DETERMINANTS

OF

REGIONAL INNOVATION CAPACITY IN CHINA

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

Since the 1980s, when the concept of innovation systems (IS) was first presented (Freeman, 2004), a large body of work has been done on IS. IS is a framework that consists of elements related to innovation activities, such as innovation actors, institutional environments, and the relationship between those elements (Lundvall, 1992; Nelson, 1993). Studies on NIS/RIS aim to understand the structures and dynamics of IS (Lundvall, 1992; Nelson, 1993), mainly through case studies and comparative case studies (Archibugi, 1996; MacDowall, 1984; Mowery, 1998; Radosevic, 2000). Research on IS has extended from the national level (NIS) to the regional level (RIS) (Cooke, Uranga, & Etxebarria, 1997; Cooke, Uranga, & Etxebarria, 1998), and from developed economies to developing economies. RIS is vital, especially for a large and diverse countries (Edquist, 2004) like China.

More recently, based on the literature of NIS, Furman, Porter and Scott (2002) introduced the framework of national innovation capacity (NIC), which employs a quantitative approach to understanding to what degree elements of NIS impact on innovation capacity. Regional innovation capacity (RIC) is the adaption of NIC at the regional level. Although regional level research is important there is limited work done on RIC and there is even less in transitional economies, which are different to developed countries.

To better understand RIC in transitional countries this thesis conducted a study of 30 administrative regions in Mainland China between 1991 and 2005. To establish the key factors driving RIC in China the study explored the impact of three elements in

the innovation system; (a) innovation actors, (b) innovation inputs, and (c) international and domestic innovation system interactions,.

The research makes three main contributions. Firstly, it examines the moderating effect science and technology (S&T) investments have on the impact of innovation system interactions. Absorptive capacity is found to be an important factor between knowledge acquisition and innovation capacity at firm level (Cohen & Levinthal, 1989) and between Foreign Direct Investment (FDI) and RIC (Fu, 2008). Investigating the interactive effects between S&T investment and RIS interactions will also enrich the literature of RIC.

Secondly, the thesis examines the impacts of RIC drivers in different transitional phases (1991 to 1998, and 1999 to 2005) in China. China has been under IS reform for decades and the reform can be divided into several phases. However, studies either compare the phases with a qualitative approach (Zhong & Yang, 2007; Zhu & Tann, 2009), or investigate RIS performance and RIC focusing on one phase (Li, 2009; Wu, Zhou, & Liang, 2010). There is a gap between these qualitative and quantitative approaches. Using a quantitative study to compare the importance of factors in two transitional phases will fill this gap and improve the understanding of transitional process of innovation system reform.

Finally, the thesis examines the different impacts of RIC drivers on regions at different stages of developing their innovation capacity. China is unevenly developed and RIC is also unevenly distributed. But studies to date either consider the regions across China (Li, 2009) or only part of China (Liu & Chen, 2003) without comparison, or a qualitative appreciation of the differences of RIC among regions (Ji

& Zhao, 2008). Hence, systematic research is needed to uncover the stories behind the irregular innovation capacity across regions. By investigating the different impacts of drivers on the regions, this research improves the understanding of RIC in China, adds knowledge to the literature of RIC and provides policy implications for regional governments.

The data collected from various official statistic yearbooks yields many interesting findings. Using a fixed effect model with panel data, supplemented with cluster analysis, the findings led to important implications. The significant impact of higher education institutions demonstrated higher education institutions are crucial innovation actors. Since innovation inputs are important resources of RIC, governments should continue encouraging increased investment in S&T activities. The impact from FDI and interaction trade implies export-oriented strategies work better than the strategy of attracting FDI. Besides, the existence of an interactive effect between investment in S&T activities and interactions suggests governments should pay more attention to the indirect impact of drivers in RIC development. Moreover, the change in the impact of RIC drivers between phases infers it takes time for strategies to show their effects. The differences in the impact of RIC drivers among regions of different innovation levels implies, to some extent, the impact of the RIC drivers relates to the innovation level of a region.

Table of Contents

List of Figures

未找到图形项目表。

List of Tables

Abbreviation

IS = Innovation System

IC = Innovation Capacity

NIS = National Innovation System

RIS = Regional Innovation System

RIC = Regional Innovation Capacity

NIC = National Innovation Capacity

HEI = Higher Education Institutions

LME = Large and medium sized enterprise

PRI = Public Research Institute

FDI = Foreign Direct Investment

S&T = Science and Technology

PRC = People's Republic of China

CSY = China Statistic Yearbook

CSYST = China Statistic Yearbook on Science and Technology

PSY = Patent Statistic Yearbook

SIPO = State Intellectual Property Office

DV = Dependent Variable

IV = Independent Variable

FIE = Foreign Invested Enterprise

SME = Small and medium sized enterprise

Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Signature: QUT Verified Signature

Date: November 2012

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Chapter 1 INTRODUCTION

This chapter will briefly introduce the research background, research questions, research methodology, potential contributes, and the structure of the thesis.

1.1 Research Background

The importance of innovation in economic systems was first emphasised by Schumpeter in the 1930s (Schumpeter, 1983). Now it is widely considered as the core driver of economic growth and a nations' competitiveness, it has become "the engine of the global economy" (Considine, Lewis, & Alexander, 2009, p. 6). In the early 1980s, to systematically study economic growth in relation to innovation, economists started to use the concept of national innovation systems (NIS) (Freeman, 2004; Lundvall, 2007). Since then NIS have become a substantial field of research, and a large body of important theoretical and empirical research on NIS has been published, focusing on comparing the structures and dynamics of NIS (Edquist, 2004; Edquist & Lundvall, 1993; Godin, 2009; Groenewegen & Steen, 2006; Lundvall, 1992; McKelvey, 1997; Mowery, 1998; Nasierowski & Arcelus, 1999).

With the development of NIS, researchers have found studies of innovation system (IS) at regional and global levels are also important (Cooke, et al., 1997). Researchers observed that regions within a nation, not just nations themselves, can display distinct innovation systems (Howells, 1999; Lundvall, 1992). In large countries, especially those in transition, there usually exists dual innovation systems, one at the national level and the other, the regional innovation system (RIS), locally embedded (Tylecote, 2006). With effective RIS, NIS can be more easily formed and implemented (Chung, 2002). Hence, studies on RIS may be more useful in large countries. With the emergence of regionally identifiable nodes, the regional level is more favourable for examining the learning economies (Asheim & Isaksen, 1997).

Originally research on IS was conducted in developed economies such as the United States (Burt, 2000; Feller, Elmes, & Meyer, 1982; Mowery, 1983), Canada (Doloreux, 2004; Globerman, 2006), Europe (Nelson, 1993), and later in Japan (Freeman, 1987), Korea (Chung, 2002; Dodgson, 2009), Singapore (Park, 1998; Winston, 2006), and Hong Kong (Chu, 1989; Young, 1992). Nowadays more emphasis is placed on emerging and transitional contexts such as China (Fuller, 2009; Hu & Jefferson, 2002; Hu & Mathews, 2008) and India (Fan, 2011; Lewis, 2007). At first researchers tried to explore the components of IS (Lundvall, 1992; Nelson, 1993) and the origin and characteristics of IS (Edquist, 1997b). When these issues became clearer they started to evaluate the performance of IS (Autio, 1998) and compare IS across countries and regions (Furman, et al., 2002; Hu & Mathews, 2005, 2008; Li, 2006, 2009).

Drawing on the concept of NIS, many comparative case studies were conducted (Edquist & Lundvall, 1993; Freeman, 2002; Lundvall, 1992; Nelson, 1993), and quantitative approaches were employed as well (Krammer, 2009; Nasierowski & Arcelus, 1999, 2003). Motivated by a desire to understand the underlying drivers of the innovation processes and the impact of country-level policy on innovation, Stern, Porter, and Furman (2000) introduced a framework, stemming from the concept of national innovative capacity (NIC), to capture the differences in NIS by observable measures of variation. While the NIS approach tends to rely on rich qualitative descriptions of different innovation systems across countries, the NIC framework tries to investigate the variations from a quantitative perspective.

As mentioned above, studies of IS at regional level are more important in the global economy than studies at the national level and have become a focal point of economic activities (Ohmae, 1995). Therefore, in addition to understanding the determinants of NIC, it is important to learn about the drivers of innovation capacity (IC) at the regional level, which in turn lead to enhanced NIC. Since the concept of NIC was established, most studies were undertaken to investigate the determinants of IC at the national level (Furman & Hayes, 2004; Furman, et al., 2002). Although there are studies based at the regional level, they either concern regions in different countries (Fritsch, 2002), regions with boundaries broader than a nation (Slavo, 2002), or one region of a nation. Only few studies systematically explore the phenomenon of IC at the regional level within a nation (Li, 2009; Liu & White, 2001b; Riddel & Schwer, 2003).

Emerging economies are attractive to researchers. China, the largest developing country central to the word economy, attracts a lot of attention from researchers in various fields, including IS. China has been transitioning and transforming from a centrally planned regime to a market-oriented system since the economic reform started in 1978. Its environment for innovation has produced a dynamic tension between old and new, between foreign and indigenous, and between cultural values and practicality (Baark, 2007). Researchers have studied various aspects of China's NIS and RIS, for example, the transition process of science and technology system reform (Zhong & Yang, 2007), innovation index (Ji & Zhao, 2008), and the measurement of RIS performance (Wu, et al., 2010). Although there are many studies on China's NIS and RIS, there are still many issues that need to be explored.

Innovation is a crucial factor for economic development and China is an influential country in the world economy. These two factors make it even more important to study the phenomenon of innovation in China. Therefore, this thesis intends to provide new insight into China's IS development by investigating IC at the regional level, namely regional innovation capacity (RIC) across China.

1.2 Research Questions and Intended Contributions

Innovation capacity has been acknowledged as a critical force in national economic development, not only for developed countries (Nelson, 1993; Porter, 1990), but also for latecomers such as China and India (Fan, 2011). The impact of RIC on economic performance has significantly increased, especially after the dot com era (Yeo, 2010). However, most IS studies focusing on rapid economic development are based on the Asian Tigers or countries in South East Asia, and there is a need to study IS in the context of other development models (Asheim & Vang, 2006). This thesis will try to address three main questions within a Chinese context.

1.2.1 Motivation of RQ1 and intended contributions

Derived from the concept of NIC and the approach of NIS/RIS, RIC is a relatively new concept and there are still many issues within this field that need to be explored. Most existing RIC research is conducted in developed countries, as RIS is better developed in those economies. Less research has been completed in developing and transitional economies. Given the particulars of a transitional economy, issues around RIC become more complex. Researchers need to connect theoretical work and empirical quantitative analysis to uncover the stories behind the phenomenon (Edquist, 2004).

China is a unique case, to which the findings from studies in other countries are not directly applicable. It is a big, developing country and it is still in the transition process. It follows a different development path to Western economies and is on the way to market-oriented socialism. Due to a long historical accumulation and unbalanced development strategy, China is unevenly developed across its regions. Regions in Eastern China are more developed than in Central and Western China, in regards to both economic and innovation development. Hence, systematic studies on China's RIS and RIC are needed and will make a great contribution to future development, economic growth, and innovation capacity.

In terms of previous studies on NIS/RIS and NIC/RIC and the characteristics of China's RIS, a RIC framework is developed in this thesis. It contains the three main components of a RIS; innovation actors, which include higher education institutes (HEI) and large and medium sized enterprises (LME); innovation inputs, which include GDP per capita, funding for science and technology (S&T) activities, skilled labour involved in S&T activities, and employment rate; and interactions between innovation actors, which include FDI, international trade, domestic technology transfer, and the interactive effects between S&T investment and innovation actors.

Based on the framework mentioned above, this thesis tries to meet the need for a systematic study of China's RIC by addressing the first research question:

RQ 1: What are the core drivers of RIC in China?

RQ1 is to investigate the major determinants of China's long term RIC. By addressing this question, the research will enrich the literature of NIS/RIS and NIC/RIC by exploring the core drivers of RIC in a transitional economy. The Chinese context is unique and special. Studies based in this context will enrich innovation research, which was originally developed based on Western countries. Besides, previous research mostly focuses on investigating the impact of drivers alone with an IS approach. There is a lack research systematically exploring the interactive effects between drivers, such as between S&T investment and interactions between innovation actors. By exploring the interactive effects, this thesis fills this gap and also broadens the definition of interaction in an IS. Interactions in an IS not only refer to interactive activities between innovation actors, but also the interactive effects between drivers of RIC.

1.2.2 Motivation of RQ2 and intended contributions

The importance of studying RIS in China has been widely acknowledged and researchers have conducted much research in regions of China. Zhong and Yang (2007) and Zhu and Tann (2009) investigated the long term reform process with a qualitative approach, while Liu and Chen (2003) compared RIS across 12 regions. There are also studies based on overall regions in China. Wu and his colleagues (2010) measured the performance of RIC across 30 regions in Mainland China (in the following, referred to as China for short) during 2001 and in 2005 employed a DEA-based model (Data Envelope Analysis). Li (2009) focused on the impact of interactions between components of RIS on RIC between 1998 and 2005, covering

30 regions in China and using econometric models. Although there are many studies on RIS in China, none of them employ a quantitative approach to systematically investigate the differences between major drivers in different phases of the transitional process. To fill this gap this thesis will try to address the second research question with quantitative approach:

RQ 2: How do the main drivers of China's RIC differ between transitional phases?

RQ2 is to examine the impact of RIC drivers in different phases in the study period and compare the differences in the impact of these drivers.

By answering RQ2, this research will improve the understanding of the trajectory of innovation system reform in China., The study will show how some innovation strategies and policies work through the change in impact over time. Moreover, employing a quantitative approach will help bridge the gap between qualitative and quantitative approaches, which theoretically enriches the NIS/RIS and NIC/RIC literature in China.

1.2.3 Motivation of RQ3 and intended contributions

China is unevenly developed due to historical accumulation and unbalanced development strategies. Although there are many studies on China's RIS/RIC, (Guan & Liu, 2005; Liu & Chen, 2003; Ma, 2010a, 2010b; Mu, Ren, Song, & Chen, 2010; Sigurdson, 2005; Wu, et al., 2010), they mainly focus on one part of China, for example Southern China (Barbieri, Di Tommaso, & Huang, 2010), or Beijing and Shenzhen (Chen & Kenney, 2007; Guan, Yam, & Mok, 2005; Zhu & Tann, 2005).

Only a few researchers have studied the differences in RIS with consideration of the innovation level of regions (Ji & Zhao, 2008). However, this study investigates the differences between drivers using a qualitative approach, which only shows the differences in the factors among regions, but does not show how influential individual factors are in driving RIC. Therefore, the differences in RIC drivers among regions of different innovation levels are not yet well understood. This leads to the third research question of the thesis.

RQ 3: How do RIC drivers differ among Chinese regions at different innovation levels?

RQ 3 tries to find out how RIC drivers vary in their impact among regions at different innovation levels. This will assist regional governments in developing more effective policies and strategies for improving RIC.

By addressing RQ3 the thesis will contribute to the literature on NIS/RIS and NIC/RIC in China, both theoretically and practically. It will uncover the stories behind the tremendous change in China at the regional level. Besides, exploring the differences in the impact of drivers among regions will add knowledge to IS research in China and provide implications for regional governments and policy makers. Overall, by addressing the three research questions mentioned above, the thesis will enrich NIS/RIS and NIC/RIC literature, provide new insights for IS research, and provide implications for practitioners in China.

1.3 Issues of Research methodology

To answer the research questions the study examines 30 administrative regions in China from 1991 to 2005, employing a quantitative approach. The study will be carefully designed and will address key issues of concern. The important methodology issues are briefly described here and the details will be discussed in following chapters.

The first issue is the research framework. According to NIS/RIS literature there are many elements to be considered. Since it is impossible to examine them all in one study, a simplified framework containing basic but important components has been developed. The basic and key components in an IS are innovation actors, innovation inputs, interactions between components, and the institutional environment of the region (Asheim & Isaksen, 1997; Cooke, et al., 1997; Lundvall, 1992, p. 2; Nelson, 1993, p. 4). These components are all included in the research framework.

The second issue is how to measure RIC and the components in the framework. To measure RIC this research employs the most commonly used proxy, patent counts. Although there are some pitfalls to using patent counts to measure RIC and some alternative measures are available (Acs, Anselin, & Varga, 2002; Fritsch, 2002; Griliches, 1990; Liu & White, 1997), patent statistics seem to be the best available output indicator of innovation activities (Freeman, 2004). A range of other proxies are used for the other components of IS. The number of higher education institutions (HEI) and the number of large and medium sized enterprises (LME) are used to measure innovation actors and financial and human capital for innovation inputs. FDI, international trade and domestic technology transfer are used for interactions between innovation actors. Institutional environments, however, are not in the scope of this study, though they are a crucial factor of RIC.

The third issue is the analysis methods. Following Furman, et al. (2002), a fixed effect model with panel data will be used. Compared to pure cross-section and time-series analysis, panel data models can better control the effects of unobserved variables and uncover the dynamics of change (Baltagi, 2008; Hsiao, Hommond, & Holly, 2002). A fixed effect model allows associations between unobserved variables and observed variables (Allison, 2009; Wooldridge, 2002), which better reflects reality than random effects models. To compare the differences in RIC drivers among groups, hierarchical cluster analysis is conducted to classify regions into groups according to their innovation capacity.

1.4 Summary of Findings

Using fixed effect panel data model and cluster analysis to interrogate the data , some significant findings appeared. In terms of the transitional process of IS reform, the data collection timeframe can be divided into two phases; 1991 to 1998 and 1999 to 2005.. According to cluster analysis, the regions are classified into three groups; high innovation regions (3 regions), medium innovation regions (6 regions), and low innovation regions (21 regions). It showed around two thirds of regions in China were at the low innovation level.

By analysing information from all the regions across the whole time frame, all regions in separate phases, and different groups over the whole period respectively, this research observed the following main phenomena: (1) innovation input and interactions between innovation actors were the major drivers of RIC in China; (2) the impact of a driver differed between radical and incremental innovation; (3) RIC is not only influenced by the drivers alone, but was also affected by the interactive effects between drivers, such as between S&T investment and interactions between innovation actors; (4) the impact of drivers changed over time with the progress of innovation system reform and economic development; (5) the impact of drivers differed among groups at different innovation levels.

Specifically, the impact of innovation actors, LME and HEI, improved over time, and HEI seemed to be more important in low innovation regions than in high and medium innovation regions.

In contrast to the impact of innovation actors, input factors influencde RIC accumulatively in the long term and their impact on radical innovation was greater than on incremental innovation. Economic infrastructure and knowledge stock measured by GDP per capita were crucial under all conditions and their effect was greater in the second phase. Financial capital did not appear to be important in either phase, but it exerted strong influence in the long term. The impact of financial capital in high and medium innovation regions was greater than in low innovative innovation regions. However, human capital made a greater contribution in low innovation regions.

Representing international interactions, FDI and international trade influenced RIC differently. FDI did not turn out to be helpful in improving RIC under any conditions, but evidence showed the impact improved in the second phase. On the contrary, international trade affected RIC positively, except in radical innovation, and the effect was greater and stronger in the later phase. Considering domestic interactions, it seems regions did not really take advantage of domestic technology transfer and there may be a U-shape relationship between the impact of domestic technology transfer and the innovation level of the region.

