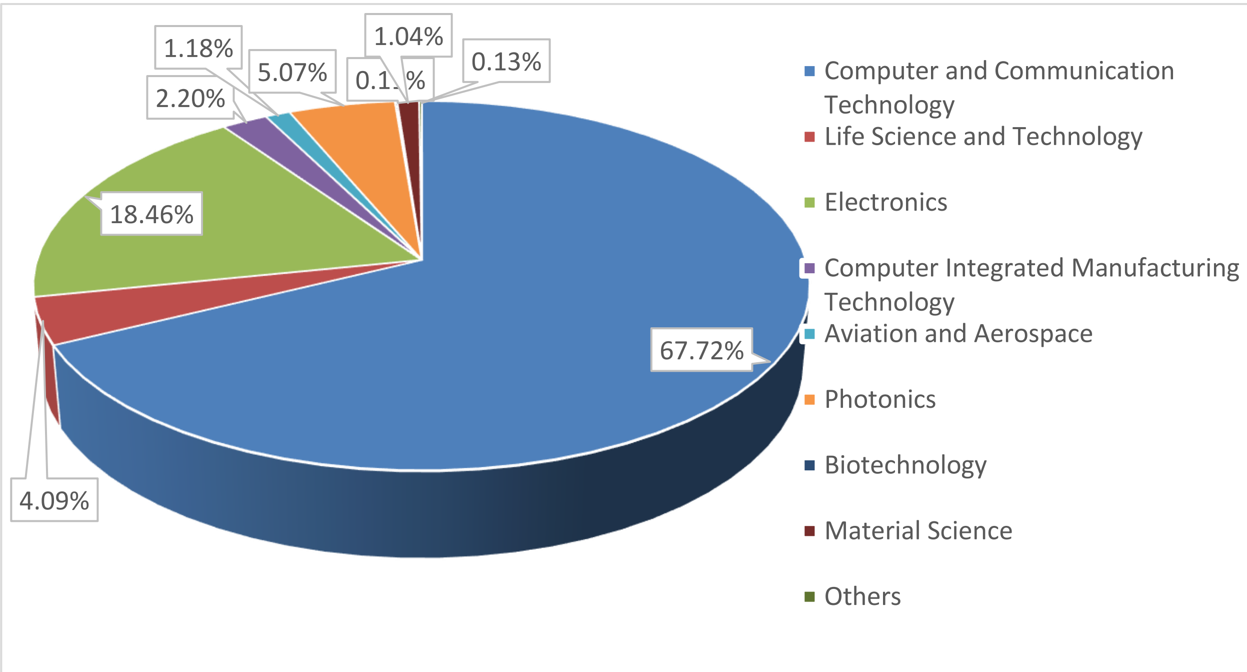
Figure 2. 22 patents granted (three types) by region (piece, 2016)



2.2.2.3 High amounts of high-tech exports vs. low value chain position & strong sector imbalance

The third challenge is China's large amount of high-tech exports contrary to the low position in global value chain and the extreme sector imbalance. Over the past decades, China has experienced dramatic increase in its general export and especially in its high-tech exports. An international comparison of high-tech exports from 2004 to 2016 shows that China has ranked top worldwide in high-tech exports since 2005 (Figure 2. 7). Although China has become the largest exporter of high-tech products, the product structure of China's high-tech product exports is highly concentrated (Figure 2. 23). The export of high-tech products are mainly distributed in nine fields: computer and communication technology, life science and technology, electronics, computer integrated manufacturing technology, aviation and aerospace technology, photonics technology, biotechnology, materials science and other technologies. Among them the sector of computer and communication technology has become China's major export of high-tech products. In 2016 its exports amounted to 409.13 billion US dollars, accounting for 67.72% of the total exports of high-tech products that year. This sector is also the one with the largest surplus in China's high-tech trade. In 2016, the trade surplus reached 301.75 billion US dollar. The sector of life science and technology has the largest amount of deficits. In 2016, the deficit amounted to 160.85 billion U.S. dollars. The proportion of other technical products in China's entire high-tech product exports is also low. As Murphree and Breznitz (2013) point out, China's export miracle in high-tech industry is very one-sided with over ninety percent of export products from a single sector of electronics and information and communication technology.

Figure 2. 23 product structure of China's high-tech product exports (2016)



The import and export trade of high-tech products in China has developed steadily these years (Figure 2. 24). However, its structure in China has been depicted as "big export and big import" with a large number of core parts and key technology products still rely on imports from abroad (Figure 2. 25). It indicates that the actual innovative capabilities of Chinese firms are still not strong enough and the efficiency of export products needs to be improved. For example, study from Wang and Lin (2013a) finds that China's ICT industry are mostly formed from assembling firms which locate in the downstream of the global value-added chain. Studies in the research field of export displacement effect have also verified the claim that high-tech products from China are mostly in the early stage of technology trajectory (Kim, 2004). Findings from Pham et al. (2007) reveal that Chinese exports have displaced those of developing and emerging competitors such as India and South American exporters in most high-tech sectors while they are still complementary to those of developed economies. Similarly, empirical results from Elleby et al. (2018) do not support the hypothesis that Chinese exports in general have displaced those from other countries to East African Community (EAC) countries, especially those from EU countries to EAC. Although EU countries have lost some market share due to the dramatic increase of China's global export share these years, the value of their products are still high, which also points out the low value position of Chinese export products.

Figure 2. 24 Imports and Exports of High-tech Products (2007 – 2016)

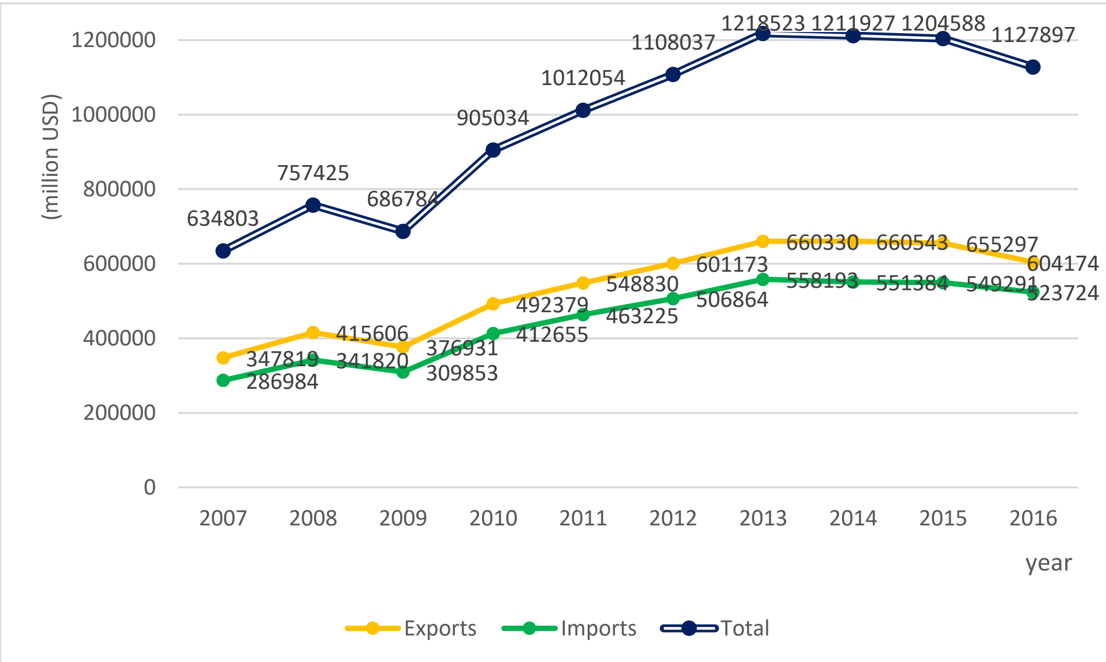
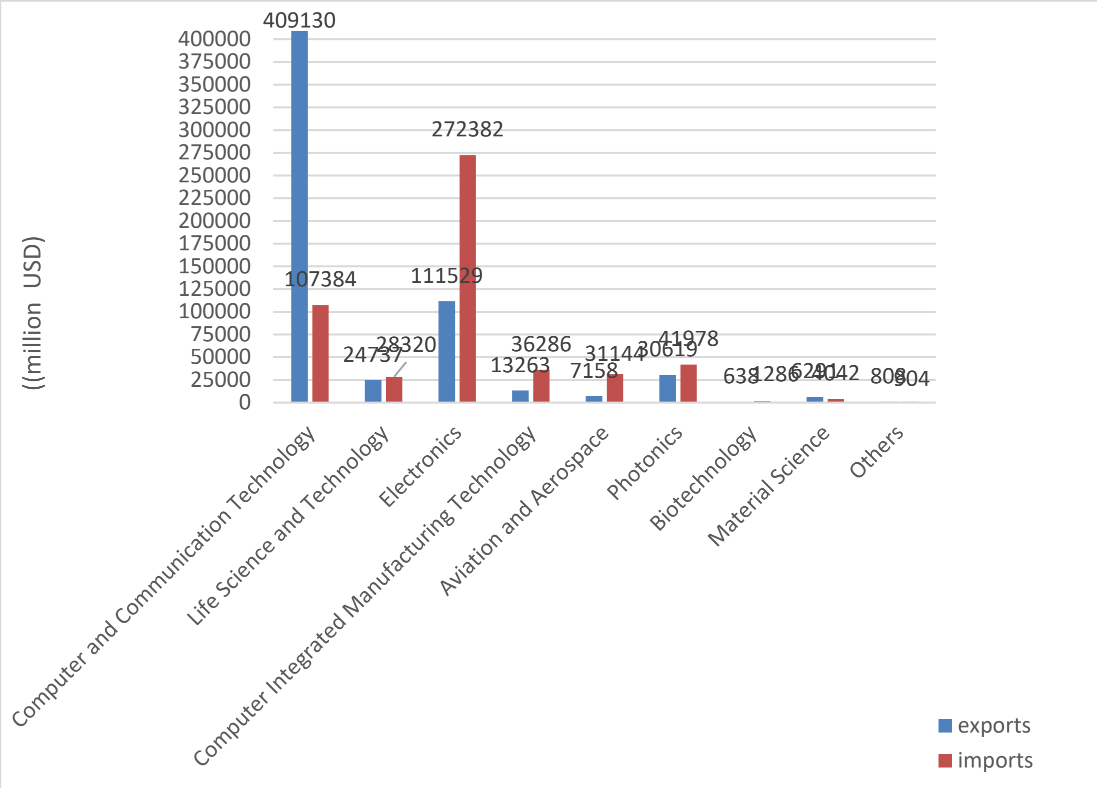


Figure 2. 25 Value of Imports and Exports of High-tech Products (2016)



The distribution of high-tech import and export are uneven among provinces (Figure 2. 26). Furthermore, Eastern region occupies almost 80 percent of total exports in 2016. The regional import and export amounts of high-tech industry might be related to the different levels of regional innovativeness in the form of R&D inputs. For example, the eastern and coastal regions have much more R&D institutions in high-tech industries in comparison with that of Western and inland regions (Figure 2. 27).

Figure 2. 26 Imports and Exports of High-tech Products by Region (2016)

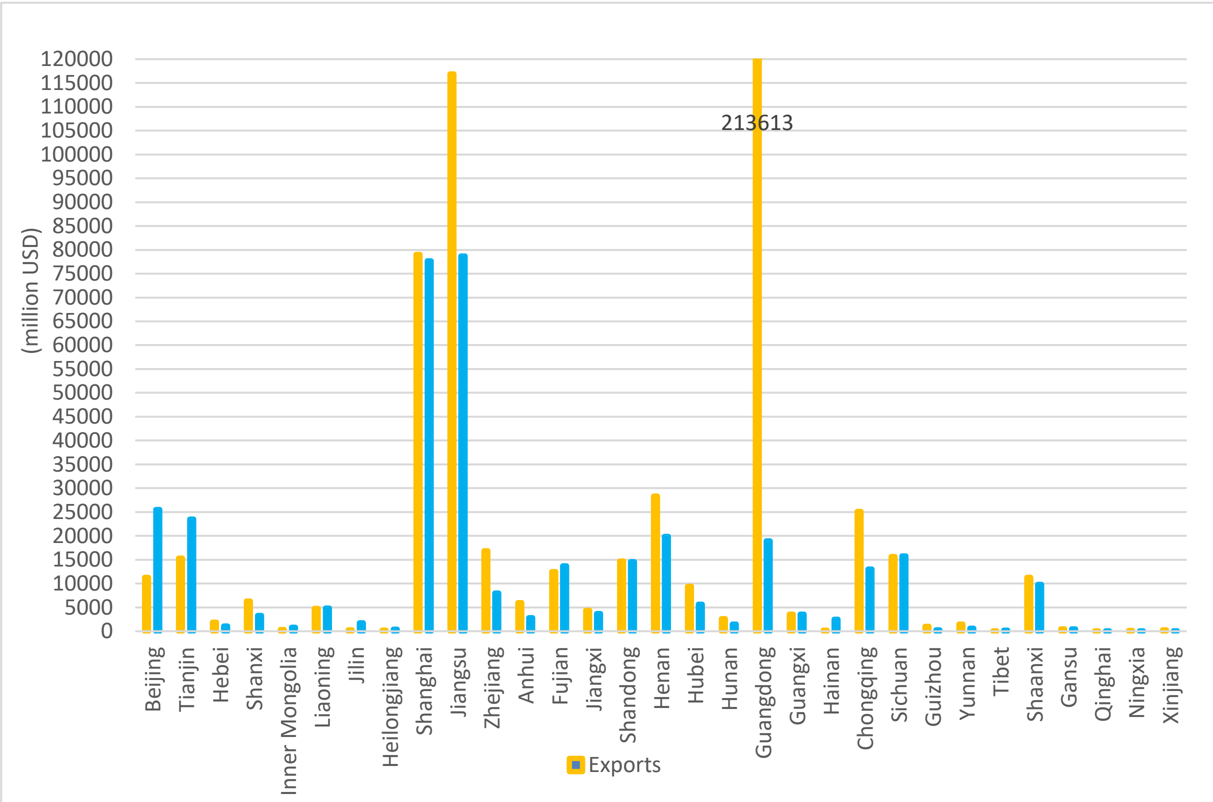
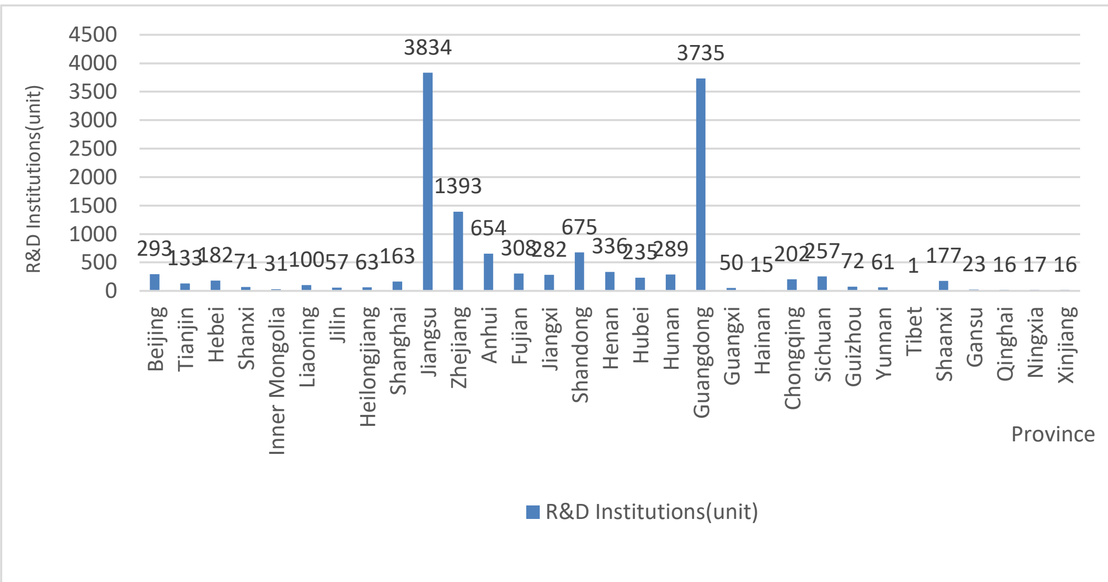


Figure 2. 27 Within-nation comparison: amounts of R&D Institutions in High-tech Industry (2016)



2.2.2.4 High R&D expenditure vs. imbalanced R&D expenditure structure

The fourth challenge in China's innovation landscape is its imbalanced R&D expenditure structure in terms of funding sources, R&D performers and types of R&D expenditures. Complying with the policy emphasis on indigenous innovation, china has invested heavily in R&D in recent years. According to the national statistical report on science and technology, the total investment for R&D expenditure in China in 2016 is 1.56767 trillion yuan, an increase of 10.6% over the previous year which is 1.4169 trillion yuan, and the growth rate increased by 1.7% from the previous year (see Figure 2. 4). However, in 1995, the total R&D expenditure is only 34869 million yuan. From a global point of view, in 2016 the total investment in R&D expenditure in China is second only to the United States, ranking second in the world. The national R&D intensity has continued to increase (Figure 2. 5). In 2014, the intensity reached 2.02%. It is the first time that R&D intensity in China exceeds 2%. In 2016 the R&D intensity is 2.11%, an increase of 0.05% from the previous year. Although there is still a long way from the average level of 2.34% in OECD countries. It has exceeded the average level of 2.08% in 15 countries in the EU (Figure 2. 6).

An observe of the funding and performing structure of R&D expenditure reveals the change of the structure characteristics identified by Sun (2002). The funding structure has changed from government-centered to enterprise-centered structure (Figure 2. 28). In 2016 funding from enterprises is 76% of total funding with an absolute value of 1192.35 billion yuan (Figure 2. 29). The performing structure has also changed from a double-centered (R&D institutions and enterprises) to one-centered (enterprise) (Figure 2. 30). Furthermore, the intramural R&D expenditure by enterprises in 2017 is 1,733.3 billion yuan, up 13.1 percent over the previous year (1214.4 billion yuan in 2016), and double-digit growth for two consecutive years. R&D institutions and higher education (including colleges and universities) in 2017 is 241.84 billion yuan and 112.77 billion yuan, respectively, an increase of 7% and 5.2% respectively over the previous year (each with 226.02 billion yuan and 107.22billion yuan in 2016 respectively). Among them IEADS are the biggest R&D performers with 1,094.466 billion yuan in 2016.

According to the types of research activities (Figure 2. 31), the national basic research funding in 2016 is 82.29 billion yuan, an increase of 14.9% over the previous year, which is significantly higher than the growth rate of the applied research funds with an increase of 5.4% and an absolute expenditure of 161.05 billion yuan and also than that of the experimental development funds with an increase of 11.1% and an absolute expenditure of 1,324.34 billion yuan. However, the expenditure structure for each type is still strongly imbalanced. For example, in 2016 funds for basic research, applied research and experimental development accounts for 5.2%, 10.3% and 84.5% respectively (Figure 2. 32). Although the proportion of basic research has reached the highest level in the past ten years, it is still very low in comparison with that of other developed countries (Figure 2. 33). China's low share of basic and applied research funds indicates its focus on innovative application rather than on fundamental research while fundamental research can affect a country's innovation capability in a long term (Grimes &Du, 2013; Sun & Cao, 2014).

Figure 2. 28 funding structure: Intramural Expenditure on R&D by Sources

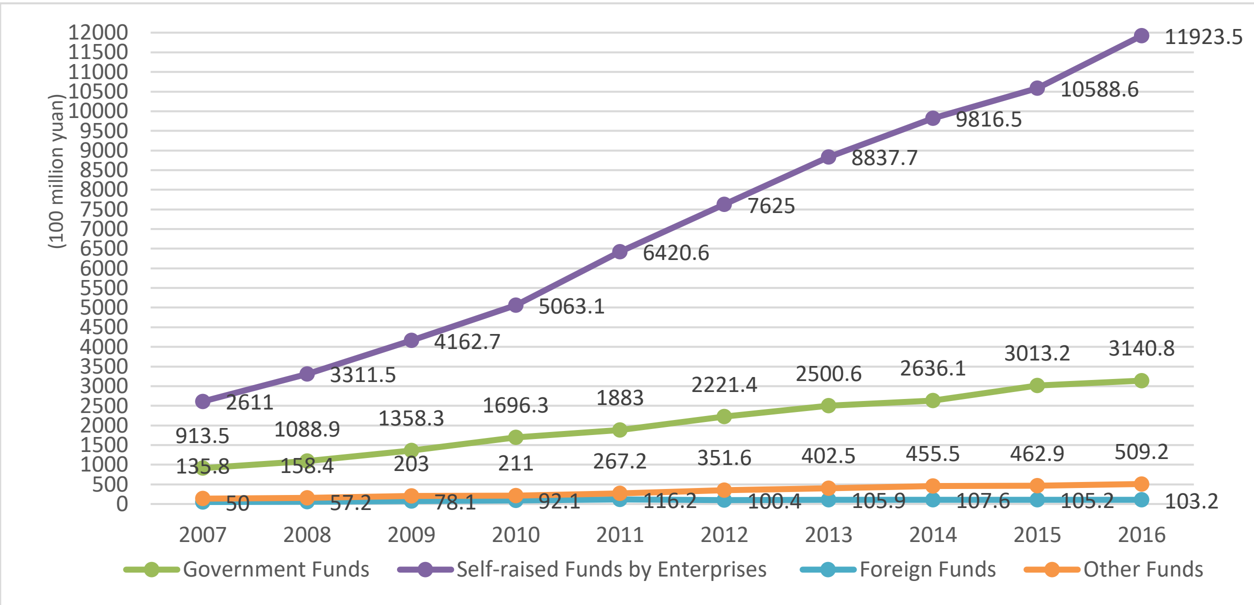


Figure 2. 29 funding structure: Intramural Expenditure on R&D (100million yuan, 2016)

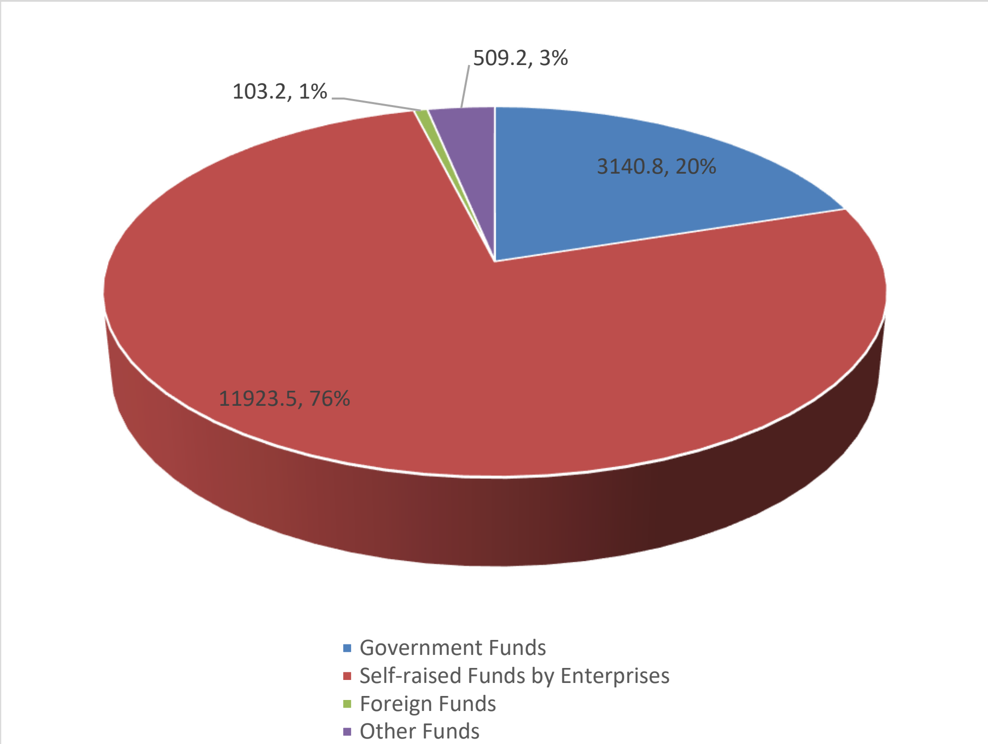


Figure 2. 30 performing structure: Intramural Expenditure on R&D by performers

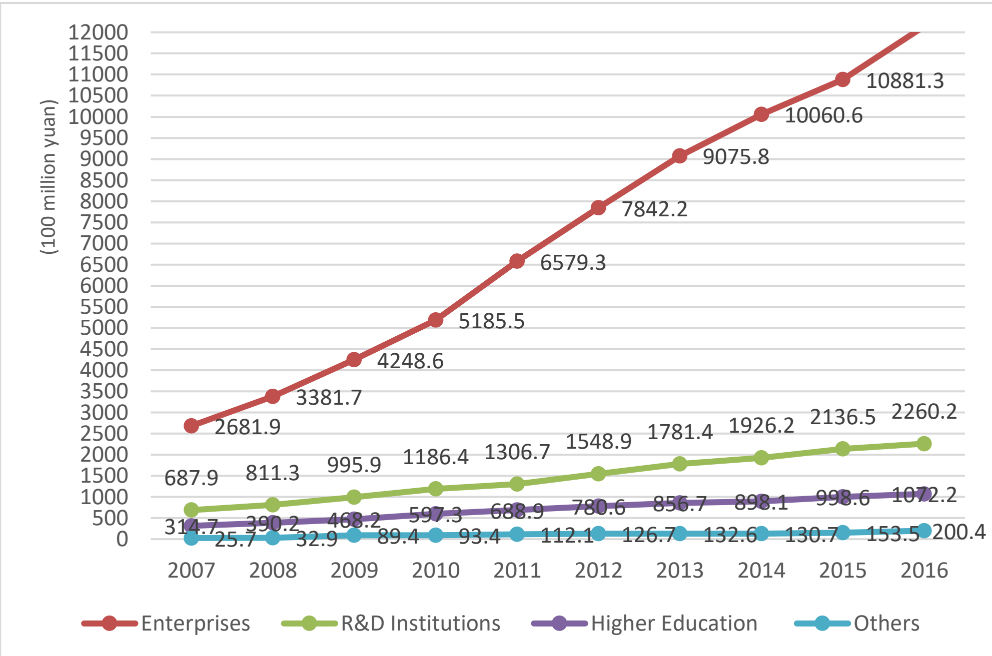


Figure 2. 31 Intramural Expenditure on R&D by Types of Research

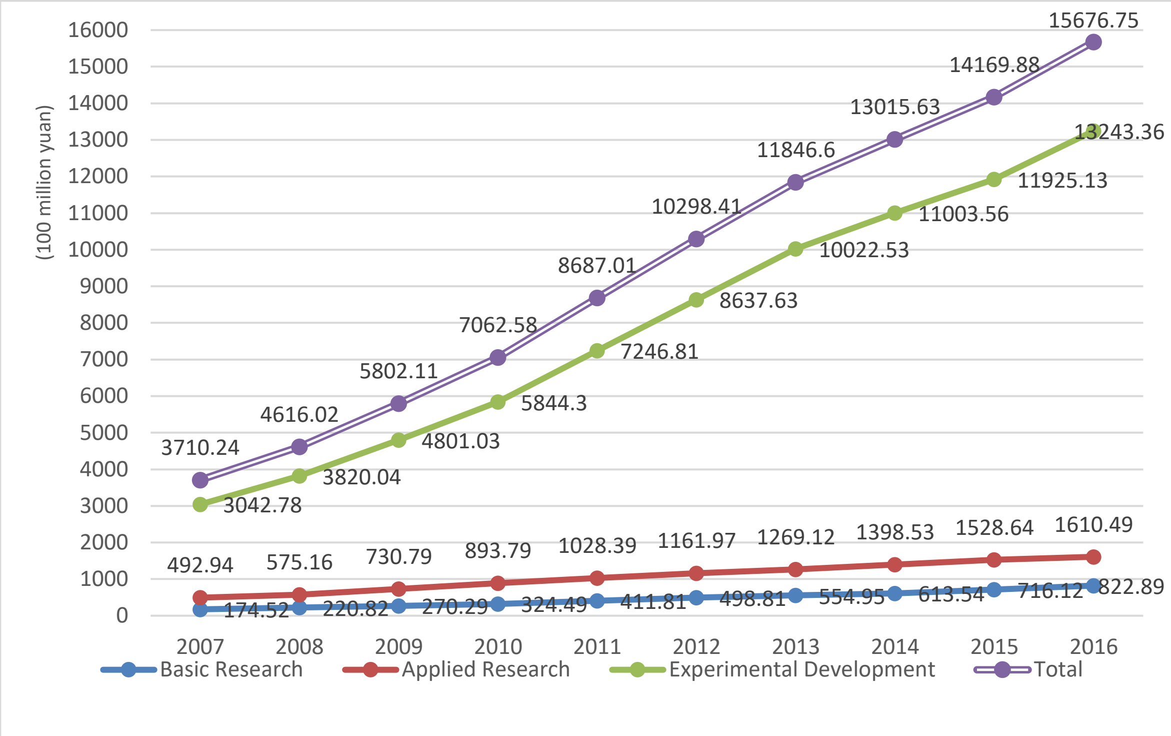


Figure 2. 32 Intramural Expenditure on R&D by Types of Research (%)

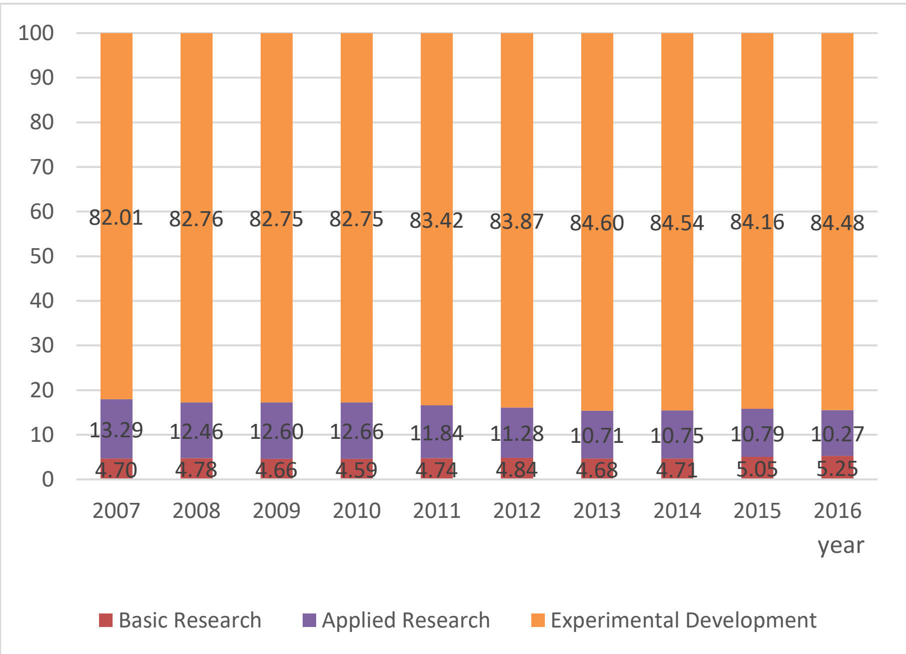
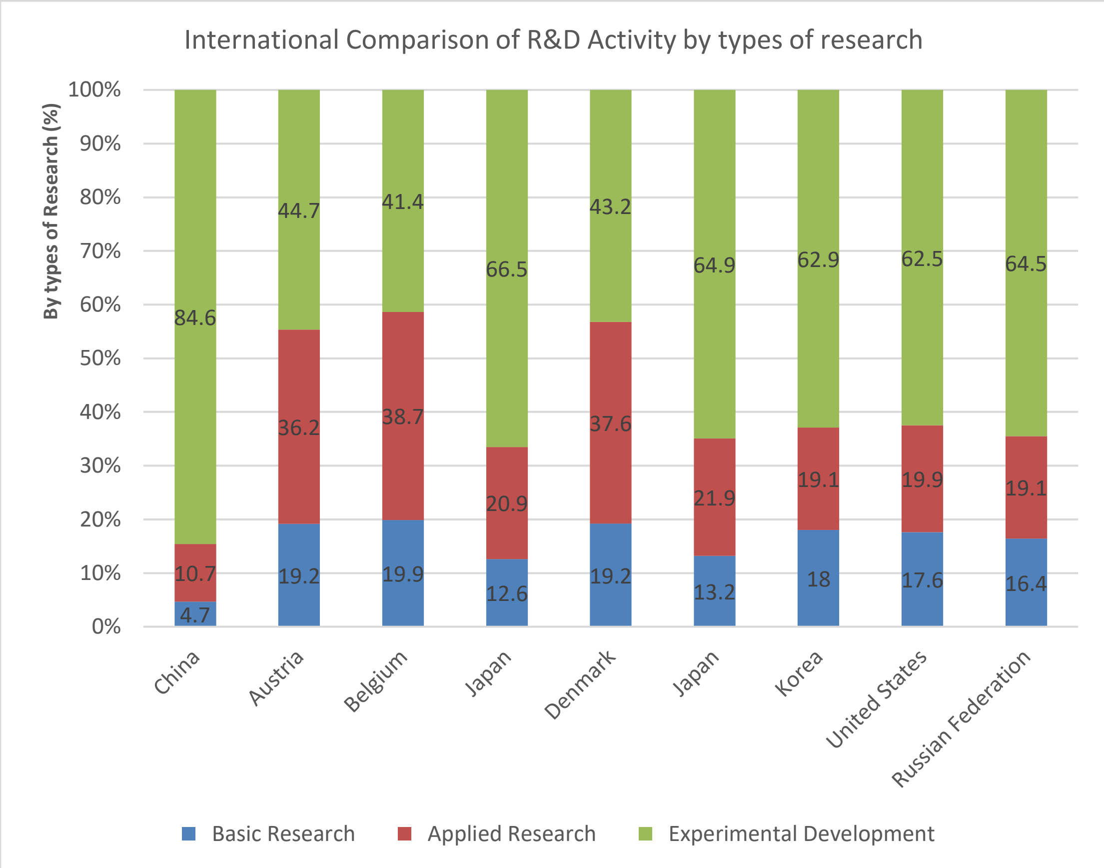


Figure 2. 33 International Comparison of R&D Activity by types of research (%) (2013)



From a regional perspective, there exists strong imbalance in both R&D expenditure and R&D intensity (Figure 2. 34). There are six provinces or municipalities where the R&D expenditures exceed 100 billion yuan. They are namely Guangdong (with 13% of the national R&D), Jiangsu (12.9%), Shandong (10%), Beijing (9.5%), Zhejiang (7.2%) and Shanghai (6.7%). The top six provinces have already accounted for nearly 60% of national R&D expenditure. Eight provinces or municipalities have the R&D expenditure intensity (ratio to regional GDP) exceeding the national average of 2.11%, namely Beijing, Shanghai, Tianjin, Jiangsu, Guangdong, Zhejiang, Shandong, and Shaanxi. In addition, the level of investment in various types of research varies from region to region. Take year 2016 as an example, although Eastern region has the most investment in basic research, the proportion of the basic research is smaller than that in Western region and in Northeast region (Figure 2. 35).

Figure 2. 34 Within-nation comparison: R&D expenditure and R&D intensity (2016)

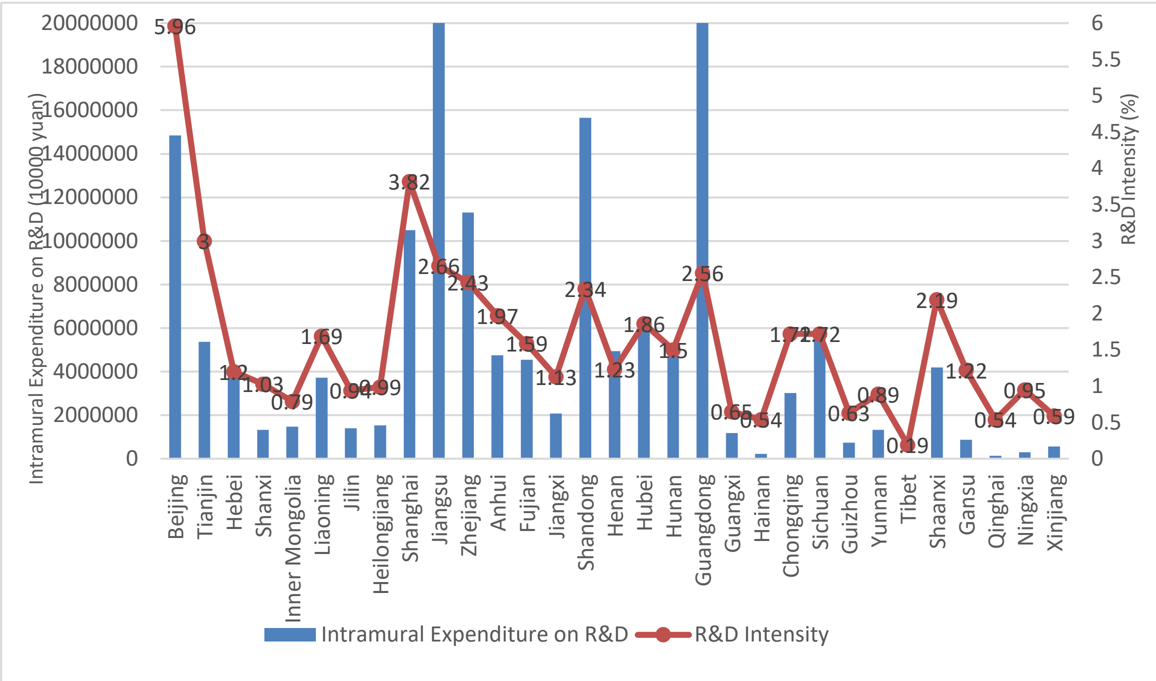
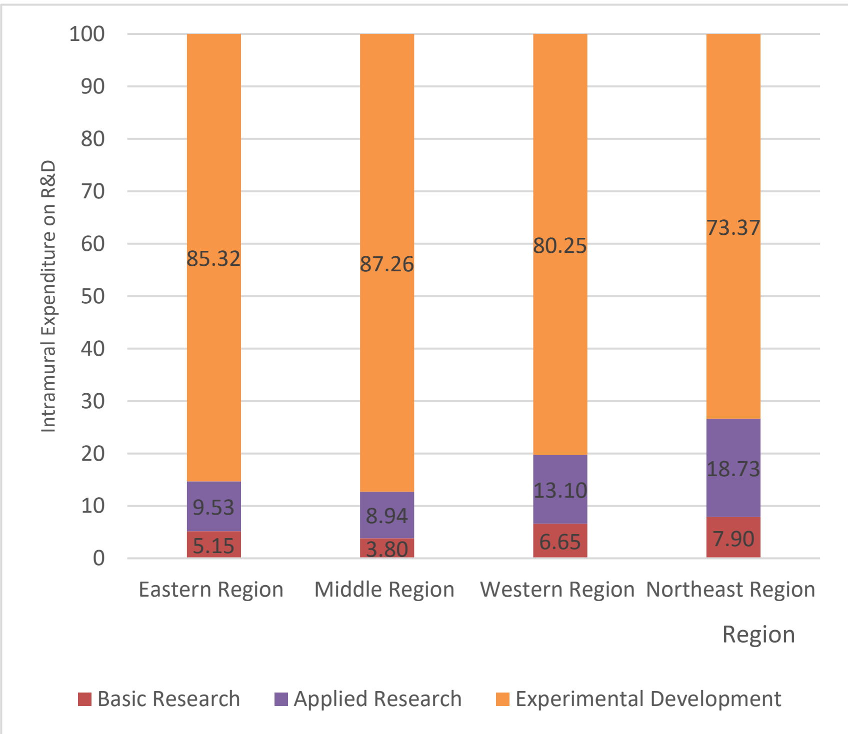


Figure 2. 35 Intramural Expenditure on R&D by research types (%): Four Regions (2016)



2.3 Analysis

2.3.1 Literature Review: from NIS to RIS

The NIS approach is initially developed by Freeman (1984). Although there are many definitions of NIS, very little variation exists among them (Buckow, 2013). NIS includes "… the institutions (the rules of the game) and the organizations that systematically interact with and have an effect on the creation and diffusion of innovations in any economic system" (Ernst 2002: 499). NIS focuses on relationships among innovative organizations including enterprise, governments, research institutions, universities, financial institutions and also on their interactions with institutions and policies in a system (Sun and Liu, 2010). The organizations and the institutional environment together contribute to the innovation capacity of a country (Li, 2009). Although NIS as an analytical framework has been extensively used to explain national innovation capacity, it does have some weaknesses when facing the Chinese case (Buckow, 2013). The first weakness lies in the NIS's scale which treats the whole country as an analyze unit. Different from most countries in the world, China is a continent-sized country with the most populations. Statistics at national level might be misleading in analyzing the innovation landscape. Secondly, as explained above, there are great regional disparities and heterogeneities among provinces and municipalities regarding their S&T policies, culture, interaction models combined with innovative input having effect on innovation performance. Therefore, it is precisely the regional dimensions beyond the national scope that can explain innovation in China. Thirdly, innovation patterns or models in China as an emerging economy might very different from those industrialized countries. For example, governmental instruction occupies more important positions than that in developed countries. Also, incremental or second generation innovation is more common in China than radical innovation. As Breznitz and Murphree (2011) argues, China's NIS consists actually of many regional subsystems with different settings. Therefore, RIS can be well fit for the analysis of innovation in a country like China.