Other than the impact from the drivers alone, there existed interactive effects between S&T investment and innovation actors, and between FDI and domestic technology transfer. In the long term the moderating role of S&T investment improved and it improved the impact of international trade but impaired the impact of FDI and domestic technology transfer. However, in Phase One, the impact of FDI, international trade, and domestic technology transfer was impaired by S&T investment, and in Phase Two, the impact of FDI and international trade was improved by increasing S&T investment.

1.5 Structure of the Thesis

As mentioned before, this thesis mainly focuses on the major determinants of RIC in China. To examine the research questions proposed in section 1.2, the thesis contains eight chapters and is structured as follows, shown in Figure 1-1.

Chapter One presents an introduction to the study. It introduces the research background, justifies the research questions, briefly discusses the methodology issues, and reviews the findings and contributions of the study.

Chapter Two reviews the literature relevant to the research. This study draws on NIS/RIS and NIC/RIC research conducted all over the world. The review identifies the structure of NIS/RIS, the importance of studying innovation at the regional level, and the determinants found in existing research, which is helpful for developing the research framework of this study.

Chapter Three introduces the innovation context in China. It reviews the transition process of China's NIS and RIS, and the disparity of RIC in China. The review identifies the innovation output is unevenly distributed among regions and the economic infrastructure and innovation capacity are changing over time. These two factors establish the significance of studying RIC in China at the regional level.

Chapter Four describes in detail the issues confronted in the study's methodology. It develops a research model based on the literature of NIS/RIS and NIC/RIC, introduces the research design, presents the sample and data sources, and finally discusses the analysis methods.

Chapter Five elaborates on the estimated results, covering all the regions in the long term.

Chapter Six compares the differences in RIC drivers across two separate stages.

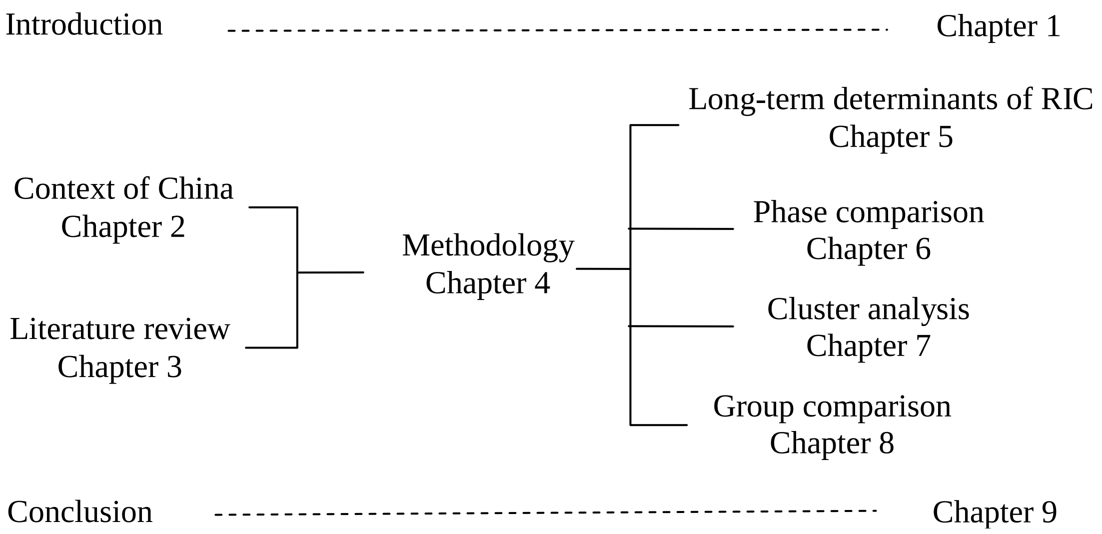
Chapter Seven displays the process of cluster analysis and discusses the results of clustering, preparing for group comparison in the next step.

Chapter Eight addresses the estimated results across different groups and compares the differences in drivers of RIC among groups.

Chapter Nine provides a summary of all the findings, some concluding remarks, and the contributions of the research. It also discusses the limitations of the research and the directions for future research.

The overview of the structure is in Figure 1-1.

Figure 1-1 Thesis Structure



Chapter 2 CONTEXT OF CHINA

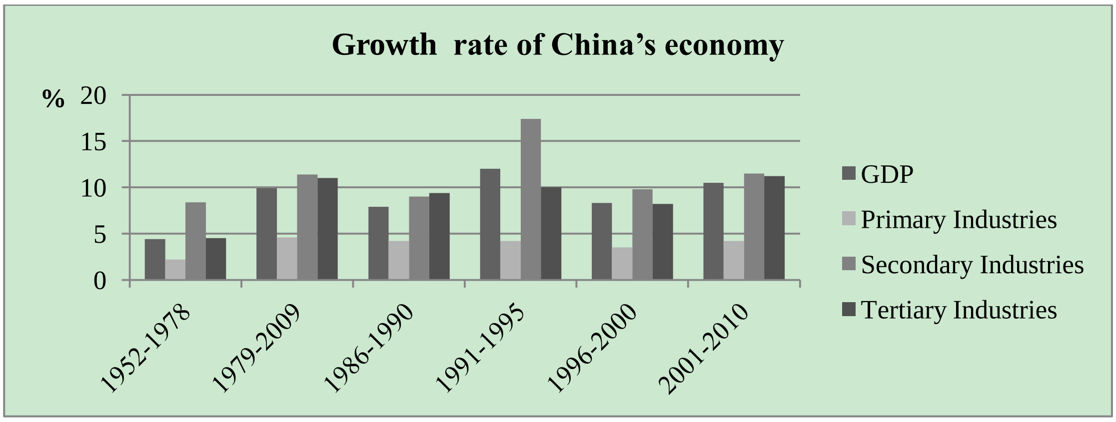
Context is the basis for theorising (Child, 2000). Experiences and theories based on one context may not be adaptable to another. Research findings about innovation systems (IS) and innovation capacity (IC) based on developed countries and European countries cannot explain the phenomenon in latecomers, especially in China. China is different from other economies in the world because of its special historical accumulation and development path. As a starting point for this research, introducing the context will help acknowledge the importance of the research undertaken. This chapter provides some information on China's innovation context. It describes the economic growth and changes of the industry structure in China, followed by the transition process of China's national innovation system (NIS) and regional innovation systems (RIS), and finally the disparity of regional innovation capacity (RIC) among regions.

2.1 Transition of China's Economy

Since its foundation, the People's Republic of China (PRC, referred to as China in the following) has undergone tremendous change. The crucial shift took place in 1978 when Xiaoping Deng initiated economic reform and opened China's door to the world. Before the open door policy China was under a centrally planned economic regime and everything followed the top-down pattern. Since 1978 China has stepped into the market-oriented reform and economic transition under the guidance of a central government, following both a top-down and bottom-up approach, which has led to extraordinary economic development. As shown in Figure 2-1, the economic growth since 1978 was tremendous, though the development speed of the three main industry categories[1] had different trends. The economic structure also changed greatly, shown in Figure 2-2.

Figure 2-1 depicts how low the growth rate of GDP was from 1952 to 1978, compared to the years after. The annual development speed was around 10 per cent from 1979 to 2010, and from 1991 to 1995 it grew to a remarkable 12 per cent. Although the economic growth slowed after 1995, the growth rate was still higher than most countries in the world (WDI, 2005, 2007, 2009, 2011). As for the three main industry categories, primary and tertiary industries grew steadily, while secondary industries share the same trend as GDP.

Figure 2-1: Economic growth rate



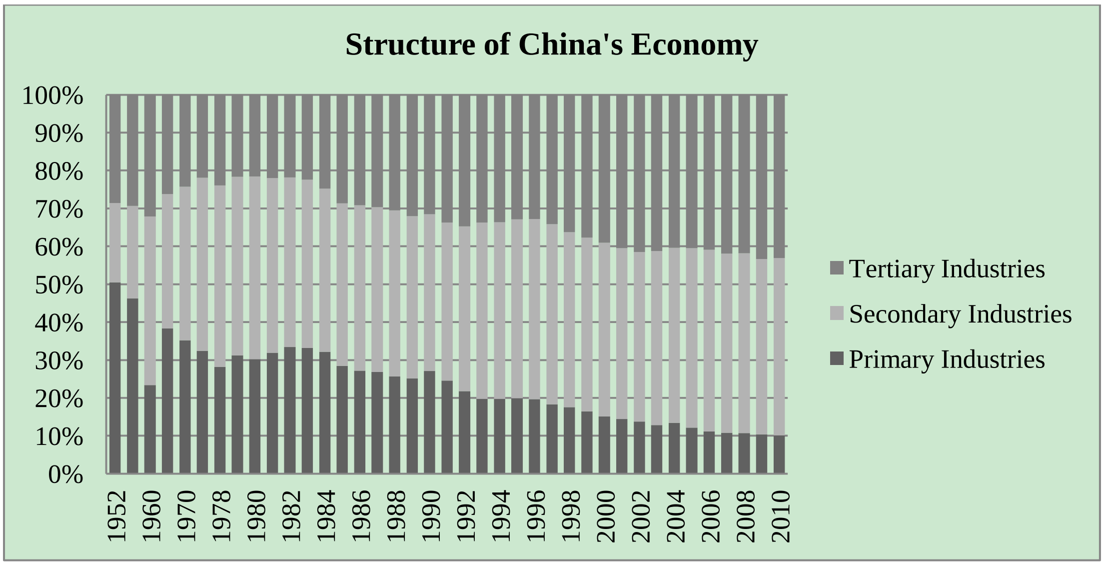
Source: Gu & Lundvall (2006), CSY 2001, 2011

Figure 2-2 shows the economic structure has changed greatly from 1952 to 2010. In the pre-reform stage the contribution of primary industries to GDP decreased from 50.5 per cent in 1952 to 28.2 per cent in 1978. However, the contribution of secondary industries was almost twice the level in 1978 as in 1952. The contribution of tertiary industries first

[1] Three main industries are primary industries, including crop farming, forestry, animal husbandry, and fishing; secondary industries, including extractive industries, manufacturing, production and distribution of electricity, gas, and water, and construction; tertiary industries, including all industries not belonging to primary and secondary industry, for example transportation, finance, education.

increased from 28.6 per cent in 1952 to 32.1 per cent in 1960, and then decreased to 23.9 per cent in 1978. The post-reform stage was dominated by industrialisation (Gu & Lundvall, 2006). The contribution of secondary industries was fluctuating between a low of 41.3 per cent in 1991 and the high of 48.2 per cent in 1980. The contribution of primary industries only increased a little in the first few years of the post-reform stage and then shrank from 33.4 per cent in 1982 to 10.1 per cent in 2010. The contribution of tertiary industries at this stage had been increasing, and in 2010 around 43 per cent of GDP was from tertiary industries.

Figure 2-2: Economic structure of China's GDP at current price



Source: calculated based on data collected from CSY 2001，2011

Overall the initiation of the open door policy brought China opportunities and challenges, and led to China's enormous economic growth as well. Meanwhile, at the pre-reform stage the increase of GDP relied mainly on primary and secondary industries. At the post-reform stage more and more GDP was from tertiary industries, which almost made a contribution equivalent to that of secondary industries in 2010. With the progress of economic reform the economic environment of innovation has been changing.

2.2 Transition of China’s NIS/RIS

In line with the economic reform and transformation, China’s NIS and RIS have been through many changes as well. The reform process of the economic and innovation system in China has been gradual (Bagnai & Ospina, 2009; Chow, 2004; Yang & Li, 2004). Usually, the government undertakes experiments in a specific area and monitors the outcomes to decide whether to extend the reforms nationally (Yang & Li, 2004). Therefore, dividing the development of China’s NIS into several stages since the foundation of PRC helps to identify the process of transformation and the development path of NIS. There are six stages in the process of economic and IS reform.

Stage one is the pre-economic reform phase, from the foundation of PRC to the beginning of economic reform in 1978. During this period the nation was the driving force of innovation, and governments, especially the central government, funded and controlled all innovative activities. The main focus of innovation was on military-related technologies, which was separated from the development of civilian technology (Zhong & Yang, 2007). During this stage almost all innovation activities were independent and there were few interactions between industries, universities, and public research institutes (Sun, 2002). Each technical innovation was to complete the task given by the government. Some outstanding achievements were made during this period, such as the first atomic bomb in 1964, the first hydrogen bomb in 1967, and the first launched satellite in 1970. Under a central-planned economy with a low level of economic development, the government was able to gather resources to conduct significant innovations without wasting caused by duplication (Gu, 2002). To some extent, it suited China's situation at the time.

The second stage is the early phase of economic reform, as well as IS reform, from 1979 to 1985. In 1978, the national S&T conference was held in Beijing and it released *The Outline of National Science and Technology Development from 1978 to 1985* (MOST), which foreshadowed the start of IS reform. Although it showed in the outline China had realised the importance of S&T in economic development, the reform of the S&T system did not eventuate until 1985 when the *Decision of Reforms on Science and Technology System* was released. This *Decision* indicated that IS reform had entered into the phase of comprehensive implementation with better leading and organising. Patent Law also came into force in 1985, which enhanced the protection of innovation. During this stage the government was searching in the dark for direction on IS.

The third stage stretches from 1986 to 1992. With the promotion of reform the role of government, both central and regional, in innovation was transferring from mandatory to directing and the development emphasis was changing as well. Based on the *Decision of Reforms on Science and Technology System*, governments put great effort into building up technology markets to facilitate technology transformation. They also dedicated resources to reshaping the relationship between knowledge producers and users. An excellence-based allocation mechanism was also introduced to re-allocate public R&D funds. The government cut down considerably on research expenditure for universities and research institutes, hoping to stimulate collaboration between universities, research institutes, and industry (Zhong & Yang, 2007). Government-funded S&T activities were reduced from 43.11 per cent in 1990 to 40.76 per cent in 1992[2]. The reduction of government funding for S&T activities reflected the government's intention to progress the reform gradually. Moreover, several programs were launched during this stage, all following the strategy of "building the nation with science and education", reflecting Xiaoping Deng's famous argument "Science and Technology are the primary productive forces" (Li & Li, 2008). In 1986, the government implemented the Spark program to promote rural economic development with S&T, and the 863 program to develop high-end technologies. In 1988 the Torch program was launched to improve high-tech industries. The programs went well and by the end of 1992 52 national high-tech development zones had been established cross the country containing 5569 high-tech enterprises[3]. The new setup of IS development had been formed.

The fourth stage extended from 1993 to 1998. After Xiaoping Deng's tour through south in 1992, the transformation of China's economic reform entered a new era. As for the IS reform, the release of *Decision on Various Issues to Build a Socialist Market Economy* in 1992 shifted the key points of innovation development. During this stage IS underwent important structural adjustment (Song, 2008; Yun, 2009; Zhang & Zhai, 2011; Zhu & Tann, 2009). The reform of both public research institutes (PRI) and HEI progressed. PRI and HEI were given more autonomy and were encouraged to establish links with enterprises through various mechanisms, such as technical service, co-R&D, and technology investment. During this period government funding for S&T activities was fluctuating between 25.96 per cent and

[2] The percentages are calculated by the author according to data from CSYST 1991 and CSYST 1993
[3] Data is from CSYST 1993

27.65 per cent[4] of the total S&T funding invested in China, while funding from enterprises increased from 27.49 per cent in 1993 to 31.12 per cent in 1998. However, the total funding for S&T activities in PRI raised from enterprises decreased from 36.93 per cent in 1997 to 14.72 per cent in 1998, while in HEI, it increased from 42.64 per cent in 1997 to 43.28 per cent in 1998[5]. The reason for the decrease in PRI is probably because of the reform of PRI. PRI were stimulated to transform into or merge with enterprises, which resulted in the reduction of number of PRI. By the end of 1998 the number of PRI was cut down to 5778. Although the change in HEI was slight, it provided a sign the interactions between HEI and enterprises were increasing. Moreover, PRI and HEI were also encouraged to set up their own high-tech enterprises. Researchers and teachers could take part-time or full-time jobs in the enterprises or establish their own high-tech companies while remaining in their positions in PRI or HEI. Those activities led to 16097 high-tech enterprises being established in national high-tech development zones all over the country by the end of 1998 (Zhong & Yang, 2007).

The fifth stage spans from 1999 to 2005. During this period the strategy of “building the nation with science and education” was reaffirmed and the objective of building the NIS was highlighted[6]. At this stage the reform focused on the macro level, which is different from the micro level, especially in terms of personnel in PRI sand HEI in the last stage (Huang, 2010). In 1999 the central government released the *Decision on Strengthening Technological Innovation, Developing High-Tech Firms, and*

[4] The percentages are calculated by the author according to data from CSYST 1993 and CSYST 1999.
[5] The percentages are calculated by the author according to data from CSYST 1998 and CSYST 1999.
[6] Before the concept of NIS was imported, the IS we called in previous stages is basically called S&T system in China, as the IS mainly focused on S&T development.

Realizing Commercialization of New Technologies, which highlighted the emphasis of this stage; strengthening the NIS and accelerating the transformation of S&T achievements. The decision recognised the complex relationships between reforms in the economy, science and technology, education, and innovation (Zhong & Yang, 2007). Therefore, to realise the objectives, innovation actors were encouraged to increase financial investment in innovation activities and collaborate with each other (*The Outline of the Ninth Five-Year Plan of the National Economy and Social Development (1996-2000)*, 1996). The commercialisation of S&T achievements and interactions between innovation actors can be measured through technology market. Although the number of technology contracts did not change much, the value of technology contract increased from 197.91 thousand yuan per contract in 1999 to 585.4 thousand yuan per contract in 2005[7]. Meanwhile, the number of contracts transferred from HEI increased from 12.37 per cent in 1999 to 15.89 per cent in 2005, and contracts from PRI decreased from 25.22 per cent in 1999 to 22.70 per cent in 2005[8]. The decrease seen in PRI was due to the number of PRI being reduced from 5778 in 1998 to 3901 by the end of 2005[9]. These changes indicated that, to some extent, the transformation of S&T achievements and interactions between innovation actors increased during this period, which means that the policies government implemented worked to facilitate technology commercialisation and enhance interactions between innovation actors.

The sixth stage extends from 2006 to the present. In 2006, *Outline of Medium and Long Term Development Plan on Science and Technology (2006—2020)* pointed out

[7] The percentage was calculated by the author according to CSYST 2006.
[8] The percentage was calculated by the author according to CSYST 2006.
[9] Data is from CSYST 2006.

that in order to become an innovation-oriented country, China must develop the NIS and enhance national innovation capacity (NIC), with enterprises as the mainstay, and concentrate on independent innovation. In order to achieve these goals the government created many supplemented policies in S&T investment, for instance, tax incentives, financial support, government procurement, talent training, intellectual property protection, construction of S&T innovation platform. All these opened a new era for the development of innovation in China.

The characteristics of the six stages are summarised in Table 2.1.

Table 2.1 Stages of the transformation of China's NIS

Stage	Characteristic
One: 1949-1978	➢ Centrally planned economy ➢ Focus on military technologies ➢ Few interactions between industries, universities, and public research institutes
Two: 1979-1985	➢ Early stage of economic reform ➢ Preparation for S&T reform
Three: 1986-1992	➢ Concentrate on technology transformation ➢ Reshaping the relationship between knowledge producers and users, and between innovation actors and the government ➢ Re-allocate public R&D funds ➢ Develop high-tech industries by setting up some programs
Four: 1993-1998	➢ Structural adjustment of S&T system ➢ Reform of PRI ➢ Encourage researchers and teachers to work in high-tech industries or build their own high-tech enterprises
Five: 1999-2005	➢ Strengthen the NIS ➢ Accelerate the transformation of S&T achievements ➢ Facilitate interactions between innovation actors
Six: 2006-Now	➢ Develop the NIS with enterprises as the mainstay ➢ Enhance NIC by improving independent innovation

Since the beginning of the open door policy and the economic reform, the central government of China has released a series of policies, laws, programs, and development plans related to innovation development, which are the evidence of the transition process. A selection is listed in Table 2.2.