According to Cooke et al. (1998), a RIS is defined as a system "in which firms and other organizations are systematically engaged in interactive learning through an institutional milieu characterized by" local embeddedness (Cooke et al., 1998: 1581).

The key of this definition is the notion of embeddedness which can be conceptualized as relationships among various innovative actors and the institutional and social environment around these actors within a region. Therefore, RIS in China means more than a NIS of smaller scale.

The literature on RIS has grown rapidly since the middle of the 1990s (Lundvall, 2007). Compared to the national perspective, analysis at the regional perspective has at least several advantages. Firstly, from a practical perspective, data suffers less from misleading and is of higher quality than that at national scale. As a result, empirical analysis and comparison among provinces become much more reliable (Li, 2009). Secondly, according to agglomeration economy and knowledge spillover theory, most innovation activities occur in certain regions with limited range. Agglomeration contributes to local knowledge infrastructure while knowledge transfer functions in appropriate distance (Audretsch & Feldman, 1996). Knowledge as source of innovation spreads more easily in same geographical area such as administrative province in China (Chaminade, 2011). Basing on the logic explained above, RIS is suited to explain precisely territorial innovation issues. Thirdly, RIS ensures the intra-national comparison of regions with similar cultural and social infrastructures (Li, 2009; Buckow, 2013). Although China possesses strong imbalance in many aspects as described above, there are still similarities existing in some regions in term of locations, historical background and cultures. For example, provinces in southern China share much more common issues in customs and social values which in turn influence innovation models to a certain extent. As a result, a comparison of innovation performance of these provinces can focus on policy issues except the cultural and social origins.

Taking above consideration into account, this paper chooses 31 administrative provincial-level regions as the unit of analysis. In China provinces are administratively and economically independent. The provincial governments have certain autonomy for developing economic and social policies and rules. As a result, the economy structure and innovation performance reveals strong provincial differences among regions.

Moreover, China's hukou system[10] has limited flows and transfer of some resources (e.g. labor) between provinces to a certain extent while the mobilization of labor benefits knowledge exchange which is decisive for innovation. Furthermore, dialect, customs and other informal institutional factors display distinct provincial characteristics. Therefore, treating provinces as independent innovation system allows intra-national comparison and helps understanding the innovation activity in China.

2.3.2 Analysis with Explanatory Framework

A review of related innovation system literatures reveals that structural components and dynamic relationships among these components are normally the two fundamental elements forming an integral system (Li, 2009). There are two types of main components, namely organizational and institutional one.

A modified conceptualized explanatory framework of RIS (Figure 2. 36) consists of:

1, actors such as enterprises, universities, public and quasi-public research institutes, governmental departments and administrative organs responsible for innovation policy and industrial regulations, legal authorities, financial institutes responsible for innovation financing are all organizational components (Li, 2009). In the innovation literature, these structural components are regarded as the basis to form a coherent innovation system (Edquist, 2005).

2, The institutional components are those relating to the institutional or legal environment inside a region. According to Lundvall et al.(2002), institutions have more importance in developing economies, especially in transition economy like China, rather than in developed economies, because the market in the former are not adequate to solve most allocation problems and institutional components are expected to play bigger role (Boeing & Sandner, 2011). The institutional components include entrepreneurship context such as investment index that encourages or discourages

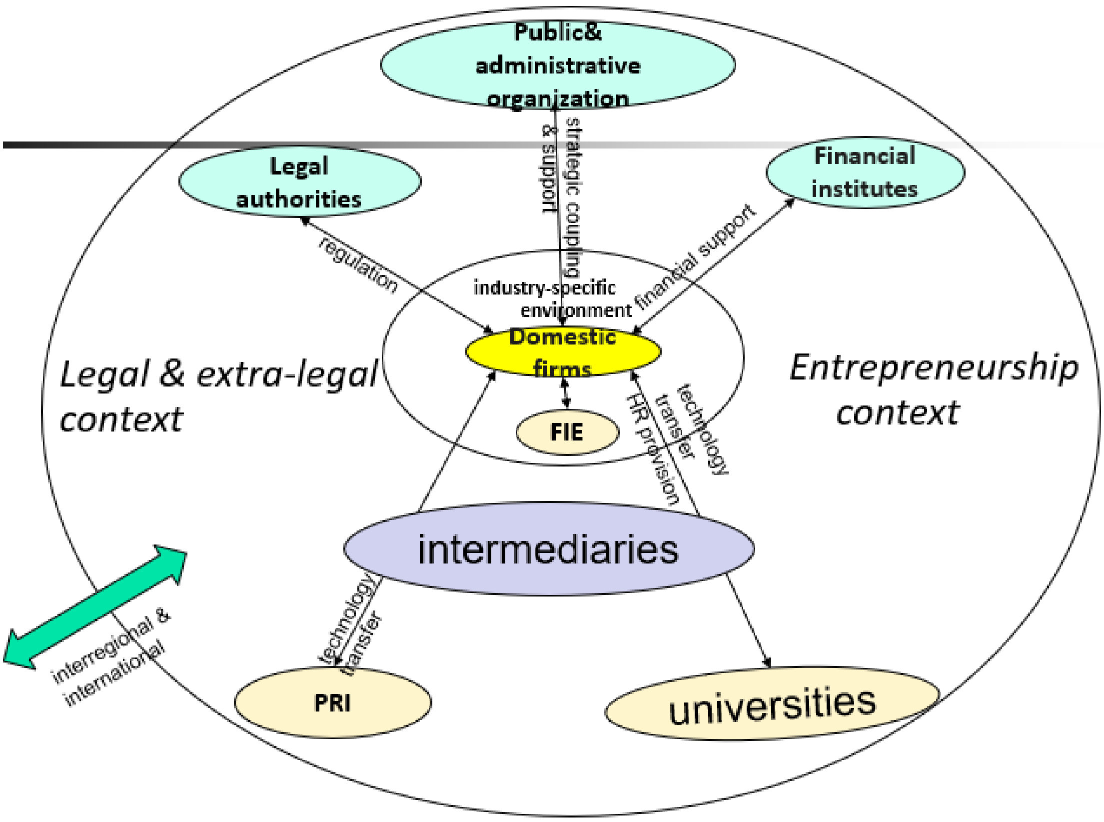
[10] China's hukou system is a household registration system, which is an institution controlling population movement and provides access to state-sponsored benefits for the Chinese citizen.

specific behavior, legal and extralegal formal institutions such as patent and tax laws that regulate and coordinate interactions, government policy and specific institutions such as industrial policies, environmental and safety regulations that direct the innovation process, norms and routines that influence the nature and extent of innovative efforts (Furman & Hayes, 2004; Li, 2009; Buckow, 2013).

3, Relationships or interactive knowledge exchange among innovation actors or R&D performers, and also interactions of these actors with technological, legal and institutional infrastructure.

The structural components and dynamic relationships among them influence the effectiveness of a regional innovation system. Under this framework various actors interact systematically with one another and also with institutional components and their joint effect contributes to a region's innovation capacity.

Figure 2. 36 Conceptualized explanatory framework



2.3.2.1 Innovation actors

Foreign invested enterprises (FIEs)

FIEs are the major market actors in RIS (Fu, 2008). A development chart of three main types of enterprises in China shows a decline of the proportion of FIE on total business entities despite of its slightly increase in the quantity from 2014 to 2015 (Figure 2. 37). Also, the distribution of FIEs in each province has large difference (Figure 2. 38).

FIEs contribute to regional innovation capacity in several ways. Firstly, the multinational R&D activities and R&D centers carried out by FIEs increase the innovation output of a region directly. Attracted by the ample supply of low-cost but high-skill engineers and liberalization of economic policies of local regions, FIEs have established many independent laboratories focusing on basic research. Theoretically, the R&D activities by FIEs can reinforce a region's strength in radical innovation (Grimes & Du, 2013). However, the positive influence on regional innovation might be

Figure 2. 37 Number of enterprises by status of registration: quantities & proportion

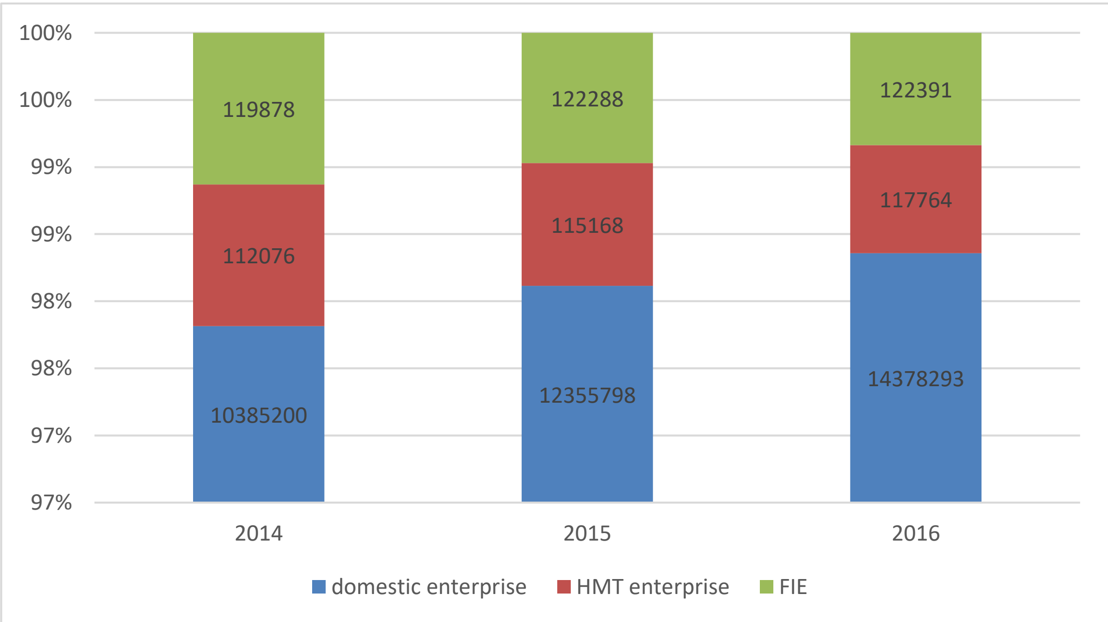
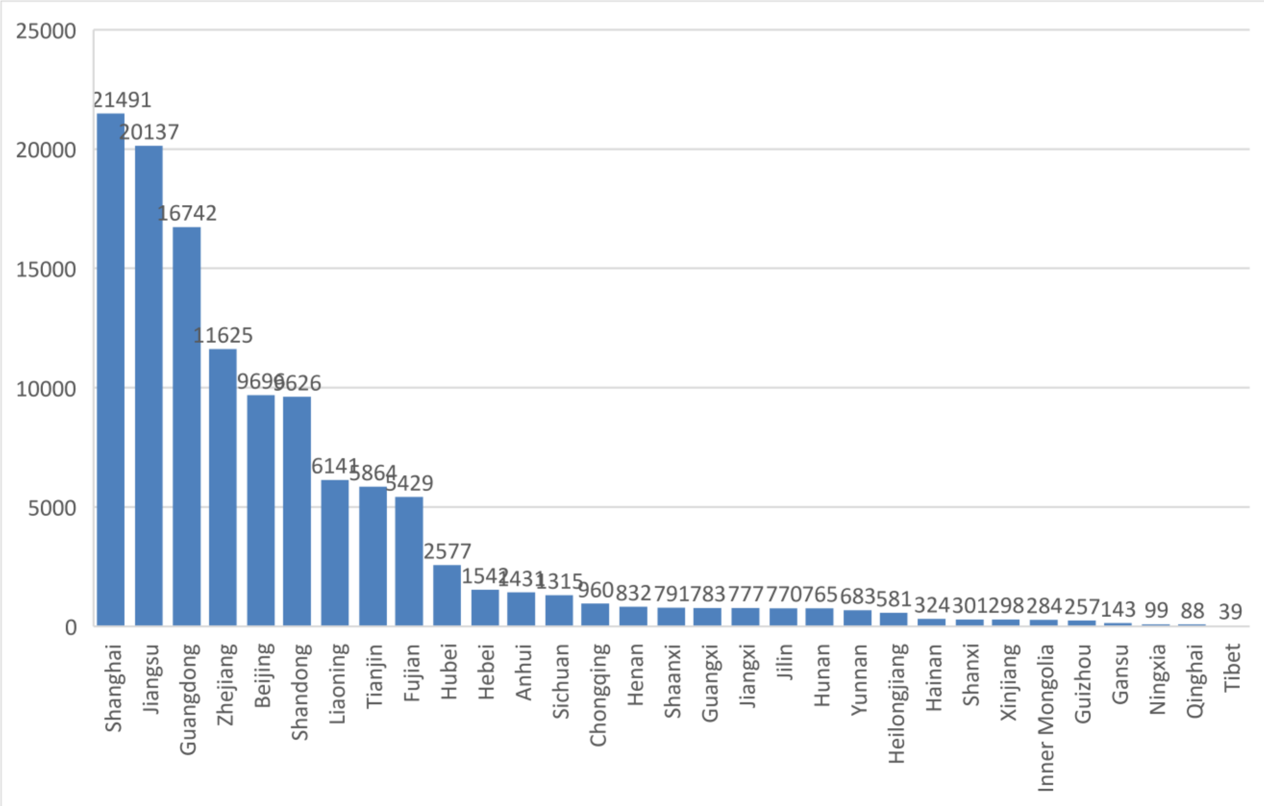
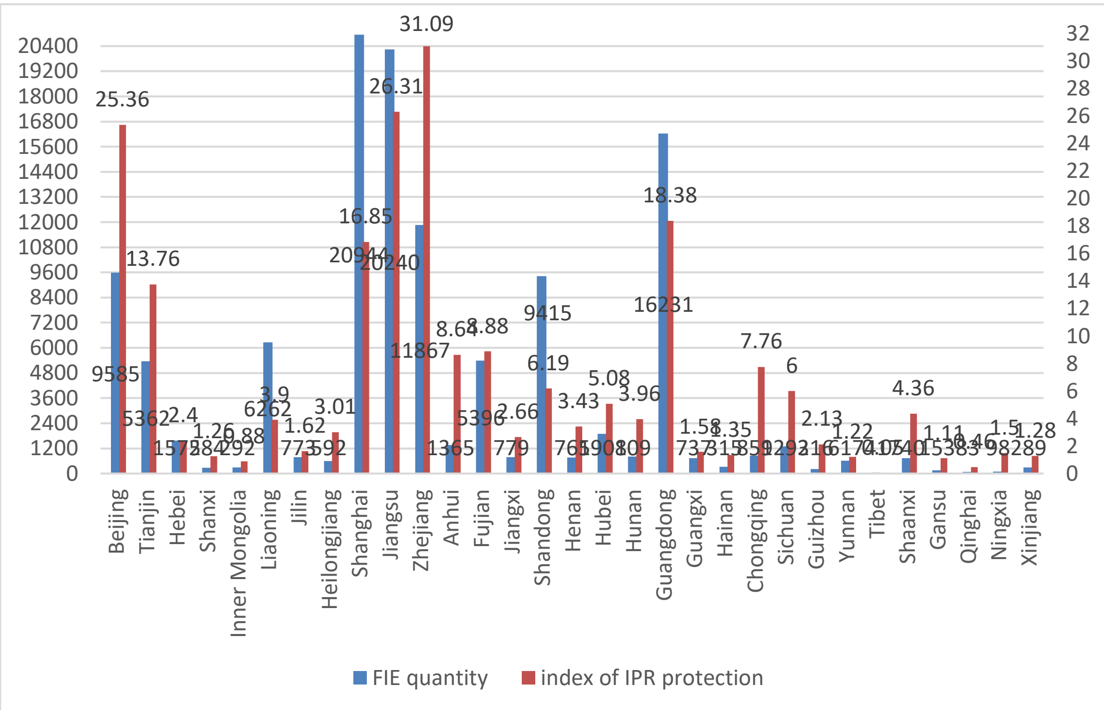


Figure 2. 38 Number of FIEs (HMT excluded) by Region (2016)



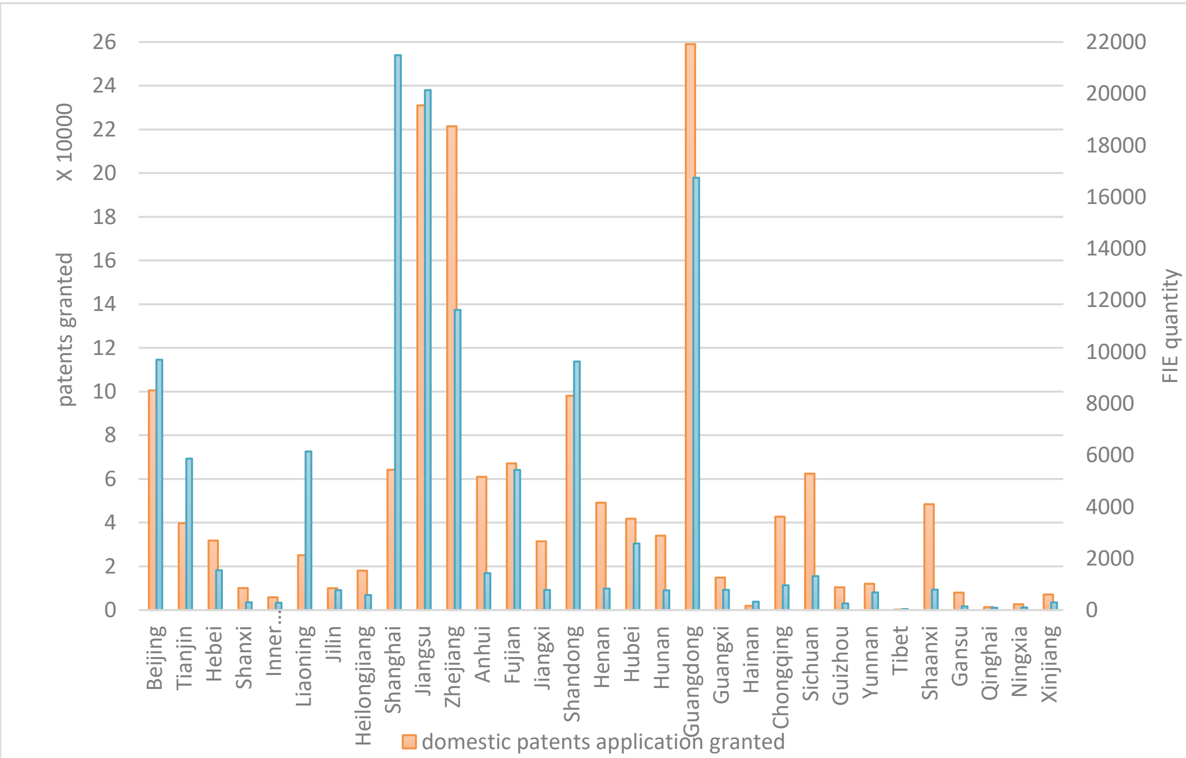
limited due to several reasons. One is that developed countries as home of these FIEs might seek to prevent competition from local regions in new industries. The other is that considerable fear of IP losing has made FIEs reluctant to introduce core technologies to Chinese firms (Grimes & Du, 2013). FIEs generally search for regions where they can gain commercial and technological benefits more efficiently. Therefore, a region's friendliness and openness in terms of information and communication infrastructure, institutional quality especially in IPR protection, economic freedom in the receptiveness to foreignness is more decisive to attract FIEs. However, the comparison between index of IPR protection and FIE quantity at provincial level shows non-proportional relationship (Figure 2. 39). It indicates that in China there exist other factors influencing FIEs' establishment. Secondly, FIEs benefit local innovation capacity through knowledge spillover effect, demonstration effect and competition effect. Knowledge from advanced side can be transferred through supply chain where local firms with customer or supplier linkage can obtain technological assistance from its partners. The inter-firm labor mobility, the movement of workers from one organization to another, is also a key channel of knowledge diffusion (Breschi & Lissoni, 2001). Previous studies have found the demonstration effects of FIEs on local firms in the host countries where local firms might monitor, observe and imitate foreign competitors in the same region (Blomstrom & Kokko, 1998). Demonstration has become an important way for both productivity and market access spillovers. In addition, market competition resulting from FDI affects regional innovation as a two-edged sword (Fu, 2008). Firms face more competition when exposing to FIEs and then have pressure and motivation to increase their in-house innovative productivity (Blomström & Kokko, 1998). Study from Liu, et al. (2014) indicates, foreign competition is positively associated with local firms' buy decision while negatively associated with their make decision. However, R&D activities have crowd-out effect through competition because they attract skilled human resource and other mobile resource from local firms. Thirdly, FIEs possess advanced firm-specific assets and competitive advantage in management. Their know-how in management practice can be transferred to local partners. FIEs are normally regarded as an important force in generating superior innovation-induced knowledge inside a region.

Figure 2. 39 quantity of FIEs vs. Index of IPR protection, by region (2014)



Although FIEs are potential knowledge source for regional innovation, empirical evidence is mixed. Study from Sun (2010) reveals that both positive and negative spillovers exist from foreign enterprises to local economy in China. FIEs influence domestic firms' innovation performance positively and significantly only when absorptive ability of the latter is taken into account (Liu & Buck, 2007). A comparison between quantity of FIEs and quantity of patents granted verifies partly the argument above (Figure 2. 40). The fact that the FDI-induced innovation policies don't gain great success in china in terms of indigenous innovation has revealed that realization of positive influence from FIEs is conditional. It requires not only the linkage among FIEs and indigenous firms, but also local firms' immaterial factor such as dynamic capabilities and competitive advantages, and local region's entrepreneurship environment, legal context and other infrastructure characteristics.

Figure 2. 40 quantity of FIEs vs. patents granted, by region (2016)



Domestic Firms

According to Lundvall (2007), "firms in interaction with other firms and with the knowledge infrastructure" is the core of an innovation system. Taking china's emphasis on indigenous innovation into account, local companies have become the most important innovation actors in a RIS. There are different criteria to categorize domestic enterprises. For example, according to the status of registration, domestic funded enterprises also named as local firms or indigenous firms can be categorized into state-owned enterprises, collective-owned enterprises, cooperative enterprises, joint ownership and private enterprises. Moreover, even if same criterion such as the annual income of main business is applied, this criterion varies depending on industries and sectors that enterprise belongs to. However, above analysis reveals that China hasn't gain great success in indigenous innovation. For example, indigenous firms are not the major exporter of high-tech products although China has become the world's leading exporter in high-tech products (Figure 2. 8).

Reasons for the lack of indigenous innovation are various. One is that Chinese firms pay more attention on rapid commercialization while their foreign competitors emphasize long-term focus on innovation (Grimes & Du, 2013). In addition, firms' complementary assets, such as management and business model relating to innovation are required to "convert technological opportunities into innovative sales and competitive market advantage" successfully (Fu, 2008: 92). Also, the importance of learning process as a firm carries out innovative activities is highlighted in researches. Literatures have identified several critical sources of learning which can facilitate firm's process of innovation. Refer to Howell (2018), there are three categories of leaning sources. One is the learning by doing which happens inside a firm where firm's experience of previous production and marketing leads to its innovation and productivity in the future. For example, firm's internal R&D investment increase its performance positively (Liu & Buck, 2007). The second is the learning through interaction between firm and environment. There are two sources of this interaction. One is learning by exporting. Studies in the field of international business have found evidence that firm's involvement in foreign market influences their ability of introducing innovations, i.e. evidence of "learning by exporting" (Bratti & Felice, 2012). The other is leaning by knowledge spillover inside a region. Theoretical perspectives on economic geography such as agglomeration theories, MAR-and Jacobian knowledge spillovers describe the phenomenon why firms near to a source of knowledge or innovation in a limited geographical boundary can receive knowledge externalities. The third learning is from the legal and institutional environment which mediate the learning spillovers. No matter what kind of channel for leaning, empirical evidence has shown that local firms' absorptive capacity is necessary to complete learning process and thus to facilitate in-house R&D.

Chinese government has realized it and carried out various programs and policies aiming at improving indigenous firms' innovative ability. The change in the funding and performing structure of R&D expenditure indicates that enterprises have become the most important player among all participants (Figure 2. 28, Figure 2. 30). Also, basic statistics about IEADS such as the proportion of enterprises having R&D institutions, proportion of enterprises having R&D activities, and total new products sales reflect the development at provincial level (Figure 2. 41, Figure 2. 42, Figure 2. 43). Not only the large-sized enterprises, SMEs (Small- and medium-sized enterprises) have gained significant development. However, as explained below institutional barriers hinder the innovation activity of SMEs in China (Zhu et al., 2012).

Figure 2. 41 Statistics on IEADS by Region: enterprises having R&D institutions (2016)

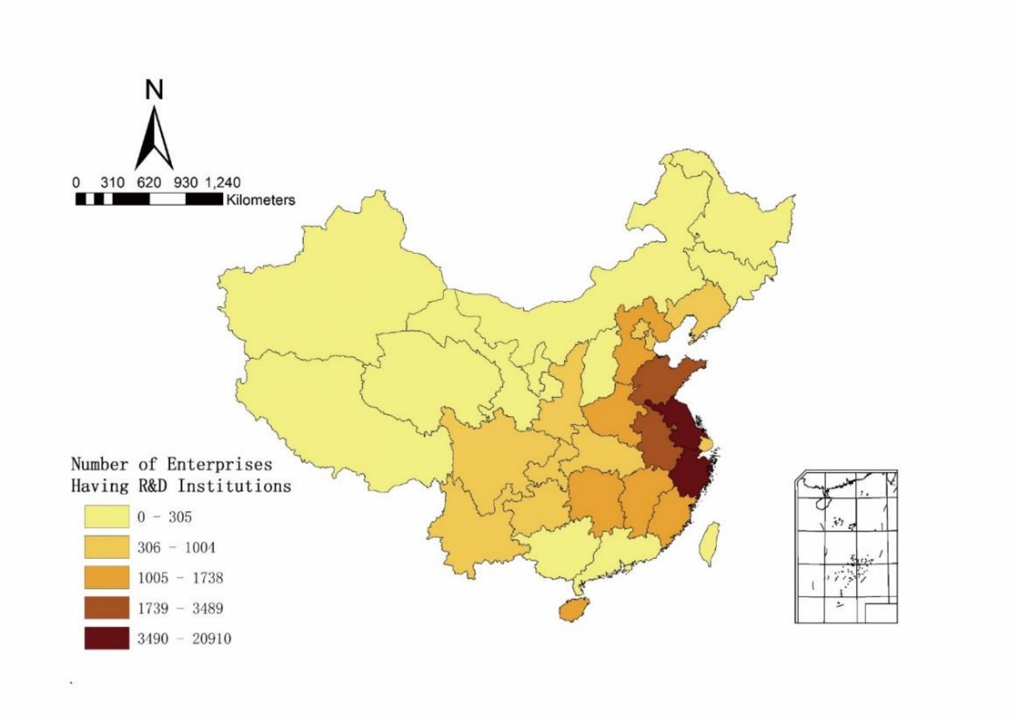


Figure 2. 42 Statistics on IEADS by Region: No. of enterprises having R&D activities (2016)

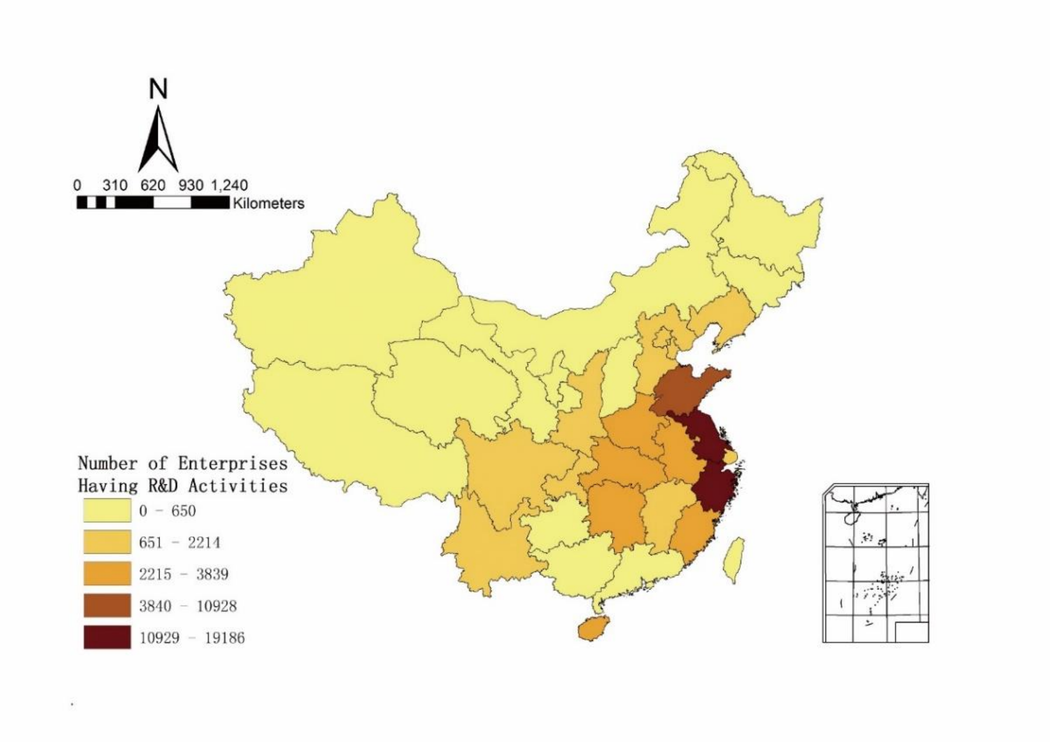
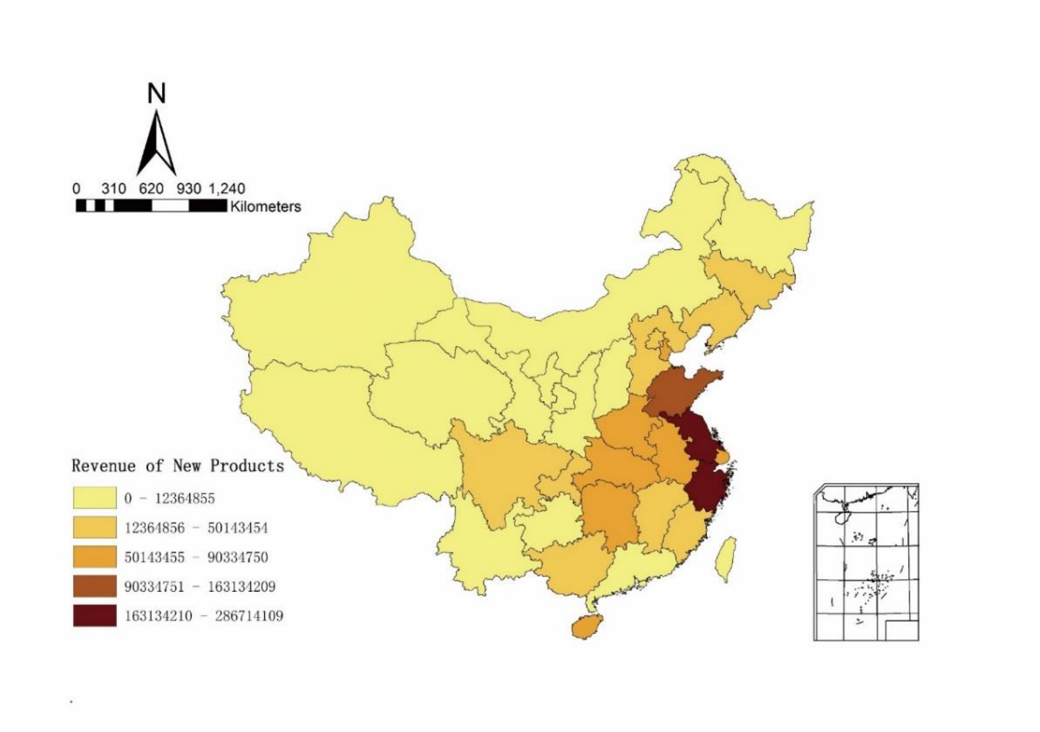


Figure 2. 43 Statistics on IEADS by Region: total new products sales (2016)



Universities & PRIs

According to evolutionary theoretical perspective, there exist other generators of knowledge externalities benefiting regional innovation such as universities and research institutions (Cooke, 1998). Education is normally regarded as the essential factor for economic growth and also innovation (Rodríguez-Pose, 2013). On one hand, investment in universities and research institutes improve the overall quality of human capital while human resource is undoubtedly the basis of innovation activity. Following figures describe the regional distribution of number of universities, of college students and of R&D personal in higher education in 2016 respectively (Figure 2. 44, Figure 2. 45, Figure 2. 46). It is clear that there is a strong uneven distribution in the quantity of both universities and R&D personals which might explain partly the differences in inter-regional distribution of patents (see Figure 2. 13). To combat the imbalance phenomenon, government has issued a series policies and programs to guide R&D personal toward western and central regions. Also, in recent years some universities have taken measures such as rewarding system to attract talents especially overseas scholars and researchers. On the other hand, education system contributes to regional innovation through R&D labs and R&D programs which focus on the development of new technologies, processes and products. Here a comparison is made between S&T input and output of higher education by region in 2016 (see Figure 2. 47 and Figure 2. 48).

Figure 2. 44 Universities by region (2016)

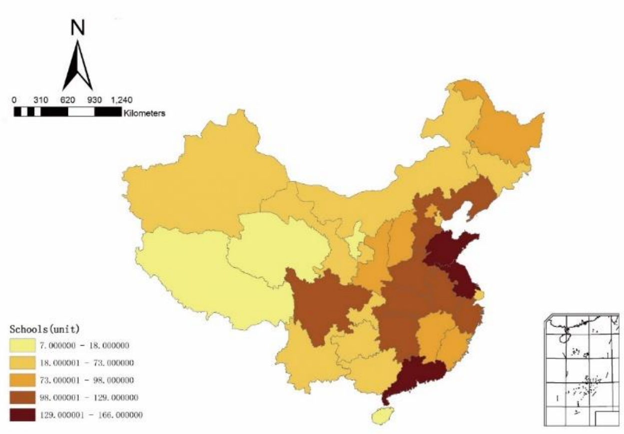


Figure 2. 45 graduated bachelor students by region (2016)

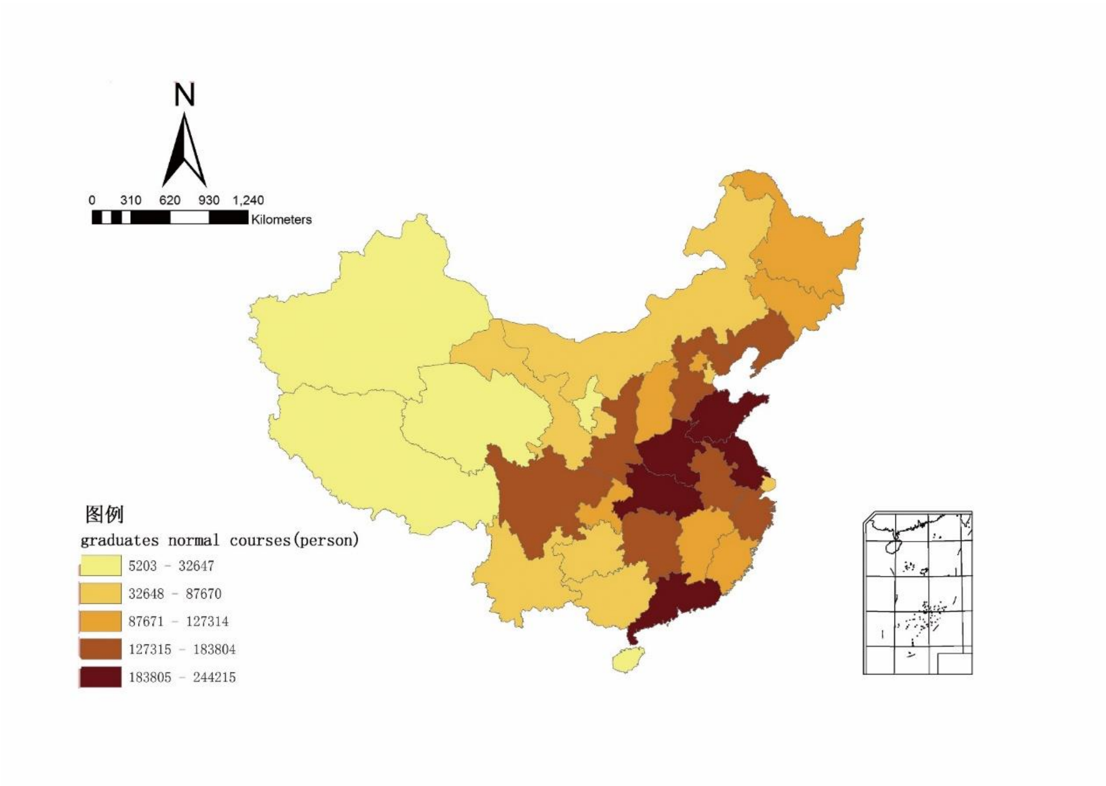


Figure 2. 46 R&D Personnel in Higher Education by Region (2016)

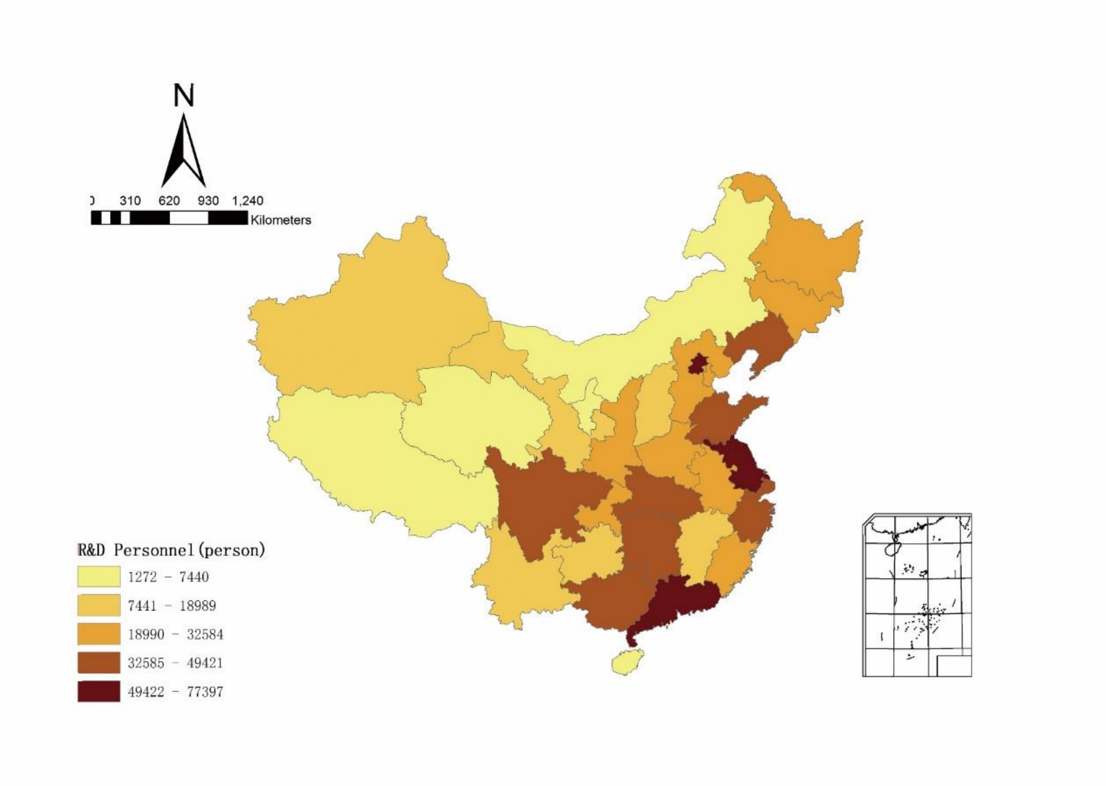


Figure 2. 47 S&T input of higher education by region: intramural expenditure on R&D (2016)

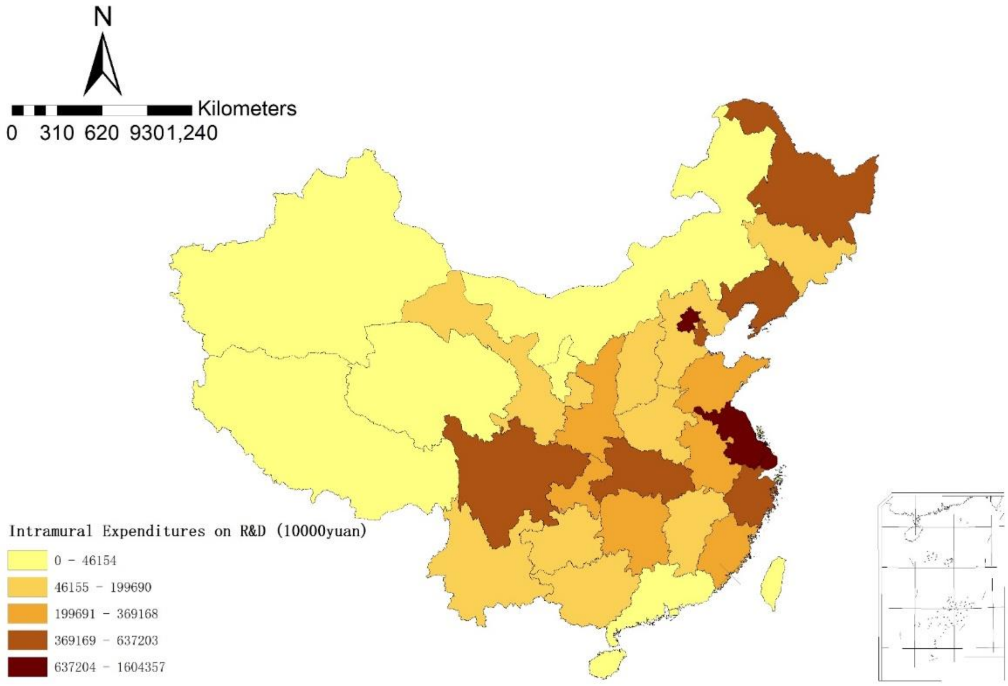
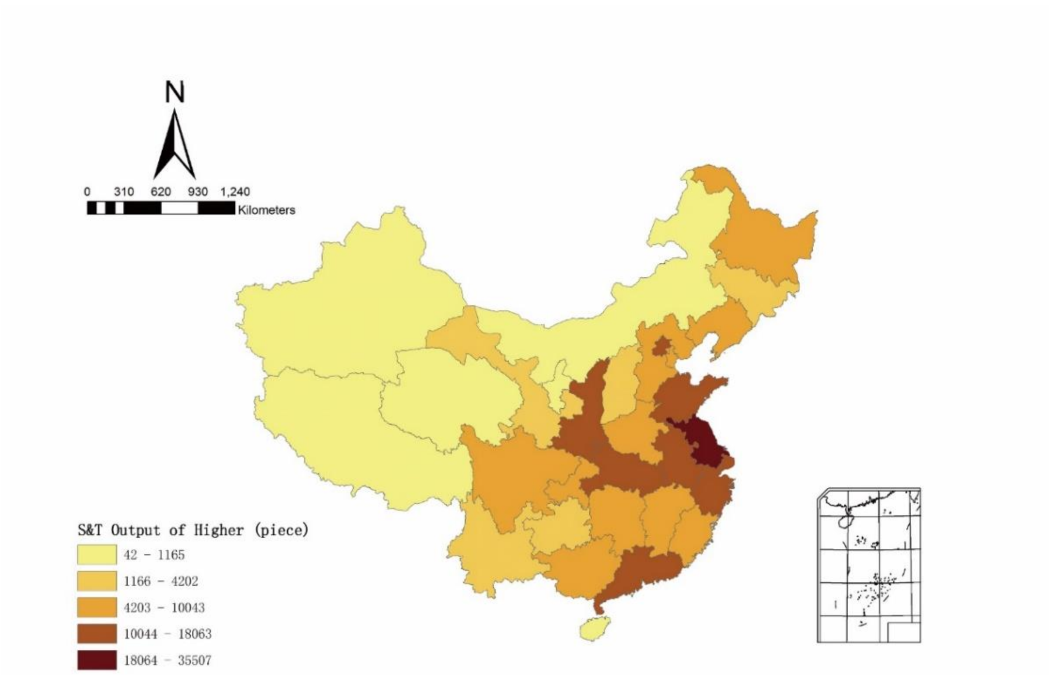
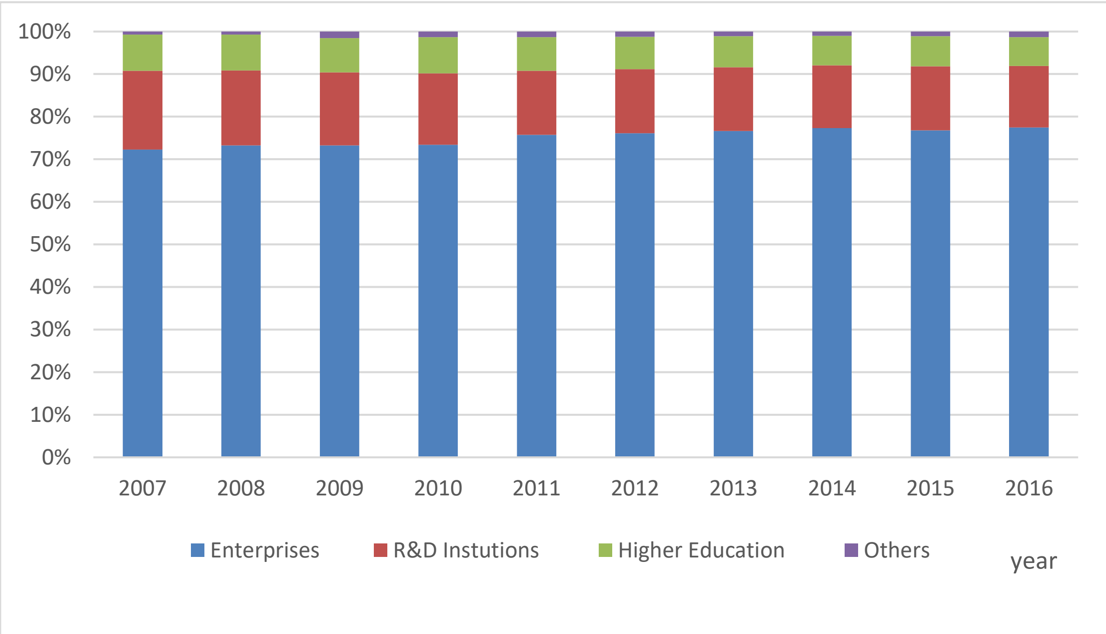


Figure 2. 48 S&T output of higher education by region: patents application (2016)



However, the Chinese education system is criticized for its little emphasis on critical thinking and initiative (Grimes & Du, 2013). Study from Lin et al. (2011) finds that, Chinese universities and research institutions are not identified as an important source of core technology even in Beijing where most famous universities and R&D institutes locate. Compared to other R&D performers such as R&D institutions and enterprises, the higher education system occupies far less proportion of intramural expenditure on R&D (Figure 2. 49).

Figure 2. 49 Performing structure: intramural expenditure on R&D by performers (%)



Recent discussion on the importance of universities and research institutions in regional innovation has attracted attention. Some basic S&T indicators in the field of higher education such as number of R&D projects, scientific papers issued, publication on science and technology, number of patents granted have gained steady increase from 2007 to 2016 (Figure 2. 50). Although all regions have gained increase in various indicators, regional disparity still exists. For example, regional imbalance exist in the distribution of R&D projects of higher education (Figure 2. 51). General situation about R&D institutions is presented here as well (see Figure 2. 52 and Figure 2. 53). Although there is a slow decline in the number of R&D institutions, both R&D input and output have gained steady increase from 2007 to 2016. Regional disparity exists in the R&D institutions aspect as well (see Figure 2. 54 as an example).

Figure 2. 50 basic statistics on higher education for S&T activities

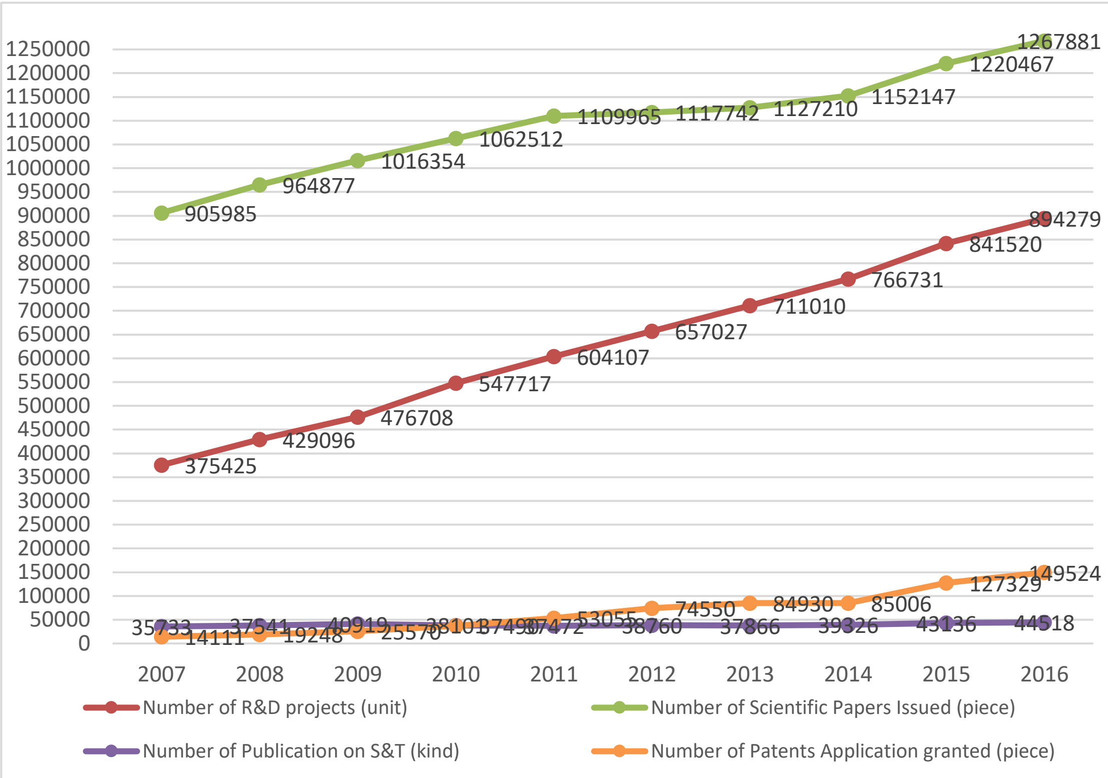


Figure 2. 51 R&D projects of higher education by region (2016)

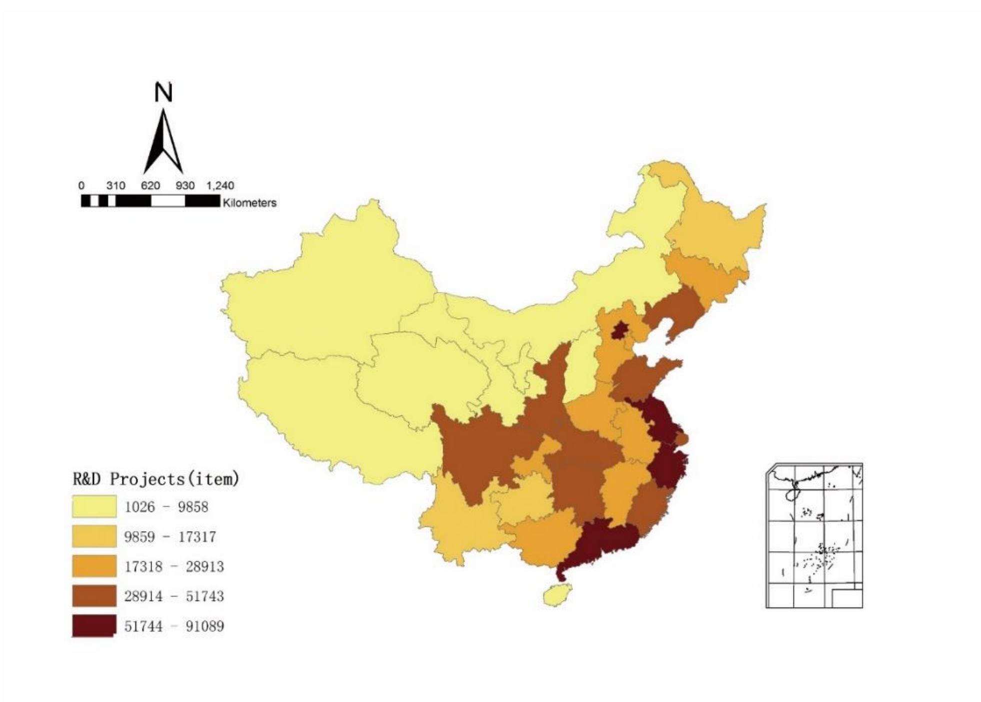


Figure 2. 52 Basic statistics on R&D institutions: No. of institutions

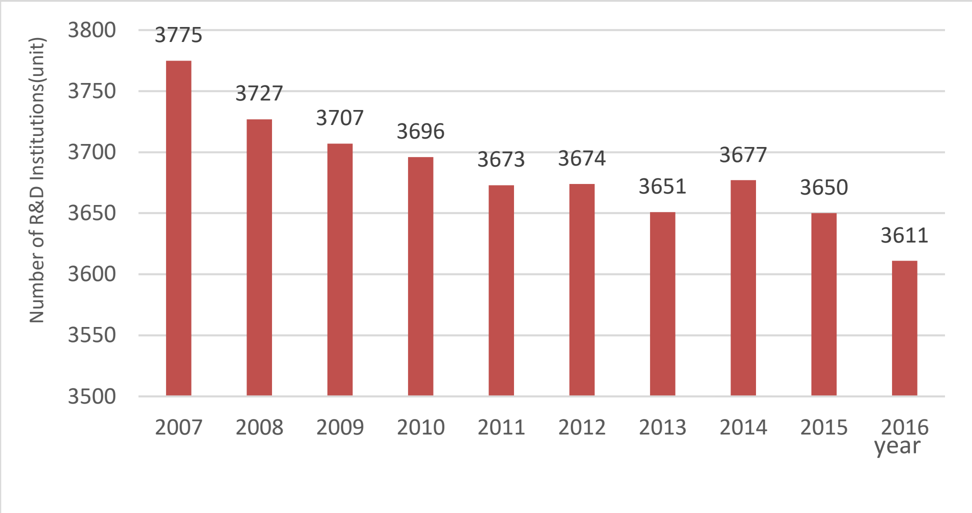


Figure 2. 53 Basic statistics on R&D institutions: R&D input vs. R&D output

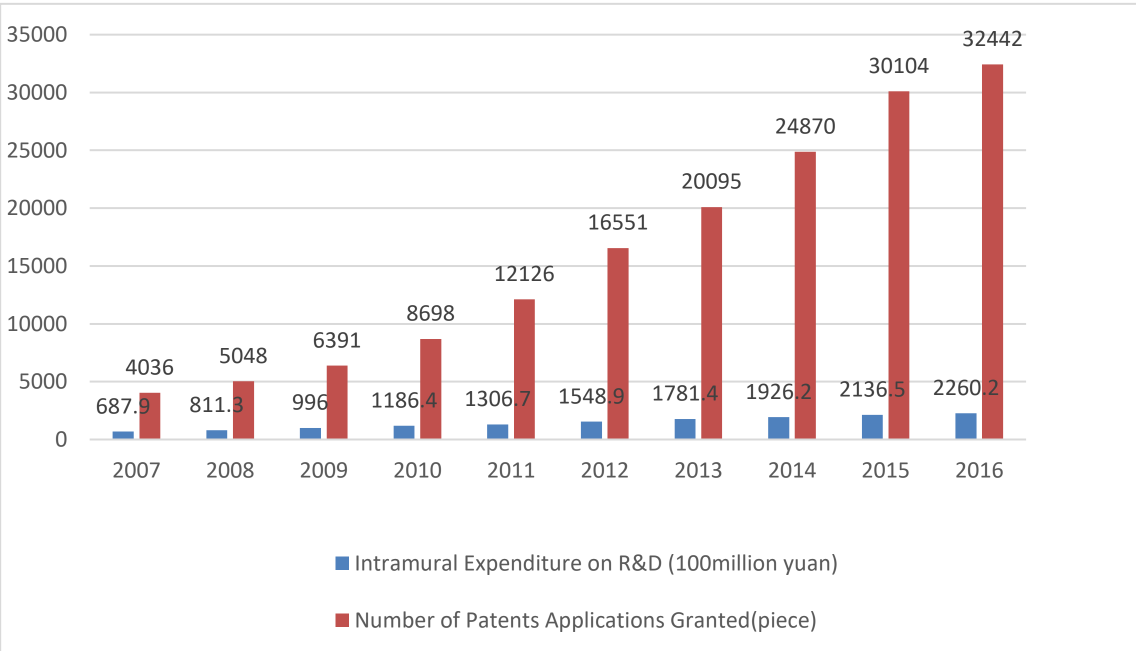
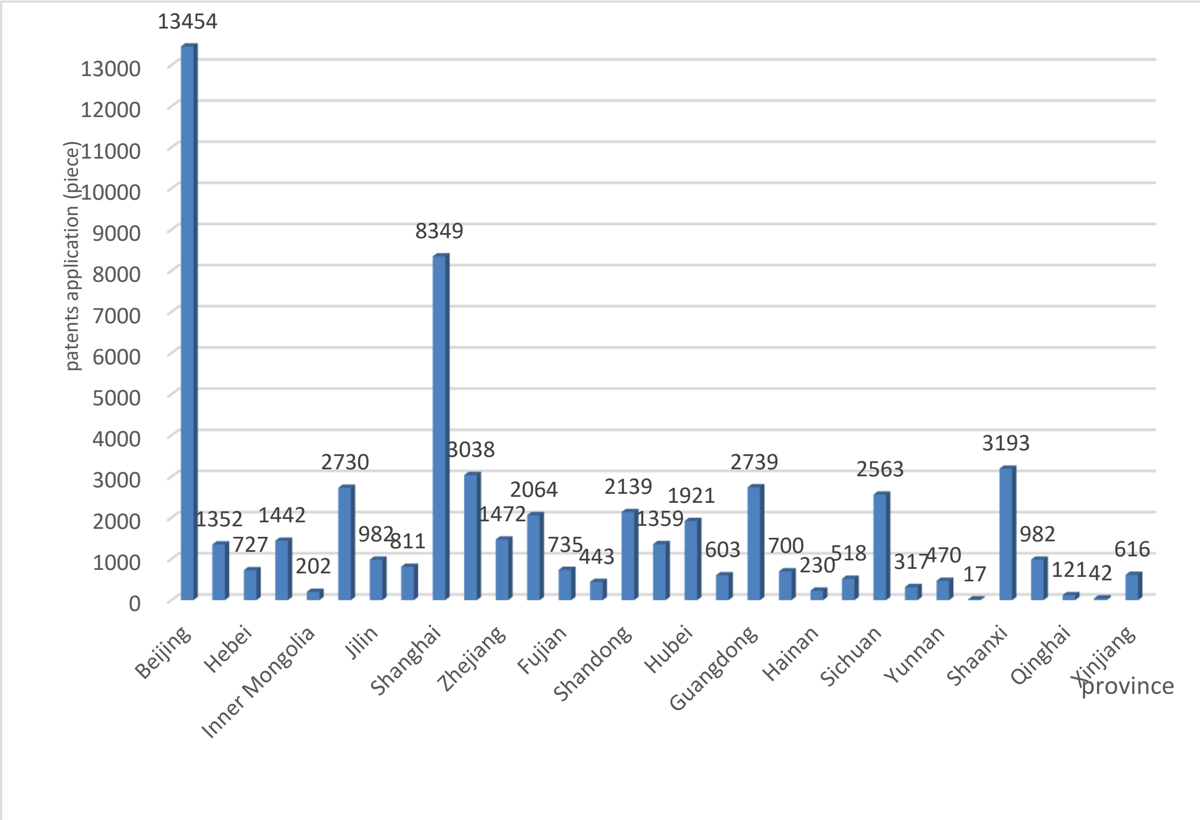


Figure 2. 54 Patents application of R&D institutions by region (2016)



2.3.2.2 Institutional environment

The second component of RIS framework is the institutional environment which include innovation-friendliness elements (Figure 2. 36). These can be entrepreneurship context, legal and extralegal institutions which create orders and reduce uncertainty in exchange and then promote personal and regional innovation. As Howell (2018) claims, without taking the social and institutional condition into account, it is not possible to correctly understand innovation. Regional innovation system (RIS) can be defined as the “institutional infrastructure supporting innovation within the production structure of a region” (Asheim and Gertler, 2005:299). According to institutional theory, institutional settings influence the effectiveness of interactions among various market players within a region and together with the constrains of economics they determine the degree of transaction costs which impede or facilitate the ability of firms to be innovative (Chadee & Roxas, 2013). Therefore, market-supporting, entrepreneur-friendly institutions should create order and reduce uncertainty in exchange and thus are central to the construction of RIS for achieving great innovative performance. Refer to Lundvall (2007), institutional environment is a "wider setting" which include education systems, labor markets, financial markets, intellectual property rights, competition in product markets and welfare regimes. The wider settings has a major impact on the interactive learning and communication and provides implications for innovation policies inside a region.

Institutions could be either formal or informal (Shu, et al.,, 2016). Formal institutions are formal rules such as laws, constitutions, regulations, property rights and contracts that structure economic, political and social interactions (North, 1990; North 1991). Informal institutions are defined as rules and norms that are created and promoted by social forces rather than the state (Xu & Yao, 2015). Informal institutions include humanly devised constraints such as norms, cultures, sanctions, taboos, customs, traditions, ethics and codes of conduct which help shape people's behavior and structure their interactions (Kriz, 2010; Sartor & Beamish, 2014; Shu, et al., 2016). Theoretical perspective normally assumes that institutions are homogeneous across sub-nation regions within a given country by legitimacy reasons. However, the fact that local governments in China control partly the governmental budget and have great authority and responsibility for regional economics and policies results in significant region-specific institutions. Previous studies have shown that considerable institutional variation exist across regions in China (e.g. Liu et al. 2014; Kafouros et a., 2015). Moreover, within a large emerging economy like china, tremendous differences in informal institutions in term of language, customs, habits exist between eastern and western China, northern and southern China, and coastal and inland China.

To capture the provincial differences in formal institutions, NERI (National Economic Research Institute) index of marketization of China's provinces have been developed since 2000. This institutional index is constructed by the National Economic Research Institute (NERI) of China (Wang, et al., 2017). It is regarded as the most comprehensive measures involving regional institutional development in China and has been widely used in studies (e.g. Gao et al, 2010; Liu et al., 2014). The NERI Index consists of five indicators that reflect a particular aspect of marketization and institutional development. They are: 1) the relationship between the government and the market, 2) the development of the non-state enterprise sector, 3) the degree of development of the product market, 4) the development of the factor market, 5) the development of market intermediaries and the legal environment. In order to fully reflect the changes in various aspects of marketization, each index of the five aspects consists of several sub-indices, and some sub-indices also have a sub-index. Basing on the performance in the above mentioned five areas an aggregated score is generated for year 2008 until year 2014 (Figure 2. 55). The overall formal institutional environment in China has experienced a certain degree of slowdown, stagnation and even decline during 2008 and 2010 and has been improved gradually since 2011. For each province there is marketization index as well (Figure 2. 56, Figure 2. 57, Figure 2. 58, Figure 2. 59). The marketization index of almost all provinces has gained an increase from 2008 to 2014 except three provinces like Xizang, Qinghai and Xinjiang (Figure 2. 60). the top five rankings in 2014 are Zhejiang, Shanghai, Jiangsu, Guangdong and Tianjin each with score larger than 9. The average score in 2014 is 6.56. However, the last five ranking are Xizang, Qinghai, Xinjiang, Gansu and Guizhou each with score smaller than 5. The data indicates great disparities existing among provinces in China. Moreover, the top ten provinces are all in eastern China except Chongqing and Anhui and the last ten provinces are all from western China except Hainan and Shanxi. It means that the construction of China's formal institutional environment still has great regional differences. In general, eastern region has a comparable strong institutions while western region has weak institutions.

Figure 2. 55 Marketization index in China (Source: Wang, et al., 2017)

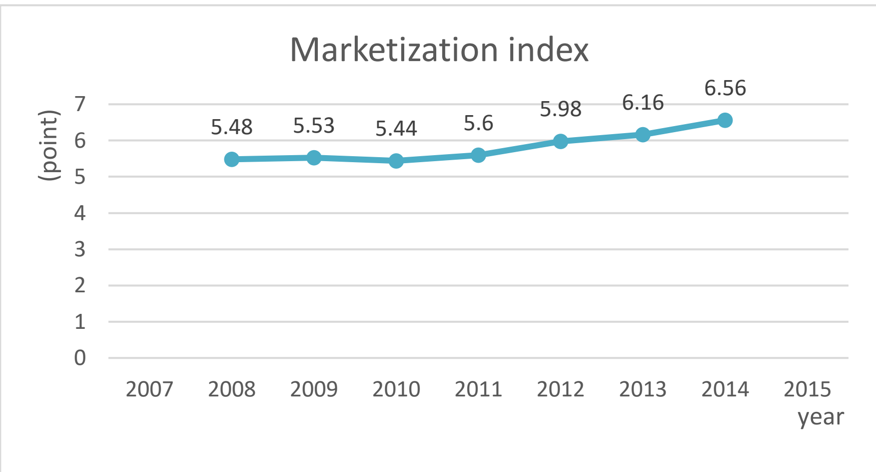


Figure 2. 56 Marketization Index by region (2008)

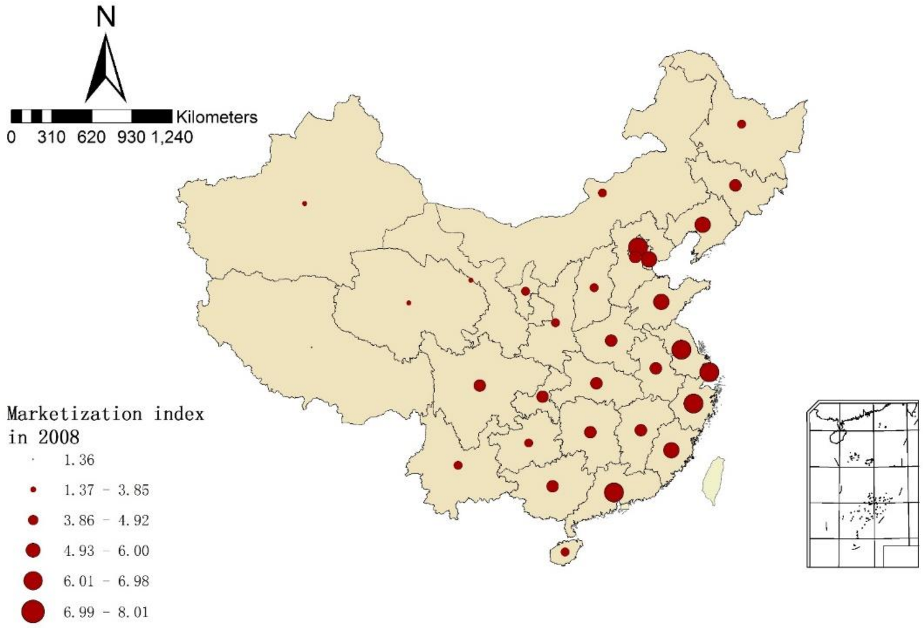


Figure 2. 57 Marketization Index by region (2010)

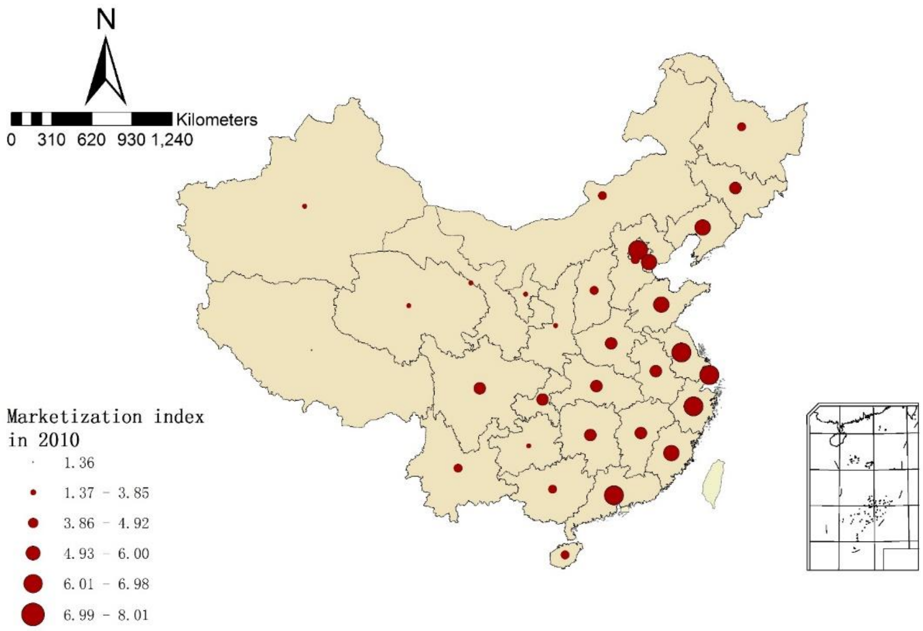


Figure 2. 58 Marketization Index by region (2012)

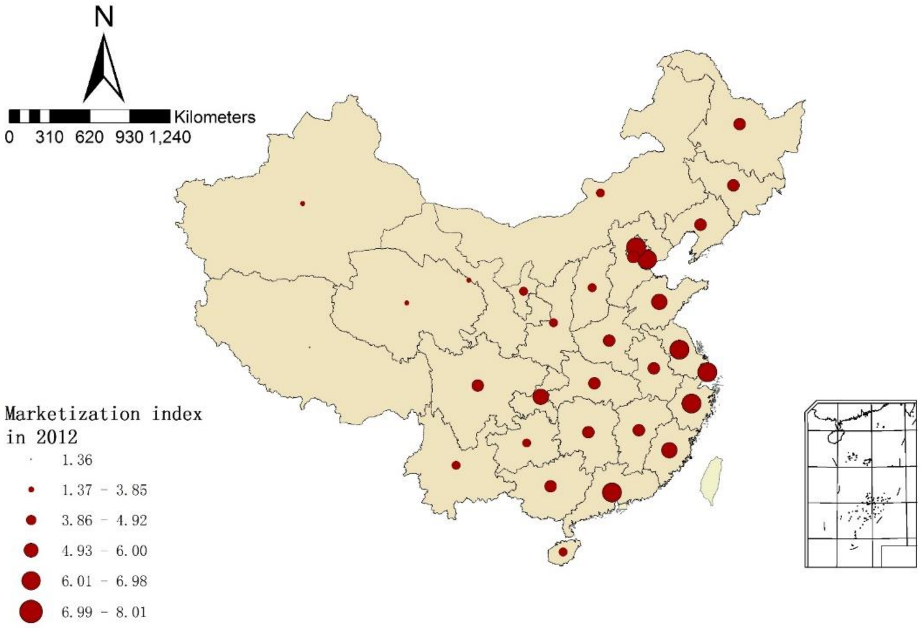


Figure 2. 59 Marketization Index by region (2014)

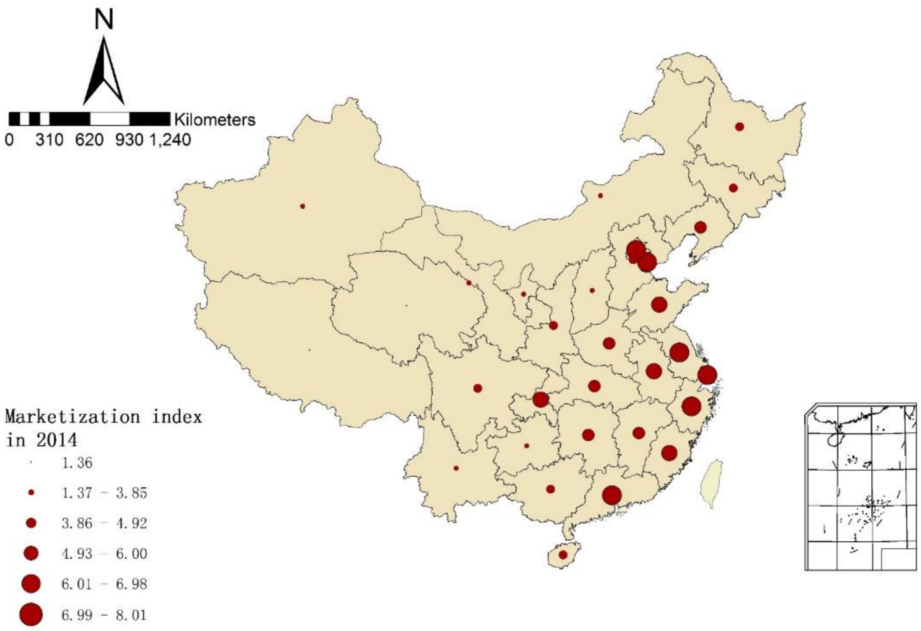
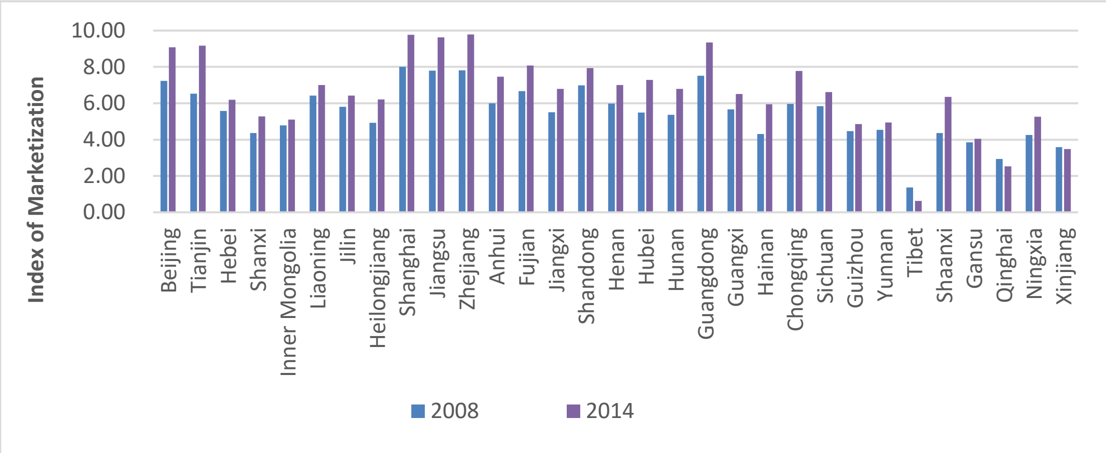


Figure 2. 60 Marketization Index by region (2008 vs. 2014)



In addition, Zhu et al. (2012) identify five key institution-based barriers affecting innovation in China. They are competition fairness, access to financing, laws and regulations, tax burden, and support systems. This essay refers to Zhu et al. (2012) and NERI index, and identifies several most important aspects of formal institutions which show substantial differences across provinces and may affect the regional innovation performance significantly. They are, respectively, the development of product market in terms of the extent of market-determined product prices and the reduction of local protectionism, the development of factor market in terms of the development of financial market, and the development of legal institutions in terms of the maintenance of the legal environment of the market and IPR protection. These are often treated as the most important institutional indicators for the business environment in emerging economies (Gao et al., 2010; Liu et al., 2014). It has to be mentioned that, I don't include education system in this part while analyze it as innovative actors in previous part. The reason is that I regard universities and research institutes as potential innovative performers and hope to discuss their fundamental importance explicitly.

I use information from NERI index to reflect the development of product market in each province. Answers for questions like whether product price is determined by market or local government, or whether local protectionism exist in the market competition are decisive for business's production and investment implementation. Generally, the index of product market development has not changed much from 2008 with score 7.59 to 2014 with score 7.77 (Figure 2. 61). Contrary to our intuition, some middle and western provinces perform better while some eastern provinces need to improve in the reduction of local protection and of governmental price intervention (Figure 2. 62). This index reflects the degree of competition fairness that enterprises face. Policy makers have realized the importance of a strong regulatory environment for innovation activities of enterprises. For example, in 1993 the Anti-Unfair Competition Law of the People's Republic of China was adopted. It is the first time that china legally creates rules to govern competition (Zhu, et al., 2012). In 2007 the Law is revised for better enforcement.