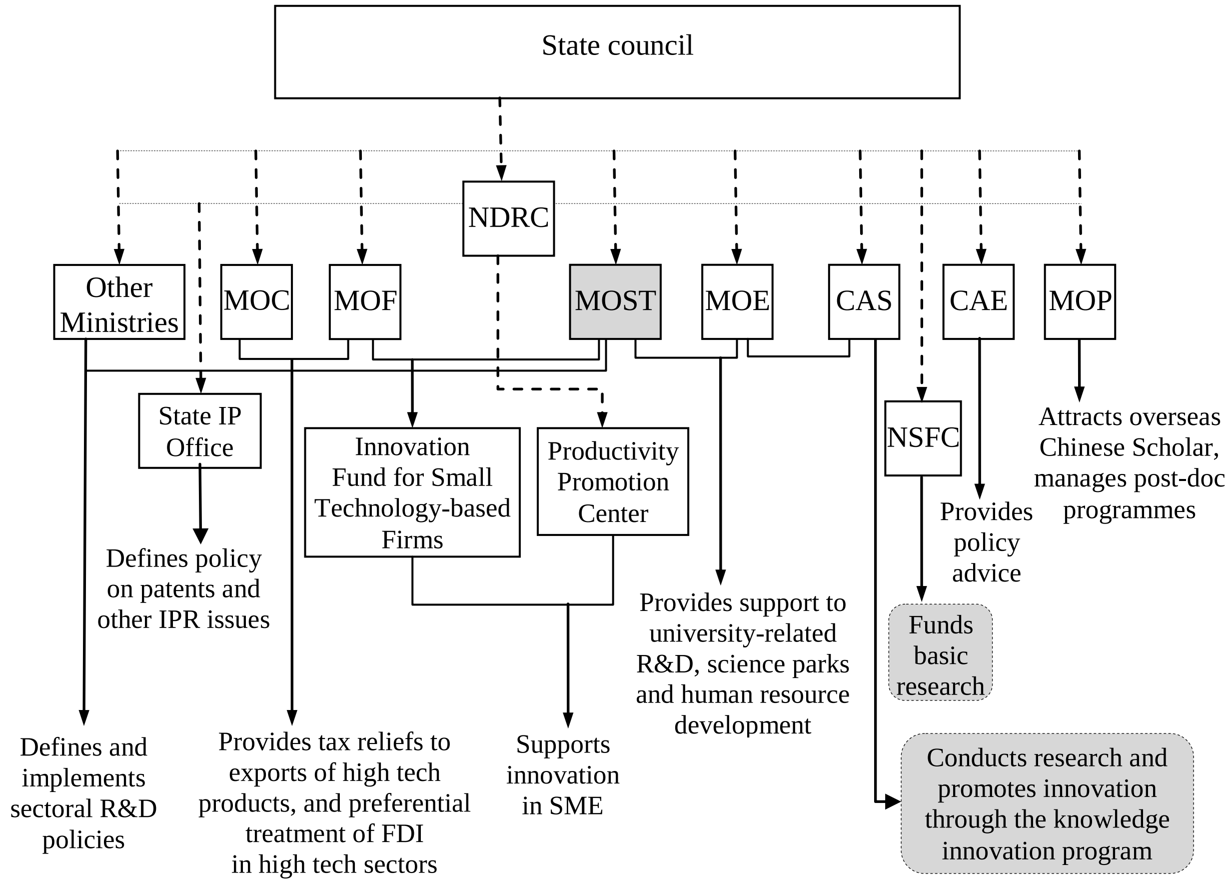
Table 2.2 Selected innovation policies, laws, programs and development plans

Year	Name
1978	➢ Outline of Development Plan on Science and Technology (1978-1985)
1982	➢ Trade Market Law
1985	➢ Decision of Reforms on Science and Technology System ➢ Patent Law (amended in 1992, 2000, 2008)
1986	➢ Development Plan of Science and Technology (1986-2000) ➢ Spark program ➢ 863 program
1987	➢ Regulations of Further Reform on Science and Technology System
1988	➢ Decision of Some Issues about Further Reform on Science and Technology System ➢ Torch Program
1990	➢ Copyright Law
1991	➢ Climbing Program
1992	➢ Outline of Long and Medium-term Development on Science and Technology (1991-2000)
1993	➢ Decision on Various Issues to Build a Socialist Market Economy ➢ Law of the People's Republic of China on Science and Technology Progress (emended in 1997)
1995	➢ Decision on Accelerating the Development of Science and Technology
1996	➢ Law of the People's Republic of China on Promoting the Transformation of Scientific and Technological Achievements
1997	➢ 973 Program
1999	➢ Decision on Strengthening Technological Innovation, Developing High-Tech Firms, and Realising Commercialisation of New Technologies
2002	➢ Law of the People’s Republic of China on Dissemination of Science and Technology Knowledge
2003	➢ Law of the People's Republic of China on Promotion of Small and Medium-sized Enterprises ➢ Regulations on State Science and Technology Prizes
2006	➢ Outline of Medium and Long Term Development Plan on Science and Technology (2006—2020) ➢ The Eighth, Ninth, Tenth, Eleventh Five-Year Plan on Economic and Social Development

Source: OECD Reviews of Innovation Policy China, 2008, and http://www.most.gov.cn

After decades of reform and adjustment the administrative mechanism of China's NIS consist of the following major bodies: the National Development and Reform Commission (NDRC), the Ministry of Science and Technology (MOST), the Ministry of Commerce (MOC), the Ministry of Finance (MOF), the Ministry of Education (MOE), the China Academy of Science (CAS), the National Natural Science Foundation of China (NSFC), the China Academy of Engineering (CAE), the Ministry of Personnel (MOP), and the State IP office. The responsibilities of each department are shown in Figure 2-3. These departments have been replicated at a provincial level for each administrative region.

Figure 2-3 Main administrative bodies of China's NIS



Main tasks of MOST

- Formulated strategies, priority areas, policies, laws and regulations for S&T
- Promotes the building of the national innovation system
- Conducts research on major S*T issues related to economic and social development
- Guides reforms of the S*T system
- Formulates policies to strengthen basic research, high-tech development and industrialisation
- Designs and implements programmes to fund basic and applied research, to induce firms to innovate, to create science parks, incubators, etc.
- Develops measures to increase S&T investments
- Allocates human resources in S&T and encourages S&T talents
- Promotes international S&T cooperation and exchanges

Main tools of MOST

- Core programs: The National Key Technologies R&D Program; the National High-Tech R&D Program (863 Program); the National Program on Key Basic Research Projects (973 Program); climbing program.
- Two group programs (Construction of S&T infrastructures; Construction of S&T industrialization environment).

Source: OECD Reviews of Innovation Policy China, 2008, and http://www.most.gov.cn

The reform of S&T and NIS has been in progress for nearly 30 years and it has produced great achievements. Firstly, the structure of NIS now has multi innovation actors and enterprises as the mainstay (Yun, 2009). Before reform, China's IS mainly relied on PRI and the production system was separated from the market. Now enterprises are the major innovators. In terms of domestic patents granted for non-individual, in 1985 HEI held 56.5 per cent, research institutes accounted for 27.5 per cent, and enterprises around 16 per cent. By the end of 2010 they accounted for 10.2 percent, 3.4 per cent, and 85.1 per cent respectively, and the remaining 1.3 per cent was from other organisations[10]. It suggests that with the improvement of NIS the roles of innovation actors change over time.

Secondly, local technology markets have been built up successfully (Johnson & Liu, 2011) and the industry-university-research (IUR) collaboration system has been initially formed (Li & Li, 2008), which together facilitates the transformation of S&T achievements and interactions between innovation actors. Take technology contract as an example, the value per contract increased from 45.56 thousand yuan in 1991 to 1701.46 thousand yuan in 2010. Reform transformed S&T achievements from pure products into commodities (Fang, 1999). These changes suggest the technology markets have been improved with of IS reform. On the other hand, it also indicates interactions are enhanced between the main innovation actors over time. Overall, the accumulation effects of policies, plans, and programs have gradually improved China's NIS and enhanced China's NIC, as well as RIS and RIC. As described above, the objectives and strategies of innovation development have been changing over

[10] Data is from the State Intellectual Property Office, http://www.sipo.gov.cn/tjxx/

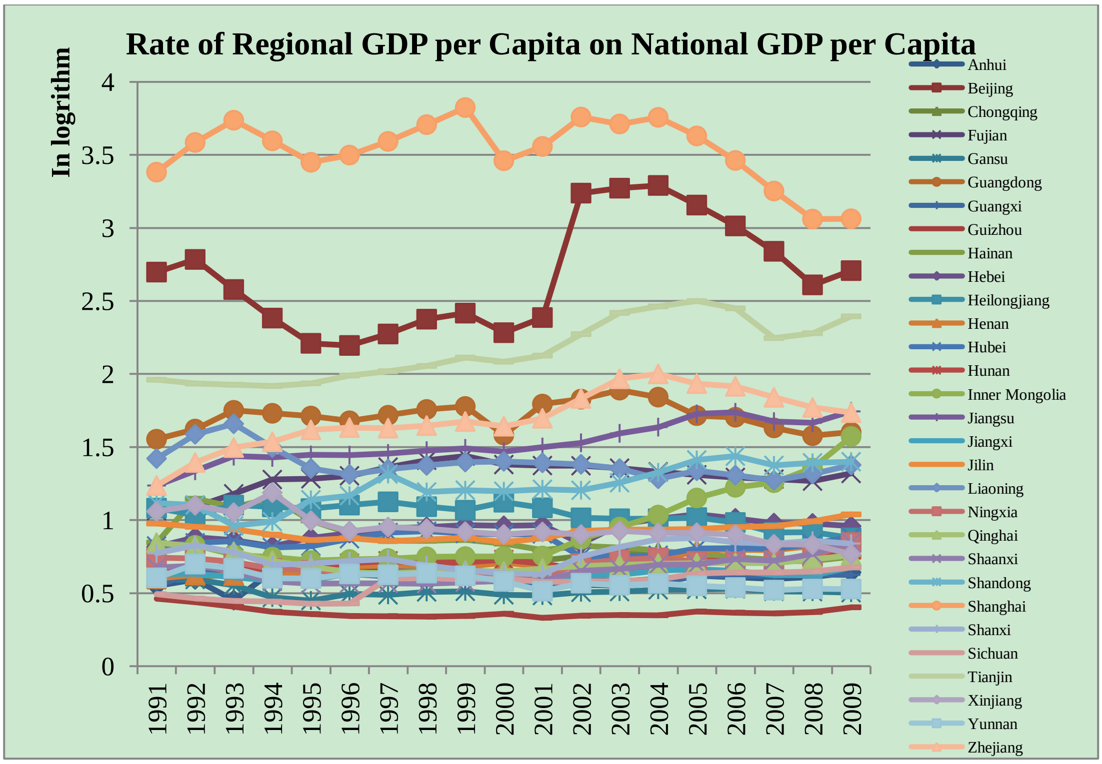
time with the progress of the reform. Meanwhile, it shows the roles of innovation actors have changed. Enterprises are becoming the mainstays instead of PRI, while HEI are starting to take advantage of their research resources to become practitioners as well as educators. Besides, a shift in the source of S&T funds indicates the interactions between innovation actors have been enhanced. Overall, the transformation is continuing and the innovation environment continues to change also during the reform.

2.3 Disparity of China's RIC

Tylecote (2006) argued there are always dual technology systems in transitional countries. One is an upper level innovation system that focuses on advanced technology and the other is a lower level innovation system that is locally embedded. This describes well the situation in China. Although the overall direction of innovation development is under the guidance of central government, the regional governments have autonomy and the inherent impetus of evolution is from micro economic agents (Sun, Peng, Ma, & Zhong, 2009). Hence, the transition process of RIS follows the trend of NIS in China, but RIS differ from each other with their own characteristics.

China has undergone great economic growth, whereas the regions are unevenly developed, as seen in Figure 2-4. Some regions' GDP per capita is much higher than national GDP per capita, while around two thirds of the regions' GDP per capita is lower than the national level. During the period from 1991-2009 Shanghai, Beijing, and Tianjin were the regions with highest GDP per capita. Shanghai was more than three times the national GDP per capita, Beijing was more than double, and Tianjin is between 1.9 and 2.5 times the national GDP. Other regions with better economic performance than the national level include Guangdong, Zhejiang, Liaoning, Jiangsu, Fujian, and Shandong. The remaining regions were mostly between 0.5 and 1 times national GDP per capita; some regions were even lower than 0.5 times, for instance, Guizhou.

Figure 2-4 Rate of regional GDP per capita on national GDP per capita

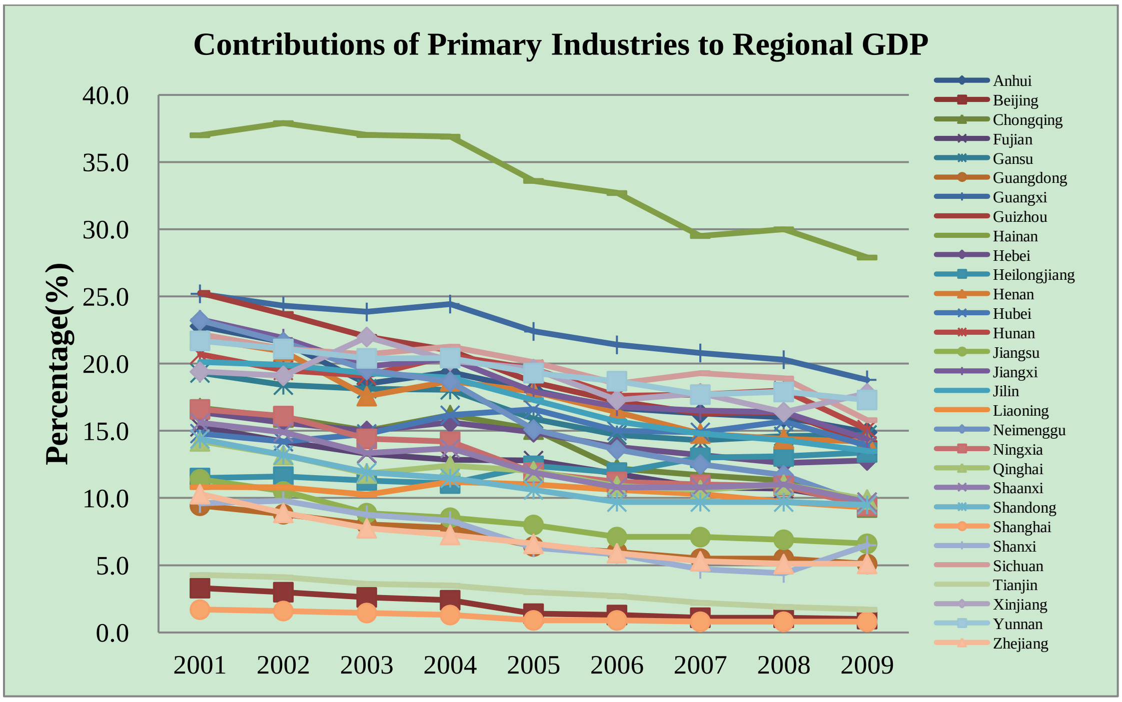


Source: CSY 1992 to CSY 2010

Aside from the disparity of economy development, the structure of industry also differs among regions. Figures 2-5, 2-6, and 2-7 describe the different industry structures of 30 administrative regions in China through the distribution of gross output shares.

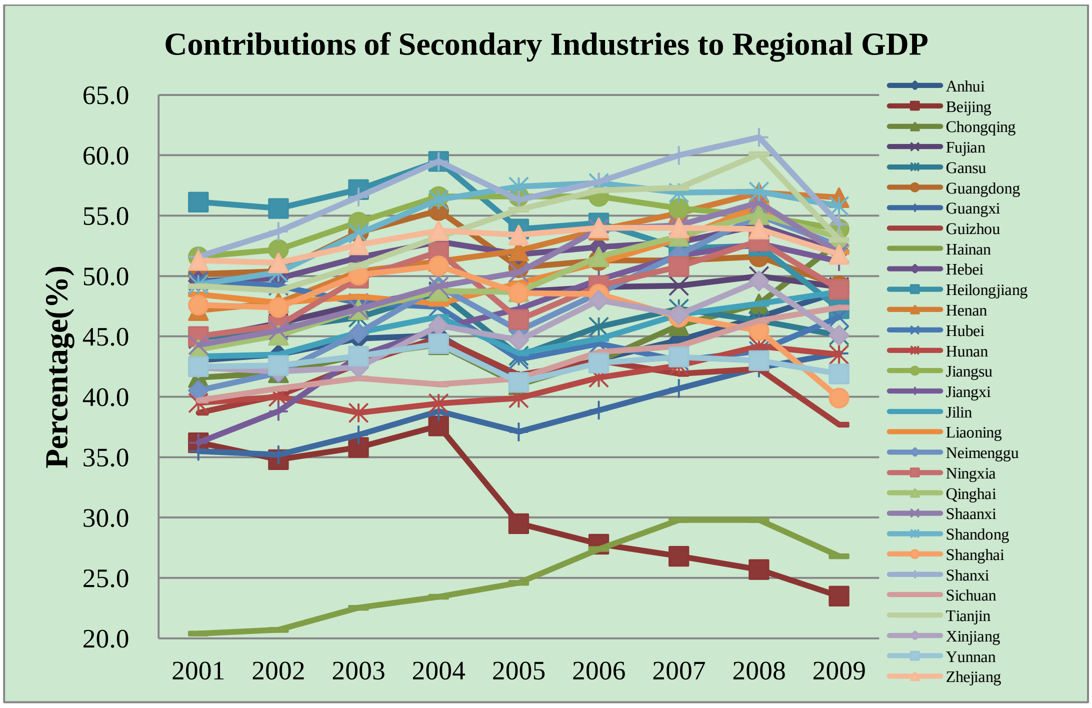
In most regions secondary industries contribute the most to GDP and primary industries contributes the least, which is consistent with the trend of national industrial structure. However, there are great differences in the contribution of the same industry categories to economic development among regions. Moreover, there are some exceptions. In Hainan, the GDP generated by the primary industries and secondary industries is almost even now and tertiary industries now make up half of its GDP. In Beijing and Shanghai the contribution of tertiary industries keeps increasing and it occupies around 75 per cent and 60 per cent respectively.

Figure 2-5 Contributions of primary industries to regional GDP



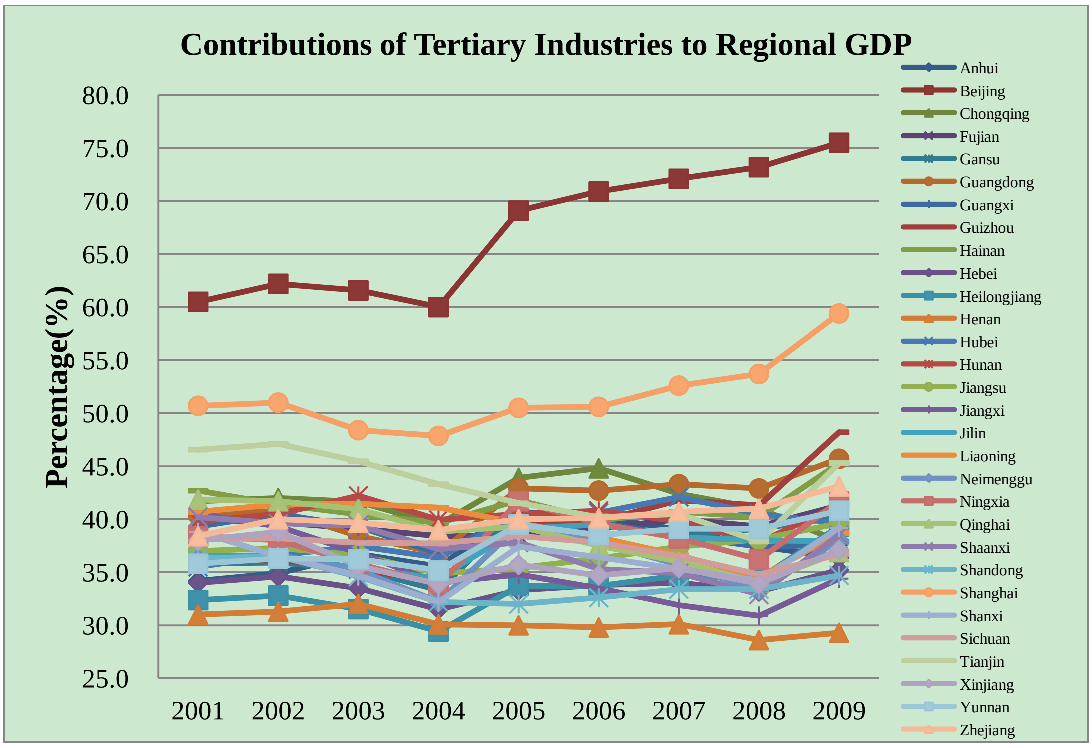
Source: CSY 2002 to CSY 2010

Figure 2-6 Contributions of secondary industries to regional GDP



Source: CSY 2002 to CSY 2010

Figure 2-7 Contributions of tertiary industries to regional GDP

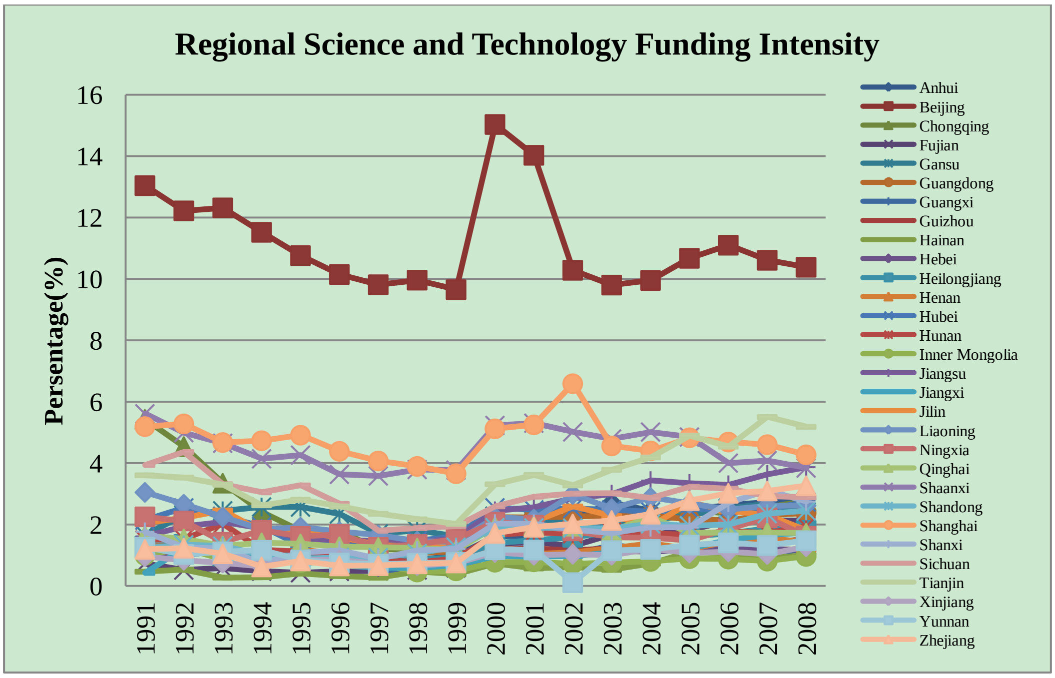


Source: CSY 2002 to CSY 2010

Funding invested in S&T activities, a factor more directly related to innovation development, also differs among regions. As shown in Figure 2-7, Beijing is the most generous of all the regions, and it spends about 10 per cent to 15 per cent of its GDP on S&T activities. Following Beijing are Shanghai, Shaanxi, and Tianjin. Although their intensities are much lower than Beijing, they are still higher than the remaining regions., The S&T funding intensities are also changing over time.

The contribution of each industry category and S&T funding intensity show the economic infrastructures of innovation development differ among regions, as do the efforts the regions put into innovation activities. This suggests the innovation environment and financial input vary among regions. Hence, the overall picture of innovation development in China cannot represent the situation of each region.

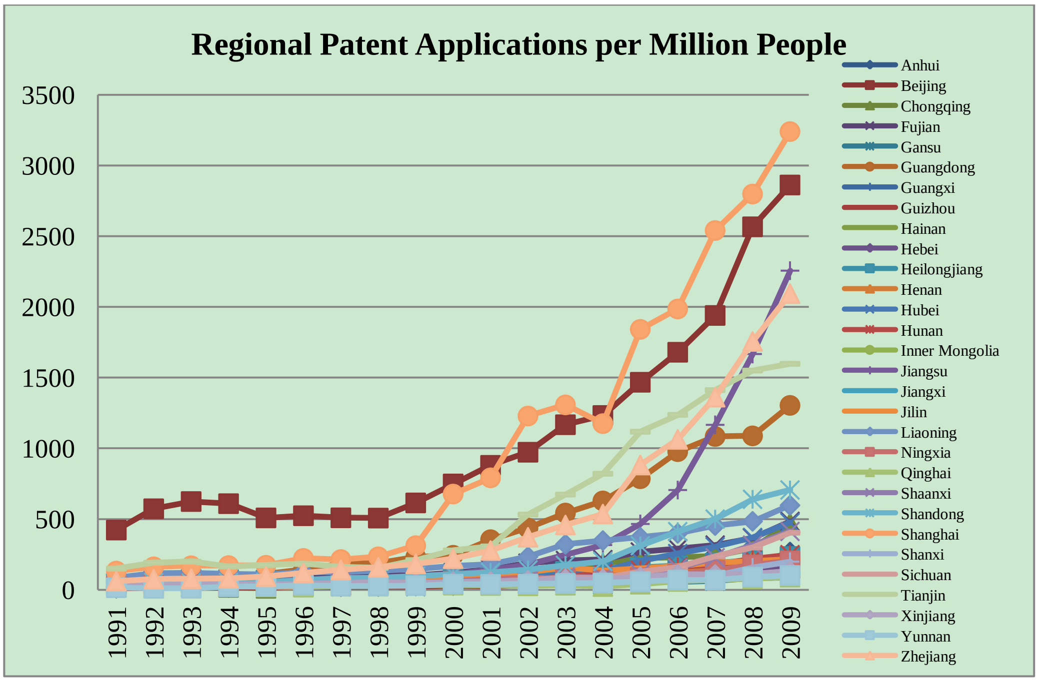
Figure 2-8 Regional science and technology funding intensity



Source: calculated based on the data collected from CSY and CSYST 1992 to 2009

In addition to the economic evidence, the innovation performance of the regions confirms the variation of RIC among regions. Figure 2-9 and Figure 2-10 show for both patent applications and granted patents the number of patents owned per million people in each region is growing at different speeds and the disparities of IC between high and low regions are becoming greater and greater. Take applications as an example; in the early 1990s the difference in patents per million people was quite small, between 10 and 135, except Beijing. However, since 1999 the differences are expanding. The most innovative regions now are Guangdong, Beijing, Jiangsu, Zhejiang, Tianjin, and Shanghai, and Shandong is catching up. Figure 2-11 shows with the rapid economic development and the reform of NIS, the increasing size of China's patent database can be attributed to some highly innovative regions. In 2009, more than 60 per cent of patents granted were from the top five regions.

Figure 2-9 Regional contribution of patent applications[11]



[11] Figure 2-9, 2-10, 2-11 are based on the data collected from various years of CSY and PSY

Figure 2-10 Regional patent grants per million people

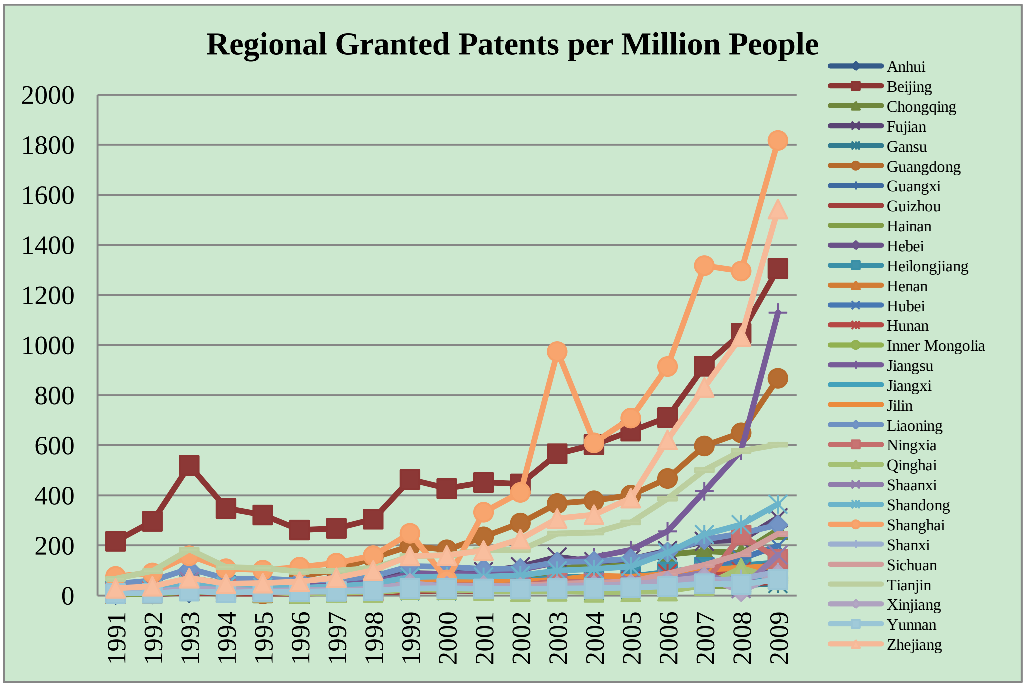
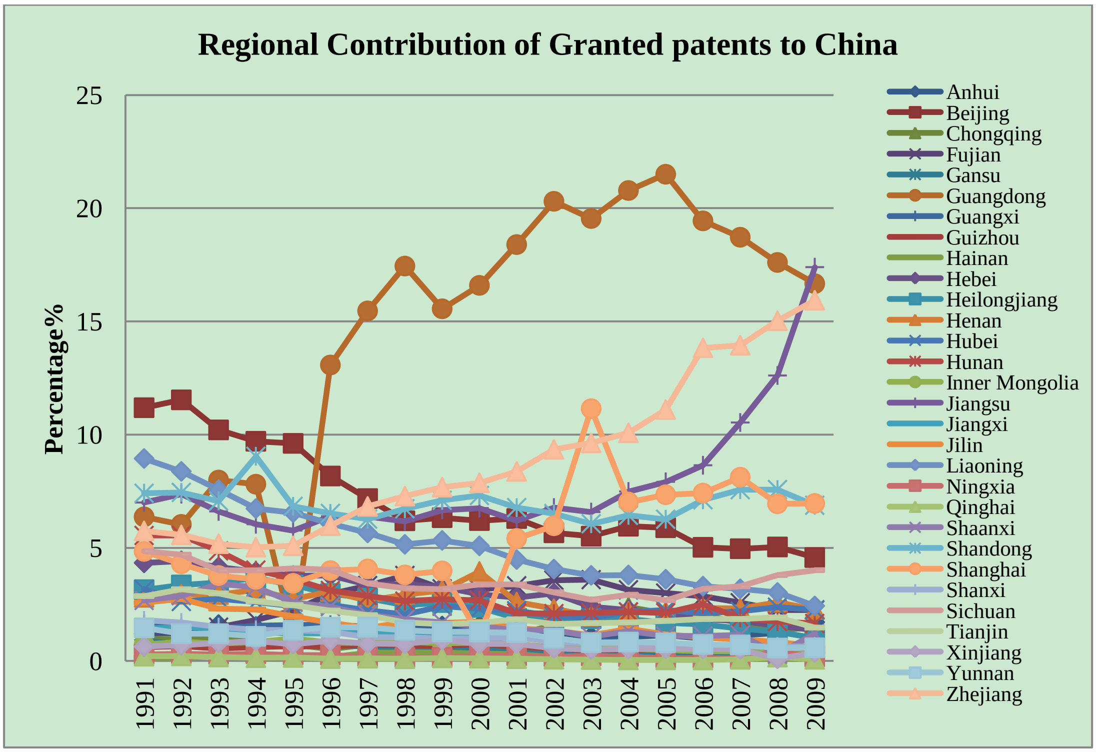


Figure 2-11 Regional contribution of granted patents



From this information on economic infrastructure, S&T effort, and innovation performance, it is clear to see the innovation capacity of regions is unevenly developed in China. Regions that perform best in economic development may not be the most innovative ones, and regions that invest most intensively in S&T activities may not be the most innovative ones either. On the whole, the evidence displayed above shows there are big differences of RIC among regions in China.

2.4 Summary

This chapter briefly reviewed the transitional process of China's NIS/RIS and the disparity of RIC among regions. The evidence showed with the reform of the economy and NIS/RIS, the innovation environment changes over time. Firstly, the roles of innovation actors have changed with the proceeding of IS reform. Enterprises are becoming the mainstays instead of PRI, and HEI act as practitioners as well as educators. Secondly, with the improvement of technology markets and enhancement of interactions among innovation actors, the impact of technology markets and interactions on innovation development is changing as well. Hence, looking at the innovation phenomenon in different phases in a long term, as well as the whole period, will help better uncover the stories during the reform process.

The information based on the regional level indicates innovation output is unevenly distributed among regions and innovation development has strong regional features. This is despite the fact all regions in China are subject to the same legal and political institutions and follow the same transitional process under the guidance of central government. Moreover, the most innovative region may not be the region with the best economic infrastructure or highest S&T intensity. From both the perspective of input and output, we can see there are differences in determinants of RIC among regions. In other words, the evidence suggests that studying IC at the regional level in China is necessary and investigating the variations of determinants of RIC among regions is important for better understanding RIC, as well as improving RIC.

Chapter 3 LITERATURE REVIEW

This chapter sets out the literature review of this thesis, discusses the gap in the literature and outlines the questions the research will address. It is structured as follows. The chapter first refers to some concepts related to RIC, such as innovation, system and innovation system. It then reviews the definition and structure of NIS/RIS and NIC/RIC, by exploring studies on NIS/RIS and NIC/RIC in China. The review then highlights an important gap existing in NIC and RIC literature. Although studies have been conducted to investigate the determinants of RIC based on European countries and some Asia countries, most of them focus on a comparison at the country level. However, the variations in determinants among regions within a country and the changes of drivers over time remain largely unknown. This chapter will discuss these gaps in detail in the following sections.

3.1 Systems of Innovation

To better understand RIC it is important to know its origins and some basic concepts related to it, including innovation, system, innovation system (IS), NIS, and RIS.

3.1.1 The concept of innovation

The widely used notion of innovation was defined by Schumpeter. In his argument innovation means “the commercial or industrial application of something new” (Schumpeter, 1983), such as a new good, a new method of production, the opening of a new market, the conquest of a new supply source or the carrying out of a new organisation of any industry. This is the broadest definition and includes all types of innovation, from, product innovation to process innovation, radical innovation and incremental innovation. From Schumpeter's perspective, innovation is the setting up of a new "production function" (Schumpeter, 1989).

From a narrower perspective, there are a number of innovation typologies of which draw on different classification. Among them, three have gained prominence: product and process innovation (Damanpour & Gopalakrishnan, 2001; Simonetti, Archibugi, & Evangelista, 1995), which is externally or internally based; radical and incremental innovation (Atuahene-Gima, 1995; Kessler & Chakrabarti, 1999), which depends on the newness of innovation; and technical and administrative innovation (Damanpour, 1991), where the former relates to direct technical activities and the latter focuses on management issues.

In the literature on innovation systems, different authors adopt different meanings of innovation according to their research aims. Nelson and Rosenberg (1993) focused on technical innovations, which is only a small part of innovations when using the broad definition. Edquist (2004) stated innovations mean product innovations plus process innovations, while Cooke and Memedovic (2003) argued the definition typically used nowadays is more broad, consisting of all activities associated with the process of technological change.

As such, how innovation is defined and what is included depends on the purpose of the research. In this study, I try to investigate the core drivers of RIC in China and focus more on technological innovations. Hence, innovation in this thesis is narrowed down to technological ones, both radical and incremental.

3.1.2 The concept of system

With regard to the specification of 'innovation' and the delimitation of innovation system, the concept of a 'system' becomes more important. In general, a system is defined as "complexes of elements or components which mutually condition and constrain one another so that the whole complex works together, with some reasonably clearly defined overall function" (Fleck, 1993, p. 17). Basically, a system consists of three main elements, namely components, relationships between components, and attributes as Carlsson et al (2002) summarised. In studies of innovation, systems are used as an analytical tool, it is conceptual rather than operational, which represents a theoretical construct for investigating relationships between variables (Cooke & Memedovic, 2003). Given innovation is an intricate phenomenon, using a systems approach allows for systematic comparative studies of innovation.

3.1.3 The concept of innovation systems

The concept of IS emerged during the 1980s and is to some extent still a new approach for the study of innovation. It first appeared in Freeman's work on technological infrastructure in 1982, which was not published until 2004 (Freeman, 2004), and was originally referred to as a system of innovation. In the published form, the expression was first used by Freeman (1987) in his book on technology policy and economic performance in Japan. Thereafter, many authors studied the concept of IS at a national level (Edquist, 1997b; Lundvall, 1992; Nelson, 1993), til Cooke and his colleagues (1997) adapted it to a lower level, such as regional, local and sectoral. To conceptualise IS two terms have to be defined first; innovation and system.

Based on the definitions of innovation and system, Cooke et al. (1997, p. 478) summarised an IS "comprises elements of consequence to innovation and the relationships amongst them". Elements here are mainly referred to as different organisations, such as firms, universities, research institutes, and agencies. However, Edquist (1997a) considered it in a broader way, arguing an IS should include all important factors that influence the innovation processes, such as economic, social, political, organisational, and institutional factors. Compared to Cooke et al (1997), the elements in this definition include more factors rather than just organisations. Thus, it can be concluded that components and relationships between them are the main points of IS.

A variety of components can be considered part of an IS, but organisations and institutions are always considered to be the major ones (Edquist, 2004). Organisations refer to firms, banks, universities, research institutes, and government agencies, and institutions are the "rules" (Scott, 1995) organisations are embedded in (Hamilton & Biggart, 1988) and have to conform to (North, 1990).