Figure 2. 61 Index of national product market development

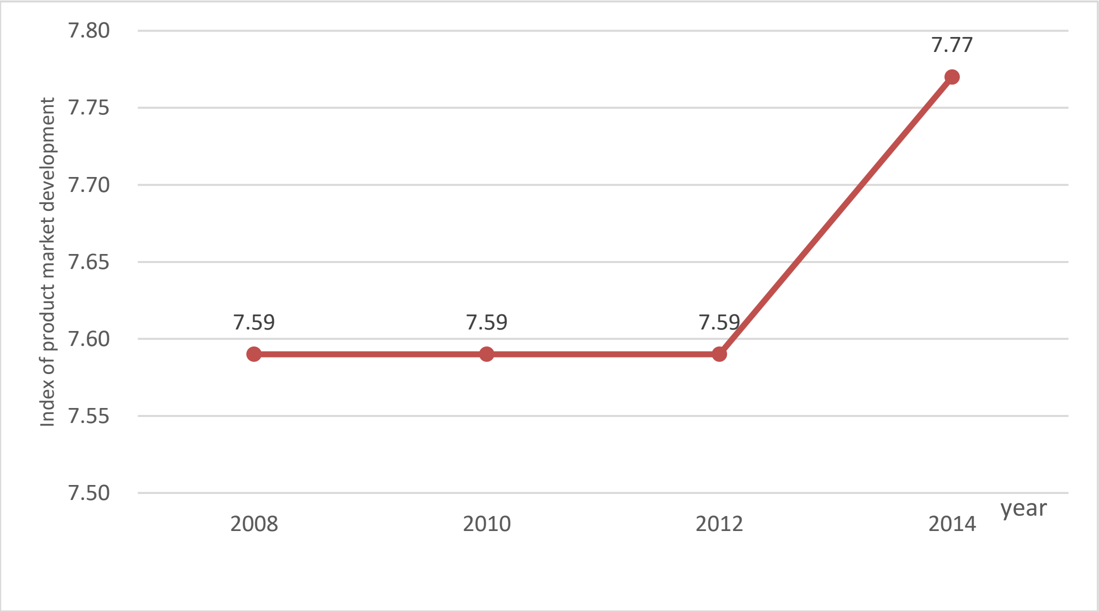
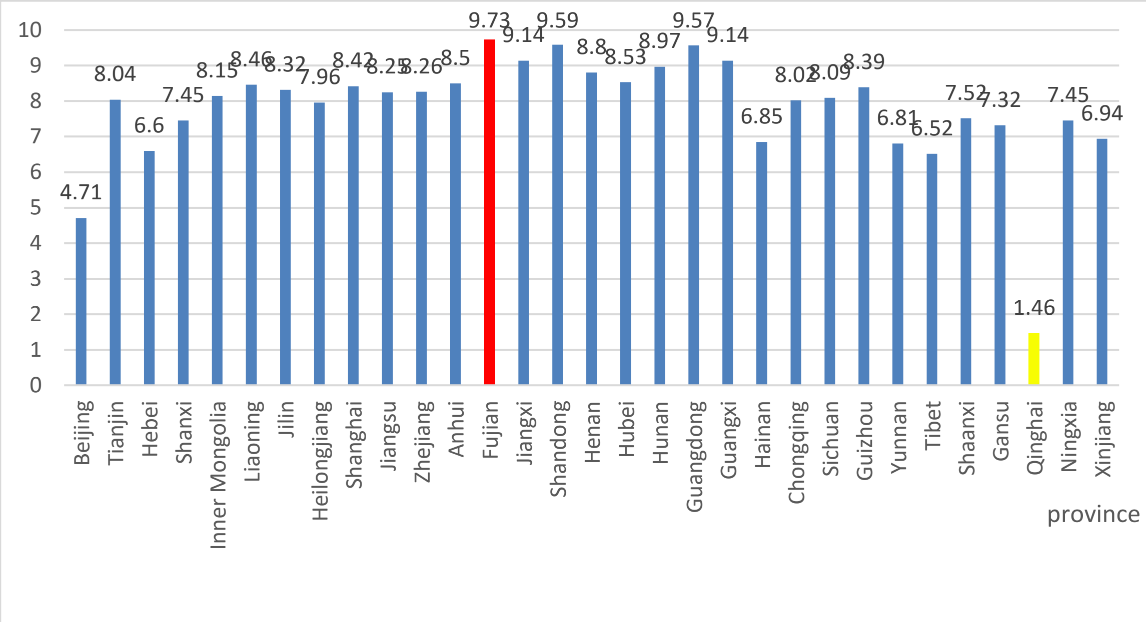


Figure 2. 62 Index of product market development by region (2014)



Financial institutions can improve access to finance and help firms get funds and carry out R&D activities. NERI provides the marketization index of regional finance industry which is measured by the proportion of non-state-owned financial institutions in accounting for the total amount of capital inflows and outflows. Most provinces have improved significantly in this aspect with the Hainan province having the largest improvement from 2008 to 2014. Differences across regions exist as well and thus influence firms' reaction to market opportunities and also the chance of innovation (Figure 2. 63).

Regional legal environment can be reflected through two sub-indicators from NERI index. They are the maintenance of the legal environment of the market, especially the producer's rights, and IPR protection. The innovation output of a firm can be protected in a region with a strong legal institutions. Conversely, firms face risks such as imitation and thus have no incentive to innovate when locating in a region with weak and inefficient legal institutions. Taking year 2014 as an example, Shanghai has the highest index in terms of the maintenance of the legal environment of the market (10.05) whereas Xinjiang has the lowest index (1.73) (Figure 2. 64). Similarly, Zhejiang has the highest index in terms of IPR protection of 31.09 points while Qinghai has the lowest of 0.46 (Figure 2. 39).

Figure 2. 63 index of finance industry by region (2014)

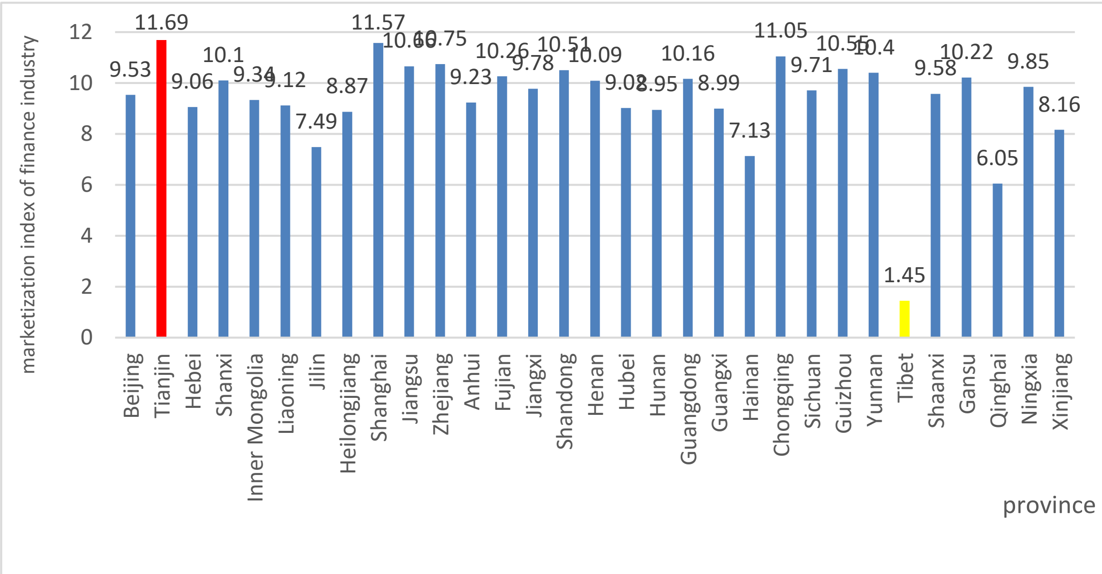
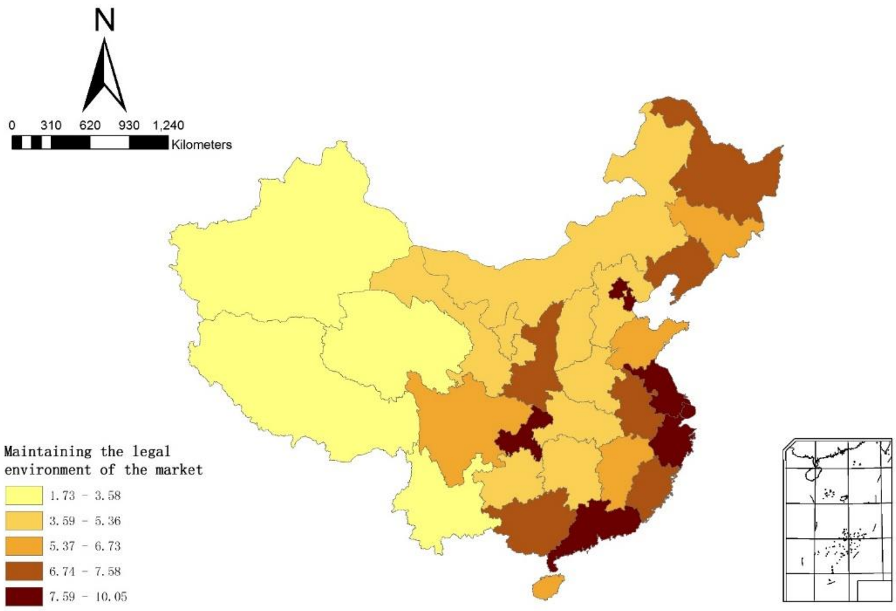


Figure 2. 64 Index of legal environment maintenance by region, 2014



As mentioned above, foreign companies are reluctant to exchange knowledge partly due to the weak IPR protection in China. Similarly, weak IPR policy will hamper firms' motivation to be innovate. As early as in 1978, the central government of China made a decision on "China should establish a patent system." Patent system, as an important component of formal institutions, is to promote technological advancement by granting the patentee particular rights to exploit their patent in return and penalizing violations (Shu, et al., 2015). In 1984 the Patent Law of the People's Republic of China was passed. In September 1992, in order to better fulfill the commitments made by the Chinese government in the memorandum of understanding on intellectual property rights reached between China and the United States, the Patent Law was revised for the first time. In August 2000, in order to comply with the needs of China's accession to the World Trade Organization (WTO), the Patent Law was amended for the second time. In April 2005, the State Intellectual Property Office initiated preparation work for the third revision of the Patent Law. In 2008, China's Patent Law was revised for the third time (hereinafter referred to as the 2008 Patent Law). Compared with the previous two revisions, the third revision is particularly for the promotion of independent and indigenous innovation and for the construction of an innovative country. Until now, China has legal framework on IPRs ranging from Patent Law to trademark law, copyright law, regulations for the protection of computer software and so on (Tang & Hussler, 2011). Although China has improved the legislation environment, there are "fairly widespread concerns about their implementation in the absence of an independent judiciary" (Grimes & Du, 2013: 1369).

GIS (governmental institutional support) is an complementary option to limit the potential negative effect of patent system. It is the "extent to which administrative institutions (including the central or local government departments) provide support (e.g., policies and programs) to firms in a nation or region in order to promote firms' innovation activities" (Shu et al,2015:292). Therefore, GIS is an extralegal formal institution that have significant influence on patenting activity and innovations. However, the study from Shu et al. (2015) suggests that, GIS functions as a double-edged sword and poses challenges to government policymakers and firm managers.

Besides formal institutions, informal institutions like language, customs and culture not only help shape individual's conception, habits and preference but also influence climate of creativity and entrepreneurial spirit which benefit innovation. China is characterized by unique political, economic and cultural features. It is important to understand Guoqing (Chinese special local characteristics) because china is not only a country with very long history rooted in Confucianism but also “the domain of one of the last Communist frontiers, where the institution of government has a direct intervening role” (Kriz, 2010: 542). Guanxi (personal connections), Renqing (reciprocal favour exchange), and Xinren (interpersonal trust) are three distinct features of Chinese culture. Guanxi and Renqing are pervasive in Chinese society. People search for helps from ones who have authority in social and business affairs (Zhang et al., 2015). In addition, the insufficient and imbalance of regional formal institutions environment result in firms or other market actors adopt informal institutions such as Guanxi and Renqing to run business (Shu et al., 2014). Chinese tend to minimize risk through Guanxi and Renqing. Chinese regions is normally characterized as a guanxi - controlled local business networks and Xinren is considered to be missing in contemporary China.

Unlike formal institutions, informal institutions are significantly more difficult to conceptualize (Sartor & Beamish, 2014). For example, regional cultural diversity (Figure 2. 65) is influenced by the percentage of minority population of a region, the dialects and religions etc.. Informal institutions like language and nationality create cultural distance which result in uncertainty for outsider. Therefore, each region has its own informal institutional environment which create different expectations and understanding regarding to specific behavior and also the risk-taking relating to entrepreneurship. For example, the area of Wenzhou in Zhejiang Province and Southern China are famous for its risk-taking capacity while most areas in North China are more conservative in start-ups. Some scholars point out that Chinese culture system as a whole is likely to impede imagination and divergent thinking while divergent thinking is crucial for innovation (Robinson, 2009; Kriz, 2010). Statistics about the regional distribution of the investment in fixed assets in high-tech industry reflect to some extent the adventurous spirit of each region (see Figure 2. 66). Informal institutions are slow to change. Nevertheless Kriz (2010) suggests several key aspects of China’s future innovative development including encouraging risk taking and nurturing a climate for creativity.

Figure 2. 65 Index of Cultural Diversity by region (2010)

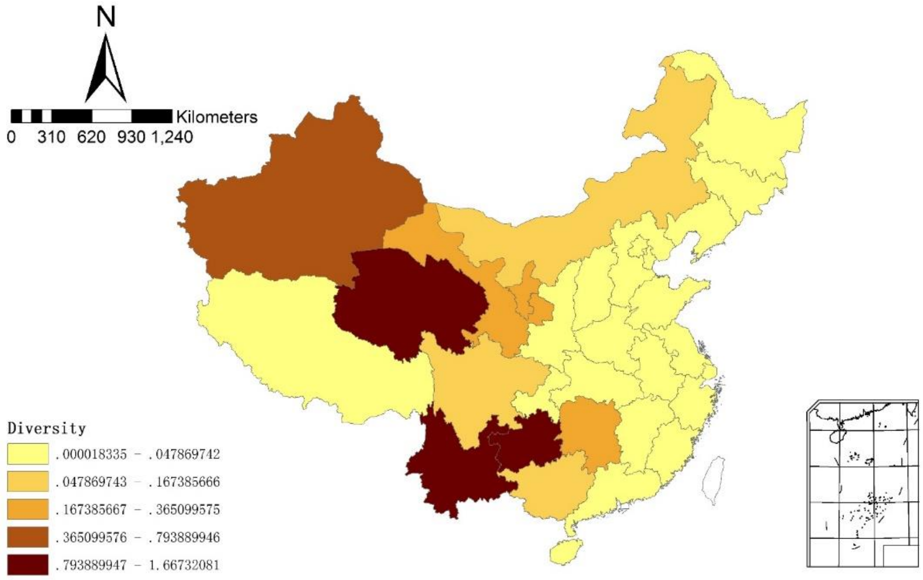
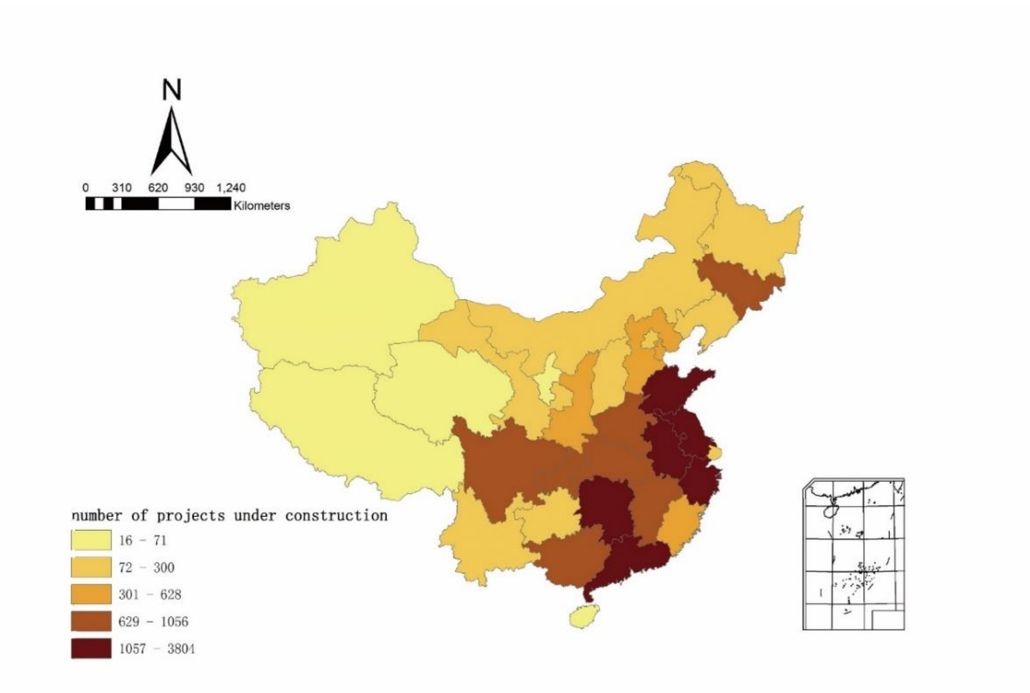


Figure 2. 66 Statistics on investment in fixed assets in high-tech industry by region: number of projects under construction (2016)



As stated above, institutional issue is of great importance in China as developing economy than in developed economy. The Chinese economy is characterized as "state or authoritarian capitalism" by Kurlantzick (2007). Many literatures have emphasized the striking feature of innovation in china including the variety of government policies and programs and the determined role that the national and regional authorities play in technological advancement and innovation capabilities. Therefore, governments need to seek the right balance in regional innovation system and achieve reasonable institutional thickness in regions (Chaminade, 2011). Furthermore, Murphree and Breznitz (2013) point out structured uncertainty as one critical institutional system problem in China. Structured uncertainty is defined as "an agreement to disagree about the proper objectives and methods of public policy or business practices" (Murphree & Breznitz, 2013: 204). It leads to unpredictability of economic policies and results in ambiguity in implementing these policies. On one hand, structured uncertainty forces firms to develop highly flexible business activities emphasizing short-term innovation. On the other hand, because there is no way to know how long the government will commit to a particular policy, Chinese firms are reluctant to engage in high-risk and long-term R&D activities, which are necessary for novel innovation. To mitigate the uncertainty, firms might spend lots of energy on cultivating the relationship with government at different levels. Therefore, structured uncertainty constrains Chinese firm's endeavor to engage in long-term innovative activity.

2.3.2.3 Relations

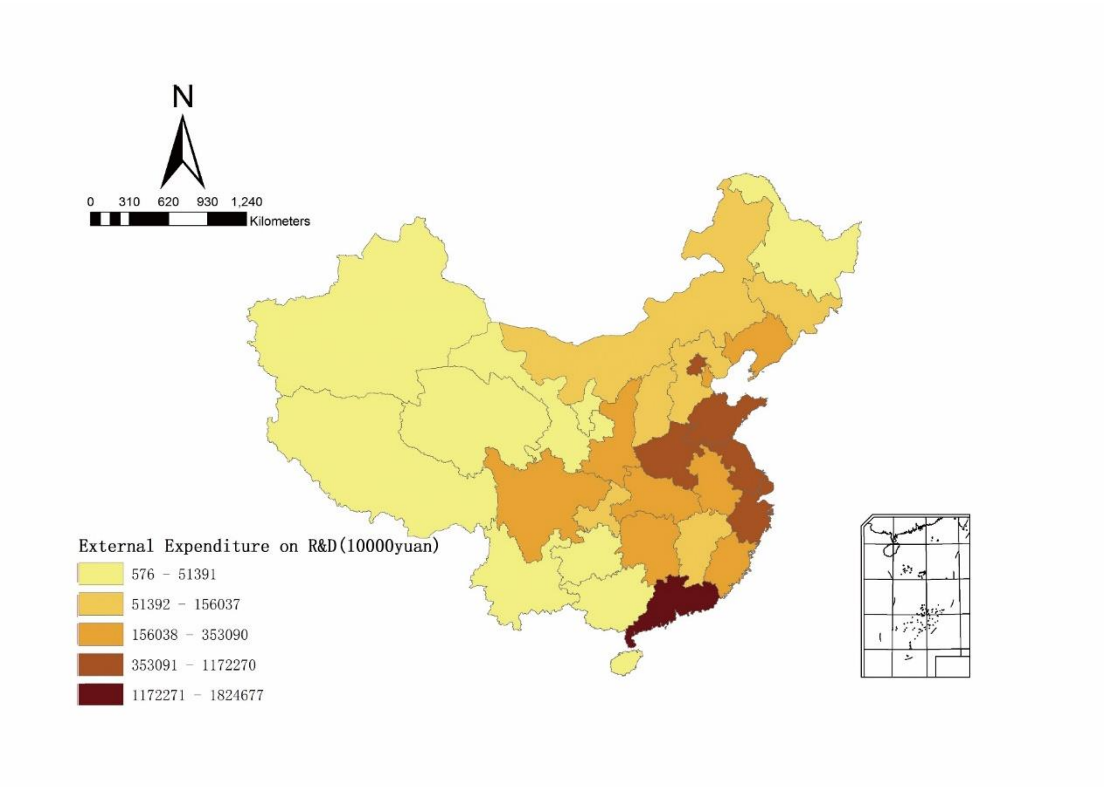
Besides actors and environment, the relations among actors and the interactive relationship between actors and environmental elements are essential to conceptualize a complete framework. In RIS theory, the inter-organizational relations are regarded as fundamental building blocks (Stuck et al., 2016). In this paper, I categorize four types of relations.

Knowledge exchange among major innovation actors

The first is the knowledge exchange among major innovation actors such as FIEs, local firms and URIs.

As analyzed above, firm-level interaction and knowledge spillover are carried out through several channels including up- and downstream exchange along supply chain, localized production network (Lin, et al., 2011), skilled labor turnover by job market, and demonstration effects initiated by industry leader (Fu, 2008). Interactive knowledge learning and knowledge exchange among firms, universities and research institutes have positive effect on innovation processes (Lundvall et al., 2002). However, due to weak IPR protection mechanism and limited internal absorptive capacity, effective knowledge spillover and absorption is hard to be realized. Empirical studies have verified this. For example, study from Lin et al. (2011) shows that a higher level of innovation doesn't co-exist with strong production linkages. The comparison between two figures (Figure 2. 67 and Figure 2. 13) supports the same argument because the external expenditure on R&D (see Figure 2. 67) can reflects partly the cooperation linkage of one province.

Figure 2. 67 External Expenditure on R&D by region (2016)



In addition, prior studies in developed countries have shown that academic collaboration between firms and URIs has improved significantly firm's innovative performance (Kafouros et al., 2015). Because most Chinese enterprises don't possess enough innovation-necessary internal capability to carry out R&D independently, their reliance on academic cooperation seems larger than those in developed countries. Chinese government has recognized it and issued various regulations and programs to encourage academic cooperation. S&T programs such as National Key Technology R&D Program and National New Products Program involve both industry and academy while firms play dominant role in these programs.

Since 2009 there is continuous increase of Chinese enterprises' R&D expenditure on cooperation with domestic research institutions, domestic higher educations and foreign institutions respectively (Figure 2. 68). The general cooperation situation in IEADS is very similar (Figure 2. 69). In addition, the R&D expenditure in IEADS on cooperation with domestic research institutions and with domestic higher education shows distinctive regional disparity (Figure 2. 70, Figure 2. 71). It indicates the degree of the reliance of enterprises' on external technological support and their openness' to exterior. However, academic collaborations might bring costs. Kafouros et al. (2015) believe that institutional heterogeneity across regions affects the value of academic collaboration and it is imperative to use a contingency approach to manage the collaboration.

Figure 2. 68 External Expenditure on R&D by Performer: Enterprises

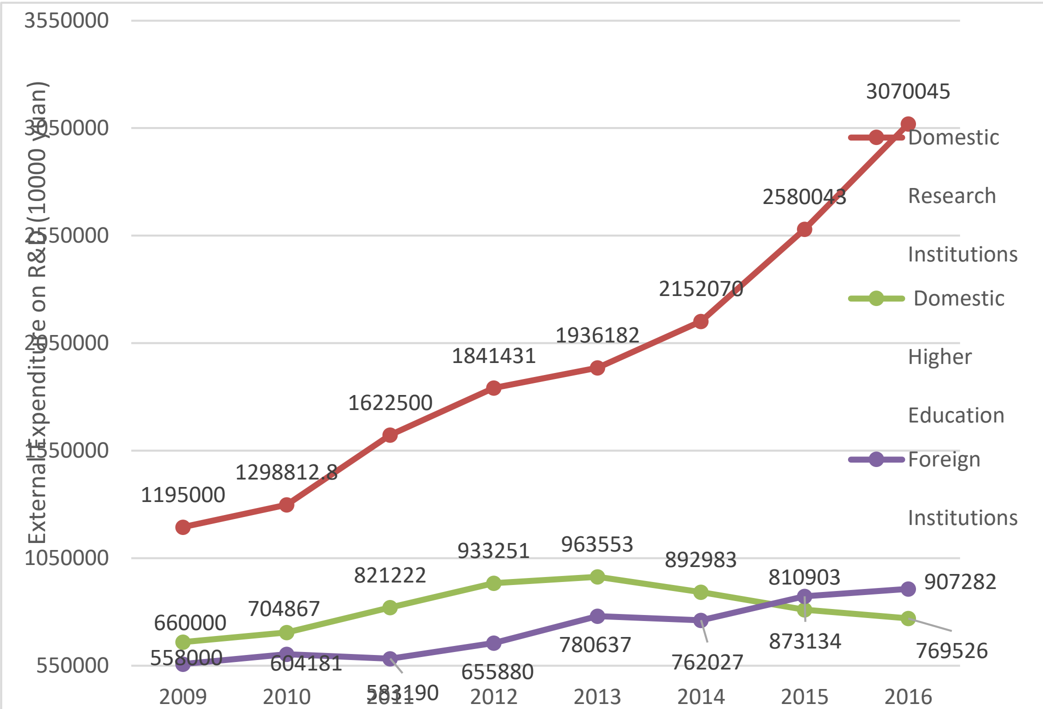


Figure 2. 69 External Expenditure on R&D by Performer: IEADS

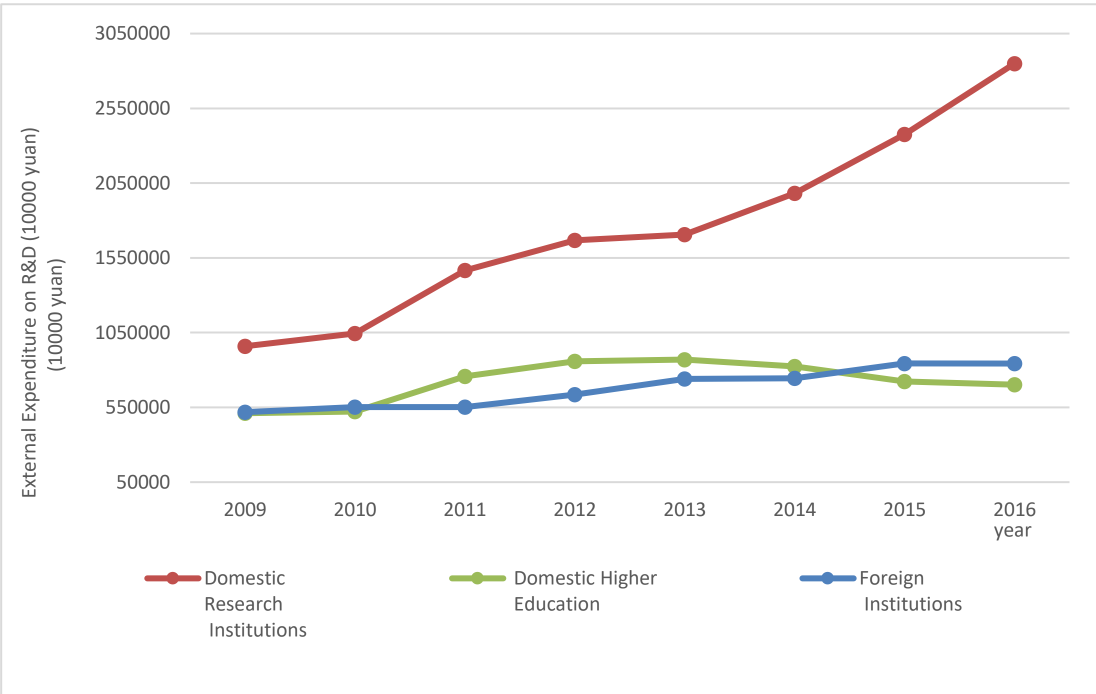


Figure 2. 70 External R&D expenditure of IEADS to domestic research institutions by region (2016)

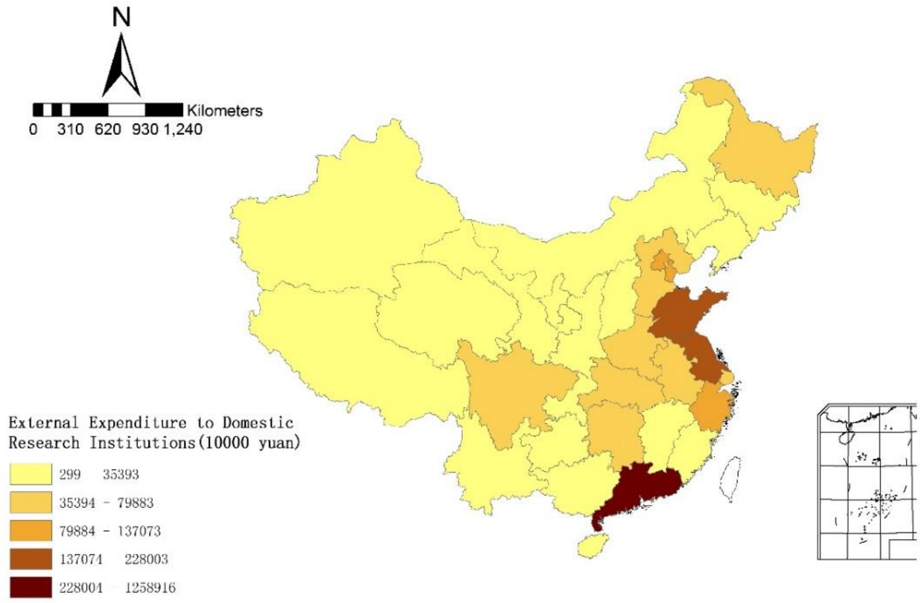
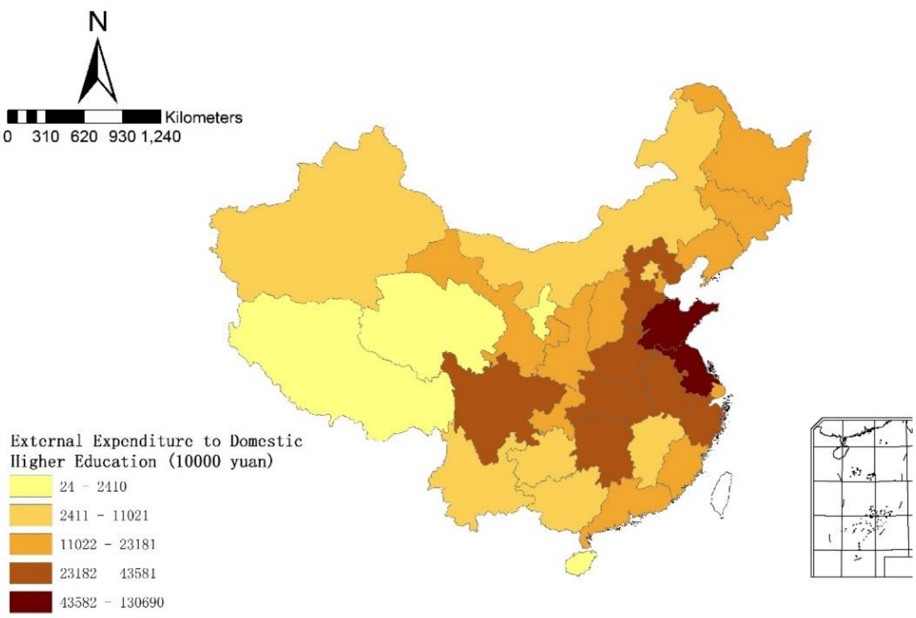


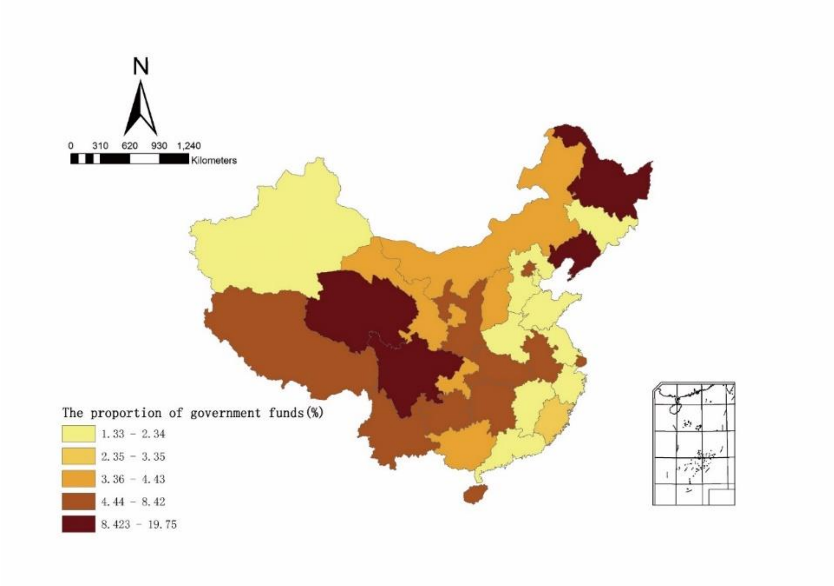
Figure 2. 71 External R&D expenditure of IEADS to domestic higher education by region (2016)



Support from government and financial institutions

The second type of relations is the support from government agencies and financial institutions like banks. As stated above, important institutions-provided government and governmental agencies contribute to innovation-friendly institutional environment for a region. Besides institutions, governmental agencies work as a mediate coordinating innovation activities between market players and provide financial support such as research grants and subsidies for the innovation actors. Literatures have emphasized the concept of “strategic coupling” between companies and local institutions (Lin et al., 2011; Wang & Lin, 2013a). It reflects the importance of local government and institutional conditions in shaping the “diverse trajectories of technological innovation in different Chinese regions” (Wang & Lin, 2013: 37). In terms of funding source, governments are the main funding source of R&D activities in enterprises. Although government funding exist in each province, the distribution is not even among them (e.g. Figure 2. 72). Enterprises in Eastern regions gain fewer funding from government than other regions. It indicates that enterprises in some regions are highly dependent on the support from the central and local governments. It is reasonable that these enterprises might have a key coupling with the government and might do better in innovation affairs.

Figure 2. 72 Intramural R&D expenditure of IEADS by region: government funds (2016)



In addition, the existence of SOE increases the competition pressure for other private or foreign enterprises to gain financial or political advantage. Because most SOEs are controlled by state or central government, they normally have close connection to local industries and authorities. As a result, provincial S&T policies might involve relations between policy makers and innovation performers such as SOEs (Kroll, Conle, Schüller 2008). For example, government can support firms R&D activities with two main S&T policies, namely direct subsidies and tax incentives policy. The R&D direct subsidies policy is executed mainly through kinds of innovation funds established by the national and local governmental revenue while tax incentive policy is mainly oriented to high-tech enterprises. The granting procedure of both policies are similar including application, evaluation, implementation and assessment phases. However, the detailed allocation mechanism is not very transparent and relies sometimes on the strategic coupling capacity of enterprises. Also, the effectiveness of supportive policies is questioned due to the lack of the consistent evaluation criteria.

Interaction between local producers and users of knowledge: Technology Market (TM), Technology Business Incubator (TBI), Productivity Promotion Center (PPC), High-tech development zone (HTDC), national technology transfer center (NTTC)

Not only the interactive exchange between innovation generators, the linkage between local producers and users of knowledge is one of the important relations in RIS framework. Although there exists cooperation between industry and academy as stated above (Figure 2. 70, Figure 2. 71), the exploitation and transfer of technology is still inadequate within RIS.

One reason is scientists and engineers' incentive in basic research rather than in applied industrial program. Moreover, they are not very familiar with industrial issues. Therefore, the dissemination and transfer of knowledge from academy to industry is limited. Taking this fact into account, government tries to make up the gap by establishing a series of quasi-governmental organizations with policy and commercial purposes. These new market attenders are technology market, science and technology industrial parks, technology business incubator, productivity promotion center, technology transfer centers and so on.

The Torch High Technology Industry Development Center of the Ministry of Science and Technology is the main department for studying China's high-tech industrialization. The Torch Program as a guiding plan for the development of China's high-tech industries was firstly approved in 1988. In October 1989, the Torch High-Tech Industry Development Center of the Ministry of Science and Technology was formally established, which was responsible for the specific implementation of the Torch Plan, and was an independent legal entity affiliated to the Ministry of Science and Technology. In May 2006, three centers namely the "Torch High-Tech Industry Development Center of the Ministry of Science and Technology", "Technology Innovation Fund Management Center for small- and medium-sized S&T enterprises of the Ministry of Science and Technology" and "Management Promotion Center for Technology Market of China" were merged and reorganized into the new "Torch High-Technology Industry Development Center of the Ministry of Science and Technology" (hereinafter referred to as the Torch Center). The new Torch center has created innovation and entrepreneurship environment through operating a series of policy tools such as the National High-tech Industrial Development Zone, the Technology Business Incubator (including Zhongchuang Space also named creative space), technology market, and innovative industrial clusters. It has achieved remarkable results in efficient allocating scientific and technological resources, in promoting technological innovation and transformation, in strengthening the combination of science and technology and economy, in adjusting industrial structure, and in enhancing regional innovation capabilities.

Technology market is an effective mechanism to promote the local technology transfer from knowledge producers to technology users (Liu and White 2001). In 1985, the "Decision on the Reform of the Science and Technology System" clearly stated "opening the technology market and implementing the commercialization of scientific and technological achievements". After that, technology market came into being as a breakthrough in the reform of the science and technology system. Until the end of 2017, 367,586 technical contracts were signed nationwide, with total contract value of 1,342.422 billion yuan, an increase of 14.71% and 17.68% respectively.

It is clear that both amount and value of contract deals in domestic technical markets have gained huge development (Figure 2. 73, Figure 2. 74). Four types of contracts can be traded on those markets. Refer to the performance of four types of contracts in 2016 (Figure 2. 75), technology service contract still ranks first with a value of 682.617 billion yuan in 2017, an year-on year increase of 16.66%. Technology development contract reaches 474.854 billion yuan, with an year-on-year increase of 36.47% while technology transfer contract decreases to 140.28 billion yuan with a decrease of 12.91% compared to that of 2016. The technology consulting contract decreases slightly by 4.08% and the value is 44.923 billion yuan.

Figure 2. 73 Contract Deals in Domestic TMs: amount of contracts

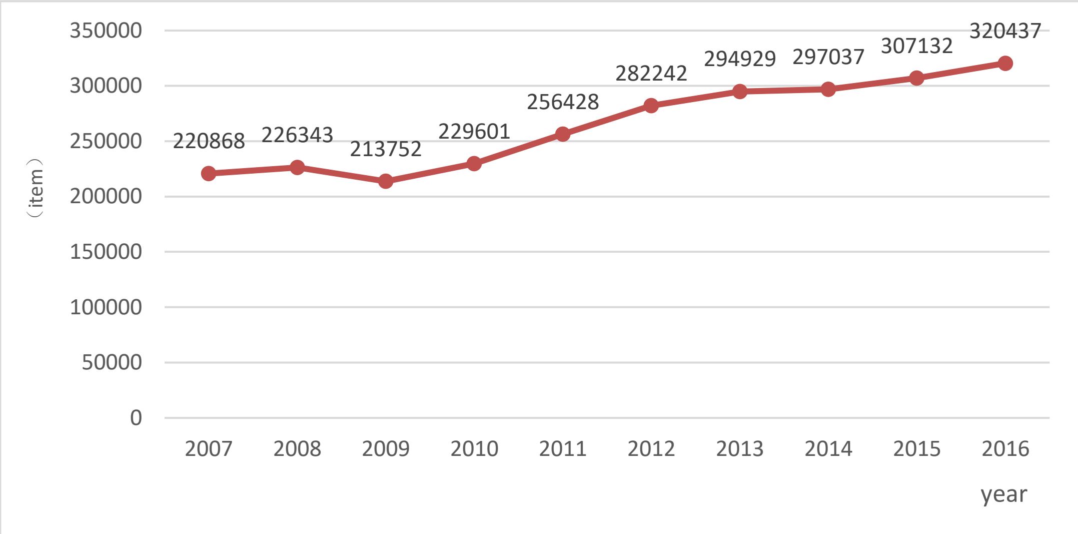


Figure 2. 74 Contract Deals in Domestic TMs: Total Contract Value

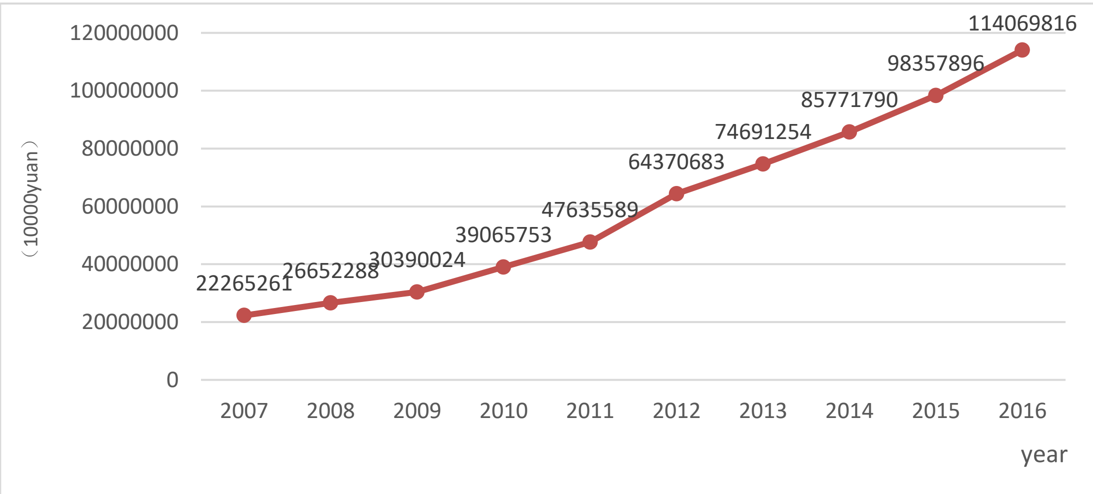
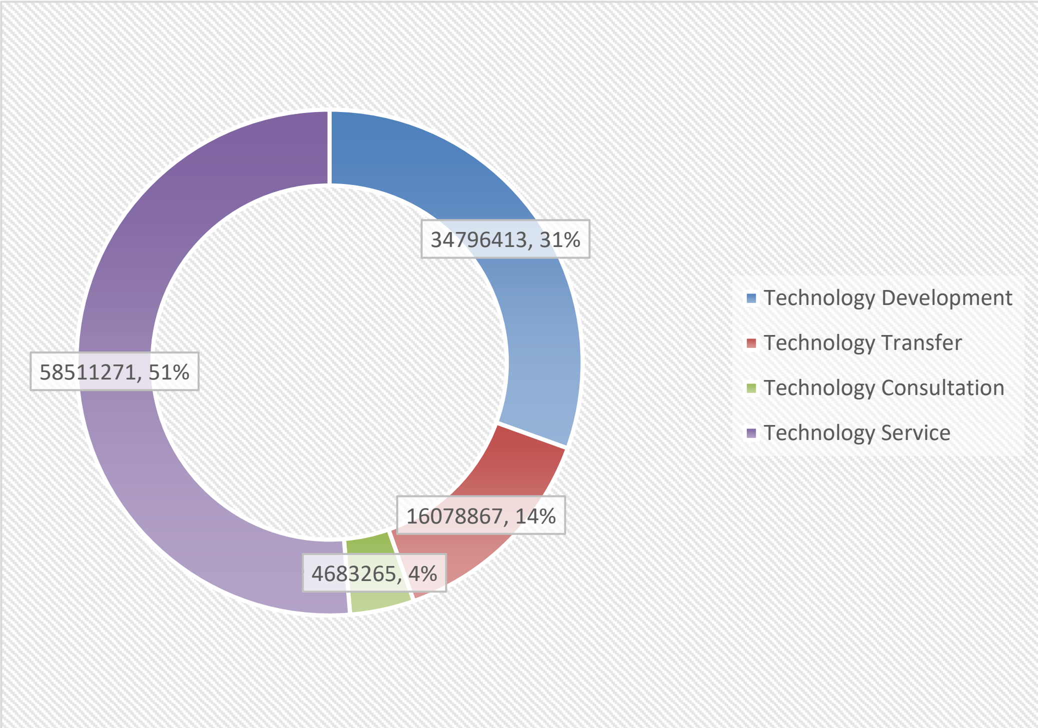


Figure 2. 75 Four types of contracts traded on Domestic TMs (10000yuan, 2016)



It is not surprisingly that higher education systems and research institutes are not the only knowledge producers. They are not even the most important knowledge providers in regional technology markets. Following figures provide the information about contract deals and values in domestic technical markets in terms of category of technology seller and buyer (Figure 2. 76, Figure 2. 77, Figure 2. 78, Figure 2. 79). Among them, enterprises are the most active market players in each category. Furthermore, official statistics indicate that, in 2017 enterprises continue to be the main transaction subjects which transfer out 250,126 contracts with value of 1,187,528 million yuan, and transfer in 50,016 contracts with value of 10,312.70 billion yuan. The total contracts value accounts for 88.46% of the national technology contract value. Public organizations are categorized into four types, namely, research institutes, higher education, medical and sanitation, and others. Statistics about contracts number and value by public organizations as buyer and seller in 2016 are reported as well (Figure 2. 80, Figure 2. 81). Higher education system and research institutes belonging to the public organization category have also gained increase in technology contract transaction with a total output of 104,836 items and contract value of 122.259 billion yuan in 2017. Among them, the output value of universities and colleges is 35.583 billion yuan with a slight decrease of 1.16% compared to 2016 and that of research institutes is 86.676 billion yuan with an increase of 22.91% compared to 2016. Enterprises here are of five types, namely, domestic funded enterprises, enterprises with funds from Hongkong, Macao and Taiwan, foreign funded enterprises, private enterprises, oversea enterprises. Statistics about enterprises as category of technology seller and buyer in 2016 are showed (Figure 2. 82, Figure 2. 83).

Figure 2. 76 contract deals in Domestic TM by Category of Technology Seller (items)

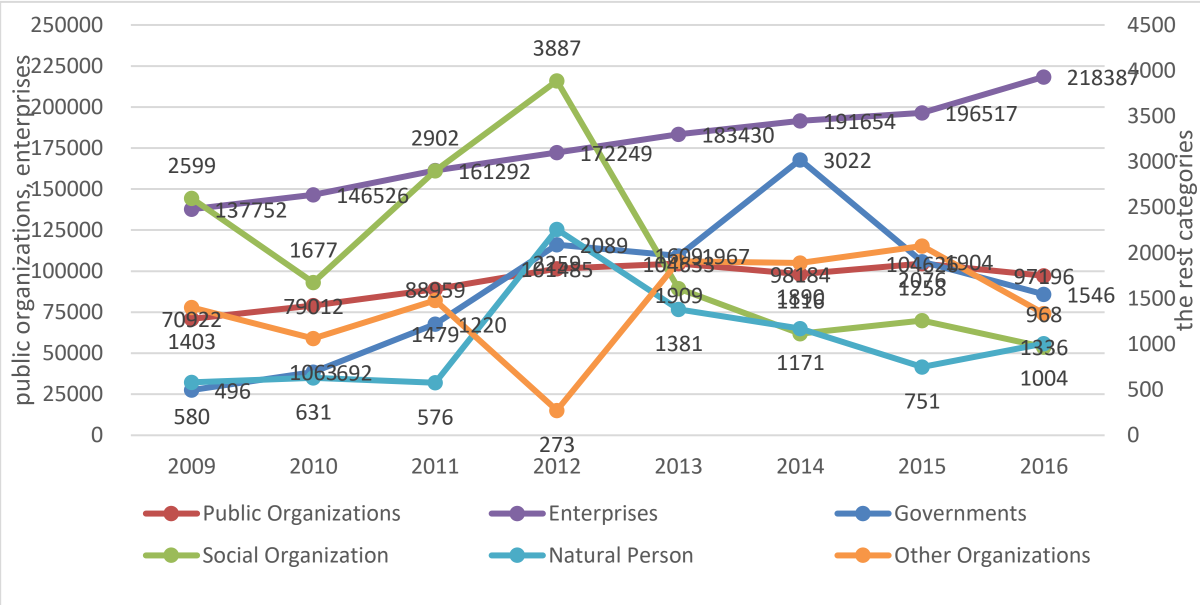


Figure 2. 77 contract deals in Domestic TM by Category of Technology Buyer (items)

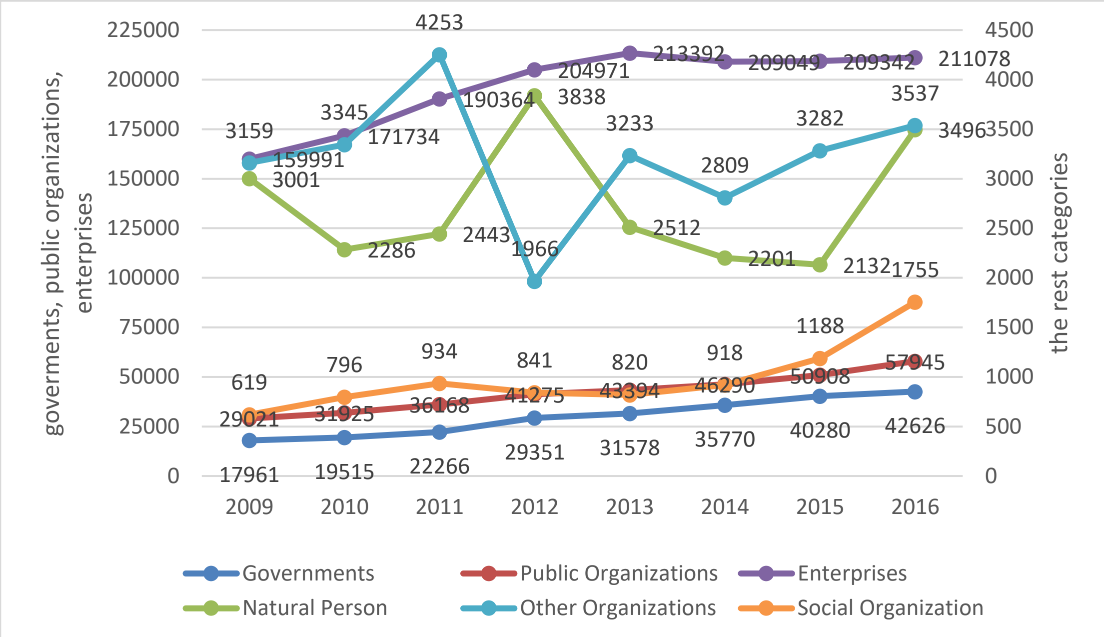


Figure 2. 78 Contract values in domestic TM by category of technology seller (10000 yuan)

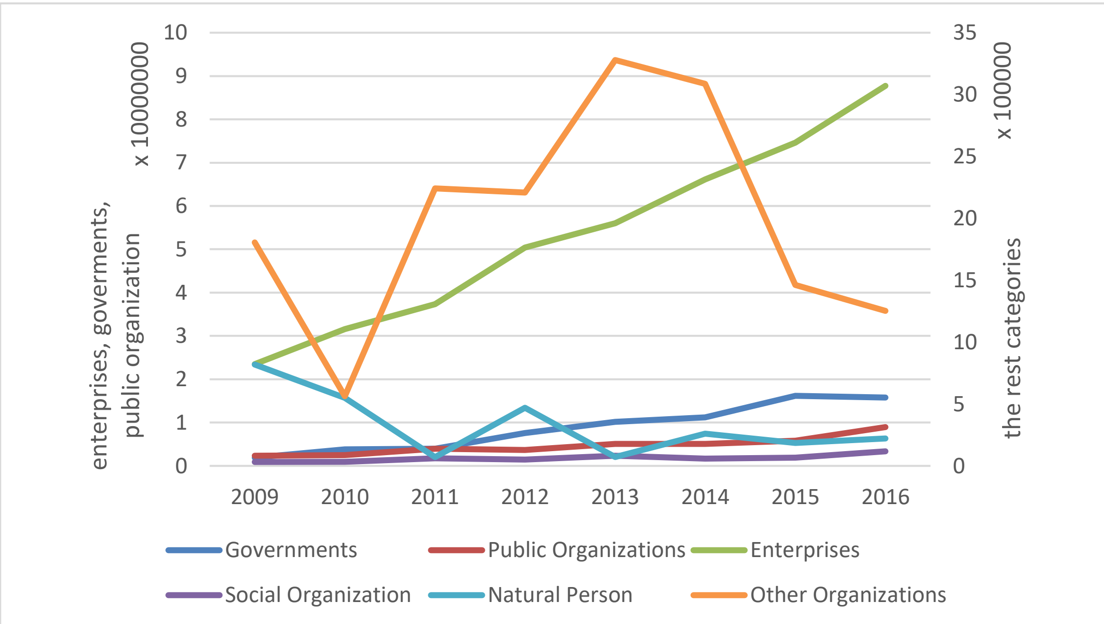


Figure 2. 79 Contract values in domestic TM by category of technology buyer (10000 yuan)

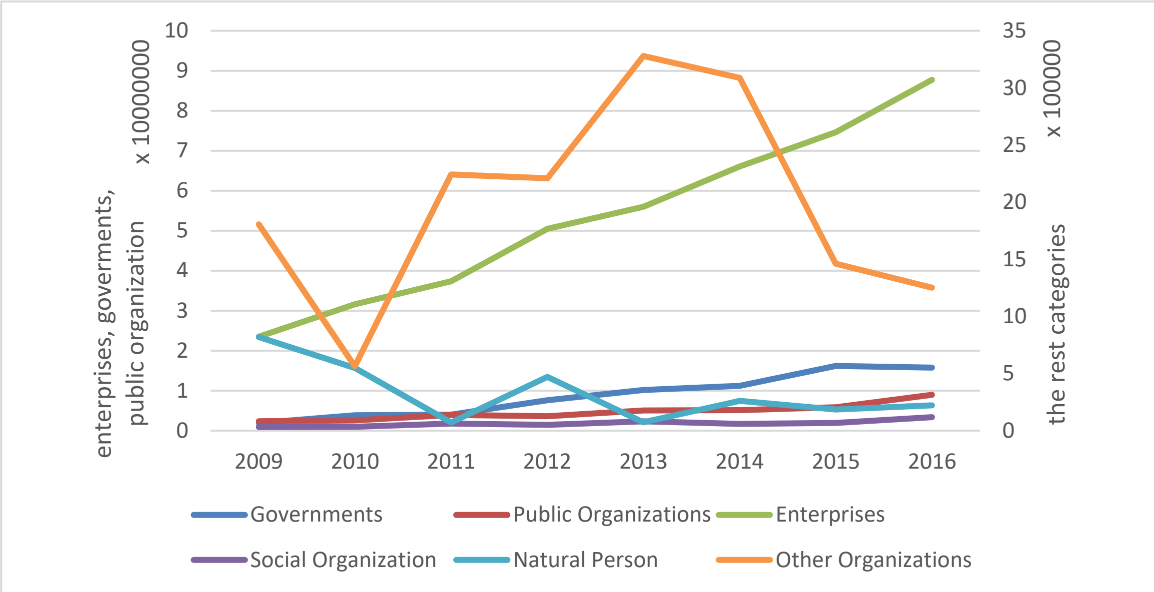


Figure 2. 80 Contracts number by public organizations as buyer and seller (2016)

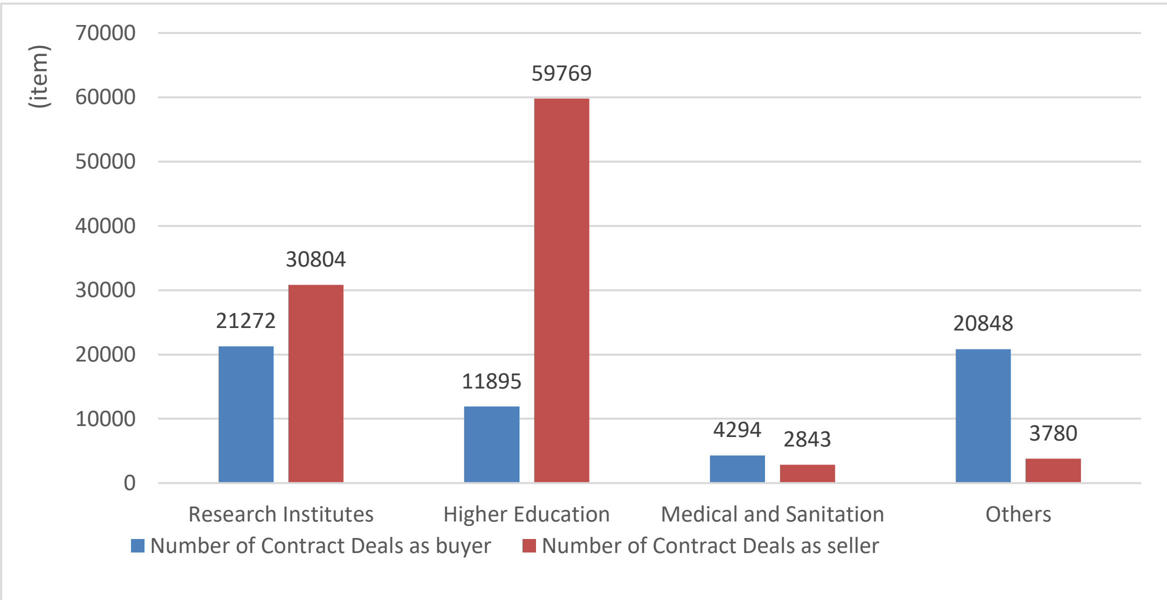


Figure 2. 81 Contracts value by public organizations as buyer and seller (2016)

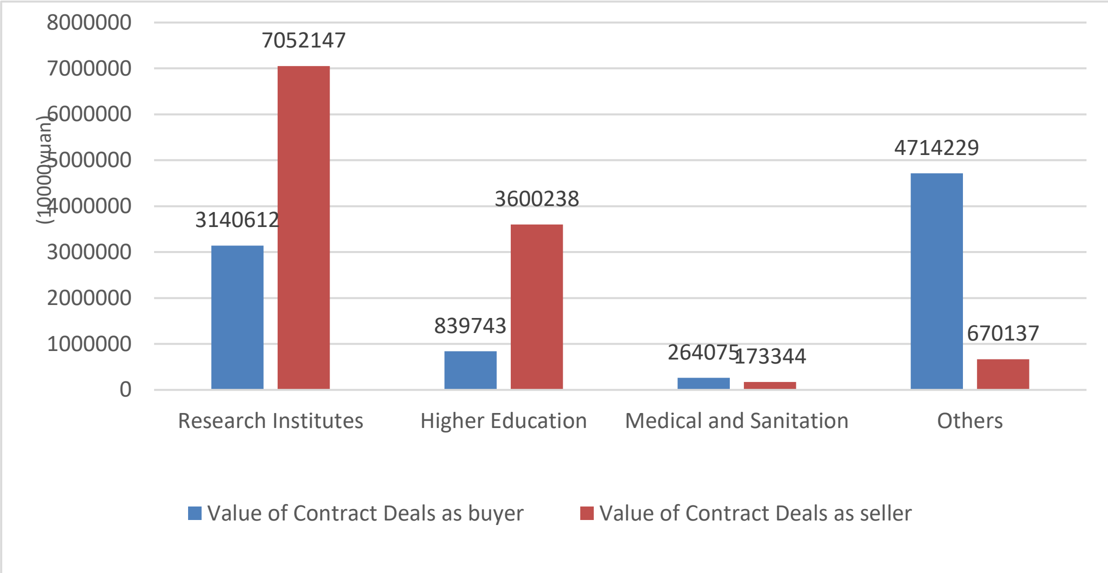


Figure 2. 82 Contracts number by enterprises as buyer and seller (2016)

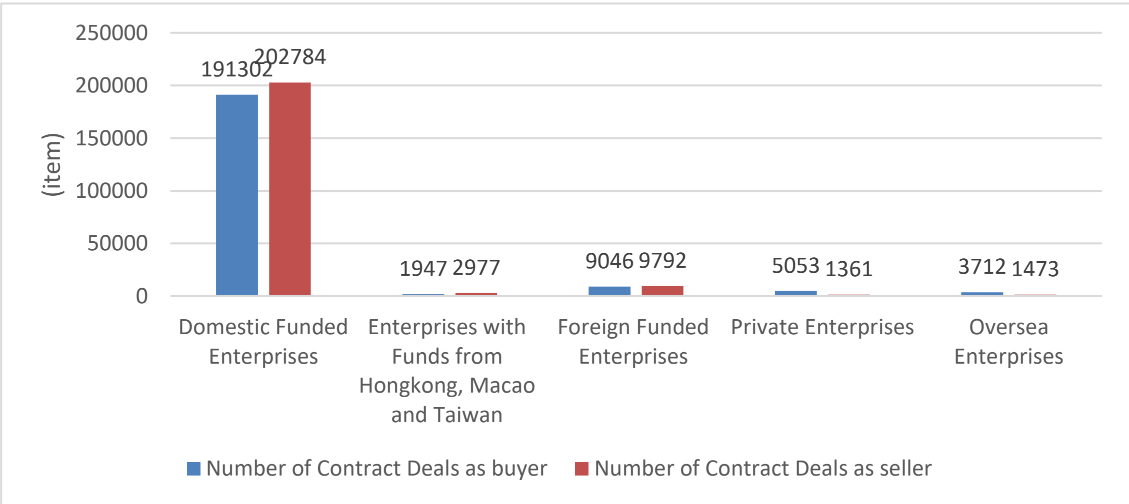
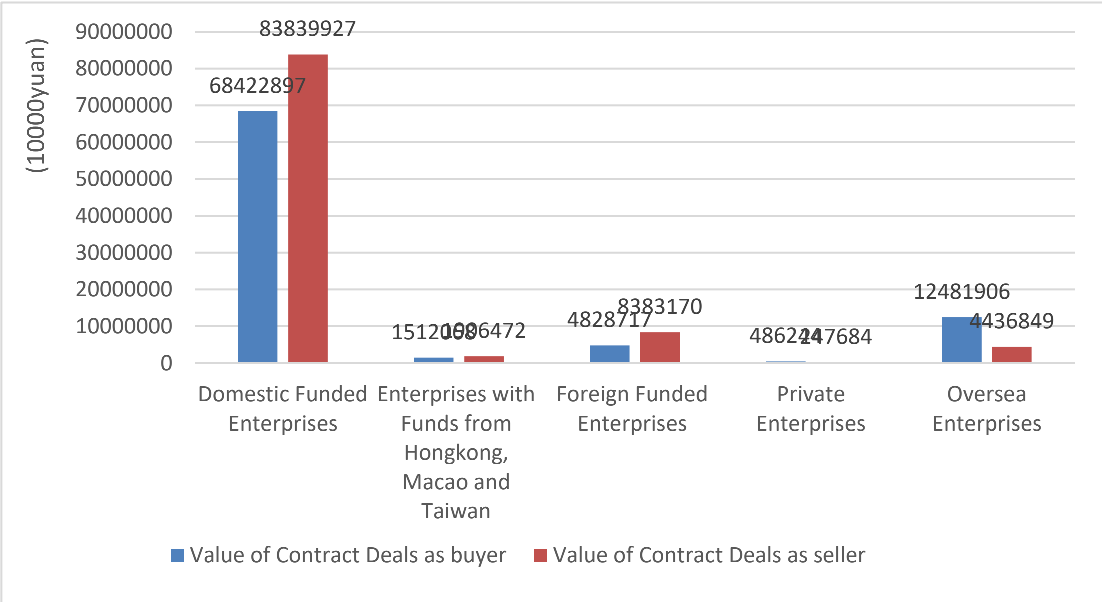
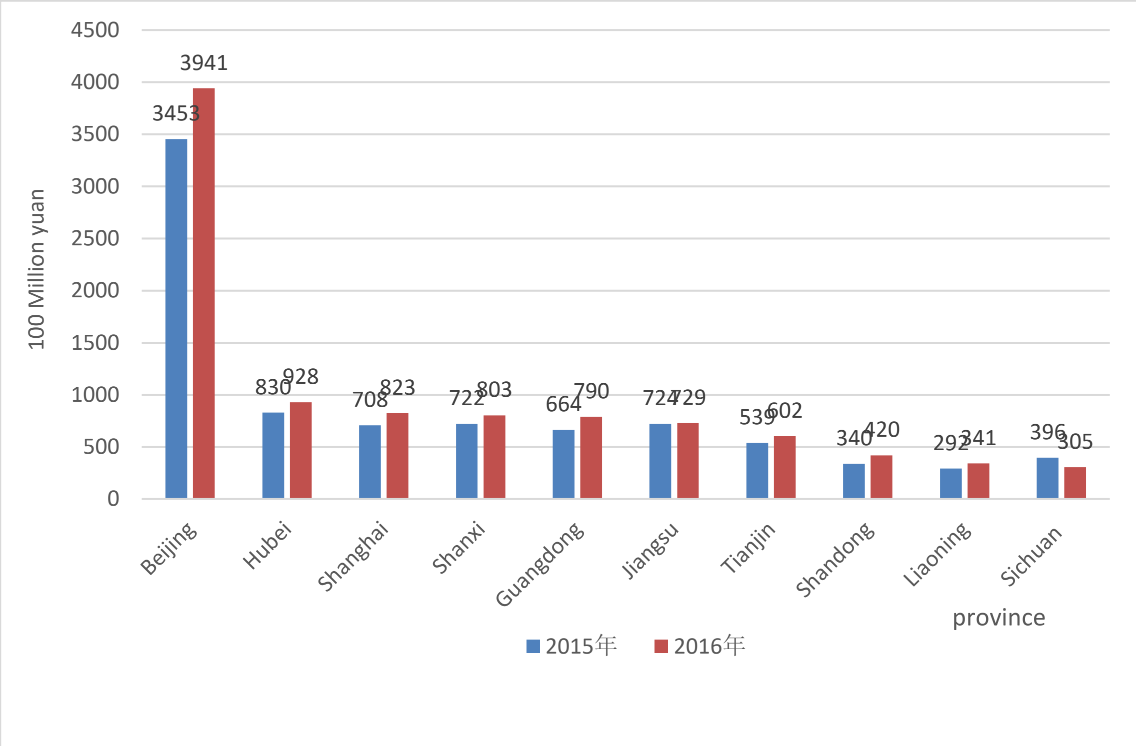


Figure 2. 83 Contracts value by enterprises as buyer and seller (2016)



Although technology market continues to maintain a high-speed growth nationwide, regional imbalance still exists in both contract number and contract value. In 2016, the contract value of most provinces across the country has increased. Following figure (Figure 2. 84) shows the top 10 provinces in the contract values with the ranking changed from 2015 to 2016. In 2016 the top ten provinces account for 77.63% and 84.87% of the total number and total value of transactions, respectively. More specifically, the eastern developed regions possess more active technology markets than the western inland regions, and the four large municipal cities are now the major regions for active technology markets. One important reason is the difference in capacity of knowledge creation from supplier side or in capacity of knowledge absorption from user side, both of which are crucial for the efficient user-producer interaction and the success of innovation (Gu and Lundvall, 2016).

Figure 2. 84 The top 10 provinces in the contract values (2015 & 2016)

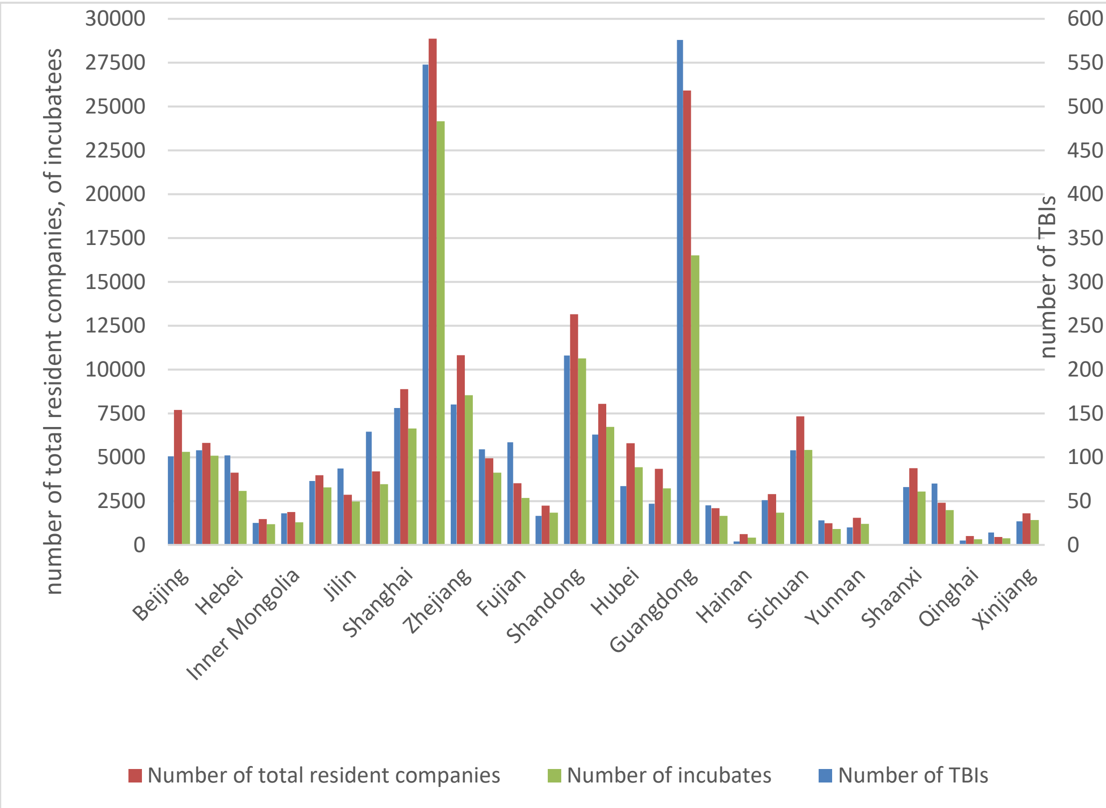


The Technology Business Incubator (TBI, also known as the High-tech Entrepreneurship Service Center) is a technology-entrepreneurial service organization that promotes the transformation of scientific and technological achievements and fosters high-tech enterprises and entrepreneurs. It is an important part of the regional innovation system. It has been 30 years since the first technology business incubator of China, the Wuhan Donghu New Technology Entrepreneur Center was established in June 1987. Until the end of 2017, china has 4,069 TBIs with total space area of 118 million square meters, 170,000 incubating enterprises, and 2.49 million employees. Some basic statistics of TBIs in China in 2015 and 2016 are showed as follows (Figure 2. 85). In terms of ownership TBIs can be classified into state-level TBIs and non-state level ones. In terms of creator there are TBIs created by returned overseas scholars, by college graduates and by High-tech enterprises. Regional heterogeneity still exists in some main indicators of TBIs by region in 2016 (Figure 2. 86) .

Figure 2. 85 Basic Statistics on Technology Business Incubators

Item	2015	2016
Number of TBIs with Data	2533	3255
State-level	733	859
Non State-level	1800	2396
Number of Total Resident Companies	145956	173779
Number of Incubatees	102170	133286
Created by Returned Overseas Scholars	8008	9497
Created by College Graduates	15197	22173
High-tech Enterprises	6527	9024
Total Income of Incuatees (1000 yuan)	481037446	479272823
Valid IPRs Held by Incubatees	155369	223066
Invention Patents	39003	51954

Figure 2. 86 Basic Statistics on TBI by region (2016)



Productivity Promotion Centers (PPCs) established in 1992, work as non-profit technology service intermediary linking government, enterprises, universities and research institutes. SMEs and township enterprises are their main service objects. They organize scientific and technological resources including technology, human resource and technical information, provide consulting services in terms of management and commercialization of technological achievements in order to improve market competition and technological innovation of enterprises. Although PPCs have increased steadily since 1992, the development in recent years has shown a downward trend in the quantities of serviced enterprises (Figure 2. 87). Until 2017, 1925 PPCs have been established. Statistics report for regional distribution of PPCs in 2015 is presented below (Figure 2. 88). Provinces like Tianjin, Jiangxi, Sichuan, Guangdong, Shanxi have the most number of centers, respectively 167, 147, 144, 142, 138. Remote areas have relative few centers such as 1 in Hainan, 3 in Tibet, 4 in Yunnan, and 4 in Qinghai. I find that, the distribution of PPCs is not consistently with that of local economic development. Sichuan is one of the provinces with the most PPCs while its economy lags far behind Jiangsu and Zhejiang. Similarly, Shanghai as the most developed area in China possesses very few PPCs.

Figure 2. 87 PPCs development in China (1998 – 2016)

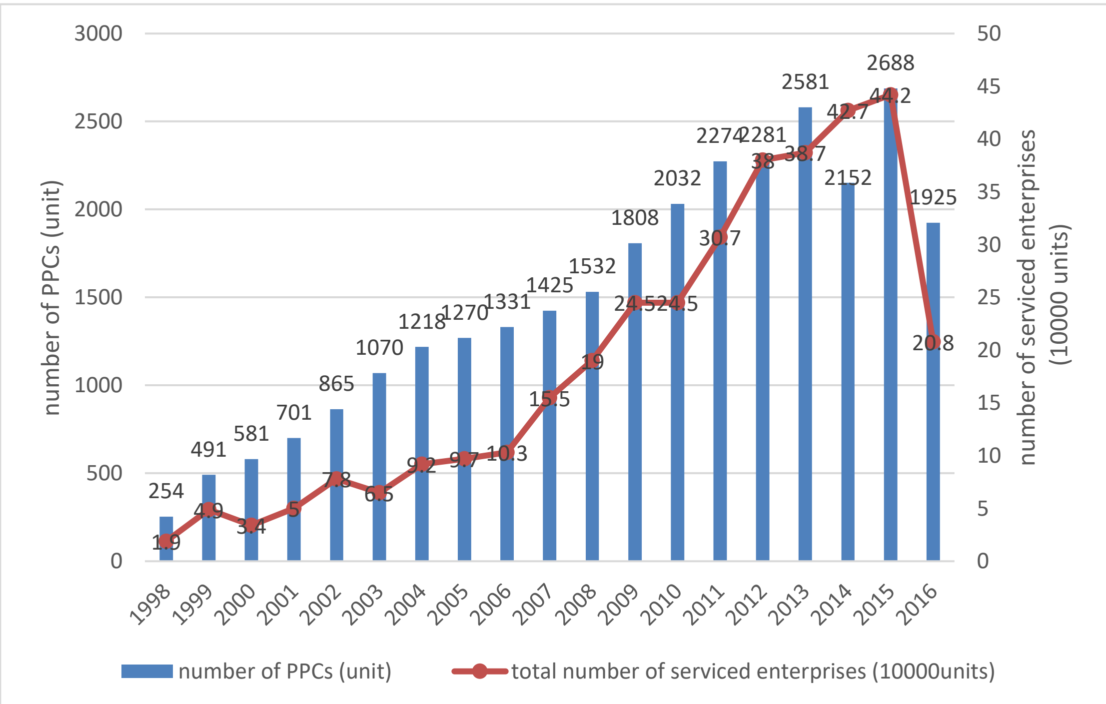
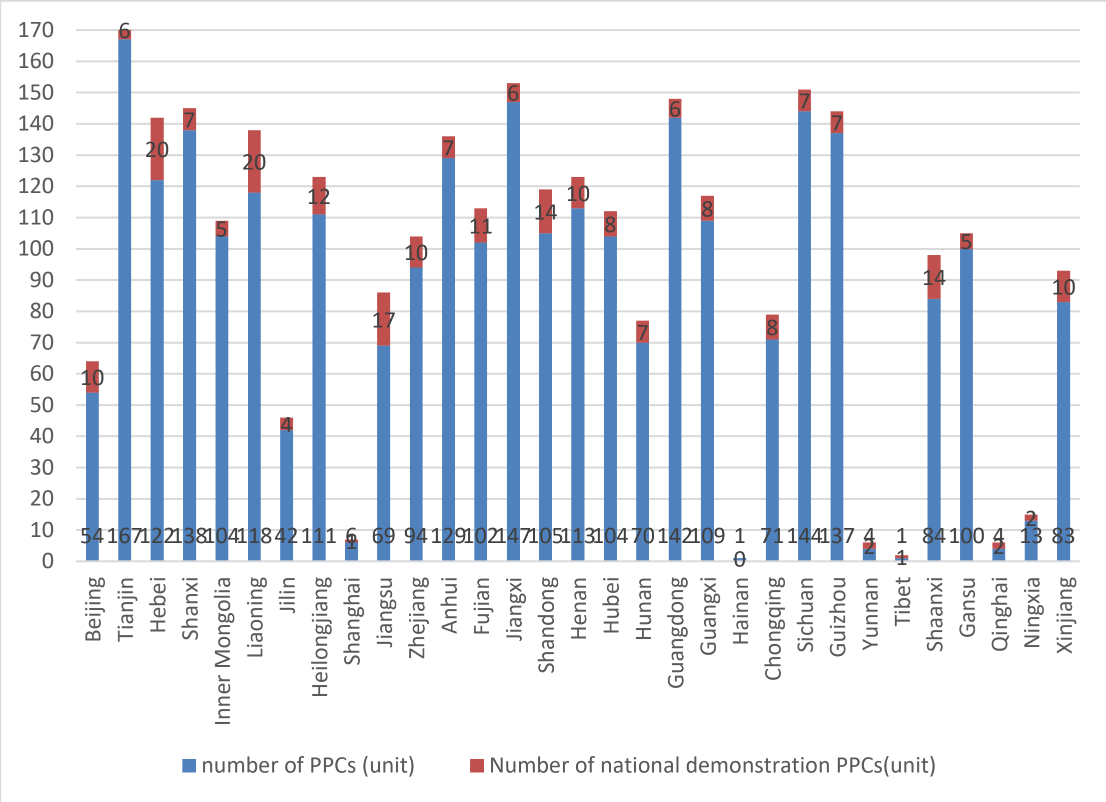
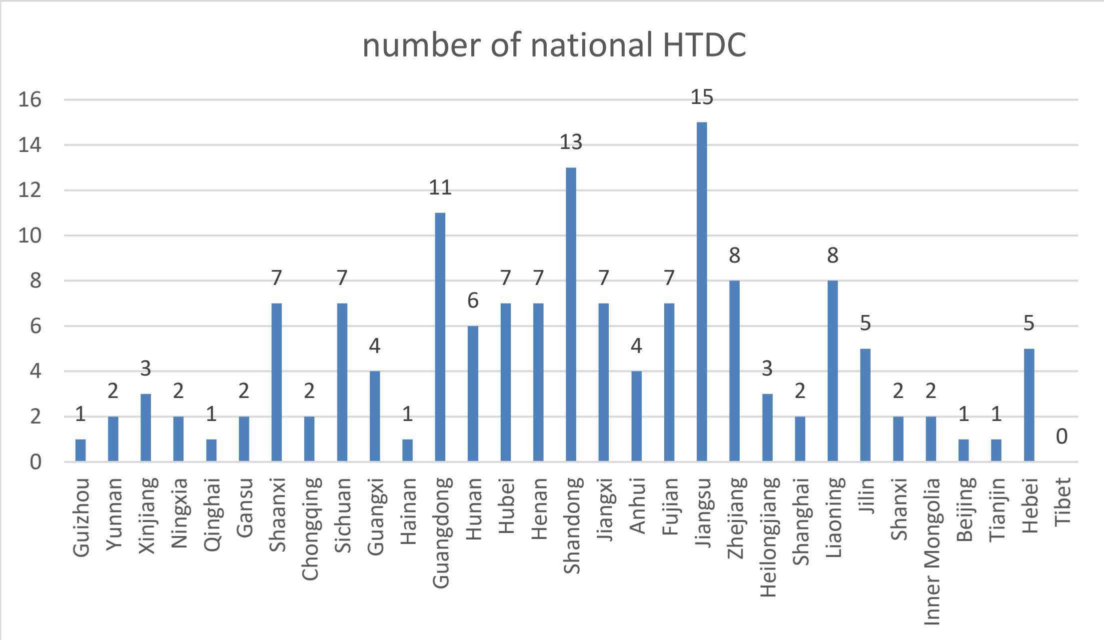


Figure 2. 88 PPCs by region (2015)



High-tech development zone (HTDC) is a science and technology industrial park approved by different levels of government. In August 1988, China National High-tech Industrialization Development Plan, namely Torch Plan was implemented. Under the guidance of the Torch Program, national and local governments have actively established HTDCs based on detailed characteristics and conditions. The National HTDC has become an important force in the development of high-tech industries, and has increased to 157 units nationwide in March 2017. In 2016, the revenue of China's national high-tech zones reached 27.66 trillion yuan and the total industrial output value was 19.68 trillion yuan. The figure below is the regional distribution of national HTDCs in 2016 (Figure 2. 89).