The relationships between components are embodied in their interactions. Because of the interdependence of components, a system is more than the sum of its parts (Blanchard & Fabrycky, 1990). Meanwhile, interactions make the system dynamic and the capabilities of actors shift and grow (Carlsson, et al., 2002). Therefore, at given time and innovation level, the function of the same actor may differ.

Although an IS may be highly structured and seem complex (Considine, et al., 2009), the understanding of the approach is open and flexible (Cooke & Memedovic, 2003). There is no need to assume an IS always consists of tightly linked actors and to expect all innovation systems to include the same actors performing the same function. This may be one reason for why IS is widely used at various levels of innovation analysis. Besides, there are many other strengths of the IS approach, which makes it even more appropriate for RIC studies. Firstly, the IS approach places a central focus on innovation and learning (Edquist, 2004), as they are considered some of the most important activities in NIS (Lundvall, 1992). Secondly, the IS approach emphasises interdependence and non-linearity, encompasses almost all types of innovations, and highlights the role of institutions (Edquist, 2004), which takes the complexity of innovation processes and innovation environment into account.

Just as every coin has two sides, the IS approach can be too complex to yield any valuable insights. Including all the important factors which shape and influence innovations makes the system complicated, however, it also brings openness and flexibility, enhancing its applicability for innovation analysis at multiple levels. The systematic approach can be used to combine and organise the various elements systematically to ascertain the drivers of RIC.

3.1.4 Analysis Level

When conducting a study employing the IS approach, the boundaries or the level of analysis is always the first issue that needs to be addressed (Carlsson, et al., 2002). During the past 20 years, the approach of IS has been applied to various levels, including a national level – NIS (Edquist, 1997b; Lundvall, 1992), regional level -- RIS (Cooke, 2001; Cooke, et al., 1997), sectoral level – sectoral innovation system (SIS) (Breschi & Malerba, 1997), technological system (TS) (Carlsson, 1995, 1997), technology district (TD) (Storper, 1997), industrial cluster (IC) (Porter, 1990, 1998), industrial district (ID) (Asheim, 1996), and innovative milieu (IM) (Camagni, 1991).

A sectoral innovation system (SIS) consists of a group of firms active in a sector and the firms relate to each other through cooperation and competition (Breschi & Malerba, 1997). The firms may be small, scattered geographically and competing between regions or large, competing globally and cooperating locally. Therefore, the sectoral system is really flexible from a geographical perspective.

Technological systems (TS) encompass the interactive activities of the actors within a specific technology area, which is embedded in a particular institutional infrastructure (Carlsson, 1995). TS are multi-dimensional, and may be regional, national, or even global. If a TS is restricted to a national level, it is similar to NIS which Nelson and Rosenberg (1993) defined; if it is confined in one industry, it is much more like an SIS, mentioned above.

Technology districts (TD) are clusters of organisations concentrating on specific industry, congregate in one district (Storper, 1997). TD can be thought of as TS with restrictions on sector and geography.

Industry clusters are “geographic concentrations of interconnected companies and institutions in a particular field” (Porter, 1998, p. 78). Industry districts (IDs) are a social and economic whole rooted in a specific territory (Asheim, 1996). These two approaches are similar to each other.

Innovative milieu (IM) is defined as a set of relationships between economic actors and an industrial culture, occurring in a given geographical area. IM “generates a localised dynamic process of collective learning" (Camagni, 1995). IM emphasises the interactions of actors and interactions between actors and the industrial environment within a territory.

NIS and RIS are the two approaches that have received the most research attention. Literally, the only difference between them is the level they are applied to, one is national and the other is regional. However, a NIS is by no means the simple sum of RIS (Evangelista, Iammarino, Mastrostefano, & Silvani, 2001; Iammarino, 2005). Compared to the other six approaches, these two are more comprehensive and flexible as they encompass more elements with fewer restrictions. The most common issue they both highlight is the importance of interdependencies between components.

There is no right or wrong, no better or worse among the eight approaches, and they are not all alternatives of each other either. Each of them has important contributions in its own way (Lundvall, 2007), and which one is more appropriate for a study depends on the purpose of the research. Choosing to examine the core drivers of RIC, at a regional level rather than a national level, is the best choice for this study. Although one may argue RIS does not exist in every region, to some extent RIS can be found in each region in terms of the research objectives and how it is defined (Asheim & Isaksen, 2002; Evangelista, et al., 2001). Issues related to NIS and RIS will be discussed in the following sections of this chapter.

3.2 NIS/RIS

3.2.1 NIS

3.2.1.1 Definition of NIS

The concept of NIS appeared simultaneously in the academic world and policymaking fields in the 1980s (Sharif, 2006). It was developed to analyse economic growth, taking innovation and learning into account when neoclassical economic thought was inadequate (Lundvall, 2007). Early NIS research was put into a historical, political and cultural context (Balzat & Hanusch, 2004) and historically there are three main stances taken by researchers when conducting NIS studies: historical (Freeman, 2004; Lundvall, 1992), institutional (Nelson, 1993; Niosi, Saviotti, Bellon, & Crow, 1993), and evolutionary (Edquist, 1997b). Nonetheless, in most studies the perspectives were combined to some extent, as the IS approach itself employed historical and evolutionary perspectives (Edquist, 2004). Despite more than 20 years development, a generally accepted definition of NIS is still lacking (Edquist, 2004), with each researcher holding their own viewpoint on the meaning of NIS.

NIS was first formally defined by Lundvall (1992), focusing on knowledge and process of learning. Next it was redefined by Nelson (1993), focusing on the analysis of institutions and how countries set up their NIS, and finally by Edquist (1997b). The first two definitions are based on an institutional perspective while the last uses an evolutionary perspective. Consequently, the two main definitions of NIS are:

"It is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation state". (Lundvall, 1992, p. 2)

"The NIS is a set of institutional actors that, together, plays the major role in influencing innovative performance". (Nelson, 1993, p. 4)

From Lundvall's (1992) perspective, NIS is comprised of elements such as innovation actors and institutions, and their relationships in the production, diffusion and use of new knowledge within the borders of a nation. Nelson's (1993) definition focuses more on the role of institutions in innovation activities. Differing from the previous two definitions, Edquist (1997a) argued NIS could be defined by identifying the determinants of innovations. Hence, in a broad way, NIS includes all parts and aspects of economic structure and the institutional set-up which may influence the development, diffusion, and use of innovations. In other words, NIS consists of several sub-systems, such as an education and training system, production system, marketing system, and financial system (Lundvall, 1992). At the very least organisations and institutions involved in innovation should be included. Consistent with the sub-systems mentioned above, organisations can be, for example, governments, universities, R&D departments, firms, banks, and financial agencies. The major functions of these institutions are policy formulation, promotion of human resource, performing R&D activities, financing R&D, technology bridging, and promotion of technological entrepreneurship (Chang & Shih, 2004). Accordingly, the

NIS approach highlights the importance of interactions and the role of nation-based institutions in national innovation performance (Asheim & Coenen, 2006).

In this study a broad definition is adopted. NIS consists of all the factors that may affect innovation activities, such as innovation actors, institutional environment, the interactions between innovation actors, and between innovation actors and institutional environment.

3.2.1.2 Analysing perspectives of NIS

As mentioned above there are three main perspectives in the literature of NIS; historical, institutional, and evolutionary.

A historical perspective is natural (Edquist, 1997a). The entire innovation process is always long, from invention to production, to commercialisation, and to widespread diffusion. Founded on a more historical theory of innovation, Lundvall (1992) demonstrated differences in historical experiences, language, and culture influence innovation performance. The norms and values related to the historical trajectories also affect the efficiency of a system. His argument showed the importance of historical accumulation in innovation processes. In Nelson's (1993) book the historical dimension was also stressed in some cases (Edquist & Lundvall, 1993).

Institutional perspective is another main school of thought. The definitions of NIS presented above all considered institutions as main elements. However, researchers use the term 'institution' in different ways. In Nelson and Rosenberg's (1993) study, institution means different kinds of organisations related to innovation, while in Lundvall's (1992) institutions were considered as "routines" and "guide-post for action" (p. 10). No matter what exactly institution means, they both highlight out the importance of innovation actors and institutional environments in the innovation processes.

The last approach is an evolutionary perspective, which is based on the evolutionary theories. The ability of evolutionary theories to explain NIS stems from the Schumpeterian emphasis on the role of innovation (Saviotti, 1997), which is at the centre of NIS (Edquist, 1997a). Evolutionary theories emerge from the convergence of several disciplines (Saviotti, 1997), interested in the process of change, the institutions which shape incentives and transaction costs, and understanding processes of institutional and organisational learning (Cooke, et al., 1998; McKelvey, 1997). Therefore the focuses of the evolutionary perspective and the infrastructural framework are on the role of agglomeration factors in innovation processes and the importance of institutions and interactive learning. The scale of the evolutionary perspective is larger than the previous two, and to some extent, the evolutionary perspective includes parts of institutional analysis of IS.

Although the three perspectives have different focuses, there are some similarities among them. Firstly, all perspectives refer to the important role institutions play in the innovation process. Secondly, they all highlight interactions and learning as the key elements of innovation systems.

To conduct a longitudinal empirical study on RIC, it is wise to combine the three perspectives together according to their specific emphasis. For example, the importance of historical accumulation from historical perspective, the roles institutions play from institutional perspective, and the process of change and interactive learning from evolutionary perspective.

In addition to NIS, RIS is another approach for IS studies (Lundvall, 1992). For huge countries, study of RIS is even more important and useful than NIS (Edquist, 2004). The following will show what RIS is and the differences between NIS and RIS.

3.2.2 RIS

3.2.2.1 Importance of RIS

NIS is not the only legitimate approach for IS research; RIS is another option. It is difficult to outline the exact distinctions between NIS and RIS in order to establish whether RIS is more important. However, the importance of RIS is recognised by more and more researchers and studies of RIS are attracting even more attention since Cooke et al. (1997) proposed to investigate IS at the regional level as well as at the national and global levels. As a matter of fact, at the emergence of the concept of NIS, researchers had already noted that regions within a nation can also display distinct or idiosyncratic IS (Howells, 1999; Lundvall, 1992). With effective RIS, the NIS of a country could be more easily formed and implemented (Chung, 2002), especially in large countries.

RIS is considered a subset of NIS by Archibugi and Michie (1997), but Howells (1999) disagrees. He maintains NIS is not a simple sum of RIS within a country and RIS is way more than a subset of NIS. To some extent studies at a regional level are more useful than at national level when you consider the following points. Firstly, the NIS focuses on the role of national institutions in innovation activities, while the role of regions is emphasised in providing local facilities and knowledge infrastructure for innovation development (Lu & Etzkowitz, 2008). Local infrastructure is more important for the locally embedded innovation actors. Secondly, de la Mothe and Paquet (1998) observed if one wanted to identify a dynamic system that may stimulate innovation, RIS would be the one. Based on this point of view, they stressed RIS would be one of the most useful meso-perspectives to understand innovation and growth. Asheim and Isaksen (1997) also deemed regions were the most appropriate scale for the increasingly popular meso-level analysis of IS, with the emergence of regionally identifiable innovative activities and the surge of regional innovation policies. Thirdly, Doloreux and Parto (2009) acknowledged innovation occurred more easily with concentration and proximity, and the important elements of innovation processes are becoming regionalised. Therefore RIS could prevent the problem of unfair geographical concentration of technological and economic capabilities, especially for centralised countries. Due to the uneven regional development and regional disparity of innovation performance, formulation and implementation of RIS becomes more important than NIS (Chung, 2002). Besides, innovation intensity varies not only across countries, but also across sub-national regions, like states or provinces (Acs, et al., 2002; Evangelista, et al., 2001; Fritsch, 2002). Finally, taking the regional perspective will reduce the relevance and usefulness of the concept of nationally demarcated innovation systems (Balzat & Hanusch, 2004).

All the evidence stated above shows the importance of analysing IS at a regional level. Literally, the basic distinction between NIS and RIS is the boundary of IS.

Therefore, how to define a region and identify its boundaries becomes the first issue to be clarified in order to understand the rationale of RIS and why it is an appropriate approach to investigate RIC.

3.2.2.2 Region

Region is one of the key concepts of RIS and its definition determines the boundary of RIS (Cooke, 2001). Therefore before defining RIS it is necessary to clarify the concept of a region. In the RIS approach the term region has been applied to a number of scales, such as the country of Denmark (Cornett, 2009), the Canadian province of Quebec (Doloreux, 2003), various cities (Simmie, 2001), and industry districts (Asheim & Isaksen, 2002). What scale is most appropriate depends on the objective of a study.

To define a region, Cooke and Memedovic (2003) proposed four criteria: (1) it has a determinate size, (2) it is homogeneous on some specific aspects, (3) it is distinguishable from bordering areas by a particular association, and (4) it has internal cohesion. Consistent with these criteria, Cooke and his colleagues (1998, p. 1573) described a region as "a territory less than its sovereign state, possessing distinctive supralocal administrative, cultural, political, or economic power and cohesiveness, differentiating it from its state and other regions". In this definition a region is a geographically defined, administratively supported, meso-level unit along different trajectories through combinations of cultural, political, and economic forces (Cooke, et al., 1997), which can intervene and support innovation development. According to Edquist (2004), when defining a region with regard to innovation processes, both administrative boundaries and geographical areas should be considered. From this standpoint the term ‘region’ in RIS is a matter of localised networks with high coherence and inward orientation within a given territory.

3.2.2.3 Rationale of RIS

RIS results from a territorially embedded, institutional infrastructure and a production system (Doloreux, 2002). The development path of the concept of RIS was derived almost entirely from regional science and economic geography (Cooke, 2001). Therefore it relies on three main bodies of research: (1) evolutionary economic theory (Nelson & Winter, 1982), which emphasises the role of uncertainty, (2) systems of innovation (Cooke, et al., 1997), which provide a more holistic approach, and (3) regional science and its explanation of the development of the socio-institutional environment (Doloreux & Parto, 2005), such as agglomeration, urbanisation and industrialisation (Cooke & Memedovic, 2003).

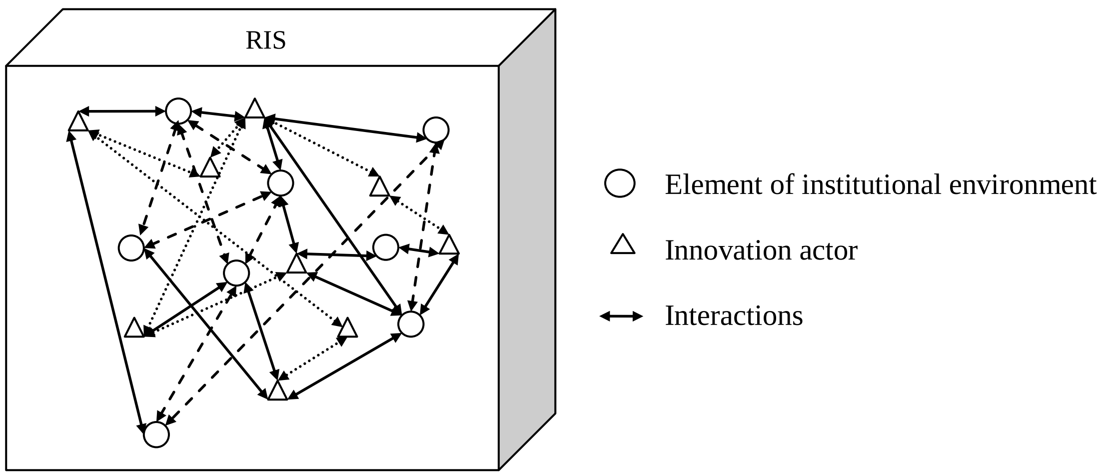
Because of the complex nature of innovation there is no implicit rationale as to the primary focus of RIS studies (Doloreux, 2002). This leads to a combination of existing theories in RIS studies. Innovation is a non-linear and interdependent process (Dosi, 1988) and is the outcome of interactions among multitudes of institutions, such as interactions among firms embedded in a specific context (Hamilton & Biggart, 1988). In such a situation, an evolutionary perspective is helpful in understanding the patterns of change between firms and other organisations, consequently regions and nations. In terms of the geographical disparity of the innovation environment, research and theory on regional science helps to investigate the change of institutional environment (de la Mothe & Paquet, 1998). As far as IS is concerned, it explicitly reorganises the complex interplay among various elements of the innovation processes. Hence, rather than a theory, RIS is a multi-discipline-based analytical approach which aims to capture how technological development takes place within a territory (Doloreux & Parto, 2009; Edquist, 1997a).

3.2.2.4 Definition of RIS

The concept of RIS has been popularly used by academic researchers and policy makers since early 1990s. However, there are no commonly accepted definitions of RIS. Cooke and his colleagues (1997; 1998) point out RIS consist of firms and other organisations systematically engaged in interactive learning, embedded in a specific institutional environment. The linkages among the organisations can be specified in terms of flow of knowledge and information, flow of investment funding, flow of authority and some informal arrangements such as networks (Cooke, et al., 1997). Asheim and Isaksen (1997) state an RIS sits on a production structure and institutional infrastructure. Later Howells (1999) argued RIS encompass a localised network of actors and institutions in the public and private sectors whose activities and interactions generate, import, modify, and diffuse new technologies within and outside the region. In Doloreux's (2003) view, RIS is a set of interactions between private and public interests, formal institutions, and other organisations that function according to organisational and institutional arrangements and relationships conducive to the generation, use, and dissemination of knowledge.

According to the various definitions of RIS mentioned above, RIS is (1) a social system; (2) involves interactions among different sets of actors; (3) through interactions, able to enhance the innovation performance of a region. Therefore the most important elements of RIS are the institutional environment, innovation actors, and interactive activities that connect the former two elements. The system of regional innovation works as all the elements “condition and constrain one another” with “reasonable defined function” (Fleck, 1993, p. 17). In other words, innovation actors generate, use, and diffuse innovation through interactive activities under the specific institutional arrangements within a region (Chung, 2002; Doloreux, 2002; Doloreux & Parto, 2009; Howells, 1999). Hence, institutional environments are the context of innovation, which all innovation activities are embedded in; innovation actors are where the innovations are from and the objects for which institutional arrangements are made; and interactions are the key activities which link innovation actors and institutional environments together. The relationships of the three main elements can be simplified as shown in Figure 3-1.

Figure 3-1 Elements of RIS



Based on the review above, in this study, RIS is defined as a set of innovation actors engaged in the innovation process through interactions embedded in specific institutional environments within a region. It is the application of NIS to the regional level. Although innovation actors are the direct source of innovations, institutional environments would need to be the first element analysed when looking into the determinants of IC. As context is the basis (Child, 2000), we will briefly look at the institutional environment and then the innovation actors, followed by interactions of RIS.

Institutional environment: The institutional environment is the “rules” (North, 1990; Scott, 1995; Scott & Meyer, 1991) individual organisations have to conform to and intend to shape and support human interactions in a society. In relation to innovation it is “the set of political, social, and legal ground rules that establishes the basis” for innovation “production, exchange, and distribution” (Davis & North, 1971, p. 6). In other words, it includes formal written innovation policies, for example, laws and regulations, and the invisible rules.