Figure 2. 89 regional distribution of national HTDCs (2016)



In 2001 six national technology transfer centers (NTTCs) were approved to fill up the connection gap because there was no institutional interaction among above mentioned technology markets, TBIs, PPCs and HTDCs despite of their coexistence (Tang & Hussler, 2011). Until 2015, altogether 455 NTTCs were approved nation-wide. NTTCs work as gatekeepers between university, industry, government and intermediaries like technology markets, TBIs, PPCs and HTDCs. The purpose is to explore and improve the effective operation mechanism of the national and local technology transfer system and also is to transform scientific and technological achievements. In 2017, the National Technology Transfer System Construction Plan was issued with the object to fully establish the national technology transfer system by 2025.

Inter-regional and international knowledge flow

Besides the internal relationships inside a regional innovation system, RIS does not function independently from external environment outside the region (Welsch, 2015). A region’s openness influences its innovation performance as well. Regions can have access to sophisticated knowledge through interaction with other regions within a country even with oversea regions. For example, export-led regions in China might gain advanced technological information from international trade. Also, regions locating in coastal China perform better in innovative activity than inland regions partly because they benefit more from their presence in clusters of developed regions and can comparably easily obtain complementary assets from other regions to develop technological advantages (Fu, 2008). Therefore, besides the internal factors mentioned above, local authorities' preference, the degree of regional protectionism, the level of a region's openness and receptiveness to new information, technology and human resource, which are transferred from outside enhance a region's capability in innovation generation.

In addition to the interregional interaction, concept of "internationally networked regional innovation systems" presented by Henning Kroll (2009) emphasizes the interaction with actors or environment outside the region even the nation. There are two circumstances leading to RIS internationally linked. One is when knowledge stock of some regions is insufficient in satisfying some sector's demand despite of the development of R&D reforms. As a result, innovative actors seek to benefit from international knowledge flow. The other one is when the produced knowledge inside of a region is not absorbed by other internal innovation actors or by actors surrounding the region. Similarly, knowledge might be transferred to international locations which have ability to assimilate and absorb it. Both interregional and international knowledge flow require region's absorptive capacity. Literatures have emphasized the importance of "regional absorptive capacity" aiming at building an innovation-friendly framework (Asheim & Vang, 2006).

2.4 Summary & Discussion

Since open-door policy in 1980s, China's national economy has witnessed decades of fast growth. In 2017 china has continued to be the top trading nation and manufacturing economy in the world. Meanwhile, China has made explosive increase in R&D

investment in recent years. According to the Global Innovation Index, in 2017 China has broken into the top 20 most innovative economies for the first time. The key drivers behind this ranking are the high amount of researchers, high level of R&D expenditure, high number of patent applications and S&T publications. However, absolute value of R&D input does not mean necessarily the proportional innovation quality. Literatures have pointed out that China's innovation performance is less impressive with the focus on second-generation innovation (Boeing, 2011; Breznitz & Murphree, 2011). A close observation indicates that, Chinese firms file a huge number of patents while these patents may not transform into new products or processes (Shu et al., 2015). Although china is the top nation of high-tech exports, the exports concentrate largely on very seldom sectors and the exported products are generally located in the low position of global value chain. Moreover, a within-nation comparison presents that strong regional innovation imbalances persevere which hampers economic and human development. A study from Fraunhofer institute (Kroll, 2009) points out that the Chinese innovation system is characterized with a technological and organizational mismatch between its main players. These paradoxes of innovation situation in China has forced the policymakers to pay more attention on the indigenous innovation and the sustainable development of all regions in China. From this point of view, RIS is more appropriate than NIS for the analysis of the China economy to map characteristics and heterogeneities in the regional political and institutional environment and thus help generate independent and endogenous innovation in China.

This chapter reviews firstly the historical development of governmental S&T policies. Although provinces in China have certain autonomy in forming regional economic policy and regulations, the spirit of the policies and regulations are still follow the guidance of central government. The paper also takes a close look at innovation situation in China and points out several major challenges for future development. China's innovative map is characterized with remarkable regional imbalance which underlines a regional institutional environment rather than production networks or others (Lin, et al., 2011). Therefore, RIS-perspective should be more supportive for analysis here than NIS-perspective. Basing on previous related studies, I develop an explanatory framework of RIS with three major components including innovation-related actors, institutional environment, and relations among actors and institutions. The RIS analysis measures innovative-related behavior of key actors, the formal and informal institutional environment and inter-organizational relations on aggregated national-level as well as on disaggregated regional level.

Nevertheless, RIS perspective has its limitations when applying to a large and transition economy such as China. One can argue that the enormous regional disparity in innovativeness and growth is inevitable in a large economy experiencing transition. The disparity may lie in the geographical location rather than the institutional characteristics of a region. That is to say, the role of RIS framework might have been overestimated.

Whatever, China is now in a stage of innovative capacity building and with a good prospect to challenge global innovative leaders.

Chapter 3

Does geography really work in firm innovation? --- a multilevel methodological approach

3.1 Introduction

A surge of theoretical disciplines have been applied to discuss the determinants of firm's innovation, including management theory, new economic geography and regional science etc. Traditional studies such as resource based view emphasize the effect from individual firm attributes including R&D investment and human capital input. Recent studies on innovation have shifted focus on firm's geographical proximity to knowledge externalities. The arguments are based on agglomeration economies and knowledge spillover literatures (Feldman, 1999). Innovation is generally considered as output of knowledge production function (Griliches, 1979). Agglomeration forces contribute to knowledge stock in a region and firms locating to each other benefit access to effective knowledge transmission and sharing.

Although considerable number of empirical studies in the field of new economic geography has testified the important role of local or regional environment[11] in production and innovative activities (e.g. Krugman, 1991a), some scholars question that the role has been overestimated (e.g. Boschma, 2005; Koo & Lall, 2007; Weterings & Boschma, 2009). Sternberg and Arndt (2001) conclude that "regional environment is

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[11] Region and geography are used interchangeably throughout this chapter.

not an independent determinant of firm innovation activity but is influenced by the characteristics of local firms" (Sternberg & Arndt, 2001: 379). Boschma (2005: 62) claims that "geographical proximity per se is neither a necessary nor a sufficient condition" for interactive learning and thus innovation. An overview shows that recent theoretical and empirical studies suffer several problems.

The first criticism is about implied assumption of homogenous firms (Baldwin & Okubo, 2006; McCann & Folta, 2011). Knowledge spillover from agglomeration economy is assumed to spread symmetrically across all firms in one region or cluster (Baldwin & Okubo, 2006). However, studies in organization and strategic management find that firm's attributes or capabilities influence its ability to benefit from knowledge externalities (McCann & Folta, 2011). As Van Oort et al. (2012) point out, the effect of agglomeration economies generally differ due to firm-level heterogeneities.

Secondly, Koo and Lall (2007) illustrate that model in estimating the contribution of economic geography to firm performance might have introduced a bias due to firm's endogenous location-decision process. When self-selected firm-location choice is controlled, the effects of geographical variables on productivity and innovation are likely less than once expected in previous literatures. It calls again the premise of new economic geography in question. The problem is also raised as endogenous spatial selection process by Baldwin and Okubo (2006).

Thirdly, confronted with the development of information and communication technologies (ICT), Torre (2008) questions the fundamental assumption residing in agglomeration economies that an effective transfer of (tacit) knowledge requires short-distance interaction such as face to face contacts. However, long-distance information or knowledge exchange might work in a particular life cycle stage of a product or industry. Basing on network theory, Lorentzen (2008) criticizes regional determinism and argues that global network has become a particularly beneficial knowledge sources for firm's innovation. Virtual proximity might have begun to substitute geographical proximity in some sectors.

In addition, lots of studies deploy extensively two knowledge spillover mechanisms (localization and urbanization) to explain agglomeration effect on firm's innovation.

However, very few of them observe the detailed patterns of knowledge diffusion, that is, the way how knowledge flows. Johansson & Lööf (2008) raises some examples of knowledge-flow channels and points out that even locating in the same region, firms with different knowledge transmission or acquisition patterns behaviors distinctively in innovative activities.

Besides above mentioned theoretical conceptualization problems, recent innovation studies have been criticized on methodological ambiguity. Some studies have included firm-specific heterogeneity to disentangle regional effect, such as Sternberg & Arndt (2001), Beugelsdijk (2007), Knoben (2009) and Pradhan (2011). However, they deal with data from both firm- and region-level as one single level and neglect the hierarchical structure resulting from different data source. Fortunately, very few researchers have realized methodological problem referred to as "ecological fallacy" (Robinson, 1950) or "cross-level fallacy" (Alker, 1969). They advocate for multilevel method in innovation research. Srholec (2010) demonstrates the benefits of using multilevel modeling and finds the regional effect varies when including firm-level micro-data. Analysis from Goncalves et al. (2011) uses both logit regression model and hierarchical regression model. The result shows that firm-level variables have more impact on innovation than region-level ones. Also, Van Oort et al. (2012) point out that the inconclusive or even conflict empirical results in innovation research are caused by "apparent impasse in the measurement and interpretation of agglomeration externalities" (Van Oort et al., 2012: 470) and the usage of multilevel approach can clarify the agglomeration-performance ambiguity in spatial economies.

Referring to above potential drawbacks in current innovation researches, have reasons for doubt: does geography really matter in firm's innovation? Whether the role of firm's geographical location has been overestimated? For a very long time, the importance of firm itself and that of the geography in innovation production have been studied separately (Mariani, 2004). Literatures in management science have proved that firm's innovative activity is influenced by its capability to generate knowledge and to profit from knowledge externalities (Kogut and Zander, 1992; Teece et al. 1997). Influence from firm-level attributes has been argued to be very important for firm's innovation. As Raspe and Van Oort (2008) suggest, it is necessary for innovation studies to take both firm- and geography-level determinants simultaneously into account.

However, very little work has been done to include both of them in a more comprehensive framework (Mariani, 2004). In addition, industry effect might also works in firm's innovation. As early as in 1979, Griliches (1979) models within-industry spillover effect on firms' productivity. One very famous work about the industry effect is from Pavitt (1984). Pavitt (1984) explains the difference in sectoral patterns on innovation. Many scholars have accepted his position in innovation studies afterwards. For example, Oerlemans and Meeus (2005) examine how industry[12] factors influence firm's innovative outcome. Study from Van Oort et al. (2012: 469) realizes that the effects of agglomeration economies "generally differ across sectors, space and time".

Therefore, to gain a precise insight of the real influence from geography on firm's innovation, we need to include all potential factors into account. This essay classifies these factors into three categories: firm, sector and region. We assume that same industry sector in different regions might works differently. That is, sector "textile" in one region might be different from sector "textile" in another region. In this essay, sector means the sector of one specific region (henceforth sector). In addition, to address methodological problem mentioned above, this essay uses multilevel analysis. The benefit is to disentangle effects from firm, sector and region.

This analysis is based on a sample of Chinese manufacturing firms. Indeed, there are very few studies on firm's innovation in emerging economy. One of the few examples is from Goncalves et al. (2011). Their research investigates the role of firm and region in individual firm's innovative activities in Brazilian economy. The results reveal that firm-level factors have more impact on firm's propensity to innovate than region-level ones. Another example is from Pradhan (2011) who analyzes the unequal roles of different regional factors on Indian firm-level R&D activities. Because "most studies have made use of data from the United states or from the European region" (Mukim, 2012: 359), it is meaningful to test whether existing theoretical propositions and empirical results still effective in developing areas, especially in China. Moreover, previous studies about Chinese economy generally focus on regional or national innovation system (see Li, 2009). And most of them conceptualize knowledge spillover

[12] Industry and sector are used interchangeably throughout this chapter.

effect by using state or metropolitan area as geographic unit. Krugman (1991b: 43) has pointed out that “states aren’t really the right geographical units”. Similarly, Glaeser et al. (2000) suggest that cities are normally the centers of idea creation and transmission. This essay therefore uses cities as the level of aggregation to account effects from geographical and sectoral aspect. We expect to get more accurate results through a relatively narrow geographical range. As stated above, this essay tries to account for effect from three levels (firm, industry and city). To serve this purpose, we combine two longitudinal dataset. One is China City Statistical Yearbook (CCSY) and the other is China Annual Survey of Industrial Firms (CASIF survey).

As a whole, after taking all three aspects into account, this essay tries to answer the question whether the role of region is more important than that of the others. In other words, this essay explains how much of the innovation is interpreted by attributes from firm, from sector and from region respectively.

This essay is structured as follows. In Section 2 we review the main theoretical and empirical arguments relating to the firm’s innovation. We describe these arguments from three aspects: relationship between firm and innovation, relationship between sector and innovation and relationship between region and innovation. Basing on the theoretical backgrounds in Section 2, we then attempt to model the effect from three levels in a comprehensive multilevel framework in Section 3. After that, the empirical findings from different models are presented and discussed (Section 4). The last section is a summary and discussion (Section 5).

3.2 knowledge and Firm Innovation

It is generally acknowledged that innovation is the outcome of knowledge production function. Despite of diversified research focuses, most empirical studies modify knowledge production function originally from Griliches (1979). As early as in 1979, Griliches (1979) develops the Model of the Firm Knowledge Production Function where human capital and R&D investment (some indicators of the knowledge stock) as internal knowledge input generates innovative output. Meanwhile, Griliches considers the spillover effect of R&D outside of the firm or industry in question. In 1986, Jaffe (1986) develops equations relating firm's innovation to firm's R&D and particularly to the spillover effect from R&D of other firms within industry. It is the first attempt to "use such a knowledge production function framework at the regional level" (Mukim, 2012: 359). In 1989, Jaffe (1989) modifies the knowledge production function framework articulated by Griliches (1979) and discusses the geographically spillover effect from university on corporate patents and on local innovation. After that, the knowledge production function approach has extensively used in empirical research. This essay adopts the view that firm's innovation is the output of a knowledge production function and the knowledge is from three sources, namely firm, sector and region.

3.2.1 Firm Heterogeneity and Innovation

Traditional view about knowledge and innovation focuses on resources inside the firm. Resource based view (RBV) treats firm's internal R&D investment as one of most important innovation sources (Barney, 1991). R&D is also considered to have dual roles: to generate new knowledge inside the firm on one hand and to enhance firm's absorptive capacity on the other hand (Cohen & Levinthal, 1989). As Schumpeter argues, "innovations are new combinations of existing knowledge and incremental learning" Kogut and Zander (1992: 392). In RBV, knowledge is firm's important source of competitive advantage. It is through knowledge that a firm is able to innovate new products and new processes. Knowledge-based view (KBV) is "an outgrowth of the resource-based view" (Grant, 1996: 110). It stresses that knowledge is "the most strategically important of the firm's resources" (Grant, 1996: 110). In 1992, Kogut and Zander (1992) develop a more dynamic view of how firms create new knowledge. They introduce a concept of combinative capabilities which believes that innovations "are products of a firm's combinative capabilities to generate new applications from existing knowledge" (Kogut & Zander, 1992: 391). Similarly, the "competence-based" approach emphasizes the importance of path-dependent, group-based, firm-level, and largely tacit and socially produced and reproduced knowledge—that is, competencies—for understanding fundamental issues such as the causes of inter-firm diversity" (Foss, 1998: 480; Nelson, 1994). The concept of "dynamic capabilities" defined by Teece et al. (1997) is complementary to RBV. Dynamic capabilities are the firm's ability to integrate, build, and reconfigure internal and external competences to respond to rapidly changing environments and thus to create new products and processes. Scholars argue that dynamic capabilities are locked-in to firm and cannot easily be transferred to outside the firm.

In short, all of these theoretical arguments underline firm's intangible capabilities (in terms of absorptive capacity, combinative capabilities, competence, or dynamic capabilities) to absorb, recombine, and produce knowledge. Furthermore, these capabilities are largely depend on the material and immaterial resource inside a firm. Basing on these capabilities, firms are capable of seeking opportunities from outside environment and benefiting from knowledge spillover from region. Especially for firm locating in an information-intensive context, the absorptive capacity it owns can help to distinguish information, to assimilate knowledge and to apply knowledge for innovative purpose. Therefore, we postulate that differences in firms' resource endowments cause differences in their innovative performance. These resources represent firm's internal knowledge capacity. Previous researchers have found that firm's age, size, market share, R&D input, export experience, past experience in innovation and ownership diversity etc. combines firm's internal knowledge capacity.

On empirical grounds, some scholars have examined effect from micro-level factors (firm-level) on firm's innovative output in comparison with that from macro-level such as regions or clusters. Sternberg and Arndt (2001) examine the absolute and relative impact of firm-specific and region-specific factors on innovation behavior of European small- and medium-sized firms. The most striking finding is that the firms-specific determinants are more important on innovation than either region-specific one. It is contrary to general results from many regional or national innovation literatures and therefore provides subsequent researchers a new insight. Another relatively well-known empirical study concerning the debate on the role of the firm versus that of the region is from Beugelsdijk (2007). The author finds that firm-specific drivers of innovation are more important. This result encourages the necessity of studying joint effect from both firm- and region-level factors. Even in the same industry, intra-industry firm heterogeneity has been incorporated into theories explaining innovative productivity differences among firms (Pradhan, 2011). For example, basing on knowledge-based view McCann and Folta (2011) test hypotheses on a sample of biotechnology firms.

Empirical result shows that firms benefit asymmetrically from agglomeration economies. More specifically, younger firms and firms with higher knowledge stocks benefit more from agglomeration.

3.2.2 Sector and Innovation

Griliches (1979) has pointed out that firm's productivity (including innovative productivity) depends not only on own R&D research but also on the level of the related industry's knowledge pool. In addition, he argues that the pool of industry's knowledge differs for different areas and also different times. This argument provides support for our assumption that even same industry might be different due to their location in different regions. Actually, the influence from industry on firm's innovation performance has become a classic issue in the economics of innovation for a long time. Schumpeter (1942) asserts that, compared to competitive market monopoly provides the most supportive market environment for firm's innovation and technological progress. That is, relatively concentrated industries are hypothesized to encourage firm's innovation because of large economies of scale. Although empirical results about which market structure is more effective in innovation are mixed, there is no doubt that industry structure (in terms of market structure, market concentration degree) has effect on firm's innovation. Pavitt (1984) in his most influential work identifies sectoral taxonomy of technological change and explains how sectoral or industrial differences relate to innovation. Indeed, a lot of empirical studies from various theoretical perspectives have found some specific aspects of industries as sources of firm's innovation (Malerba, 2002). For example, studies in the field of evolutionary theory emphasize the sectoral differences in firm's technological and knowledge environment while studies in innovation and technological system focus the sectoral differences in interaction among firms or between firms and institutions. Even in the same geographical circumstances some industries benefit more than others (De Bok & Van Oort, 2011). The reason is that some industries are able to provide firms with rich knowledge capacity and sectoral technological opportunities while others are not.

In general, industries are heterogeneous in two ways. One is the sectoral knowledge stock or capacity including sectoral R&D intensity, sectoral industry concentration, external competition from foreign investment etc. The other is the knowledge spillover mechanism including competition knowledge spillover and technological knowledge spillover.

Recent empirical studies have verified the influence from industry heterogeneities on firm's knowledge creation and innovative activity. Mariani (2004) compares drivers of innovation in traditional chemical industry with that in modern biotechnology industry. Her conclusion is that different industries lead to "different innovation models in sectors with different characteristics or in different stages of the industry life cycle" Mariani (2004: 1567). It is consistent with the key assumption in the study from Audretsch and Feldman (1996: 639): knowledge externalities beneficial for innovative activity "are more prevalent in industries where new economic knowledge plays a greater role". Study from Oerlemans and Meeus (2005) shows that, besides firm-specific resource, network activity and proximity, industry factors namely the sectoral R&D spillover influence positively firm's innovative and economic outcomes. Also, McCann and Folta (2011) category firms into several subsectors of biotechnology and find these firms benefit asymmetrically from the knowledge-stock in a same region. Very few scholars have studied this phenomenon in emerging economy. For example, a study about Indian economy by Mukim (2012) shows that industrial diversity in terms of Herfindahl Index has an important effect on innovation.

3.2.3 Geography and Innovation

Now we turn to the focus of this essay: the geography, whose effect as stated above needs to be reconsidered. Arguments supportive of geography are normally based on two theories: agglomeration economies and knowledge spillover theory. Agglomeration contributes to region's knowledge stock and knowledge infrastructure. Because the cost of transmitting knowledge, especially tacit knowledge, rises with distance, knowledge flow is limited in a geographical boundary (Audretsch & Feldman, 1996). As a result, only firms near to the "source" of knowledge or innovation can receive knowledge externalities. In such a way, local economy is able to provide comparative advantage to firms in appropriate distance. Many territorial innovation models like innovative milieu, industrial districts, clusters and regional innovation system originate from the logic explained above.

Generally, scholars in region studies apply two knowledge spillover concepts in explaining agglomeration effect. The Marshall-Arrow-Romer (MAR) model emphasizes that the concentration of one industry in a region promotes knowledge spillovers between firms and facilitates innovation in that particular industry within that region. Contrarily, Jacobs (1969) model argues that variety of industries promotes knowledge spillover and innovative activity. Their difference is whether proximity of firms in common industry or from different industries promotes knowledge spillover. However, both of them focus on the knowledge flow between economic actors (e.g. firms). "It is not sufficient to just consider how MAR-and Jacobian spillovers impact on firms within a region" (Harris, 2011: 932). From evolutionary theoretical perspective, there are other generators of knowledge externalities: institutional actors such as education institutions, government departments, chambers of commerce, technological actors such as technology transfer agencies and social subsystems (Cooke, 1997: 362). Therefore, knowledge spillover is not merely between firms, but also through social connects (Harris, 2011). For example, study from Varga (2000) shows that academic institution proximate to knowledge-intensive industry can be a source of positive knowledge externalities. In the light of the source of knowledge externalities, we can define it as "local university knowledge spillover" or "academic knowledge spillover". Similarly, both localization and urbanization externalities can be generalized as "location-specific knowledge spillover" because both of them are confined in a specific geographical unit. Factors constituting local knowledge infrastructure can be investment in R&D by regional private corporations and universities (Audretsch & Feldman, 1996), gross regional product (GRP), regional market size and education level etc. (Raspe & Van Oort, 2008). Foreign direct investment (FDI) complements to local knowledge stock because it provides local firms opportunity to link to global market and to benefit from there (Harris, 2011).

Another important issue about geography and innovation lies in the right level of spatial scale. Because knowledge spillover decays with increased distance, it is essential to quantify a scale of agglomeration where spatial knowledge environment is enough to cause knowledge to spillover to others. That is, a relatively accurate geographical scale needs to be fixed for the observed region to achieve a critical mass of agglomeration (Varga, 2000). Empirical researchers argue for as small as geographical unit of analysis as possible (Fritsch& Franke, 2004; Raspe & Van Oort, 2008; Mukim, 2012). In consideration with region’s population density, position in national spatial hierarchy and degree of congestion (Fritsch& Franke, 2004), this essay uses a very low spatial scale – the level of cities – as a geographical context to understand its effect on firm’s innovation. It advances most empirical studies where state is used as spatial scale due to data limitation. It is consistent with the study from Raspe and Van Oort (2008) which defines the spatial knowledge environment of firms on a level of Dutch municipalities.

3.3 Explanatory Framework: Multilevel Methodological Approach

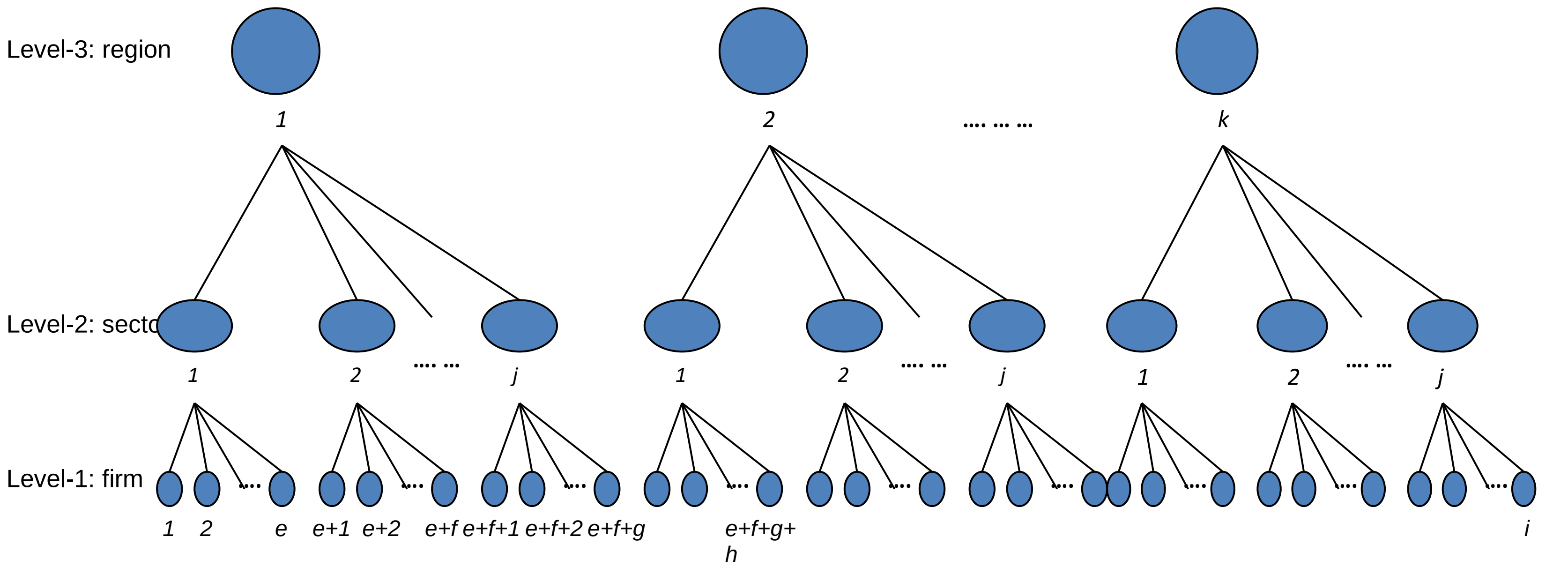
3.3.1 Construct of A Multilevel Model

By combining individual firm-level data with aggregate group- (industry- or region-) level data, innovation has become a multilevel phenomenon. If single-level model is applied to handle nested-structure data, either of following problems occurs. One is “ecological fallacy” where “relationships between characteristics of individuals are wrongly inferred from data about groups” (Robinson, 1950; Selvin, 1958: 613). The other one is “atomistic fallacy” where aggregates results are made only from individual level data. Researchers in social science have recognized this issue and advocated the use of multilevel or hierarchical models. Despite of data’s multilevel nature, a substantial body of studies on innovation assumes independence between firm-level data and region-level data and then uses single level models to test hypotheses. Sternberg and Arndt (2001) have realized firm’s innovation behavior might be influenced by both firm-level and region-level factors. However, they treat both individual and aggregate data in one level and apply normal logit regression in analysis. Similarly, although Beugelsdijk (2007) argues theoretically the potential ecological fallacy problem when blurring macro-level data with micro-level one, he doesn’t resolve this problem methodologically. Fortunately, Hitt et al. (2007: 1385) assert that “most management problems involve multilevel phenomena, yet most management research uses a single level of analysis”. They recommend to apply multilevel designs and to consider bottom-up effects in addressing real-world problems. Van Oort et al.

(2012) think, micro-macro ambiguity leads to the inconclusive results about the exact effect of agglomeration circumstance on firm productivity. As a result, they adopt multilevel approach in their empirical study. Very few innovation studies adopt multilevel or hierarchical models. One example is from Goncalves et al. (2011) who use logit and hierarchical regression models to estimate the role of territory and individual firm in innovation.

Following the theoretical and methodological arguments presented earlier, this essay constructs a multilevel explanatory framework to illustrate how various factors from different level influence firm's innovation (Figure 3. 1). Firm as an individual lies undoubtedly at bottom of the explanatory framework (Level-1). All variables specific to firms are in Level-1. Different from previous studies (Srholec, 2010; Goncalves et al., 2011; Van Oort et al, 2012), this essay adds one level more, namely sector level (Level-2). As explained above, within-industry heterogeneity might exist in terms of spatial distribution (Knoben, 2009). This kind of heterogeneity resulting from locating in different regions probably contributes to firm's difference in innovation to some extent. Therefore, we conceptualize sector-level between firm- and region-level. That is, individual firms combine several industry sectors of one region. As a result, there exists progressive hierarchy from firm to sector in one region and finally to the region. When data hierarchy is properly recognized, it allows us to decompose variance components to each level and to assess following problems. 1) which firm-specific, sector-specific and region-specific variables are related to the firm-level innovative outcome. 2) What proportion of variation in innovative performance occurs between firms, between industries and between regions respectively? 3) How much of firm-level, industry-level and region-level variation is explained when more explanatory variables are included in the model step by step?

Figure 3. 1 Multi-level Constructs

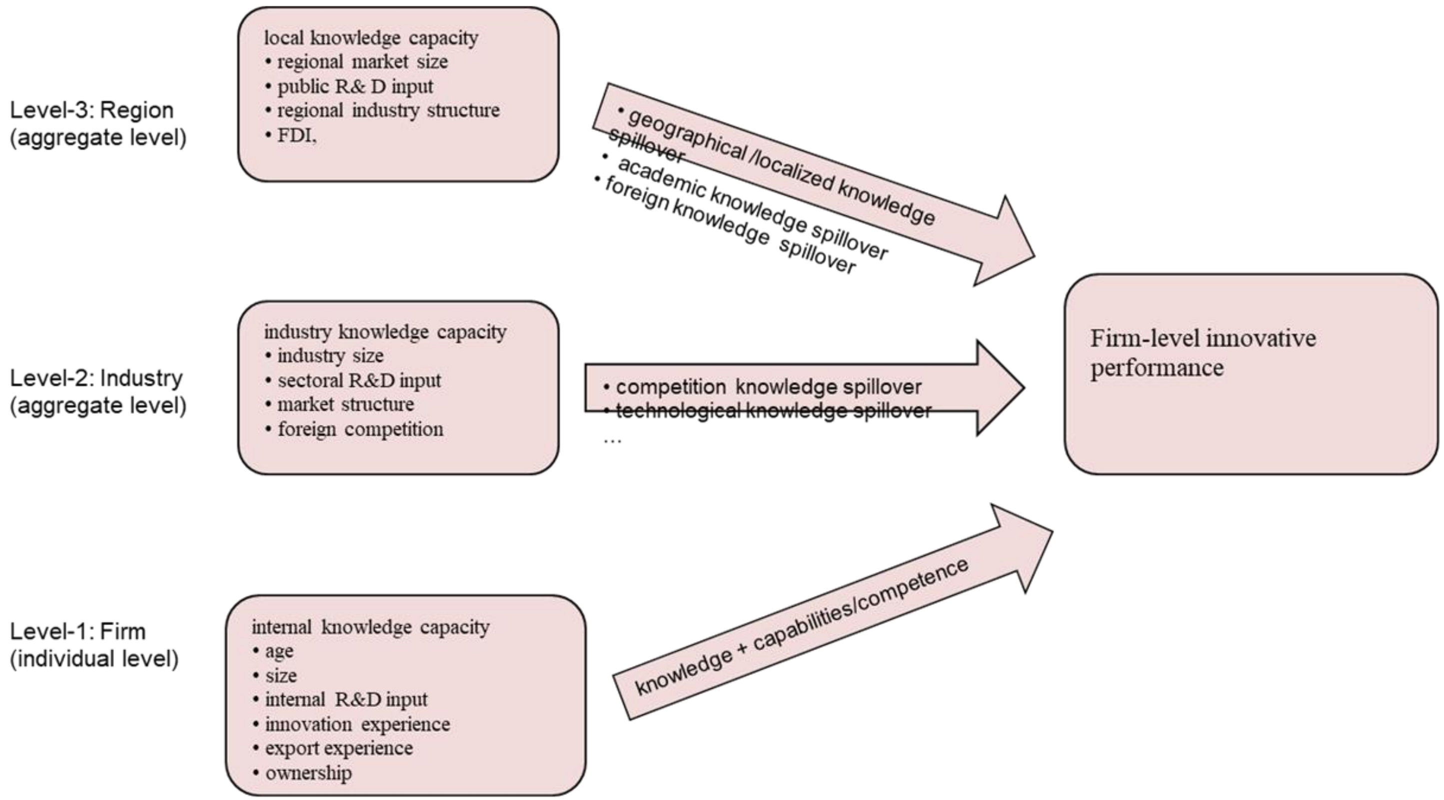


3.3.2 Explanatory Framework

Basing on the consideration that innovation is the output of production process where knowledge is an input, an explanatory framework is constructed where knowledge originated from three levels flows to firm through different spillover mechanisms (Figure 3. 2).

Individual firms are at Level-1. Firms are heterogeneous in their internal characteristics and thus possess unequal internal knowledge capacity. We summarize six firm-specific variables to account for the firm-level effect. Age and size are the most frequently used firm attributes. According to industrial organization and organizational ecology literatures, age represents the amount of firm's experience in learning and size indicates firm's scale advantage. Therefore, older and larger firms are likely to possess excessive amount of resource base, wider access to information and greater opportunity to innovation. However, other literatures, especially entrepreneurship theory of innovation argues that organizational routines developed with firm's age constraint firm's flexibility in absorbing and generating knowledge in dynamic market conditions. As a result, younger and smaller firms are able to recognize opportunities faster and respond to external change quicker. The transfer of knowledge spillover is regarded to be more efficient in younger firms than in older ones. Results of empirical tests are not consistent as well. Even in one research study, the effect of firm's size or age changes depending on the indicators of innovation. For example, Knoben (2009) finds that firm's size is significantly positively related to innovativeness in terms of products new to the firm or to the market while it has no relationship with innovativeness in terms of improved products. However, no significant relationship between age and firm's innovativeness is found no matter which indicator is chosen. In addition, R&D input is generally accepted as key driver of innovation. Some literatures think that firm's or nation's R&D investment represents its innovative capacity and explains its economic heterogeneity or disparities. There is also no consensus in the role of R&D expenditure. For example, study from Crescenzi et al. (2012) finds that R&D spending in China has no significant relationship to local innovation in terms of local patenting activities. In this essay, we postulate that firm's past experience in innovation might be able to explain firm-level innovativeness in some degree.

Figure 3. 2 Explanatory Framework



Teece (1996)'s dynamic capabilities concept views technological development as path dependent. That is to say, related knowledge in previous innovative activity endows firm with ability in recognizing useful knowledge (Harris, 2011). Similarly, competence view of the firm stresses the importance of path-dependent knowledge for firm's seeking and grasping opportunities within uncertain contexts (Foss, 1998; Raspe & Van Oort, 2008). Furthermore, international business literature has found evidence that exporting is a channel for knowledge spillover and that firms engage in international trade benefit from "learning by exporting" (Liu & Buck, 2007; Salomon & Jin, 2008). On one hand, firms with customer or supplier linkage in foreign market can obtain technological assistance from its partners and thus have more chance to become innovative. On the other hand, firms especially those from developing countries faces more competition when exposing to foreign market and then have more motivation and pressure to increase innovative productivity. A number of studies have provided evidence about the knowledge spillover from exporting. Additionally, one distinctive feature of Chinese economy is ownership diversity. There are state-owned enterprises, collectively-owned enterprises, Hong Kong, Macau and Taiwan owned (HMT) enterprises, family- or insider-owned and foreign-owned firms. Theoretically, firms with foreign ownership have more access to technological resources and other tangible resources. However, the branch-plant effect undermines the advantages (Love et al., 2009). Also, state-owned firms have political ties which might bring them institutional benefits while other firms have not. Empirical evidence in Chinese economy is very limited. Most of them appear to suggest a superior advantage of non-state ownership than state ownership. Choi et al. (2011) find that Chinese firm's innovation performance is most strongly influenced by foreign ownership compared with other ownership types. Study from Li et al. (2014) shows that both state-owned and foreign enterprises advance regional innovation performance in Chinese provinces. However, foreign enterprises achieve higher-quality innovation.