The institutional environment influences innovative activities. The institutional environment is deeply involved in the process of innovation (Considine, et al., 2009; Geels, 2004) and innovation actors are embedded in the institutional environment (Doloreux, 2002; Hamilton & Biggart, 1988). Warshaw and his colleagues (1991) summised the outcomes an organisation produced, to a great extent, depended on the environment, from which it can be inferred the innovative performance of an organisation is greatly affected by institutional environment. As Scott (1987) stated, institutional environment is one of the resources for shaping a form of power to impress organistations’ behaviours, no matter whether it may constrain innovation activities by limited scope of choices with political and economic incentives (DiMaggio & Powell, 1983), reduce risks and uncertainties with regulations (van

Waarden, 2001), or make it easier for innovation actors to access resources (Oliver, 1997). Hence it is necessary to take institutional environment into account.

The invisible rules of the institutional environment, which are not in the scope of this study, are formed with cultural, social and market backgrounds and they cannot be directly observed and measured (Scott, 1995). The formal written rules, such as laws and public policies, generally called innovation policies, are developed by governmental bodies and official authorities (Anderson, 2010), namely different government departments and their agencies. These policies guide the day-to-day activities of innovation actors within the system, carrying historical experience (Kuhlmann, Shapira, & Smits, 2010).

In the formation of the institutional environment of innovation systems, government is in a central position as it is the policy maker. Some scholars even argue political interventions shape the institutional environment of innovation systems (Kuhlmann, et al., 2010), which again shows the important role of government in innovation development.

Innovation actors: In RIS, innovation actors mainly refer to the organisations who generate innovations directly, namely firms, research institutes, universities, and government agencies (Cooke, et al., 1997; Doloreux, 2002). In the system, each actor has its fundamental role. Firms generalise productive activities (Etzkowitz, 2008); research institutes most frequently influence the generation and development of new ideas for innovative firms (Fritsch & Schwirten, 1999), and serve as technology incubators (Chen & Kenney, 2007); universities preserve and transfer knowledge (Iammarino, 2005; Mathews & Hu, 2007), and provide human capital (Chen &

Kenney, 2007); and some government agencies generate and diffuse innovations, others guarantee innovation policies (Etzkowitz, 2008). Besides the basic tasks, each of them “takes the role of the other” according to the Triple-helix theory (Etzkowitz, 2008).

Another important role of innovation actors is to be a rule-follower. They are the objects of all innovation policies. Innovation policies establish the context for innovation development (William & Balaji, 1979) to improve the innovation capacity. As innovation actors are innovation generators and diffusers they are the subjects innovation policies want to affect in order to achieve the government’s innovation development objectives. On the flip side, following the government’s innovation policies helps innovation actors get more resources and support for innovation activities (Oliver, 1997). Obeying the laws also helps protect and promote their innovations and pursuing the directions government prioritises helps them seize more opportunities for long-term development. Therefore, the influences between innovation policies and innovation actors are two-way. To look into the determinants of RIC, innovation actors cannot be ignored.

Interaction: Interaction is acknowledged as the key activity in the innovation process as it is the process by which innovation actors connect to each other and produce innovations (Cooke & Memedovic, 2003). The main interactive activities are collaboration, competition, transaction, and networking (Edquist, 2004). They lead to information flow, knowledge flow, capital flow, and personnel mobility (Chang & Shih, 2004; Cooke, et al., 1997), which result in innovation. In other words, innovation is not an isolated outcome of one organisation or individual, it is the result of interactions with resource providers, competitors, cooperators and government (Cooke & Memedovic, 2003). The better the collaborative relationship is, the more novel the industry innovation will be (Guan, et al., 2005).

A region's innovative capacity depends not only on the innovative capacities of organisations, but on their interactions with each other and the public institutions in a region (Doloreux, 2002), as interactions make the capabilities of actors shift and grow (Carlsson, et al., 2002). The greater the interactions among components of a system, the more dynamic and flexible the system is and the more sustainable the changes in the environment will be (Carlsson, et al., 2002). Moreover, the effect of innovation policies is determined to a great extent by the degree of the interaction between industry and regulatory authorities (Rothwell, 1992), which means interaction may influence the change of institutional environment in which innovation actors are embedded as well.

The review above shows the importance of interaction in the development of RIS; it joins innovation actors and innovation policies together. Meanwhile, the interactive activities improve the innovative capacity of the system and contribute to the effectiveness and improvement of innovation policies. Thereby, interaction is another factor that should not be neglected when investigating RIC.

3.3 RIC

3.3.1 Concept of RIC

Innovation capacity (IC) is defined as an actor's ability to create competitive advantage through innovation activities by sensing the changes in the environment and exploiting existing resources and competencies (Teece & Pisano, 1998). In short, it is the capability of an actor to make an innovation. RIC, as the name implies, is the innovation capacity of a region. Similar to the relationship between NIS and RIS, RIC stems from the concept of NIC and is the application of NIC to the regional level.

NIC is defined by Stern, Porter and Furman (2000, p. 1) as "the ability of a country—as both a political and economic entity – to produce and commercialise a flow of innovative technology over the long term". This definition is based on Romer's (1990) endogenous growth theory, Porter's (1990) cluster theory of national industrial competitive advantage, and Nelson's (1993) research on NIS. The framework of NIC consists of three main parts; common innovation infrastructure, the cluster-specific innovation environment, and the quality of the linkages among them. In the definition of NIC (Furman, et al., 2002; Porter & Stern, 2002; Stern, et al., 2000), "potential" and "commercialisation" are the core, which differentiate innovation capacity from pure scientific and technical competitiveness.

Based on the definitions of IC and NIC, Tura and Harmaakorpi (2005) defined RIC as the ability of regional innovation networks to exploit existing resources to create a sustainable competitive advantage by conducting innovation activities in the constantly changing environment. In other words, RIC is the joint innovation capability of all innovation actors within a given region. It is formed from the innovative capability of individual actors and innovation networks taking part in the RIS. The overall innovation capability of a region can be expressed both in practice and potential (Giovanni & Antonio, 2008).

In Stern, Porter, and Furman's (2000) framework, the NIS, a system of innovation actors and institutional environments engaged in the innovation process through interactions (Edquist, 1997b; Lundvall, 1992; Nelson, 1993), is the infrastructure of NIC. Correspondingly, the RIS, which derives from NIS, can be considered as the infrastructure of RIC. Following various definitions, RIC in this study means the joint ability of innovation actors within an administratively independent region to produce a stream of commercially relevant innovations long term.

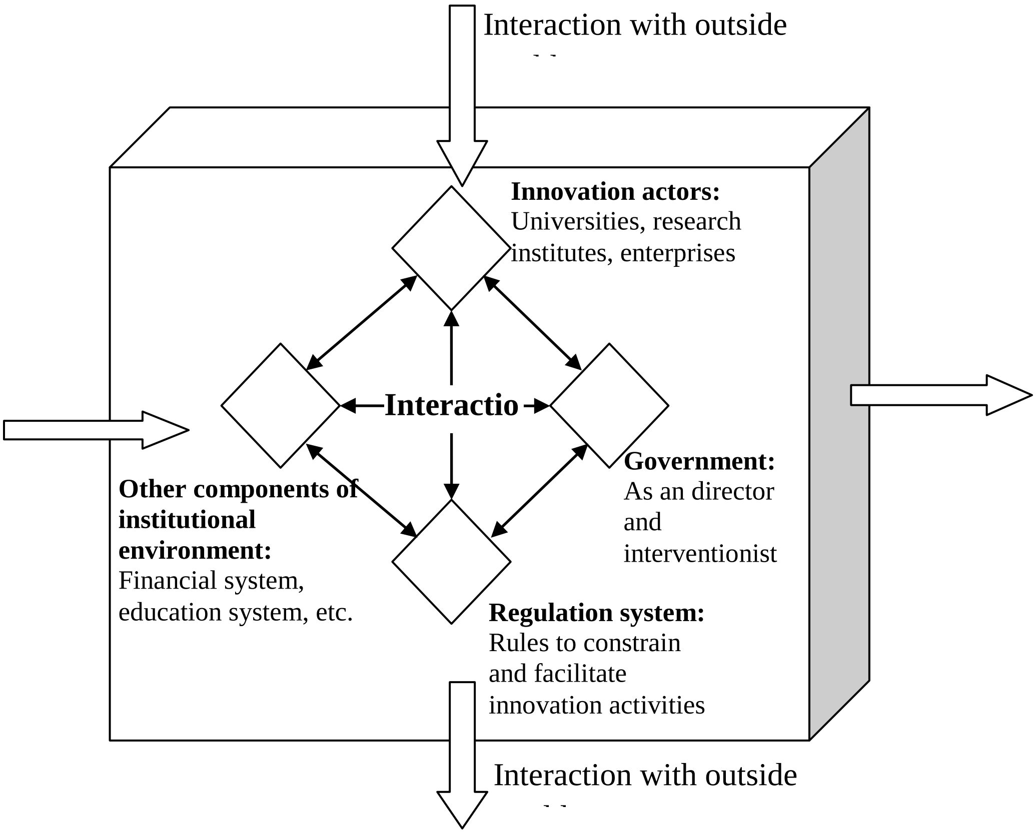
3.3.2 Relationship between RIC and RIS

The review of RIC and RIS shows there is a tight relationship between them. Firstly, RIS is the infrastructure of RIC and RIC can be considered as the innovative capability of RIS. The concept of RIC stems from NIC, while RIS is the application of NIS at the regional level. Meanwhile, research on NIS is one of the theoretical foundations of the framework of NIC (Stern, et al., 2000). Therefore, it can be inferred that RIS is one of the sources of RIC.

Secondly, RIC depends on the settings of RIS. Giovanni and Antonio (2008) noted three main dimensions would affect RIC; regional stakeholders, networking, and local context, while RIS outlines how to establish them up in the innovation processes (Asheim & Isaksen, 1997; Cooke, et al., 1997). The following shows the evidences for this argument. (1) Effective institutional settings and interactive learning between major actors within RIS are very important for generating innovations (Chung, 2002), which are the core of RIC. (2) Specific factors of the regional innovation environment are able to influence the technological performance of different regions and the dynamics of regional patterns of technological specialisation (Evangelista, et al., 2001), thus affecting the regional innovation efficiency (Li, 2006). (3) The density and quality of the network in a certain region decisively influences the innovation activities of the region (Fritsch, 2002), which then affects the regional innovation performance. (4) In the broadly defined notion of NIS, it can be determined the structural and functional profiles of a nation determine its innovative capability and economic performance (Park & Park, 2003). This is also true at the regional level. (5) The region's competitiveness, which encompasses innovative competitiveness, depends on the innovative capacity of firms, science, industry policy, and RIS as a whole (Evangelista, et al., 2001; Freeman, 2004).

Accordingly, to a great extent, the improvement of RIC rests on the development of RIS. In terms of the literature on RIS and RIC discussed above, the relationship between RIS and RIC can be interpreted as Figure 3-2 shows. A RIS can be seen as a container and the contents inside, like innovation actors and the institutional environment, form the innovation system by interactive innovative activities within and between each group of elements. The size of the container can be considered the innovation capacity, which results from the conjoint innovation capabilities of each element within it.

Figure 3-2 Relationship between RIC and RIS



Other than the close relationship between RIS and RIC, there are some differences between the two approaches. The NIS/RIS studies focus on understanding the relationships, processes, structures, and dynamics of the innovation system (Cooke, et al., 1997; Cooke, et al., 1998; Lundvall, 1992; Nelson, 1993). The main empirical tool of NIS/RIS research is case studies and comparative case studies (Archibugi, 1996; Edquist & Lundvall, 1993; MacDowall, 1984; Mowery, 1998; Radosevic, 2000). However, the primary objective of NIC/RIC is to understand the determinants of IC and how much different factors matter for driving IC (Furman, et al., 2002). Therefore quantitative methods are mainly employed for empirical studies (Boeing & Sandner, 2011; Hu & Mathews, 2005; Li, 2009; Yam, Lo, Tang, & Lau, 2011). In terms of the differences in objectives and empirical tools employed by these two approaches, as well as the objective of the thesis, this research will mainly focus on a quantitative approach.

3.3.3 Determinants of RIC

In previous studies of innovation which employ the system approach, researchers have investigated in depth the origin and characteristics of IS (Edquist, 1997b), components of IS (Nelson, 1993), system performance and evaluation (Autio, 1998), and the conditions of the use of IS as a framework to help develop regional innovation policies (Doloreux, 2002). However, most studies are based on a qualitative approach. Since the emergence of the framework of NIC in 2000 (Stern, et al., 2000), there has been a rush to establish the index system for NIS and RIS (Bao, 2010; Ji & Zhao, 2008; Wonglimpiyarat, 2010), and examine the drivers of NIC and RIC using a quantitative approach (Furman, et al., 2002; Hervas-Oliver & Dalmau-Porta, 2007; Hu & Mathews, 2005; Li, 2009; Porter & Stern, 2002).

In Furman and his colleagues' (2002) framework they divided the determinants of NIC into three categories: (1) common innovation infrastructure, consisting of a common pool of institutions, resource commitments, and policies supporting innovation; (2) particular innovation circumstances, investments, and policies for industrial clusters; (3) quality of linkages between the former two. Based on 17 OECD countries and employing patents granted in United States as the index of innovation capacity, they found NIC depends on the cumulative technological sophistication and human capital in a given economy. An important suggestion from the results is public policy plays a crucial role in improving a country's NIC. They may increase the level of R&D resources, which will in turn lead to the improvement of NIC available to the economy; shape human capital investment, which will result in more trained talents for innovation development; form innovation incentives to facilitate innovation actors to initiate more innovation activities; and improve the quality of the linkages. Therefore, from their study on OECD countries, it can be seen the direct determinants of IC are financial resources and human resources, and the main indirect determinant of IC is public policy, which may influence almost all direct determinants.

Following Furman and his colleagues' (2002) framework, Hu and Mathews (2005) investigated the determinants of NIC in East Asia. Concentrated on R&D inputs, cluster-specific innovation environment, and accumulated knowledge capacity, the study in East Asia obtained some similar findings to the study in OECD countries. They found variations in the rate of patenting across countries are accounted for by patent stocks, levels of R&D manpower, R&D expenditure by the private sector, and industrial specialisation. Moreover, they found public R&D funding was the most important factor.

In addition to the studies mentioned above, other research highlighted some additional influential factors of IC. Defined as innovation potential, RIC will be influenced by both hard and soft infrastructures, such as the information and communication technology infrastructure of the region and the commitment to engendering a culture of innovation (Thomas, 2000). Resources are another important element and the availability of resources for innovation greatly affects innovative productivity (Furman & Hayes, 2004). Tura and Harmaakorpi (2005) argued social capital influenced IC by reducing general uncertainty, transaction costs and coordination costs in the network, and affecting innovation processes. Giovanni and Antonio (2008) stated knowledge-based capital would selectively influence RIC. However, Guan and Liu (2005) demonstrated innovative inputs are not the most important, RIC is determined to a great extent by the interaction between the actors involved in the innovation process. Last but not the least is government policies. Actually, government policies are a key factor in sustaining high levels of NIC, as they can ensure a better economic framework for conducting business, enhance the national knowledge platform and consequently to improve the IC (Hervas-Oliver & Dalmau-Porta, 2007).

In summary RIC will be determined by not only the broad-defined institutional environment and the achievability of variety of resources, but also by how innovation actors use them and interact with them and the interdependencies between the actors.

3.4 China's NIC/RIC

China has undergone extraordinary changes on economic development as well as the innovation system. However, before the reform on science and technology started in 1985, there was not exactly an innovation system in China, it is more appropriate to call it a S&T system. An IS consists of elements of consequence to innovation, such as firms, universities and research institutes, as well as economic, social and institutional factors, and the relationships between the elements (Cooke, et al., 1997; Edquist, 1997a). But before the S&T reform, China focused on developing scientific technologies and innovations which mainly relied on research institutes. Meanwhile there were few interactions between different innovation actors. Therefore, strictly speaking, there was no innovation system in China at that time. With the progress of the S&T reform, the IS has been gradually built up.

During the process of IS reform, FDI was one of the main focuses of policies and strategies established to improve independent innovation. Since initiating the open door policy in 1978, China has greatly encouraged inward FDI. But the inflow of FDI was low until China opened further to FDI, permitting joint ventures in the early 1980s and wholly foreign-owned enterprises in the 1990s (Lin, Liu, & Zhang, 2009). Through FDI policies China promotes technology transfer to China by encouraging FDI flow to cutting-edge and technology-oriented industries and building local R&D centres (Long, 2005). The question of whether inward FDI in China promotes innovation has been studied in recent years and will be reviewed later in this section.

With its extraordinary economic growth and growing importance to the world economy, China attracts the attention of researchers from all over the world and across many fields, including research on NIS/RIS and NIC/RIC. There are many studies on NIS/RIS and NIC/RIC conducted in China and they investigate various issues.

The first is the reform and the structure and dynamics of innovation systems, which follows the major objectives of studies on NIS/RIS in other contexts. Researchers introduced the major phases of the reform, the innovation strategies and policies implemented to improve NIS/RIS, the changing of roles of practitioners, and the achievements of the reform (Gao & Tisdell, 2004; Gu, 2002; Sun, 2002; Xue, 1997; Zhong & Yang, 2007; Zhu & Tann, 2009). They also investigated the changing structure and dynamics of China's IS (Liu & White, 2001a; Sun & Liu, 2010; Xue, 2006; Zhang, 2007). These studies clarify the transitional process of China's IS and add knowledge to the literature of NIS/RIS, which is mostly developed in Western economies. The main empirical tool of these studies is case studies, with most employing a qualitative approach.

The second is about the performance of NIS/RIS employing quantitative approaches. Researchers found innovation performance is unevenly distributed in China and the regional contribution to national innovation has been changing over time (Liu & Chen, 2003; Sun, 2000). It is also found that innovations in China are strongly correlated with the regional development level (Sun, 2000), R&D investment is closely related to the differences of regional patenting activity (Liu & White, 2001b; Sun, 2000), and the difference in innovation performance among regions also depends on the diversification of major innovation actors (Liu & Chen, 2003) and international interactions, such as FDI and international trade (Chen, Chen, & Yu, 2007; Cheung & Lin, 2004; Wang & Kafouros, 2009; Xian & Yan, 2005).

The third is the determinants of IC following the framework of NIC (Furman, et al., 2002). At the national level, Hu and Mathews (2005, 2008) found public R&D funding is a crucial factor in China, and universities play a more important role in shaping innovation capacity in China than in other Asian countries.

As innovation performance varies not only among nations, but also among sub-national regions, Li (2009) expanded the investigation of IC down to China's regional level. Based on the framework of NIC Furman and his colleagues developed and the characteristics of China's innovation systems, he investigated factors such as effort of innovation actors, interactions between innovation actors, support from government agencies and financial institutes, interactions between knowledge users and producers, interactions between local innovation actors and innovation actors from other countries, and regional industrial structures (high-tech and light industries). Hence, in this study, Li mainly focused on the interactions of components within and between innovation systems and the innovation environment. However, he did not include FDI, which was found in previous literature to be important in IC development (Chuang & Hsu, 2004; X. Liu & C. Wang, 2003; Tian, 2007). Using the stochastic frontier model with regional level data from 1998 to 2005, this study found accumulated knowledge plays an important role in radical innovation. The study also confirmed the importance of interactions between system components, and discovered universities and research institutes contribute more to radical innovations while firms prefer to patent incremental innovations.