We use four variables to capture the inter-industry difference. Industry size has been recognized as an important influential factor of innovation since Schumpeter. On one hand, greater market size implies greater profitability and thus induces more new entry. Increased market competition encourages firms to innovate especially in high-tech industries. Acemoglu & Linn (2004) develops a model linking innovation to potential market size and finds a positive effect of market size on entry of new drugs in U.S.

pharmaceutical industry. On the other hand, greater market size indicates immense industry networks and business associations which promote firms' interaction and cooperation for innovative purpose. Similarly to firm-level R&D input, sector-level R&D input might contribute to industry knowledge capacity. In addition, market structure representing population density of one industry is often discussed because of its impact on innovation performance of the firms operating within the industry. Market structure comprises several competitive forces such as threat of entry, threat of substitute products, and rivalry amongst existing firms (Pecotich et al., 1999). Competitive market structure or industry dynamism requires firm's higher organizational learning capabilities and innovation strategy and thus results in more rapid technological change (Utterback and Suarez, 1993; Weerawardenaa et al., 2006). A study by Hashmi and Bieseroeck (2016) about worldwide automobile industry finds that innovation is declining with the number of firms and the innovation gap between the leader and other firms increases with competition. Besides the above mentioned three variables, this essay focuses on the effect from foreign competition. Few studies have examined the relationship between foreign competition and innovation (Liu et al.; 2014). Even the evidence about the relationship between competition and innovation is ambiguous (Baldwin & Scott, 1987; Tang, 2006). The reality that firms in emerging market are facing more competition from foreign rivals encourages us to discuss the impact from foreign competition on firm's innovation capability. Several empirical examples are available. Li and Vanhaverbeke (2009) investigate Canadian innovation and a U-shaped relationship between foreign competition and innovation. Liu et al. (2014) use a panel data of Chinese high-technology industries and find impact of foreign competition on innovation activities. As above figure presents, industries are able to provide industry knowledge which through competition knowledge spillover or technological knowledge spillover flows to firm.

On regional level, four variables are used to account for local knowledge capacity. Regional market size is generally regarded to be proportionally to R&D stock, especially when region dominated by firms operating in technology-intensive activities. Material or immaterial public R&D input is widely accepted as a factor influencing a region's knowledge stock. The material input take the form of granted, tax credits or recruitment aids etc. Immaterial input is from public academic and research institutes. The knowledge influence from public institutes can be realized through several channels (Varga, 2000). One is the information diffusion via personal networks or employment activities in the form of well-educated students. The second one is the technology transfer between academic institutes and industries. The third one is spillover promoted by physical research facilities such as liabilities and scientific laboratories. Although many literatures have studied the efficiency of public R&D policies, their results are not consistent. Regional industry structure in the form of specialization or diversification is also essential for regional knowledge spillover. Literatures show that type and composition of local economic activities might affect firm's technological progress. Debate about how the extent of specialization or diversification fosters MAR or Jacobs spillover has never stopped. For example, Li and others (2014) rely on panel data in Chinese provinces and find that regional innovation systems in China benefit more from Jacobs externalities than MAR externalities. However, there are very few empirical examples studying the relationship between regional industry structure and firm-level innovativeness. In addition, economic geography and other related knowledge literatures consider foreign direct investment (FDI) might be generator of knowledge spillover. Study from Van Pottelsberghe and Lichtenberg (2001) concludes that FDI transfers knowledge only in one direction: outward FDI can increase host country's productivity while inward FDI cannot. In contrast, Bitzer and Kerekes (2008) find new evidence that inward FDI benefit strongly receiving countries and no evidence for positive outward FDI effect. We might think that, local firms in China as developing country can benefit from FDI-related technology transfer from technology-advanced to not-advanced countries or areas. However, study from Hu et al. (2005) indicates that FDI doesn't facilitate the technology transfer across border. Result from Wang et al. (2016) illustrates that the effct of FDI on regional innovation is diminished by a specialized industrial structure. Above figure (Figure 3. 2) shows that knowledge resulting from these regional variables flows to firm through different mechanisms, such as geographical knowledge spillover (MAR spillover or Jacobs spillover), academic knowledge spillover, or foreign knowledge spillover.

3.3.3 Database and Indicator Descriptions

This analysis is based on a two longitudinal datasets. One is CASIF survey conducted annually by the National Bureau of Statistics of China (NBS). It includes all Chinese industrial firms that are either state-owned or above-scale[13] non-state owned firms. Industrial firms here refer to the firms from mining, manufacturing, and public utilities (gas, water service, electric power) sectors[14]. The CASIF survey contains firm-level information such as ownership, location, data about firm production activities and financial data etc. Since year 2007, the CASIF survey data has been used extensively in studying topics like macroeconomics, international economics industrial organization (Brandt et al., 2014). The other one is CCSY which provides information about all 287 Chinese cities[15]. Variables relating to industry level are derived from both datasets.

We omit firms with incomplete records and get an unbalanced panel database of 857,753 observations from 39 sub-sectors (by using four-digit industry code) in 286 cities over 2005-2007. Altogether 369985 firms are included. During this period, no related firms exist in the Lhasa city (code: 5401) in Tibet. This leads to 286 cities[16] in regional level including four largest municipals of China (Peking, Shanghai, Tianjin and Chongqing). In addition, to provide a basis for different regional development policies, the Chinese government divided the whole China into three economic areas (eastern, central and western area). Following this criterion, we obtain three sub-samples for each area.

One purpose of this essay is to discuss the determinants of firm-level innovation performance. A variety of indicators are available to measure firm's innovation such as R&D expenditure, patents, new products announcements and outputs. However, it has not lead to a consensus on a generally accepted indicator (Hagedoorn & Cloodt, 2003)

[13] According to NBS, Firms with revenues above 5 million RMB are referred to as "above-scale" firms (The criteria changes in year 2010).
[14] The sector classification relies on NBS's industrial classification standard (GB/T 4754- 2002). In 2011 Chinese NBS made adjustment for industrial classification standard (GB/T 4754- 2002) and published new standard (GB/T 4754-2011) for national economic activities. This adjustment has no impact upon our analysis because our resulted panel data is from year 2005 to year 2007.
[15] According to NBS, there are now altogether 287 cities with 4-digit codes in China.
[16] City and region are used interchangeably henceforth throughout this essay.

because empirical settings are diversified in industries, counties, constructs and measurement methods etc. In consideration of our research focus, R&D expenditure is generally viewed as an input of innovation production process and thus is problematic as indicator here. Patent represents firm’s purely technological endeavor and is usually adopted in the research about science and technology firms. In terms of observed manufacturing firms, we choose new product intensity (*int_npv*) as indicator of firm’s innovative performance. New product intensity is the ratio of new product sales to total sales. The advantage is that it represents the demands of the market and meets the general conception of the market introduction of innovation (Knoben, 2009).

Table 3. 1 Explanatory variables (i : firm, j : industry, k : region)

Firm-level variables	***Indicator***	***Definition***
age	*age*	number of years since firm began operations
size	*emp*	number of employees inside a firm
R&D input	*int_rd*	R&D intensity=R&D input/sales
innovation experience	*d_exper*	Dummy variable: whether firm has (1) or has not (1) new products output in previous years.
export activity	*d_export*	Dummy variable: whether firm exports (1) or not (0)
ownership	*d_owner*	dummy variable: firm is (1) or is not(0) foreign (including HMT) company
sector-level variables	***Indicator***	***Definition***
industry size	*indu_emp*	Number of employees of one industry in one region
R&D input	*indu_rd*	R&D input per resident of one industry in one region
industry structure	*indu_HI*	Herfindahl index= $\sum_i (\frac{sales_i}{sales_j})^2 \quad (i \in j)$
foreign competition	*indu_foreign*	$= \frac{\sum_i sales_i}{sales_j}$ ($i \in j$ & the ownership of firm i is foreign (d_owner=0))
Region-level variables	***Indicator***	***Definition***
regional market size	*reg_area*	Region’s area
public R&D input	*reg_rd*	amount of governmental science and education input in one region
	reg_uni	Number of universities in one region
Regional industry structure	*reg_spe*	$SPE_{kj} = \frac{E_{jk}}{E_j}$
	reg_div	$DIV_k = \sum_j (\frac{E_{kj}}{E_k})^2$
FDI	*reg_fdi*	Foreign invest amount in one region

Explanatory variables from three levels are described (Table 3. 1). At firm-level, dummy variable (*d_owner*) is to indicate whether the firm is owned by foreign investors including investors from Hong Kong, Macau and Taiwan (HMT) or not. Firm's export activity is represented also by a dummy variable (*d_export*) indicating whether the firm exports at that year. At sector-level, we use Herfindahl index to examine one specific industry's structure. Foreign competition of an industry (*Indu_foreign*) is represented through the proportion of all foreign firm's sales in the whole industry. As many literatures suggest, region's area (*reg_area*) is used to indicate region's market size. For the public R&D input, we use two indicators (*reg_rd*, *reg_uni*). Specialization and diversification measurement are used to describe regional industry structure. We refer to the measurement criteria from Mukim (2012). Specialization (*spe*) is measured as the proportion that one sector's employment in one district accounts for in the total employment of this sector in whole country. Diversification (*div*) is measured as the sum of squares of one sector's employment shares in total employment of all sectors in one district. Statistics for the whole sample are in appendix.

3.4 Empirical Results

Given differences in explanatory variables results of five alternative model specifications are summarizes (Table 3. 2). Test is carried for total data sample. The above part of the table is the estimates for fixed effects. Estimates of the random effect are reported in the lower part with variance components expressed in standard deviation.

Model A is a null model including only one response variable and one intercept without other explanatory variables. The estimate of the overall population mean is .0438803. sd(Residual) is the estimate of the standard deviation of the Level-1 (firm-level) within subject residuals. sd(_cons) at region-level is the standard deviation of random intercept between regions while sd(_cons) at the sector-level is that between different sectors inside one region. Hypothesis of Model A is rejected. It means the necessity to include both regional and sectoral variables in a three-level model rather than standard single-level regression model.

Table 3. 2 Multi-level model with total sample

	Model A		Model B		Model C		Model D		Model E	
	Null model		Level-1 (firm-level)		Level-2 (sector-level)		Level-3 (region-level)		Full model	
Fixed effect	Est	(SE)	Est	(SE)	Est	(SE)	Est	(SE)	Est	(SE)
Intercept	.0438803***	(.0060719)	.0283116***	(.0062485)	.0448397***	(.0079273)	.0454858***	(.0090712)	.0336034***	(.010269)
age	-		-.0011668***	(.0002148)	-		-		-.0011674***	(.000215)
emp	-		2.20e-06	(1.68e-06)	-		-		2.32e-06	(1.68e-06)
int_rd	-		1.022901***	(.0218305)	-		-		1.022858***	(.0218309)
d_exper	-		.1851904***	(.0064402)	-		-		.1851262***	(.0064445)
d_export	-		.0220621***	(.0048342)	-		-		.0222591***	(.0048674)
d_owner	-		.0014136	(.0100883)	-		-		.0015928	(.0101418)
indu_emp	-		-		-5.42e-08	(9.72e-08)	-		-3.21e-08	(1.22e-07)
indu_rd	-		-		1.05e-08	(9.32e-09)	-		7.04e-09	(9.61e-09)
indu_HI	-				-.010275	(.0176778)			-.0105821	(.0177362)
indu_foreign	-				.0101839	(.015847)			-.0037956	(.0160995)
reg_area							-1.94e-07	(3.10e-07)	-1.04e-08	(3.01e-07)
reg_rd	-		-		-		2.74e-10	(8.85e-09)	-4.38e-09	(9.01e-09)
reg_uni	-		-		-		.0001677	(.0005082)	-.0000496	(.0004919)
reg_spe	-		-		-		-.1788499	(.2781576)	-.1801548	(.3489325)
reg_div	-		-		-		.0000812	(.0001811)	-.0000148	(.0001816)
reg_fdi	-						-3.89e-09	(6.12e-08)	1.47e-08	(6.10e-08)
Random effect										
region: sd(_cons)	.0792364	(.0076851)	.0746687	(.0078487)	.0798725	(.0077172)	.0789249	(.0077218)	.0748217	(.007875)
sector: sd(_cons)	.1602845	(.0042776)	.1570661	(.0043581)	.1599917	(.0042874)	.1603302	(.004279)	.1569693	(.0043627)
sd(Residual)	1.752368	(.0013429)	1.749256	(.0013407)	1.752372	(.0013429)	1.752367	(.0013429)	1.749256	(.0013407)
Level-1 observations	857753		857753		857753		857753		857753	
Level-2 groups	8826		8826		8826		8826		8826	
Level-3 groups	286		286		286		286		286	

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Null model can be used as a baseline for comparing the variance with that of other models (see Table 3. 2). Model B is an unconditional model which incorporates Level-1 explanatory variables. We notice that the variances for all three levels are reduced after adding firm-level variables. Variables including firm's age (*age*), R&D input (*int_rd*), innovation experience (*d_exper*) and export activity (*d_export*) are highly significant related to firm's innovation while variable size is not. Model C includes only sectoral variables. Standard deviation of random intercept between sectors is reduced slightly (from .1602845 to .1599917). However, none of sector-related indicators are significant related to firm's innovation. Model D including only regional variables exhibits the similar situation as Model C.

Model E contains all three-level variables. It is a random-intercept model where the overall level of the response is allowed to vary over sector and region after controlling for covariates. As we have seen, adding Level-2 or Level-3 covariates reduce the variance only at their corresponding level. After including both Level-2 and Level-3 variables in Model E, all variance proportions are reduced. Although Model B reduces all variances as well, Model E contributes most to explain the within-firm, between-sector and between-region variances. Therefore, we choose Model E as main explanatory model despite indicators from sector- and region-level do not seem to have significant effect on response variable. It appears that firm's age (*age*) has a significant negative effect on firm's innovation output. This means that younger firms are more likely to report 'new to the firm' product or process when they are just established (Srholec, 2010). Although empirical results about the relationship between firm's age and innovation are not consistent, our result is consistent with some literatures such as Huergo and Jaumandreu (2004) and Thornhill (2006). Firm's size in term of employee numbers (*emp*) is found not significantly related to firm's innovation. It is not surprising. As explained above previous researches have achieved different conclusions about the effect of firm's size due to various empirical settings. Firm's R&D intensity (*int_rd*) is found to have significant impact on firm's innovation with relative large magnitude. It reinforces the resource based view that in-house R&D effort is one of the most important innovation sources. Firm's previous experience in innovation (*d_exper*) increases positively firm's future innovation performance. This result is in accordance with path-dependency argument. Firm's export activity (*d_export*) has also positive effect although the effect is not as large as that of other influencing factors. It is in line with our expectations. However, dummy variable about firm's ownership (*d_owner*) doesn't seem to affect firm's innovation.

Besides the effects from most firm-level variables, there are no significant effects in Model E. It might be too early to conclude that spillovers from sector and region do not work when we notice the very large sample used here. Furthermore, the four main municipalities (Peking, Tianjin, Shanghai and Chongqing) may have specialties which can influence econometric results. Therefore, we exclude them from our total samples. Model F tests the new sample without firms from the four main municipalities. It shows that there are no distinct differences between Model E and Model F (see Table 3. 3). Very similar to Model E, only firm-level variables in Model F exhibit significant effect. Coefficients of these variables are very close to each other except R&D input (*int_rd*). Coefficient for R&D intensity in Model F is about 12 times than that in Model E.

To examine the robustness of the results in Model E, we test the model by using three different sub-samples representing three economic areas (eastern, central and western area). Model G (see Table 3. 4) tests all three-level variables on a subsample where firms are from eastern part of China. It involves 632772 observations from 101 regions and 39 sectors (3396 sub-region-sector). Regarding to the firm-level variables, an obvious change is that effect of firm's size (*emp*) becomes significant and positive although the magnitude is weak. Except for the ownership variable (*d_owner*), all estimated firm-level parameters are highly significant.

Table 3. 3 Multi-level model (total sample vs. sub-sample)

	Model E		Model F	
	Full model		Exclude four municipalities	
Fixed effect	Est	(SE)	Est	(SE)
Intercept	.0336034 ***	(.010269)	.033389***	(.0101467)
age	-.0011674***	(.000215)	-.0010076***	(.0002381)
emp	2.32e-06	(1.68e-06)	2.40e-07	(1.78e-06)
int_rd	1.022858***	(.0218309)	12.03056***	(.0801042)
d_exper	.1851262***	(.0064445)	.1300159***	(.0071768)
d_export	.0222591***	(.0048674)	.0178285***	(.005377)
d_owner	.0015928	(.0101418)	-.0052517	(.0113988)
indu_emp	-3.21e-08	(1.22e-07)	5.41e-08	(1.26e-07)
indu_rd	7.04e-09	(9.61e-09)	-7.65e-09	(1.04e-08)
indu_HI	-.0105821	(.0177362)	-.0237772	(.018206)
indu_foreign	-.0037956	(.0160995)	-.0166378	(.0163666)
reg_area	-1.04e-08	(3.01e-07)	-2.37e-08	(2.98e-07)
reg_rd	-4.38e-09	(9.01e-09)	-2.49e-08	(2.40e-08)
reg_uni	-.0000496	(.0004919)	-.0006541	(.0005145)
reg_spe	-.1801548	(.3489325)	-.1378872	(.3561144)
reg_div	-.0000148	(.0001816)	.0000456	(.0001999)
reg_fdi	1.47e-08	(6.10e-08)	1.39e-08	(6.77e-08)
Random effect				
region: sd(_cons)	.0748217	(.007875)	.0662615	(.009164)
sector: sd(_cons)	.1569693	(.0043627)	.1463705	(.0049025)
sd(Residual)	1.749256	(.0013407)	1.820179	(.0014722)
Level-1 observations	857753		770908	
Level-2 groups	8826		8680	
Level-3 groups	286		282	

Table 3. 4 A comparison among three economic areas (eastern, middle and western)

	Model E		Model G		Model H		Model I	
	Full model		eastern		Middle		western	
Fixed effect	Est	(SE)	Est	(SE)	Est	(SE)	Est	(SE)
Intercept	.0336034 ***	(.010269)	.0119541***	(.0042703)	.0138372***	(.0051938)	.1130672**	(.0485906)
age	-.0011674***	(.000215)	-.0008992***	(.0000249)	-.0002779***	(.0000493)	-.0035748**	(.0018198)
emp	2.32e-06	(1.68e-06)	2.70e-06***	(2.21e-07)	1.69e-06***	(2.88e-07)	-4.08e-06	(.0000168)
int_rd	1.022858***	(.0218309)	.0729161***	(.0020704)	.3921597***	(.0216383)	19.77549***	(.3172116)
d_exper	.1851262***	(.0064445)	.2045423***	(.0007367)	.0817981***	(.0014845)	.2309619***	(.0602786)
d_export	.0222591***	(.0048674)	.0188271***	(.0004953)	.0491971***	(.0015795)	-.0309286	(.0731749)
d_owner	.0015928	(.0101418)	-.0003468	(.0013118)	.0038029*	(.0021134)	-.0100441	(.0724437)
indu_emp	-3.21e-08	(1.22e-07)	-3.72e-08**	(1.51e-08)	7.51e-09	(8.12e-08)	3.62e-07	(1.85e-06)
indu_rd	7.04e-09	(9.61e-09)	5.06e-09***	(1.05e-09)	-5.23e-09	(8.70e-09)	-5.03e-08	(2.27e-07)
indu_HI	-.0105821	(.0177362)	.0005716	(.0029762)	.0155768***	(.0040426)	-.0713131	(.1045961)
indu_foreign	-.0037956	(.0160995)	.0040053*	(.0023592)	.0111667**	(.0049609)	-.0270472	(.1340293)
reg_area	-1.04e-08	(3.01e-07)	-1.42e-07	(3.24e-07)	8.73e-08	(2.48e-07)	-3.42e-07	(7.10e-07)
reg_rd	-4.38e-09	(9.01e-09)	-5.99e-09***	(9.00e-10)	-5.15e-08***	(1.33e-08)	4.83e-08	(1.72e-07)
reg_uni	-.0000496	(.0004919)	.0002318*	(.0001282)	.0007363***	(.0002613)	-.0029888	(.0024781)
reg_spe	-.1801548	(.3489325)	.0232771	(.0477646)	-.3744**	(.1511906)	-.8675077	(4.124221)
reg_div	-.0000148	(.0001816)	.0000453*	(.0000243)	-6.78e-06	(.0001052)	-.0003018	(.0020211)
reg_fdi	1.47e-08	(6.10e-08)	4.38e-08***	(7.18e-09)	-7.24e-08	(6.57e-08)	2.37e-07	(7.73e-07)
Random effect								
region: sd(_cons)	.0748217	(.007875)	.0201781	(.0015536)	.0250423	(.0020763)	3.26e-06	(7.27e-06)
sector: sd(_cons)	.1569693	(.0043627)	.0220769	(.0004467)	.0357203	(.0010813)	.1176782	(.0980304)
sd(Residual)	1.749256	(.0013407)	.1607981	(.0001432)	.1882789	(.000354)	5.580471	(.0140618)
Level-1 observations	857753		632772		144704		80277	
Level-2 groups	8826		3396		3174		2256	
Level-3 groups	286		101		101		84	

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

At the sectoral level, industry's size (*indu_emp*) has a weak negative influence on the generation of new products. Although it seems contradict to our intuition, it become reasonable when considering that innovations might occur in new sectors or niche market. Sectoral R&D input (*indu_rd*) is proved to be positively related to firm's innovaton. However, Herfindahl index (*indu_HI*) has no relationship with innovation. The output intensity of new products is also strongly influenced by the degree of foreign competition (*indu_foreign*) inside a sector. The fact that foreigners might bring more advanced technologies provides the local firms with pressures and motivation to innovate. Among regional variables, four variables are significantly related to firm-level innovation. The amount of universities in one city (*reg_uni*) attributes to local knowledge stock and is proved to influence positively firm's production of new products. Industry diversification within a geographic area (*reg_div*) promotes knowledge spillover and then innovative activity there. In addition, it is beneficial for firms to locate in areas with FDI (*reg_fdi*). Contrary to expectation, regional R&D input (*reg_rd*) has a significant negative effect on firm's new products intensity despite of a very slight magnitude. It is probably caused by the indicator we choose. This essay uses the amount of governmental science and education input as the indicator of regional R&D expenditure. We postulate that the sources of public R&D capital and different operation mechanisms in using public R&D capital might influence econometric results.

Data sample in Model H include firms from middle part of china. The data sample includes 144704 observations from 101 regions and 39 sectors (3174 sub-region-sector). The observations number in Model 2B is largely less than that in Model 2A although both samples cover the same number of regions and sectors. All firm-level variables in this model have significant influence on firm's innovation. The dummy variable (*d_owner*) which is insignificant in Model G becomes significant now. It indicates that with other things being equal a firm which is not foreign-owned is able to produce more new products. The sectoral variables behave quite differently from those in Model G. Herfindahl index (*indu_HI*) is positively proportional to firm's new products output. That is, when the sector or industry is occupied by one or very less firms, firms inside of the sector achieve more innovation progresses. A main finding here is that localization externalities influence negatively firm's new products output. It implies that industry diversification of one region can promote knowledge spillover among firms from different sectors and thus improve individual firm's innovation performance.

Model I is a test for firms from western part of China. The results are very similar to that of Model E except the insignicance of dummy variable (*d_export*).

A comparison among these three models shows that variables especially those from sectoral and regional level exhibit different effect on firm's innovation. For example, industry size in term of the employee number (*indu_emp*) is detrimental in eastern area while no effect in other two areas. The reason may be that eastern part is the most advanced area in china and therefore has more new high-technology industry sectors which are still small in terms of industry size. Similarly, whereas FDI has a positive effect on firms from eastern area, it has no effect on firms in middle and western area. A possible explanation is that there might be a threshold for FDI functions as knowledge source while Eastern area can receive the most amount of FDI because of its location close to pacific area.

Obviously, firm's attributes exhibit statistically significance across all models. Although the ownership in Model E doesn't play a role, firm itself can be regarded as the most important innovation promoter in comparison with region and industry. This result is consistent with Nelson (2000): in "most industries the lions share of innovation effort is made by firms themselves" (Nelson, 2000: 13). The fact above (Table 3. 2) that variables from both region and sector don't have significant effect on firm's innovation doesn't mean they can be ignored. When we category the whole samples into three sub-samples, the effects from some sector- and region-level variables vary among the three areas. It is probably because the effect from regional innovation system. Regional innovation systems are different in their innovation history, the distribution of public resource, the management of innovation environment etc.

3.5 Conclusion and Discussion

Many studies in the field of regional science or economic geography have emphasized the influence of regional characteristics on firm's innovativeness. Their main theoretical arguments are knowledge spillover theory and proximity theory. However, some scholars have questioned the major assumption and mechanism used in these studies and thus the possible overestimated role of firm's geographical position. Meanwhile, scholars from organization and management fields advocate the importance of resources inside the firm on firm's innovativeness. Also, industry characteristics have been argued to influence firm's innovation in some degree. Further, the effect from industry might be region-specific. Therefore, it is necessary to reassess the exact effect from geographical circumstance. To accomplish this purpose, we need to take all possible influencing variables into account. After deeply theoretical analysis, we summarize explanatory variables from three levels into an explanatory framework and formulate the different mechanism of knowledge flows from each level to firm. In addition, this essay uses a multi-level econometric approach which goes beyond normal OLS approach frequently applied in previous empirical studies. The advantage of this approach is to avoid the "ecological fallacy" (Robinson, 1950) and to disentangle effects from firm, sector and region.

On the whole it can be concluded that that firm-level variables are the most important influencing factors on firm's innovation and their effects are robust. Especially, the effect of firm's R&D intensity remains significant positive across different model specifications. Although the fact that the regional attributes are weakly linked to the firm's innovation remarkably undermines the generally recognized effect of geography, economic geography still matters for some firms when firms are categorized in three parts. Similarly, industry variety within a geographic region exhibits limited effect.

This essay contributes to the empirical studies on firm's innovation in some ways. Firstly, this study is one of the very few researches which relate micro level firm's innovation with macro level agglomeration in emerging economy. Secondly, this essay uses city as spatial scale which advances most of studies about Chinese economy where state is frequently used as unit of observation. Thirdly, this essay accounts for variables from three levels and thus has a very high data requirement. Finally, the usage of multi-level econometric method makes our results more robust and reliable.

This study has also a few limitations. As Sternberg and Arndt (2001: 379) point out, "the distinction between firm-level and region-level determinants of innovation is not strictly an “either/or” matter. This essay might neglect possible cross-level effect among the three level variables. In addition, this essay limits the geographical spillover effect within a city. However, knowledge can diffuse over distance and interregional knowledge spillover exists in some situations.

The findings of this essay could provide implication for regional policy makers. Firstly, while regional financial R&D input is not necessarily influence firm’s innovation positively, it would be important to focus on immaterial R&D input in the region. Secondly, results from Model G and H indicate that industry diversification can influence firm’s innovation positively. As a result, local government can promote a variety of industries within a geographic region. Thirdly, firms benefit positively from their exporting behaviors. Therefore, policy makers need to pay attention to related sectors and advocate international exchange activities. In one word, the differences existing in regional innovation systems lead to the knowledge spillover effect on individual firms and thus the innovative capabilities. Therefore, it is very necessary for regional policy makers to manage effective regional innovation system.

Chapter 4

Innovation determinants: effects from spatial distribution of customer-supplier relationships

4.1 Introduction

The importance of a firm's innovation capacity or potential has been widely recognized, particularly in technological industry. Prevailing theoretical literatures explaining determinants of innovation are multi-disciplinary including resource-based view, network approach and economic geography theory etc. Traditional analysis of innovation focuses on Schumpeterian hypothesis of a positive linkage between market power (e.g. firm size, market concentration) and innovation capacity. The implicit view is a linear relationship between organizational internal resource, e.g, R&D (Research and development) as input, and innovation as output. The network approach, based on Granovetter's weak ties (1973) argument and developed mainly by Håkansson (1987), emphasizes the influence of a firm's external linkage on innovation. Though in many varieties, such as innovative milieus (Maillat, 1995) and innovation system in regional science (Lundvall, 1995), the basic mechanism of this approach is that businesses acquire knowledge through their formal economic network relations and then use heterogeneous resources to generate innovation by learning process. In recent years, a growing body of studies has paid great attention to the role of local conditions and spatial proximity in achieving innovation performance (Jaffe et al., 1993; Cooke, 2002; Asheim & Gertler, 2005). Taking enterprises' geographical aspect into account, these studies focus on the localization effect in process of knowledge spillover, learning and innovation. Literature review shows that among them "there is a general agreement on the importance of spatial proximity for innovation" (Oerlemans et al., 2001a: 60). The key idea lies in: geographical concentration of focal firm and its related market participants (such as cooperation partners, and research and education institutes etc.) affects knowledge flow, which facilitates innovation as an informational commodity. This kind of argument is generally viewed as an extension of Marshal's "industrial atmosphere" and is called "local buzz" by some researchers (Storper & Venables, 2004; Bathelt, Malmberg & Maskell, 2004). Complementing to "local buzz" argument, Owen-Smith and Powell (2002) use the term 'pipelines' as another available knowledge base of innovation. "Pipeline" is a concept from global network view and refers to the channels used in global or distant interactions. Channels are mostly firm's strategic partnerships of interregional and international reach (Malmberg & Maskell, 2006).

As a summary, we develop a figure (Figure 4. 1) to show the theoretical perspectives so far in discussing determinants of innovation. We categorize them into three parts. The first part of theories emphasizes focal firm's internal resource and neglects external resource (Lee et al., 2001). The second is "local buzz" argument, which focuses on the effect from local conditions including local environment and neighbor market players. This argument neglects influence from distant environment such as long-distance market players in supply chain, long-distance institutions or organizations and the natural, economic and political environment around these players. The third one is above mentioned "global pipeline" argument, which underlines information channel resulting from interaction between focal firms and other cooperators (Owen-Smith & Powell, 2002, 2004). While it complements "local buzz" argument to certain degree, "global pipeline" argument doesn't pay much attention to effect from both distant environments and distant market players themselves. Although most previous studies employ one of above mentioned theories, recent studies have begun to integrate these perspectives to discuss their joint effect on innovation (see Whittington et al., 2009).

There exist many market players or events (oval box in Figure 4. 1) which might have no direct connection to focal firm. Yet they influence focal firm's performance as well. For example, import policy from foreign country might encourage focal exporter to change its manufacturing plan and thus its production outcome. Taking into account the diversification resulted by physical distance, it is reasonable to assume that some attributes of distant environmental events or of distant market players might have influence on focal firm's innovative activity. These attributes are market players' spatial distribution, their age, their industry category, cultural or political characteristics of their residence and others.

Very few researchers have realized the role of these attributes, especially the influence from focal firm's upstream or downstream market players, namely the influence from firm's customer or supplier. Malmberg and others are among the most active advocators who criticize both local buzz and global pipelines arguments and therefore stress the effect resulting from characteristics of distant customers (Bathelt, Malmberg & Maskell, 2004; Malmberg& Power, 2005a; Malmberg& Maskell, 2006). In addition, Grabher et al. (2008) argue that customer "has largely been absent from the portrayals of geographic innovation models" (Grabher et al., 2008: 254) in consideration of the physical distance with space. Nevertheless, little empirical evidence is available to support these claims.

This paper fulfills the gap by including the spatial distribution of a focal firm's customer-supplier relationship into innovation analysis. Deploying the customer-supplier relationship concept from supply chain management literature, we define different types of customer-supplier relationships for a focal firm. Basing on the country where focal firm's main supplier or customer locates, four types of customer-supplier relationships exist: ① domestic supplier-domestic customer relationship, ② domestic supplier-foreign customer relationship, ③ foreign supplier-domestic customer relationship, ④ foreign supplier-foreign customer relationship (Figure 4. 2).

Figure 4. 1 Theoretical perspectives in discussing determinants of innovation

(Jaffe et al., 1993; Lee et al., 2001; Cooke, 2002; Owen-Smith & Powell, 2002, 2004; Asheim & Gertler, 2005; Malmberg& Maskell, 2006 etc.)

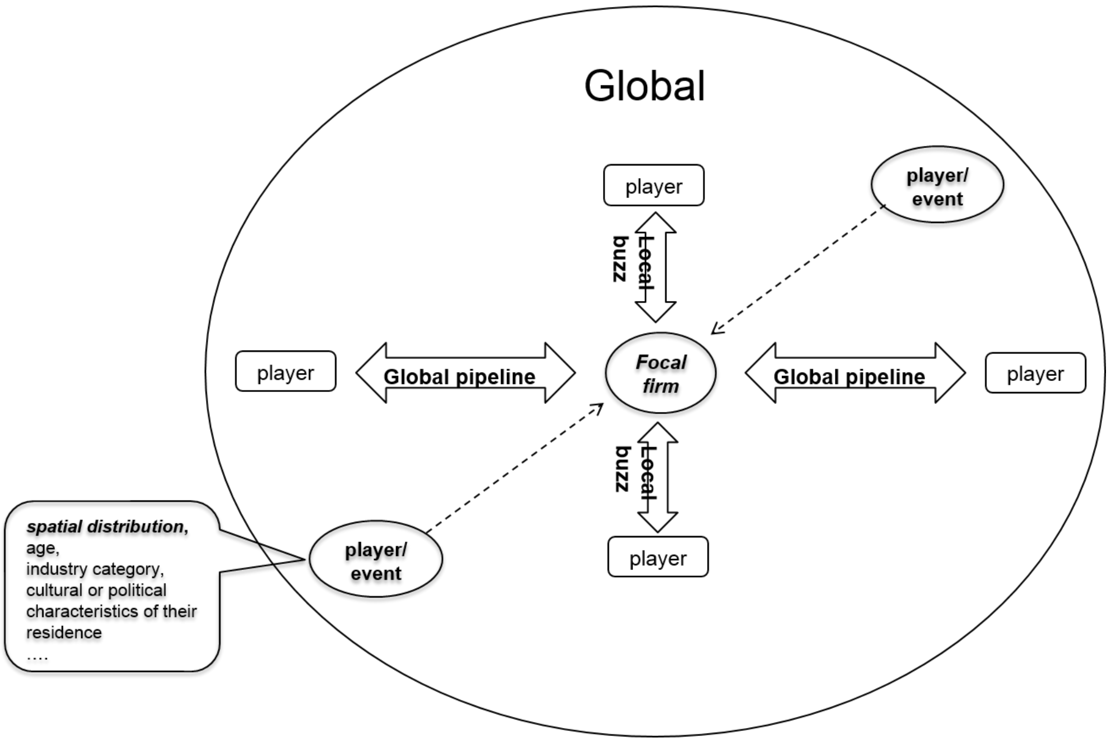
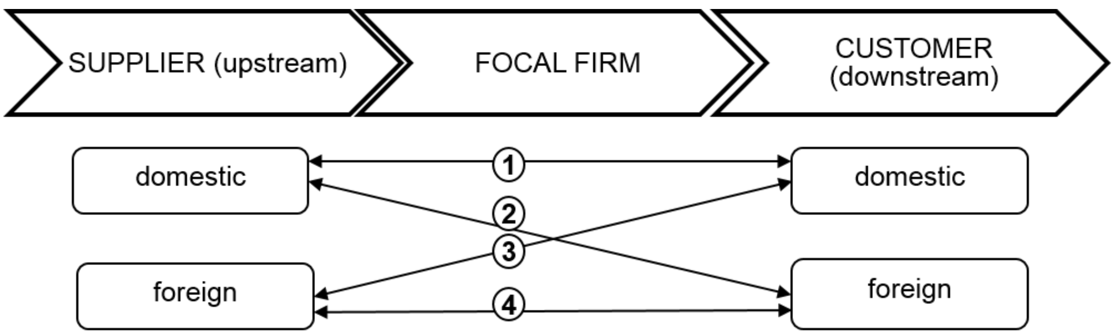


Figure 4. 2 Four Types of Supplier- Customer Relationships



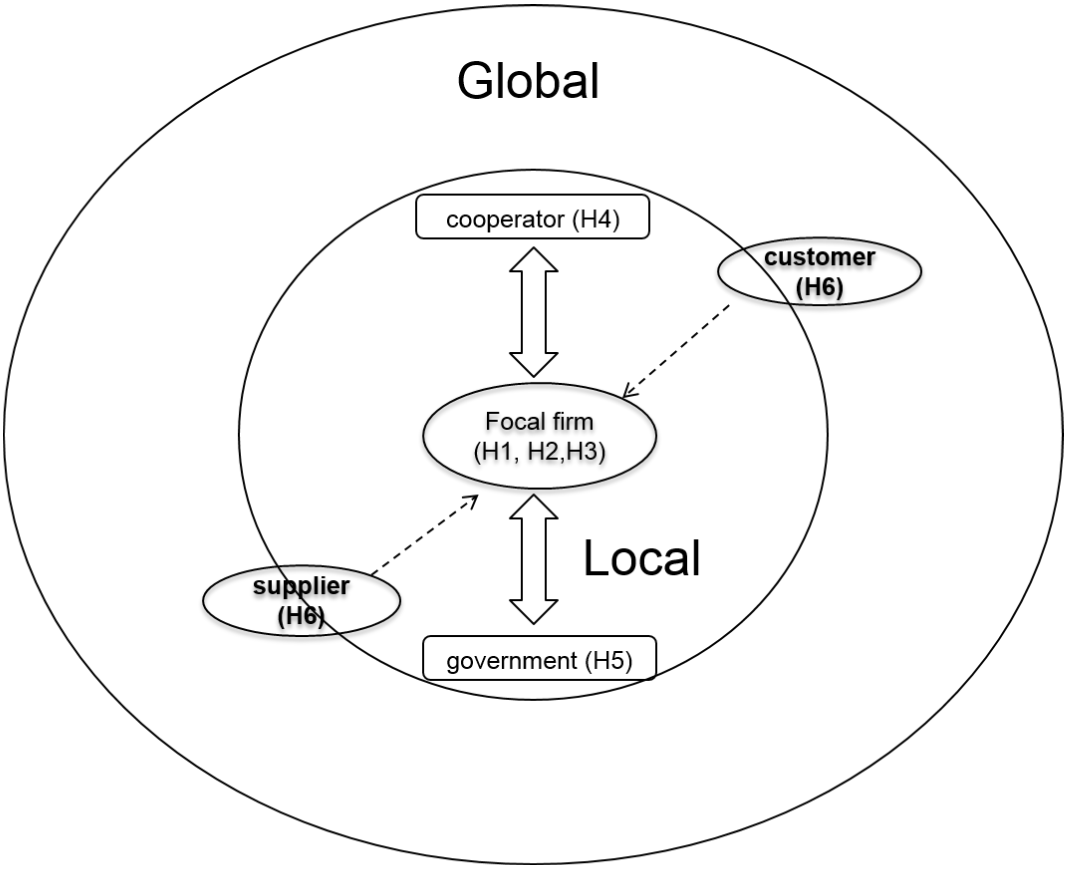
This paper argues that spatial difference in customer-supplier relationship influences focal firm's innovative performance. In consideration of knowledge heterogeneity caused by physical and cognitive difference, we propose that a firm possessing either foreign customer or supplier relationship can generate more innovative performance than a firm without foreign customer or supplier relationship. The paper seeks to broaden the theoretical and empirical discussion of the relation between networking, innovation and location. We are not meant to undermine the value of existing perspectives mentioned above. The objective of this study is to pursuit a more broad perspective and to advance our understanding of the determinants of innovation through an empirical study.

In the following section we review the relevant studies and put forward hypotheses. After that, methodological issues concerning empirical study are discussed and findings are presented. The final section summarizes and discusses the most important findings of our analysis.