Li investigated the drivers of China's RIC based on the framework of NIC, but there are some important factors missing in his framework. One of the biggest is FDI. There are a number of studies exploring the spillover effects FDI has on innovation development in China. Some of these studies employ the IS approach and some do not. Most of these studies find FDI exerts positive effect in China. Qi and Li (2008) stated FDI is a positive factor in China's knowledge creation and management. With a large dataset of Chinese industrial firms, Lin and his colleagues found (2009) FDI had positive forward spillovers on Chinese firms. At the industry level, Liu and Wang's study (2003)found a positive relationship between technological progress and FDI. Using provincial data Cheung & Lin (Cheung & Lin, 2004) discovered FDI positively affects innovation in China. At the country level, FDI is stated to be critical in upgrading technology in China (Tuan, Ng, & Zhao, 2009). However, negative effects of FDI also exist in China. For example, Xu & Sheng (2012) find negative vertical spillovers of FDI at the regional level. Anwar & Nguyen (2010) propose the effect of FDI on domestic firm would be negative if it brought too much competition. Hence, the findings on the spillover effects of FDI in China are mixed. Although the impact of FDI on innovation development has been studied at various levels in China, it has not been systematically investigated within a RIC framework.

Overall, the core drivers of RIC in China need further investigation and the role of factors such as FDI have in RIS needs further verification. To meet this requirement the first research question of this thesis is:

RQ 1: What are the core drivers of RIC in China? What role do drivers such as FDI play in RIC?

RQ1 tries to investigate the long-term impact of RIC drivers in China, especially the impact of FDI and interactions between innovation actors and between drivers. To answer the question the thesis extends Li's research to long-term and adds FDI and the interactive effects between S&T investment and interaction factors into the framework. This research will enrich the NIC/RIC literature by exploring the long-term interactive effects.

As discussed in Chapter 2, it has been nearly 30 years since the innovation reform started in 1985. The reform process is one of the favoured topics of China's IS and the studies mostly employ a qualitative approach, as discussed above. These studies clarified the transitional process, but did not shed any light on how the impact of drivers differed between phases. To better understand the reform process and bridge the gap between qualitative and quantitative approaches, we propose the second research question of the thesis:

RQ 2: How do China's RIC drivers differ between transitional phases?

RQ 2 examines the impact of RIC drivers in the two phases encompassed by the study period and compares how these drivers impact differently on the two transitional phases. This will deepen understanding of the IS reform in China.

China is unevenly developed and the innovation capacity is unevenly distributed. Li's work investigated RIC across the regions in China, but did not consider the innovation level of the regions. From 2001 to 2007 Ji and Zhao (2008) compared the differences among regions at different innovation levels by scoring innovation related factors and tried to explore the differences in determinants of RIC. However, they did not explain to what extent different factors matter in driving RIC among the regions. Hence, here is the third research question of this study.

RQ 3: How do RIC drivers differ among Chinese regions at different innovation levels?

RQ 3 is designed to identify the variations in the impact of RIC drivers among regions at different innovation levels. This understanding can assist regional governments to develop more effective policies and strategies to improve RIC. It will add knowledge to the literature of RIS/RIC and provide practical implications for governments and policy makers in China.

By addressing the three research questions the thesis will enriches the literature of NIS/RIS and NIC/RIC theoretically and provide practical implications as well.

3.5 Summary

This chapter extensively reviewed the literature related to RIC and brought out the three research questions of the thesis. First it introduced the approach of IS by simply explaining the concept of innovation and systems. Then the levels that innovation systems are applied to were briefly reviewed. Next, the two most favoured approaches in innovation studies, NIS and RIS, were elaborated. According to the literature RIS is the adaption of NIS to the regional level, while the boundary of a region depends on the purpose of a study. Then RIC, which stems directly from NIC and indirectly from NIS and RIS, was demonstrated. RIC is the innovative capability of a region and may be determined by financial inputs, human resources, interactive activities, and public policies. Finally, the studies on China's NIS/RIS and NIC/RIC were briefly reviewed, and it was concluded that systematic studies on RIS/RIC were needed to better investigate the determinants of RIC in China, to further elaborate on the transitional process of IS reform, and to explore the differences in the impact of drivers of RIC among regions at different innovation levels.

Based on the review, three main research questions are highlighted:

RQ 1: What are the core drivers of RIC in China? What role do drivers such as FDI play in RIC?

RQ 2: How do China's RIC drivers differ between transitional phases?

RQ 3: How do RIC drivers differ among Chinese regions at different innovation levels?

Chapter 4 RESEARCH METHODOLOGY

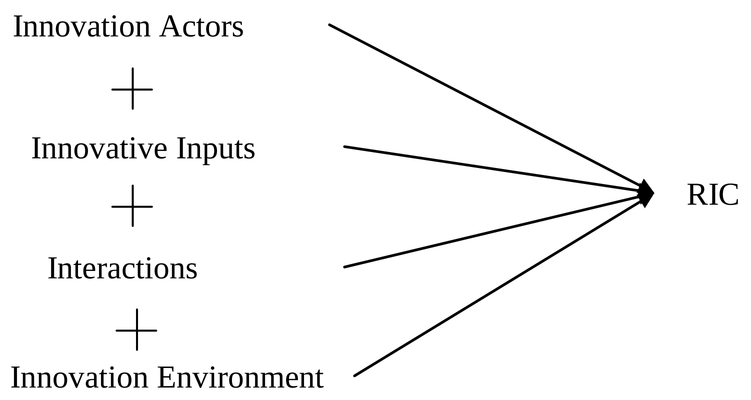
This study aims to answer the research questions "What are the core drivers of China's RIC? What are the variations in drivers of RIC between different phases and among regions at different innovation level?" Therefore, the research conducted in this thesis is designed to investigate the drivers of RIC and explore the variations of these RIC drivers between phases and among regions based in China. This chapter introduces the research design and methods employed. Firstly, it provides the research model and introduces the sources of both qualitative and quantitative data. Secondly, it explains the measures used in the model. Patent counts are employed as the proxy of RIC. Finally, it identifies the suitable methods, panel data regression and cluster analysis, for analysing the data. Panel data regression is to examine the relationships between possible IC drivers and IC indicators and cluster analysis is to classify regions into different groups according to their innovation output and possible drivers to sever group comparison.

4.1 Research Model

When investigating the differences in innovation capacity among countries, Furman et al. (2002) developed the framework of NIC which consisted of common innovation infrastructure, cluster-specific environments for innovation and the quality of linkages between them. As mentioned before, we adopt the concept of NIC and adapt it to the regional level. However, the detailed framework adopted in NIC studies is not directly applicable to the Chinese context, especially at the regional level, because there are inherent differences in IS between developed countries and transitional ones (Gu & Lundvall, 2006; Hu & Mathews, 2005; Liu & White, 2001a). In developed countries firms are the major innovation actors, while this is the case in only some regions of China. In others, universities and research institutes take the lead in innovation activities (Li, 2009). The different roles of innovation actors in the system lead to quite a different NIS structure in China. Even the structure of RIS within China vary from each other. Therefore the specific framework of this study will consider the characteristics of China.

The conceptual framework here is principally based on the literature of IC and IS. In the IS literature innovation actors, institutional environment, and relations within and between the them are regarded as the constituents that form a system (Edquist, 1997a, 2004). In the literature of IC, besides the NIC framework, there are some other models measuring IC, such as ICCI (Oliver & Porta, 2006) and ICRI (Hervas-Oliver & Dalmau-Porta, 2007). They highlight technological infrastructure, human resources, economic performance, government policies, and the linkages are crucial to IC development and upgrading. In Chinese literature on the NIC index, innovation input, innovation infrastructure, and networking are considered as some of the main factors improving IC (CAS, 2009; Ji & Zhao, 2008). Taking both IC and IS approaches into consideration, the simplified framework for this study is formed by extracting the factors that have direct influences from previous studies, shown in Figure 4-1.

Figure 4-1 Framework of RIC measuring



Innovation actors are mentioned as higher education institutions, enterprises, and public research institutes; innovation inputs include the two most important resources, financial capital and human resource; interactions mainly refer to domestic and international interactions between innovation actors; innovation environment means national and regional innovation policies, which is out of the scope of this thesis; and innovation output represents the IC of a region.

4.2 Data Collection

4.2.1 Sample selection

There are 33 administrative regions in PRC, including 22 provinces: Anhui, Fujian, Gansu, Guangdong, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Jiangsu, Jiangxi, Jilin, Liaoning, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang; four municipalities, Beijing, Shanghai, Tianjin, Chongqing (separated from Sichuan in 1997); five autonomous regions: Guangxi, Inner Mongolia, Ningxia, Tibet, and Xinjiang; and two special administrative regions: Macau and Hong Kong. Three regions, Tibet, Macau, and Hong Kong, are not included in this study. Tibet becomes the exception as it has too much missing data. Governance of Macau and

Hong Kong was transferred back to China in 1997 and 1999 respectively. They are also distinct in that they operate largely in the Western economic system, whereas regions in Mainland China are transforming from a socialist system to a market-based system. Correspondingly, they follow a quite different development path, which makes them non-comparable with regions in Mainland China.

Administrative regions are an appropriate unit of analysis for studying regional differences in China. Firstly, the level the unit of analysis adopts depends on whether the units at that level differ in institutional environment and cultural tradition, which will affect economic and social activity (Doloreux & Parto, 2009). The administrative regions chosen meet this criterion. Provinces, municipalities, and autonomous regions are administratively and economically distinct and independent geographical regions in China. Although they are under the same legal system and the guidance of the central government, each regional government has the authority to develop their own technology policies and innovation plans according to its own circumstance, which makes the regions vary from each other. Particularly since the open-door reform began in 1978, the administrative activities and resource allocation decisions have been decentralised to regional governments (Liu & White, 2001b), which leads to the co-existence of three parallel regional administrations, decentralised spending, autonomous spending, taxation authority (Cooke, 2001), and increased power for the regional government.

Moreover, each region in China has its own specific cultural tradition. According to the classical definition of ‘nation’, the administrative regions can be called “cultural regions”, where people share common culture, language, and territory (Cooke, et al., 1997). Throughout China's long history each region has developed its own distinctive dialect, custom, and culture, which make the social capital more locally embedded. Research shows social capital, defined as a field-specific social resource of an actor, influences the innovation processes and affects the improvement of RIC (Tura & Harmaakorpi, 2005).

Secondly, economic infrastructure and economic development are unevenly distributed in China, as stated in Chapter 3. Since they will influence the efficiency of institutions (Howells, 1999), which may affect the regional innovation environment and then impact the development of innovation capacity, the analysis of units at sub-national level may provide strong evidence of determinants of RIC and the variations between phases and among regions.

Lastly, from a practical perspective, data covering the innovation indicators are easy to access at provincial level. Importantly, the datasets are comparable as they were collected and calculated under the same statistical caliber. Thus, a comparison among regions with these data is possible and reliable.

According to the reasons stated above, the factors which may determine the development of IC of administrative regions have their context-specialty. Since context-specific factors will influence RIC and the constantly changing regional patterns of technological development (Evangelista, et al., 2001), administrative regions are a reasonable choice for the thesis.

4.2.2 Data sources

In this study, secondary data are used as a sole basis, which is one of the three main usages of secondary data (Emory & Cooper, 1991). When using secondary data, the most important issue is the fit of the data to the research questions (Smith, 2008). For this study, longitudinal data are required to uncover the change in impact of explanatory variables on RIC. Secondary data can serve this requirement better than primary data. Besides, the official documents and statistics used in this thesis have some advantages. Official statistics are permanent, and not time consuming or costly (Bryman & Bell, 2003; Emory & Cooper, 1991). They can also result in unforseen discoveries (Saunders, Lewis, & Thornhill, 2003). What is more important is they are feasible for longitudinal studies (Bryman & Bell, 2003; Saunders, et al., 2003) and they can be used to make powerful comparisons between different groups, societies and nations (Smith, 2008). Moreover, official statistics, such as statistic yearbooks, are not based on samples, so a complete picture can be obtained.

In this study we will investigate the impact of the drivers on RIC from 1991 to 2005. According to the transitional process the period can be divided into two phases. Phase One starts in 1991 and extends to 1998, which fits the fourth stage of the reform. Phase Two extends from 1999 to 2005, which is the fifth stage in the long run. Considering time lag between input and output, the time range for output variables is from 1992 to 2009.

Quantitative data, such as official statistics, is mainly used in this study, and qualitative data, such as government documents, is used to supplement quantitative analysis. The quantitative data for the thesis are from three types of yearbooks;

Patent Statistic Yearbook (PSY) from 1991 to 2009; China Statistic Yearbook (CSY) from 1992 to 2011; and China Statistic Yearbook on Science and Technology (CSYST), from 1992 to 2009. The sources of each variable are listed in Table 4.1.

PSY are achieved from the website of State Intellectual Property Office of P.R.C[12], and data on patent counts are all from PSY. CSY 1992 to 1995 was retrieved from the database of China Knowledge of Infrastructure (CNKI)[13], and CSY 1996 to 2009 was retrieved from the website of National Bureau of Statistics of China[14]. Data about GDP, population, FDI, imports and exports, and employment rate were all collected from CSY. Data about funding for S&T, engineers and scientists employed full time, value of domestic technology contracts, the number of higher education institutions and the number of large and medium-sized enterprises were extracted from CSYST, and CSYST were all retrieved from CNKI[15].

Aside from the statistics, qualitative data were also collected. Qualitative data were used to supplement the quantitative analysis, and to assist in uncovering the big picture and understanding the results. The main qualitative data for the thesis were government documents, including implemented developmental plans, policies, laws, and regulations, published development and research reports written during the study period, and related information from newspapers, journals, and industry associations. Government documents are the guidelines of innovation activities, record the history and may lead to historical changes. Hence, the information from qualitative data will

[12] http://www.sipo.gov.cn/tjxx/
[13] CNKI is an e-library in China, including knowledge information, such as information from journals, conferences, newspapers, and published statistics from government departments, in various areas.
[14] http://www.stats.gov.cn/tjsj/ndsj/
[15] http://tongji.cnki.net/kns55/Navi/HomePage.aspx?id=N2011010068&name=YBVCX&floor=1

help in understanding the transitional path of innovation development and the changing impact of drivers over time and across the regions.

Government documents were collected from government websites, particularly the Ministry of Science and Technology and National Development and Reform Commission[16]. Other documents were sourced from newspapers, for instance China Daily and industry associations, such as China Association for Science and Technology.

4.3 Measures

Based on the framework developed above, this section describes how the variables were operated for the empirical analysis. The definition and sources of variables are summarised in Table 4.1. To enable comparison of regions of vastly different sizes, all financial variables were divided by regional GDP and other variables were divided by regional population. To ensure distributions are approximately normal, the logarithm transformation of most metric variables was used.

[16] http://www.most.gov.cn/, and http://www.sdpc.gov.cn/

Table 4.1 Definitions and sources of variables

Variable	Definition	Source
Dependent variables		
lgPApm	The number of total patent applications per million people (in logarithm)	PSY: 1992-2006
lgPGpm	The number of overall granted patents per million people (in logarithm)	
lgIPGpm	The number of granted invention patents per million people (in logarithm)	PSY: 1992-2009
lgUMPGpm	The number of granted utility model patents per million people (in logarithm)	
Independent variables		
Innovation actors		
lgNHEIpb	Number of higher education institutions per billion people (in logarithm)	CSY:1992-2006
lgNLMEpm	Number of large and medium-sized industrial enterprises per million people (in logarithm)	CSYST: 1992-2006
Innovation inputs		
lgGDPpp	GDP per person (in logarithm)	CSY: 1992-2006
lgFSTpthGDP	Funding for science and technology activities per thousand GDP (in logarithm)	CSY:1992-2006
lgFTE_SEpm	Full time employed scientists and engineers per million person (in logarithm)	CSYST: 1992-2006
Emprate	Employment rate	CSY: 1992-2006
Interaction		
lgFDIpthGDP	Inward foreign direct investment per thousand GDP (in logarithm)	CSY: 1992-2006
lgEITpthGDP	Import and export trade per thousand GDP	
lgVDTCpthGDP	Value of Domestic technology contract per thousand GDP (in logarithm)	CSYST: 1992-2006

Note: prior to logarithm, the scale of each variable is as follow: lgPApm, lgPGpm, lgIPGpm, and lgUMPGpm -- item per million people; lgNHEIpb – unit per billion people; lgNLMEpm – unit per million people; the rest are with no scales as they are all calculated based on two indicators with the same scale originally.

4.3.1 Innovation capacity

To measure the innovation capacity of regions this thesis, following Li (2009), employs the number of domestic patents as the proxy for commercially valuable innovation output. It is used as the dependent variable (DV) in the estimation.

Patent data are the favoured, and most commonly used, indicators in measuring innovation output in regional innovation studies. Although patent information is not perfect, it provides a fairly reliable measure of innovation activity (Acs, et al., 2002; Acs & Audretsch, 1989). Practically, patent statistics are easy to access, available from various patent databases. It is possible to use patent data for longitudinal analysis (Acs & Audretsch, 1989) and the dynamics of technological change (Acs, et al., 2002). It seems patent statistics offer the best available output indicator for innovation activities (Freeman, 2004).

Meanwhile, issues associated with equating patent counts with the level of innovation activity are widely documented in the literature (Acs, et al., 2002; Archambault, 2002; Basberg, 1987; Griliches, 1990; Hagedoorn & Cloodt, 2003; Mansfield, 1986; Pavitt, 1985; Trajtenbery, 1990). According to Griliches' (1990) argument not all innovations are patentable, and not all innovations are patented, which questions the representativeness of patents on innovations. Accordingly, some alternative indicators for innovation were used in some empirical studies, such as the number of new products (Fritsch, 2002), new product sales (Liu & White, 1997), and literature-based innovation counts (Acs, et al., 2002). However, these indicators have similar pitfalls as patents, for instance the measurement of economic value of innovations and the quality of innovations.

In contrast to some initial studies on IC (Furman, et al., 2002; Hu & Mathews, 2005), domestic patents rather than international patents were used. Although international patents are a good proxy for commercially relevant innovations, they do not reflect the entire spectrum of innovative activities in a country, especially a developing one (Krammer, 2009). Besides, domestic patents reduce the source bias by using international patents from two different databases such as in Furman's (2002) work, as the criteria for a patent to be granted in each database may differ. Moreover, domestic patents are more comparable because all the regions are subject to the same national patenting laws, go through the same patenting procedures, and pay the same cost. Therefore domestic patents are much more suitable for this study than international patents.

The State Intellectual Property Office (SIPO) has systematically collected domestic patents since 1985 when China's patent law came into force. According to patent law, domestic patents are classified into three categories: invention, utility model and design. Inventions represent the most technologically sophisticated innovation output, radical innovations such as a new products or new methods. Utility models are less innovative compared to inventions. They are incremental innovations, such as the structure change of a product. Designs mainly reflect superficial novelty, such as changes of the shape and color of a product. The basic condition for a patent to be granted is whether it differs from existing technologies and designs, both domestically and internationally, regardless of the patent type. For inventions and utility models, they have to be novel, inventive and practically applicable. As a result, the variation of patent quality is remarkable across the three categories and they differ from each other in terms of novelty, economic value, technological importance, and resource commitment (Li, 2009).

In light of the characteristics of each patent type, it is appropriate to compare the regional capacity according to specific categories. Focusing on more technologically important innovations, this study considers inventions and utility models. As not all innovations are patentable, both total number of applications and granted patents are examined separately to investigate as broad a range of innovation as possible. Granted patents represent innovations with more commercial value than patent applications. Therefore, for specific categories only granted patents are included in this study. Hence, there are four DVs; overall applications, overall granted patents, granted invention patents, and granted utility model patents. The data are divided by the regional population to reduce the bias from regional size differences. Following Furman, et al. (2002) and other researchers (Hu & Mathews, 2005; Li, 2006, 2009), this research use the logarithmic transformation to ensure the distribution of each variable is approximately normal.