4.2 Explanatory Framework and Hypotheses

When we include buyer or supplier in our explanatory framework (Figure 4. 3), we actually think that some characteristics of a focal firm's supplier or customer along with its internal and external resources influence its innovation. Internal resources such as human resource, capital and existing technologies are discussed frequently in innovation research. Linkages to academic institutes, industry associations and other public sectors are normally treated as external resources (e.g. Freel, 2003). Firm's innovative output is generally presumed to be dependent on the usage and combination of a firm's internal and external resource base.

Figure 4. 3 Explanatory framework to develop hypotheses



According to resource based view (RBV) (Barney, 1991), R&D is undoubtedly one of the most important innovation sources inside the firm (Lee et al., 2001). In "most industries the lion's share of innovation effort is made by firms themselves" (Nelson, 2000: 13). Various R&D indicators (e.g. R&D intensity, R&D financial spending per employee etc.) are used to discuss the relationship with innovation performance. Initial researchers have found R&D having dual role (Cohen & Levinthal, 1989). It can not only generate new information, but also enhance a firm's absorptive capacity—the ability to recognize the value of new information, and to assimilate and exploit it, then to apply it to commercial ends (Cohen & Levinthal, 1989, 1990). Although there is no consensus in current literature concerning the importance of R&D on innovation performance (Freel, 2003; Gertler & Levitte, 2005), some empirical studies about Chinese industry highlight significant and positive rates of return on R&D (e.g. Hu et al., 2005). National Bureau of Statistics of China reports that R&D spending in China has reached one trillion yuan ($164.1 billion) in 2012, about 1.98 percent of its gross domestic product (GDP). Moreover, the increase in spending has helped developments in science and technology, and has improved the country's innovation capabilities. In this regard, we draw our first hypothesis:

H1: Firm's innovative performance tends to be higher in firms with more R&D capital.

Besides capital input, RBV suggests that highly qualified people is an important internal resource in generating successful new products or process, particularly in knowledge-intensive industry. „Much of the knowledge created by a firm's activities is embedded to some extent in the human capital of its employees" (Hall & Mairesse, 2006: 296). Moreover, "absorptive capacity" concept mentioned above is strongly related to human capital. It is empirically verified that highly educated and technically qualified workforce is positively related to higher level of a firm's absorptive capacity and thus leads to higher innovation performance (Vega-Jurado et al., 2008). For example, Vinding (2006) uses survey data from 1500 Danish firms and confirms that education of employees can improve a firm's innovative performance. Therefore, it is necessary to include the human capital variable into our analysis. Previous research results lead to second and third hypothesis:

H2: Firm's innovative performance tends to be higher in firms with more R&D workforce.

H3: Employee's education level is positively related to a firm's innovative performance.

In addition to internal resource, recent research works emphasize heavily the effect of external resource on innovation performance. Theories like network theory, regional science, economic geography, cluster and agglomeration theory have shown that knowledge flow induced by local linkage and inter-firm collaboration or interaction is the principal source of technological dynamism (Gertler & Levitte, 2005). Innovation research "has quite convincingly demonstrated that innovations predominantly occur as a result of interactions between various actors" (Malmberg & Power, 2005a: 274). These actors are regional research institutions and organizations, universities, governmental agencies, firm's strategic alliance partners and competitors etc. In addition, regional characteristics - such as infrastructure, institutions, governance and government systems, and social or cultural proximity - typically affect innovation activities. Empirical studies in discussing networks, proximity and innovation have been conducted in different industries with various data source from different countries. For example, research from Arndt and Sternberg (2000) shows that about 90% of the businesses surveyed have informal or formal innovation-related connections. Firms suffering internal resource scarcity normally pursue connections to nearby organizations. These connections bring focal firms financial or intellectual assistance. Our fourth hypothesis therefore is:

H4: Firm's innovation-related connections with other firms improves its innovative performance.

When taking Chinese empirical setting into account, we find that government plays an important role in determining firms' innovative output. Sheng et al. (2011) explicitly distinguish the differential effects of business and political ties on firm's performance. They find that effect from political ties change depending on institutional and market environment. Crescenzi et al. (2012) compare the geography of innovation between China and India. Their results show that infrastructure endowment is one of the main drivers of the Chinese innovation. Therefore, we draw the fifth hypothesis:

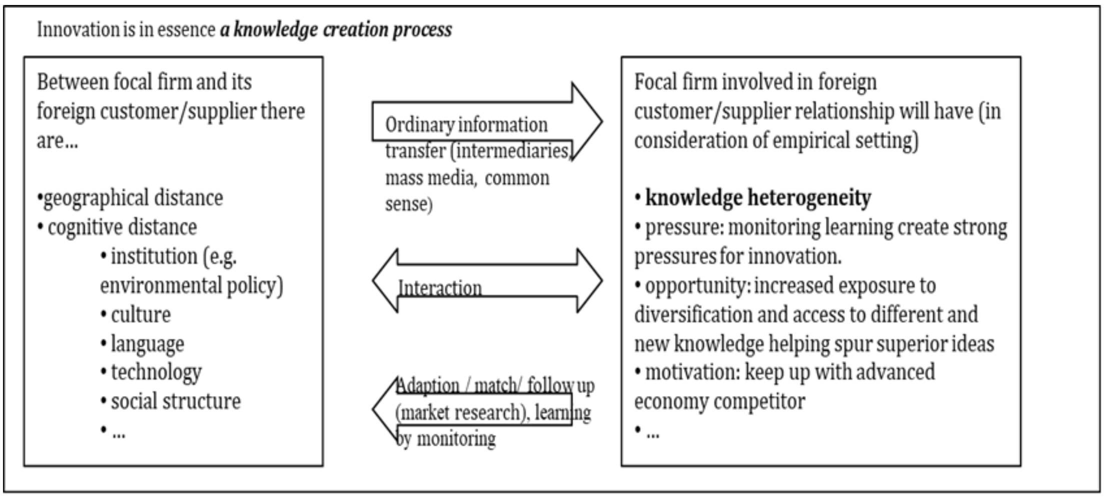
H5: Firm's innovation-related connections with government improves its innovative performance.

In previous section, we argue that few current theorists have questioned the effect from the attributes of focal firm's main customer or supplier in innovation process, especially the spatial distribution of its customer-supplier relationship. Indeed, as early as in 1970s, some scholars have realized the importance of customer to a firm's innovation process. Von Hippel (1978) suggests that successful industrial products are from customer ideas and certain characteristics from customer side are the adequate tools in developing new products and technologies. Moreover, the concept "open innovation" arising recently believes that useful knowledge is widely distributed and external technological base is from user, supplier and others (Chesbrough, 2003). In addition, Mudambi (2008: 699) finds that "firms from both advanced and emerging economies are globally dispersing their value chains" to benefit from cost and innovative capabilities. Studies in the field of international business have also found more evidence that firm's involvement in foreign market has effect on their capacity of introducing innovations, i.e. evidence of "learning by exporting" (Bratti & Felice, 2012). While researchers have begun to notice the effect from customer or supplier's spatial distribution, only several empirical study are available. For example, Oerlemans et al. (2001a, 2001b) draw on the survey in the Dutch region and test the effect of the distance between firm and its supplier or customer on firm's innovation. Li and Vanhaverbeke (2009) discuss the effects of inter-industry and country difference in supplier relationships on pioneering innovations. However, what still uncertain is the exact mechanism of this effect.

We formulate the mechanism to show how the difference in spatial distribution of customer-supplier relationship influences a focal firm's innovative performance (Figure 4. 4). Generally speaking, focal firm has more geographical and cognitive distance with its foreign customer or supplier than with home one. Innovation is in essence a knowledge creation process while geographical and cognitive distance leads to knowledge heterogeneity for innovation.

Figure 4. 4 Mechanism

(Hofstede, 1980; Kress, 1992; Morgan, 1997; Malmberg & Maskell, 2006; Mudambi, 2008; Li & Vanhaverbeke, 2009; Bratti & Felice, 2012).



Porter (1990) has pointed out the lock-in risk: „if rivalry ebbs and homebuyers become pliant or lose sophistication, there is a tendency for the local cluster to become insular, a closed and inward-locking system. The problem is exacerbated if most firms lack significant international activities and their primary commercial relationships are with each other" (Porter, 1990: 171). It indicates the benefit from monitoring distant supplier or customer. The spatiality of supply or demand might be very different and the resulted knowledge heterogeneity may induce new ideas. Resource diversity provides a more robust basis for firm's learning and stimulates its creativity especially in uncertain environment (cohen& levinthal, 1990). Especially in today's context of globalization, there are also "some forms of knowledge creation and exchange that are still very much rooted in the cultural, institutional, and social structures of particular places" (Malmberg & Maskell, 2006:3). Country differences in institutions (e.g. environmental policy) (Morgan, 1997), culture (Hofstede, 1980), language (Kress, 1992, 1996), technology and social structure "may jointly affect the learning and innovation between the focal firm and its suppliers" (Li & Vanhaverbeke, 2009: 846) or customers.

Previous literatures emphasize interaction with customer or supplier contributes to focal firm's knowledge heterogeneity. For example, communication with customers to know what they want and then modification with exiting products leads to incremental innovation. However, innovation activities of today's enterprises are mostly spontaneous, especially in the process of path-breaking innovation. More and more business practices have testified that technology can guide consumption. The success of Apple Company is one of the most convincing examples. According to network theorists or economic geographers, knowledge from linkage to local conditions and from network interaction complements to firm's internal knowledge assets. However, Freel (2003) finds that 53% of science-based firms in database record no external collaboration and "external collaboration is, unequivocally, neither a necessary nor less a sufficient condition for successful innovation" (Freel, 2003: 767). It indicates that the complement through formal and purposeful interaction with partners sometimes is not adequate or even an obstacle for a firm to innovate. Moreover, Malmberg and Power (2005a) review literatures on clusters and summarize that rivalry, labor mobility and knowledge spillover are more likely to be important than organized inter-firm collaboration and transactions in the effect of knowledge creation. Therefore, besides interaction among market players, there exist other knowledge transfer mechanisms when the spatial distribution of buyer-supplier relationship involves foreign market. As Bratti and Felice (2012) point out, the innovation process does not always originate from interaction with others, but it is spurred directly through market research or indirectly through intermediaries. Malmberg and Maskell (2006) insist, in spite of the existence of learning through regular and direct contact, there are other learning effects associating with communal sharing of cognitive repertoires. Ordinary information transfer path such as mass media gives focal firm common sense about distant environment. Moreover, when focal firm comes from developing countries or low-tech areas, they follow up or adapt to idiographic information with or without intention.

Different from frequent empirical settings in western countries, this paper draws upon the database from China. Firms from emerging markets normally try to keep up with advanced economy competitor, particularly in knowledge intensive industry, such as ICT (information and communication technologies). Their monitoring learning from western mature customer or supplier market can create strong pressures for innovation. Not only from advanced market, but also from distant customer or supplier market, firms have more chance of increased exposure to diversification and access to different and new knowledge helping spur superior ideas (Malmberg & Maskell, 2006; Mudambi, 2008). A diversified set of technological information and various experiences of a particular solving techniques resulting from geographical or cognitive distance might have become motivational backgrounds to firm's innovation. For example, both Malmberg and Maskell (2006) and Malmberg and Power (2005a) argue that innovation can be understood as demand motivating activity.

As stated above, several researchers have recognized the influence from the difference in spatial distribution of buyer-supplier relationship on firm's innovative performance. Oerlemans et al. (2001a) use the location of supplier and buyer of Dutch manufacturers as measure of proximity effect and find no general explanation of the proximity effect in innovation network. Freel (2003) investigates the spatial distribution of firm linkage with a sample of manufacturing firms within the UK. The results are variable depending on firm's innovativeness characteristics (novel innovation or incremental innovation). Li and Vanhaverbeke (2009) use the Canadian innovation database and find the country difference between focal firm and its suppliers has a negative effect on the likelihood of generating pioneering innovations. Notwithstanding, empirical studies are still very few and the results are not always consistent. In light of this emerging perspective and the different spatial distribution of buyer-supplier relationship, we postulate that:

H6: Difference in spatial distribution of firm's buyer-supplier relationship generate difference in firm's innovative outcomes. More specifically, firm with foreign customer-supplier relationship generate more innovation than firm without foreign customer-supplier relationship.

4.3 Data and Method

The basic data used in this study is a longitudinal dataset of all small and medium-sized science and technology firms in Shanghai. Shanghai is the largest city and economic center in China. The data collection has started in year 2009 and carried out yearly by Science and Technology Commission of Shanghai Municipality (STCSM). Due to its compulsory nature, the data suffers less from unreliable observations and is of higher quality than survey data or questionnaire. The classification standard for science and technological firms can be obtained from STCSM. The definition of SMEs varies from countries to countries and even from industries to industries. In China, the usual SMEs are called also under-scale enterprises whose main revenue is smaller than 20 million RMB each year[17]. The dataset presented here is a panel data. It spans a period of five years from 2009 to 2013. To facilitate a comparison with other countries, we use the American Small Business Administration (SBA)'s definition of SMEs (emp<=500) and thus have an unbalanced panel data of 72243 observations (33779 firms) from 18 one-digit industries[18].

Some descriptive statistics for the whole sample are as followed (Table 4. 1, Table 4. 2). The first table presents one-digit industry distribution for 72,243 observations (Table 4. 1). Four industries (scientific and technical services; Manufacturing; Wholesale and

[17] For further elaboration of the criteria used to classify firm size, please see the website of the China's NBS (www.stats.gov.cn).

18 According to Chinese NBS, there are altogether 20 one-digit industries (from letter "A" to "T"). In 2011 Chinese NBS made adjustment for previous industrial classification standard (GB/T 4754-2002) and published new standard (GB/T 4754-2011) for national economic activities. This adjustment has no great impact upon the analysis presented below because we focus only on the main category (Both standards classified industries in 20 categories from letter A to T). In this paper, we follow the GB/T 4754-2002. The sample in this paper includes 18 industries (see Table 4. 1).

retail trade; transfer information, software and IT services) account for most surveyed populations (about 85.88%). Among them, firms from industry of scientific and technical services occupy 43.33% of the total sample. Although other firms (56.67% of the total sample) are not categorized into the one-digit scientific and technical services industry, an examination about their two- and four-digit sectors show that their activities

Table 4. 1 Number of observations by industry (criterion: GB/T 4754-2002)

one-digit industry code (A-T)	Freq.	Percent	Cum.
A. Agriculture, forestry, animal husbandry and fishery	241	0.33	0.33
C. Manufacturing	**11,351**	**15.71**	**16.05**
D. Electricity, heat, gas and water production and supply industry	15	0.02	16.07
E. Building industry	2,011	2.78	18.85
F. Transportation, storage and postal services	588	0.81	19.66
G. transfer information, software and IT services	**8,664**	**11.99**	**31.66**
H Wholesale and retail trade	**10,726**	**14.85**	**46.5**
I. Accommodation and Catering Services	136	0.19	46.69
J. Financial Industry	78	0.11	46.8
K. Real Estate	396	0.55	47.35
L. Leasing and Business Services	6,064	8.39	55.74
M. scientific and technical services	**31,302**	**43.33**	**99.07**
N. Water, environment and public facilities management industry	181	0.25	99.32
O. resident services, repairs and other services	255	0.35	99.67
P. Education	74	0.1	99.78
Q. Health care and social welfare	23	0.03	99.81
R. Culture, Sports and Entertainment	109	0.15	99.96
S. public administration and social organizations	29	0.04	100
Total	72,243	100	

Table 4. 2 Number of observations by size, year 2009-2013 (%)

	year 2009	year 2010	year 2011	year 2012	year 2013	Total
small (50 or less employees)	11, 381	13, 994	15, 943	18, 586	7498	67, 402
	(93. 84)	(94. 01)	(93. 07)	(93. 28)	(91. 74)	(93. 3)
51-100 employees	573	682	780	958	562	3, 555
	(4. 72)	(4. 58)	(4. 55)	(4. 81)	(6. 88)	(4. 92)
101-200 employees	149	173	334	358	102	1, 116
	(1. 23)	(1. 16)	(1. 95)	(1. 8)	(1. 25)	(1. 54)
201 or more employees	25	36	74	24	11	170
	(0. 21)	(0. 24)	(0. 43)	(0. 12)	(0. 13)	(0. 24)
Total	12, 128	14, 885	17, 131	19, 926	8, 173	72, 243

relate to science and technical issues more or less. It is reasonable in consideration that all observations are from a scientific and technological database. Distribution of employee numbers among observations is also described (Table 4. 2). More than 90% observations have number of employees less than or equal 50. Moreover, there is no great change in each year. It reflects again the reliability of the dataset.

As many researchers have done, this paper models the innovation output as result of firm's knowledge production process (Freel, 2003; Crescenzi et al., 2012). A modified knowledge production function is used here to investigate relationship of internal and external resource with firm-level innovative performance (Freel, 2003). The measurement of the variables used to do empirical test is described as well (Table 4. 3).

$$INN_{it} = \beta_1 HR_{it} + \beta_2 RD_{it} + \beta_3 GOV_{it} + \beta_4 COOP_{it} + \beta_5 SD_{it} + \ldots + u + \varepsilon \qquad (1)$$

Table 4. 3 Variables used in equations

variable	description	indicators
INN	innovative performance	***pat_app***: number of patents that firm applies during the specified year
RD	R&D input	***rd_wf***: R&D expenditure per employee
HR	human resource	***perc_uni***: percentage of employees with higher education (university and above) of total employees
		perc_rdemp: percentage of R&D employees of total employees
GOV	connection with government	***cap_gov***: the amount of capital from government for innovative purpose
COOP	connection with other firms	***cap_coop***: the amount of capital firm has invested for innovative activity with external cooperators
SD	spatial distribution of customer-supplier distribution	***sc_1***: dummy variable focal firm has (1) or has not (0) domestic supplier and domestic customer
		sc_2: dummy variable focal firm has (1) or has not (0) domestic supplier and foreign customer
		sc_3: dummy variable focal firm has (1) or has not (0) foreign supplier and domestic customer
		sc_4: dummy variable focal firm has(1) or has not (0) foreign supplier and foreign customer
AGE	firm age	***age***: number of years since firm began operations
SIZE	firm size	***emp***: number of employees inside a firm
INDU	one-digit industry code	***indu***: industry dummy

There are a variety of indicators to measure innovative performance. Among them are R&D inputs, patent counts or citations, new product announcements (also called literature-based innovation output indicators (LBIOs), and product or process output (Beneito, 2006; Jiang& Li, 2009). However, the quite extensive studies have not yet lead to a consensus (Hagedoorn & Cloodt, 2003). Determining the measurement of innovation is essential for a deeper understanding of our research question (Acs et al., 2002). Different from in manufacturing firms, innovation in science and technology firms is viewed as a purely technological endeavor rather than a commercial endeavor. Therefore, patents can be used as the indicator of innovative output. According to Chinese state intellectual property office, there are three kinds of patent in China, including patents for invention, patents for utility model and patents for design. In terms of observed firms' innovative nature and data availability, we use the amount of applied patents as explained variable (*pat_app*). It is consistent with a large body of studies discussing the nature and performance of innovation in biotechnology and tech industries (see Gertler & Levitte, 2005).

Nine independent variables are used to explain the influence from internal and external resource. We use R&D expenditure per workforce (*rd_wf*) to capture R&D input in first hypothesis. Two independent variables, percentage of R&D employees (*perc_rdemp*) and that of high-education employees (*perc_uni*), are used to indicate the quality of human resource in second and third hypothesis respectively. As H4 posits, the nature of partnership with surrounding institutes or organizations are discussed. We have one independent variable to describe firm's innovation-related connections with others. Variable (*cap_coop*) represents the capital firm has invested for science and technology activities with external cooperators. In addition, central and local governments normally provide various types of support to stimulate innovation. These supports include government grants, tax benefits, export promotion, financing support and government procurement etc. Therefore, we use R&D capital flow from government (*cap_gov*) to capture the influence from governmental aspect in H5.

Our main concern in this paper is to discuss the influence from the spatial distribution of firm's customer-supplier relationship. We use four indicators to capture the spatial distribution of firm's customer-supplier relationship in above figure (Figure 4. 2).

Variable *sc_1* indicates a customer-supplier relationship where both customer and supplier of focal firm locate inside of China. Variable *sc_2* represents the relationship where focal firm' upstream partner is from China while its downstream partner is from foreign country. Variable *sc_3* shows a foreign supplier and domestic customer relationship. Variable *sc_4* is a relationship where both firm's supplier and customer locates both outside of China. In addition, firm size, age and one-digit industry category are control variables which have influence on innovative performance in previous researches and thus are likely bias our results.

Because the distribution of many statistics might suffer outliers (Wooldridge: 309), we winsorize the continuous variables at 1% of their respective distributions in each tail to avoid the influence of outliers (Belsley et al.,1980). To avoid collinearity, we need to exclude one of the four spatial variables in our estimation. In this paper, we drop the variable sc_1 as the base category. All other variables will show the relative differences from this category. Following table (Table 4. 4) reports the correlation matrix of main independent variables in estimation equation. All correlations are fairly low. The variance inflation factors (VIF) range from 1.01 to 1.52 with a mean of 1.15, which are well below the acceptable level of 10 suggested by Ryan (1997).

When modeling a count variable such as patents, there are several available estimation methods to choose from. The Poisson regression method is used because the dependent variable, the number of applied patents, is either zero or some positive integer. However, the observed distribution sometimes have variation which is largely greater than the mean. This situation is called "over dispersion". In this regard, Negative Binomial regression is more flexible than Poisson regression. In addition, Tobit model is used here as a reference. The Tobit model, also called a censored regression model, is designed to estimate the non-negative dependent variable, those at the limit or above it.

Table 4. 4 Correlation matrix of independent variables

	variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	sc_2	1									
2.	sc_3	-0.021	1.000								
3.	sc_4	-0.013	-0.016	1.000							
4.	per_uniabo	0.033	0.056	0.041	1.000						
5.	per_rdemp	0.069	0.081	0.057	0.437	1.000					
6.	rd_wf	0.077	0.058	0.058	0.246	0.473	1.000				
7.	cap_coop	0.050	0.030	0.017	0.081	0.168	0.215	1.000			
8.	cap_gov	0.033	0.028	0.022	0.070	0.170	0.217	0.201	1.000		
9.	emp	0.070	-0.004	0.041	-0.121	0.018	0.045	0.072	0.139	1.000	
10.	age	0.007	-0.004	-0.005	-0.143	-0.042	-0.023	-0.000	0.024	0.135	1.000

4.4 Empirical Results

Estimation results based on equation (1) and on the 72243 observations are reported (Table 4. 5). Column (1) as a reference corresponds to the result from Tobit model. Colum (2) and (3) are Poisson regression and negative binomial regression respectively. Column (4) and (5) are estimation models without controlling several variables. To save space, we do not report the estimated coefficients for industry dummy variables.

Despite of different statistical methods, a common result is that all estimates are roughly consistent. The model appears to predict reasonably the determinants of innovative performance. The inconsistent in coefficients are caused mainly by estimated distribution functions. Taken together, these findings appear to highlight the reliability and robustness of our empirical results.

Table 4. 5 Estimation results of models

Dependent variable	innovation performance				
	(1)	(2)	(3)	(4)	(5)
Independent variables					
SC_2	0.669***	0.399***	0.629***	0.674***	0.753***
	(12.02)	(8.11)	(9.28)	(9.79)	(10.79)
SC_3	0.119***	0.0763*	0.228***	0.262***	0.238***
	(2.67)	(1.7)	(3.71)	(4.23)	(3.77)
SC_4	0.447***	0.448***	0.872***	0.824***	0.968***
	(6.55)	(6.43)	(10.42)	(9.88)	(11.44)
per_uniabo	0.192***	0.651***	0.565***	0.459***	0.269***
	(8.43)	(16.93)	(11.91)	(9.83)	(5.92)
per_rdemp	0.602***	1.328***	1.986***	1.958***	1.978***
	(22.73)	(34.92)	(42.25)	(41.96)	(42.09)
rd_wf	0.00323***	0.00229***	0.00251***	0.00255***	0.00227***
	(16.12)	(12.29)	(10.13)	(10.20)	(8.94)
cap_coop	0.00111***	0.000485***	0.000796***	0.000762***	0.000992***
	(9.24)	(5.91)	(6.79)	(6.44)	(8.28)
cap_gov	0.00199***	0.000188***	0.000744***	0.000737***	0.001072***
	(21.94)	(3.69)	(9.77)	(9.65)	(13.80)
Control variables					
emp	0.0100***	0.0173***	0.0160***	0.0168***	no
	(31.59)	(33.86)	(30.96)	(32.04)	
age	-0.00769***	-0.000684	-0.0222***	-0.0147***	no
	(-4.04)	(-0.21)	(-6.87)	(-4.55)	
industry dummies	yes	yes	yes	no	no
_cons	-0.18	-2.984***	-2.344***	-1.748***	-1.382***
	(-1.12)	(-8.45)	(-7.19)	(-35.28)	(-33.85)
Log likelihood	-141998.95	-44798.941	-41699.789	-42066.418	-42607.823
N	72243	72243	72243	72243	72243

z statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Column (1) uses Tobit regression method which treats the zeros as censored values. Tobit model assumes a mixed distribution including the discrete variable zeros and other continuous dependent variables. Therefore, Tobit method is not as effective as Poisson method in estimating distributions with count dependent variable. Now we need to consider whether a Poisson or negative binomial distribution is more appropriate for the data. An analysis of our data shows that the mean of the distribution is 0.51 and the standard deviation is 1.99. The fact that the variance exceeds the mean by a great deal indicates an existence of "over dispersion" phenomenon in our data set. While the Poisson distribution is normally characterized by equal mean and variance, the negative binomial distribution is able to provide more accurate models than the Poisson distribution by allowing the mean and variance to be different. That is to say, the results in Column (2) are unbiased and consistent but are not as effective as results in Column (3).

Estimation from Column (3) provides the positive results for the variable measuring the degree of firm's internal R&D inputs (H1). The positive and statistically significant coefficient suggests that firms investing more R&D capital per employee promote the innovative performance. It is not surprisingly that this hypothesis is supported. Although there is no consensus in the role of R&D input, a large body of literatures has empirically confirms the positive relation between R&D input and innovation output. Estimates on human resource (H3&H4) are also positive and quite significant. It indicates that innovative performance tends to be higher in firms with larger percentage of high-educated employees or of R&D workers.

Even though our analysis shows that internal resource as a whole has impact on innovativeness of a firm, innovative firms rely on external source as well. Both cooperative (H4) and governmental aspects (H5) have very significant correlation with innovativeness of firms. This situation satisfies the local buzz and network arguments that "innovation processes are embedded processes" and "innovating firms are not islands of planned co-ordination in a sea of market relations" (Oerlemans et al., 1998: 307). The reality in China is that, most Chinese enterprises do not have enough R&D capability to solve complex technological problems by themselves alone. Moreover, they are lack of the "absorptive capacity", the ability to recognize, assimilate and use new information to commercial ends (Cohen & Levinthal, 1990). Consequently, firms become dependent on external environment. Contrary to previous research that highlights the linkage to research institutions and plays down that to government resource (e.g. Gertler & Levitte, 2005), innovative firms in our setting relate closely to governmental sector. Firms which heavily use governmental resource such as direct grants, tax incentives and policy support exhibit higher innovative performance. Therefore, these enterprises seek more support from outside to improve innovative performance. It suggests that "the institutional environment in which firms operate will determine the possibilities for fruitful cooperation and therefore economic performance and efficiency" (Oughton & Whittam, 1997: 22). A study about Chinese manufacturing SMEs finds also that linkage and cooperation with government or government agency has the most significant positive impact on these firms' innovation performance (Zeng et al, 2010).

Notably, test for spatial variables (*sc_2, sc_3, sc_4*) echoes our expectation. We drop variable (*sc_1*) because of collinearity. The positive and statistically significant coefficients for the three spatial variables mean that, compared to firms with both domestic customer and domestic supplier (*sc_1*), firms with either foreign customer or foreign supplier promotes innovation. A foreign customer-supplier relationship (*sc_2, sc_3, sc_4*) is particularly conducive to firm's innovative activity. It indicates that knowledge diversification is improved when the distance between focal firm and its partners becomes longer. Also, especially in today's high-tech environment, the transfer of information or knowledge is not limited by longer distance. Information acquisition is not necessarily through interaction between market players. As Figure 4 shows, there exist other effective mechanisms helping the transfer of information from foreign to domestic market. Moreover, not only the knowledge, but also psychological resource such as pressure, motivation provide focal firm with source to be innovated. The increased exposure to international market has not only intensified competition, but also posed an opportunity to get competitors' information (Kandampully, 2002).

Our result concerning foreign customer-supplier relationship (H6) is somewhat consistent with previous researches. Papers in international business have found evidence that "exporters are more likely to introduce product innovations" (Bratti & Felice, 2012:2) than suppliers producing only for domestic firms. Furthermore, our result highlights the influence from foreign supplier on focal firm with regard to innovative output. This result is different from some existing studies. Li and Vanhaverbeke (2009) find that country difference has a negative effect on the likelihood of generating innovation and suggest having suppliers in same countries for effective communication and coordination. Their consideration is based on the importance of geographical proximity on information exchange and thus on innovation capacity. However, "proximity is not simply a spatial phenomenon" (Freel, 2003: 753). As

Boschma (2005) claims, besides geographical proximity, other dimensions of proximity including cognitive, organizational, social and institutional proximity might have impact on interactive learning and innovation. Especially when we take the mechanism in Figure 4 into account, we find that "geographical proximity per se is neither a necessary nor a sufficient condition" for learning and innovation (Boschma, 2005: 61). Another rationale is that the dataset used for the study by Li and Vanhaverbeke (2009) is from Canada, a developed North-America country, while we use the data from China, a developing country. Nevertheless, further caveat needs to be added here. Our empirical results about spatial distribution of buyer-supplier relationship are not contrary to the nature of proximity theory. While proximity theory emphasizes the interaction between focal firm and market players around it, customer or supplier distributing in foreign countries influence focal firm through different mechanism as depicted in Figure 4.

With reference to the control variables, result of the variable "*age*" seems to be counter to intuitions. Firm age represents the industry experience a firm has. Normally, firms in stable industries benefit more from their years of operation. However, it is less striking when given the nature of investigated firms in this study (science and technology firms). When industry dynamism is high, e.g. in technology sector, industry experience is not necessarily positively correlated with the probability of innovation. Even in manufacturing industries which are often viewed as stable business environment, results about the relationship between firm age and innovation probability are not consistent. Study from Huergo and Jaumandreu (2004) shows that new firms present higher probability of innovation while old firms show lower one. Thornhill (2006) also finds that firm age demonstrates significant negative relationship with performance in technology sector. These findings are consistent with our result.

Traditional literature often emphasizes larger firms' advantage in innovation (Roger, 2004). Our result shows significant positive relationship between firm size and the probability of innovation. However, it is hard to conclude that our analysis verifies this advantage. Indeed, the vast majority of firms (above 90% each observed year) in our dataset have employee number less than or equal 50 (see Table 2). Strictly speaking, empirical result here is not able to represent general large firms. Previous empirical results show that innovation varies widely by activities, industries and other factors.

Small firms might be more flexible in generating innovation compared to larger ones, especially in rapidly changing environment. For example, Thornhill (2006) finds size is not a significant predictor of performance in technology industries. More precisely, our result shows that the larger a firm is, the greater amount of innovation it has, but in a limited range of firm size (small- and medium sized firms).

Another concern regarding the estimation in Column (3) is that some industries might be more innovative than others. Therefore, we use the one-digit industry code to control the industry effect. However, the results remain the same even after controlling the industry variable.

In general, empirical results (see Table 4. 5) provide support for all hypotheses. Furthermore, the panel data spanned for 5 years does provide insight that these hypotheses are stable over time.

Table 4. 6 Group means and Test

	whether firm has foreign customer-supplier relationship		
	Group1	Group2	F
pat_app	0.46960204	1.2084768	495.29***
per_uniabo	0.41801929	0.53883362	431.48***
per_rdemp	0.22068187	0.39672209	1099.29***
rd_wf	12.714463	31.826119	917.45***
cap_coop	7.3881417	21.957616	240.17***
cap_gov	12.062388	28.702781	170.04***
N	68475	3775	

***,significant at 1% level; ** significant at 5% level.

We further expand our analysis by answer the question: to what extent do firms with foreign customer-supplier ties (at least one foreign customer or foreign supplier) differ from firms with domestic ties (both customer and supplier are from home country)? Result of an Analysis of variance (ANOVA) in above table (Table 4. 6) answers this question. Observations are divided into two groups based on the spatial distribution of their main customer-supplier relationship. All observations with *sc_1*=1 are categorized into Group1 where all observations has neither foreign customer nor foreign supplier. The left belong to Group 2 where firms has at least one foreign customer or supplier. Group means are calculated for each indicator and F-test is carried out to check for differences between two groups. We notice that, F-test for all variables are statistically significant. The result reflects a significant difference between these two groups. In particular, the indicator of innovative performance, namely variable "*pat_app*" shows significant difference between two groups. Firms with foreign customer or supplier have significant higher innovation performance than firms only with domestic ones. Both internal and external resource do differ significantly between two groups. Above finding (see Table 4. 6) is very important. It supports the rationale behind our hypotheses and confirms again the empirical result (Table 4. 5). Therefore, firms with different spatial distribution in customer-supplier relationships perform significantly different innovative activity.

4.5 Conclusions and Discussions

Determinants of firm's innovative performance have been extensively discussed with kinds of theoretical perspectives, including resource based view, network approach, economic geography and proximity theories etc. In this paper, we consider a specific perspective, the spatial distribution of firm's main customer-supplier relationship, which contribute to explain firm's innovation performance to some degree. We rationalize this evidence in an explanatory framework and develop mechanism to show how the existence of a foreign customer-supplier relationship influences focal firm's innovative activity in comparison with a domestic one.

Our analysis highlights the importance of internal resource as well as external cooperation for innovation purpose. These results in general are in line with findings from previous studies. The effect of governmental support on innovation issues is also underscored here. However, it is different from previous study (Gertler & Levitte, 2005). This implies an idiographic feature of Chinese business environment: institutional benefit from government might bring firms benefit in improving innovative performance.

The newest insight of our analysis is the significant positive effects from three types of spatial distribution of customer-supplier relationship on firm's innovative performance. Furthermore, the result is robust based on panel data and on different estimation methods.

Although we underscore the importance of distant customer or supplier in innovation research, our intention is not to undermine the value of previous studies such as proximity theory or local argument. We hope that this study is not contradict but complement to existing literatures. Empirical result testifies our anticipation and might evoke the necessity to include other characteristics of customer-supplier relationship besides their spatial distribution in future research. Another novelty is the empirical setting in China as emerging economy, which is different from previous innovation research. China has experienced large-scale improvements over the last three decades, which makes it a particular interesting case study. Moreover, Shanghai is the most developed area in China. Empirical test about firms from Shanghai makes the results comparable to those from developed countries. Furthermore, investigation about small and medium-sized enterprises, which form the vast majority of firms in Chinese private sector, makes our study more meaningful and valuable.

This study also provides several important implications for innovation management, especially in China. First, both internal and external resources are useful in improving innovation performance. However, firms in China might lack of absorptive capacity, management capacity and other immaterial assets inside of a firm. Therefore, linkage to actors outside of a firm is important as well. In this case, both investment in cooperation activity and capital flow from government benefit firm's innovative activity. In consideration of china's idiographic feature, firms need to explore other institutional benefits around it.

Second, international market participation increases firm's performance in terms of number of applied patents. Although geographical proximity might have provided firms with new information and knowledge, country difference in buyer-supplier relationships brings firms opportunity, pressure and motivation in generating innovation. The findings of this paper suggest that for innovative purpose, it is important for enterprises in emerging economics to search for customer or supplier from different countries.

Finally, it is worth noting that this paper defines the spatial scale at the country level: home (domestic) country and foreign country. In consideration that Shanghai as the most developed area in China might possess institutional or market feature and advantage which are distinguished from other regions in China. We need to ask: How do different regional parts inside the home country function? It might be interesting when we set the spatial scale at the local level. Future research including regional dimension may deliver a better understanding of the impact from spatial difference on innovative activities. In addition, although we include both customer' and supplier's spatial distribution in our analysis, it is very possible that "a comparison of the results of the two types of linkages leads to some striking differences" (Oerlemans et al. 2001: 71). It will be interesting to execute an in-depth comparison between the differential effect of buyer' and supplier's spatial distribution.

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Appendix

Appendix 1. Descriptive statistics for sector (sector classification according to NBS)

2-digit code	sector	2005	2006	2007	Total
6	Coal mining	5,224	5,761	7,005	17,990
7	Oil and gas	110	99	162	371
8	Ferrous metal mining	1,874	2,204	2,696	6,774
9	Nonferrous Metals	1,228	1,446	1,783	4,457
10	Nonmetal mining	2,036	2,264	2,917	7,217
11	Other mining	15	17	24	56
13	Agro-food processing	13,370	14,804	17,303	45,477
14	Food Manufacturing	4,997	5,378	6,333	16,708
15	Beverage Manufacturing	3,101	3,377	4,165	10,643
16	Tobacco industry	149	123	129	401
17	textile	21,034	23,517	27,306	71,857
18	Textiles and clothing, footwear, headgear	11,644	12,614	14,724	38,982
19	Leather, fur, feathers (down)	6,057	6,651	7,417	20,125
20	Wood processing and wood, bamboo, rattan, brown grass products	5,083	5,977	7,605	18,665

21	Furniture	2,921	3,413	4,038	10,372
22	Paper and paper products	7,078	7,343	8,186	22,607
23	Printing, recorded media	4,140	4,224	4,989	13,353
24	Sporting Goods	3,266	3,506	4,076	10,848
25	Petroleum, coking and nuclear fuel	1,807	1,920	2,054	5,781
26	Chemical materials and products	17,510	19,145	22,145	58,800
27	Pharmaceutical Manufacturing	4,664	4,987	5,470	15,121
28	Chemical fiber	1,160	1,286	1,524	3,970
29	Rubber	2,843	3,172	3,674	9,689
30	Plastic products	11,494	12,771	15,263	39,528
31	Non-metallic mineral products	18,213	19,280	23,628	61,121
32	Ferrous metal smelting and rolling	5,916	6,171	6,735	18,822
33	Non-ferrous metal smelting and rolling	4,591	5,284	6,292	16,167
34	Fabricated Metal	13,507	15,042	17,947	46,496
35	General equipment	19,244	21,985	26,393	67,622
36	Special equipment	10,100	11,252	13,340	34,692
37	Transportation Equipment	10,914	11,991	13,983	36,888
39	Electrical machinery and equipment	16,135	17,342	19,920	53,397
40	Communications equipment, computers and other electronic equipment	7,849	8,621	10,404	26,874
41	Instrumentation and culture, office machinery	3,662	3,894	4,410	11,966
42	Crafts	4,369	5,025	5,921	15,315

43	Waste Resources and Materials Recycling	372	458	595	1,425
44	Electricity, heat production and supply	3,401	2,867	4,779	11,047
45	Gas Production and Supply	429	445	574	1,448
46	Water production and supply	1,691	1,371	1,619	4,681
Total		253,198	277,027	327,528	857,753

Eidesstattliche Erklärung

Hiermit erkläre ich, die vorliegende Dissertation selbständig angefertigt und mich keiner anderen als der in ihr angegebenen Hilfsmittel bedient zu haben. Insbesondere sind sämtliche Zitate aus anderen Quellen als solche gekennzeichnet und mit Quellenangaben versehen.

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