In this thesis, data are collected at the regional level. In terms of patent counts, regional means the location of the patent owner. Regional patent counts are the total number of patents that applied by or granted to the owners who are located in a specific region.

A time lag between explanatory variables and patent data (output) is required in the models. It takes time to transform innovation effort to innovation capacity, in other words, transform input to output, and also to process and approve patent applications. In this thesis, one year is taken as the average lag for applications and four years as the lag for all granted patents. However, in reality it is difficult to decide how long it will take R&D efforts to become innovations. Besides, the time lag differs between invention and utility model innovation and it may take more time for invention than for utility models.

For applications, it is assumed it will take at least one year to transform innovation effort to output and to prepare the document for patenting. For the processing time of a patent application, there are different opinions. Cheung & Lin (2004) stated it usually takes the State Patent Office one to one and a half years for an invention patent application, about six months for an utility model patent, and even shorter for design patent. Li (2009) states it usually takes around three years for an invention patent and one year for a utility model patent. A recent study using patents filed at the Chinese State Intellectual Property Office (CSIPO) finds the average duration of invention patent examination is 4.71 years (Wagner & Liegsalz, 2011). In terms of these different opinions and findings, this study takes three years as the patent examination time, disregarding patent type. This amounts to four years lag between input and output for granted patents

To verify if the time lags give best fit, other time lags were checked by analysing a dataset with a fixed time period for IVs and different time lags for DVs using the method of panel data analysis (see results in appendix one). The results show for applications, zero, one year, and two year lags are equal best fit for the model, no matter which type of patent, as there are no big differences between R squares. There are slight differences between the effects of the same IV on different DVs. For granted patents, models with four and five year lags explain more variances than the others for all three DVs. Meanwhile the key results are robust in these two models. Therefore, considering both the verified results and what has been used in previous research, the time lags chosen here are appropriate and reasonable.

4.3.2 Innovation actors

The main innovation actors considered in innovation systems are firms, universities and research institutes. Universities in IS are considered in a broad way. In China universities can be referred to as higher education institutions, which consist of universities, special colleges, such as medical schools and musical colleges, and professional technology colleges. Accordingly, the number of HEI in each region is included.

There are many types of firms in China in terms of the classification criteria. The total number of all types of firms is not accessible for the study period. Thus, the number of large and medium-sized industrial enterprises was used to explore the influence of firms on innovation capacity. According to the latest criteria issued for firm classification in 2003, for a large-sized industrial enterprise the annual operational revenue should be over 300 million Chinese Yuan, and the number of employees should over 2000; for a medium-sized industrial enterprise the operational revenue should be between 30 million and 300 million Chinese Yuan, and the number of employees between 300 and 2000 (NDRC).

Research institutes are not included in the analysis. However, this does not mean they are not important, as a matter of fact, they are a critical factor in China's NIC (Hu & Mathews, 2008). With the reform of research institutes, however, the number of research institutes is not a suitable proxy for investigating its effect on RIC. Many RI are merged with or transformed into enterprises (Huang, 2007) and the statistical approaches differ in different years according to the public official data, which means the data are not comparable. Therefore, only the number of HEI (lgNHEIpb) and the number of large and medium-sized industrial enterprises (lgNLMEpm) are included as innovation actors in the analysis.

4.3.3 Innovation input

A range of innovation inputs has been employed in previous studies. Resource commitments such as funding for science and technology activities, R&D expenditure (Evangelista, et al., 2001; Freeman, 2004; Lundvall, 1992; Pan, 2007; Park & Park, 2003), scientists and engineers (Lundvall, 2007), and knowledge stock such as patent stock (Zabala-Iturriagagoitia, Voigt, Gutiérrez-Gracia, & Jiménez-Sáez, 2007) are considered as the most direct input factors to innovation activities.

With regard to financial input, funding for science and technology activities (lgFSTpthGDP) was included. The original data were divided by regional GDP to control the effect of the size differences among regions, and then they were transformed into the format of a logarithm to ensure normal distribution. Since FST can be used for all science and technology related activities, including R&D activities, purchase or construction of fixed assets, it may represent the effort put into innovation development better than R&D expenditure. In terms of human resources, the number of scientists and engineers employed full time per million people (lgFTE_SEpm) and employment rate (Emprate) were used in the analysis. FTE_SE is normalised and transformed for the same reason as other variables. The original data of employment rate as used as it is approximately a normal distribution. Scientists and engineers are the most important human resources for innovation development, but they also need support from other staff with general administrative issues. This is why employment rate is also included.

For knowledge stock, GDP per capita (Furman, et al., 2002) and patent stock (Furman, et al., 2002; Zabala-Iturriagagoitia, et al., 2007) are proposed as two indicators. GDP per capita captures the ability of a country or a region to bring about the economic value of its knowledge (Li, 2009), while patent stock directly measures the national or regional pool of technology. As GDP per capita is strongly correlated with patent counts and patent counts are used as independent variable in the analysis, only GDP per capita is included in this study. GDP per capita represents the economic infrastructure of a country or a region as well.

4.3.4 Interactions

It has been widely recognised that interactions between components of IS are very important activities in the process of innovation development (Chang & Shih, 2004; Cooke & Memedovic, 2003; Cooke, et al., 1997; Edquist, 2004). Through interactions, innovation actors can learn from each, share knowledge and resources, and consequently accelerate the progress of innovation. With respect to domestic interactions, Li (2009) used the proportion of S&T funds raised from firms by universities and research institutes to measure the interactions among firms, universities and research institutes and contract value in the regional technology market to measure interactive learning. These two measures together consider both financial capital flow and knowledge flow. In view of knowledge, the value of domestic technology contracts (lgVDTCpthGDP) in technology market is employed to measure the technological interactions between innovation actors. A strong technology market is important for technology transfer and utilisation of patents across regions, while the measure of technology contracts set by the State Science and Technology Commission captures activities of transforming patented technologies into commodities (Johnson & Liu, 2011). Hence, technology contracts represent both knowledge flow and interactive learning between regions and within a region.

Beside domestic interactions, the development of RIS is becoming more dependent on external linkages. Technological knowledge from advanced countries is an important connection for China (Asheim & Vang, 2006; Giuliani, Rabellotti, & Dijk, 2005). Hence, international interactions are covered in the analysis as well. Regions can access foreign technology and knowledge through FDI, international trade and the mobility of human capital across borders and collaborations (Liang, 2008; Liu, 2008; Peng & Wang, 2000; Zhang & Rogers, 2009). Domestic innovation actors can benefit both from foreign technology providers and users.

FDI was found to be an important factor in innovation development, either positive (Chuang & Hsu, 2004; X. Liu & C. Wang, 2003) or negative (Hu & Jefferson, 2002; Huang, 2004). Inward FDI is one of the main channels transferring technologies from the source countries to the host countries (Zhu & Jeon, 2007). It may also bring financial capital, human capital, advanced knowledge, new and innovative ideas and advanced management skills (Branstetter, 2006; Hu & Jefferson, 2002; Liu, 2008; Madariaga & Poncet, 2007; Tuan, et al., 2009). However, the spillover effect of FDI was seldom studied in developing economies (Anwar & Nguyen, 2010), especially with the approach of RIC in China.

Other than FDI, international trade is another channel to reach advanced technologies and knowledge to improve innovation capacity of a country or a region. Technology traded with international innovation actors will increase the quality of goods (Spulber, 2008), as foreign users may facilitate exporters to improve their product to meet the criteria of foreign markets (Chuang & Hsu, 2004; Lin & Lin, 2010).

Accordingly, both FDI and international trade may have direct and indirect impact on the development of innovation capacity in China. Therefore, the annual inflow of FDI (lgFDIpthGDP) and the sum of imports and exports (lgEITpthGDP) were used to measure international interactions of a region.

Other than interactions among innovation actors, interactions between drivers of RIC are also important. Absorptive capacity is frequently mentioned as an important factor to capture spillovers from FDI (Anwar & Nguyen, 2010). It is found that absorptive capacity affects the impact of knowledge acquisition on innovation capacity at the firm level, industry level, as well as the national level (Anwar & Nguyen, 2010; Fu & Gong, 2011; Liao, Wu, Hu, & Tsui, 2010). Researchers found R&D efforts improve organisations' absorptive capacity (Liu & Zou, 2008). R&D investment is the commonly used proxy of absorptive capacity (Cohen & Levinthal, 1990; Kostopoulos, Papalexandris, Papachroni, & Ioannou, 2010; Lai, Peng, & Bao, 2006). Hence, we can infer that S&T investment, which is a broader measure of R&D effort, may influence the impact of interactions between innovation actors such as FDI, international trade, and domestic technology transfer. As this has not been studied with the approach of RIC, this study imports S&T investment as the measure of absorptive capacity to explore the interactive effects between S&T investment and interactions in China.

4.4 Analysis Methods

To answer the three research questions: what are the core drivers of China's RIC, what are the differences in the drivers of China's RIC at different transitional stages, and what are the differences in the drivers of RIC among regions at different innovation levels in China, the research is conducted in three steps, employing panel data regression with fixed effect models and cluster analysis. Step one was to identify the drivers of RIC between 1991 and 2005, employing a GLS regression of fixed effect models with panel data of overall regions. Step two was to explore whether the impact of drivers changes over time, using a GLS regression of fixed effect models with panel data of overall regions for two phases separately. Comparing the drivers of RIC between two stages helped to better understand the impact of the drivers and the transition process of China's RIS. Step three was to investigate how the drivers impacted differently among regions. Hierarchical cluster analysis was employed to classify the regions into different groups in terms of regional similarities and differences of RIC, and then GLS regressions were run for the groups from the clustering results. The two major methods are discussed in the following sections in detail.

4.4.1 Cluster analysis

One of the purposes of this study was to see if there were any differences in RIC drivers among regions. Discussion in section 2.3 suggests both in innovation input and innovation output some regions are quite similar, while some are far different from others. This suggests it is necessary to divide all the regions into different groups and then compare the differences among those groups. To classify the regions, cluster analysis was employed, which will serve as group comparison.

The nature of cluster analysis is to split up objects into a number of subgroups based on a chosen measure of similarity so "the similarity between objects within a subgroup is larger than the similarity between objects belonging to different subgroups" (Backer & Jain, 1981). Cluster analysis is used to develop a classification, investigating conceptual schemes, generate and test hypothesis (Aldenderfer & Blashfield, 1984). The nature and objectives of cluster analysis served the objective of this study well, as the differences among groups with different innovation capacity was the focus.

Hierarchical clustering was selected from the two basic methods of clustering, hierarchical and nonhierarchical (Hair, Black, Babin, & Anderson, 2010). Hierarchical techniques are applicable to most research questions and it is fast and simple for the researcher to capture the entire range of clustering solutions with the treelike structures revealing the clustering process. However, hierarchical methods have some limitations. The way they try to reduce the impact of outliers may distort the solution and they are not suitable for large samples and large number of variables. Non-hierarchical methods can overcome these shortcomings. However, it is complicated for researchers to select the best solution, as they will get a different final solution for each set of seed points. Meanwhile, hierarchical techniques are considered better than non-hierarchical techniques with random seed points. Hence, comparing the advantages and disadvantages of the two approaches and considering the purpose of the research and the data collected, hierarchical methods are superior to nonhierarchical techniques.

Ward's Method was chosen from types of clustering algorithms to calculate the similarity between clusters. This method has the advantage that the similarity between two clusters is the sum of squares within the cluster, summed over all variable rather than a single measure of similarity as with other methods (Hair, et al., 2010). Although this method may be distorted by outliers and tries to produce clusters with the same number of observations (Hair, et al., 2010), it minimises the increase of the within-class sum of squared errors (Xu & Wunsch, 2009), which means there is minimum variance within a cluster. This makes it the best choice for this study.

In cluster analysis, the most commonly used measures for similarity are distance measures rather than correlational measures in other multivariate techniques (Hair, et al., 2010). As for Ward's method, squared Euclidean distance is the recommended distance measure (Hair, et al., 2010). As distance measures are very sensitive to different scales of variables (Hair, et al., 2010), the variables are standardised to standard scores.

4.4.2 Panel data analysis

Following Furman, et al. (2002), Hu & Mathews (2005) and Li (2009), a panel data model was employed. There are several advantages of panel data compared to pure cross-section and time-series analysis (Baltagi, 2008; Hsiao, et al., 2002). Panel data considers both time variances and cross-section variances and is able to control the time and entity invariant variables (Baltagi, 2008). On the other hand pure cross-section data covers the variances between sections but no time-variant information (Wooldridge, 2002) and the primary purpose of time-series analysis is understanding dynamics (Hamilton, 1994). Since this study was comparing many regions over a long time period, panel data is needed. Panel data also have the following advantages (Baltagi, 2008; Hsiao, et al., 2002). First, using panel data can better uncover the dynamics of change. It is suitable to study economic phenomenon and can reveal the speed of adjustment to economic policy change with panels that are long enough. Second, panel data is able to control the effects of missing or unobserved variables, and consequently control the heterogeneity among individuals, regions, or countries and reduce the bias of the results. Third, panel data allows construction and testing of more complicated behavioral models. Finally, panel data can sometimes generate more accurate predictions for individual outcomes and provides more informative results, less collinearity between variables, and increased efficiency.

Every method has pros and cons and panel data are no exception. Selectivity and heterogeneity biases are the two main issues that need to be considered (Baltagi, 2008; Hsiao, et al., 2002). As the study has a population of relevant regions, selectivity is not a problem. However, heterogeneity biases exist due to the influence of factors not included in the model. Since it is impossible to include all the factors affecting the outcome of all the regions, the heterogeneity biases are unavoidable. Overall, the advantages of panel data outweigh the limitations, and using panel data will serve the purpose of this study well.

According to Wooldridge (2002) and Baltagi (2008), the basic econometric model which considers both time-variant and time-invariant variables with panel data is interpreted as follows:

$$y_{it} = \beta x_{it} + \varepsilon_{it} \qquad i = 1, 2, \ldots, N, t = 1, 2, \ldots, T \qquad (1)$$

Where i represents the cross-sectional unit and t represents time; y_{it} is the dependent variable; β is the coefficient for the independent variable; x_{it} represents one independent variable; and ε_{it} is the error term. The two basic approaches are the random effects model and fixed effect model.

Following Allison, Baltagi and Wooldridge (2009; 2008; 2002), the study employed a fixed effect model, which can be specified as:

$$y_{it} = \alpha + \beta x_{it} + u_i + \varepsilon_{it} \qquad i = 1, 2, \ldots, N, t = 1, 2, \ldots, T \qquad (2)$$

Where i represents the cross-sectional unit and t represents time; y_{it} is the dependent variable; β is the coefficient for the independent variable; x_{it} represents one independent variable; α is the intercept; u_i is the unobserved unit effect; and u_{it} is the error term.

A fixed effect model has several advantages over a random effect model in the context of this study. In the case of this research, the most important consideration is the random effect model is appropriate if the sample is randomly drawn from a large population, and the fixed effect model is more suitable for a specific set of units (Baltagi, 2008). The units used here are not randomly sampled, they are the specific 30 regions in China (it is almost the population of China, except Tibet). This rules out the appropriateness of random effect model at the first instance. Second, in a random effect model the unobserved variables are assumed to be independent of all the observed variables, while in a fixed effect model the unobserved variables are allowed to have associations with the observed variables (Allison, 2009; Baltagi, 2008; Wooldridge, 2002). Allowing associations is the way to control the effects of unobserved variables, as the unobserved variables are treated as fixed parameters (Allison, 2009). In this study only some factors that may have direct influence on the innovation capacity are included, so it is a big risk to assume the unobserved variables are not correlated to the observed ones. For example, the number of graduates from HEI may be correlated to full time employed scientists and engineers.

Substituting the variables of this study into the generic fixed effect model (2), the following model for patent applications results:

$$\begin{aligned} lgPApm_{i,t+1} = {} & \alpha + \beta_1 lgGDPpp_{it} + \beta_2 lgSTFpthGDP_{it} + \beta_3 lgSTFpthGDP_{it} \\ & + \beta_4 Emprate + \beta_5 lgFDIpthGDP_{it} + \beta_6 lgEITpthGDP_{it} \\ & + \beta_7 lgVDTCothGDP_{it} + \beta_8 lgNHEIpb_{it} + \beta_9 lgNLMEpm_{it} + u_i \\ & + \varepsilon_{it} \end{aligned} \tag{3}$$

For granted patents, the model is:

$$lgPGpm_{i,t+4} = \alpha + \beta_1 lgGDPpp_{it} + \beta_2 lgSTFpthGDP_{it} + \beta_3 lgSTFpthGDP_{it} + \beta_4 Emprate + \beta_5 lgFDIpthGDP_{it} + \beta_6 lgEITpthGDP_{it} + \beta_7 lgVDTCothGDP_{it} + \beta_8 lgNHEIpb_{it} + \beta_9 lgNLMEpm_{it} + u_i + \varepsilon_{it} \quad (4)$$

In this study fixed effect models are estimated in STATA, which is one of many packages, such as SAS, LIMDEP, which can perform panel data analysis,. As we applied the fixed effect model with the command xtreg and option fe in STATA, the model was estimated by fixed-effect estimator in other words, within estimator (Baltagi, 2008; StataCorp, 2009). Different from GLS random estimator, which considers both within and between variation, the within estimator subtracts the between variation and only the within variation is left (Allison, 2009; Baltagi, 2008).

4.5 Summary

Drawing on the literature of NIS/RIS and NIC/RIC this chapter developed the conceptual framework of the thesis, consisting of innovation actors, innovation inputs, and interactions as the explanatory variables. Data for the measures were collected from various statistic yearbooks, detailing 30 administrative regions in China from 1991 to 2005. According to the research questions, the data will be analysed in three steps. Step one is for overall regions covering the whole period. Step two is to compare the differences in drivers of RIC between two phases and step three is to compare the variations in drivers of RIC among regions. Fixed effect models with panel data were employed as the main research method to explore to what extent different factors matter for RIC in different situations. Cluster analysis was also employed to classify regions according to their innovative capacity.

Chapter 5 ALL REGIONS

The purpose of this chapter is to address the first research question "*What are the core drivers of RIC in China*" and the two sub-questions by investigating the relationship between explanatory variables and DVs in the model developed in this thesis. Other than the impact of factors alone, we also explore the interactive effects between variables, which may add potential knowledge to the literature of NIS/RIS and NIC/RIC. This chapter first summarises the characteristics of the data, and then explains the estimated results from panel data analysis.

5.1 Data Summary

The descriptive statistics utilised in this analysis, summarising the experience of the 30 regions over the period from 1991 to 2005, are listed in Table 5.1. The regional means of dependent and independent variables are graphed in Figure 5-1 and Figure 5-2 separately.

Table 5.1 Descriptive statistics of variables

	N	Period T	Mean	Min	Max	Std. Dev
$lgPApm_{T+1}$	450	1992-2006	1.871	1.01	3.30	.445
$lgPGpm_{T+4}$	450	1995-2009	1.768	.83	3.26	.490
$lgIPGpm_{T+4}$	450	1995-2009	.617	-1.01	2.72	.653
$lgUMPGpm_{T+4}$	450	1995-2009	1.527	.56	2.84	.444
lgNHEIpb	450	1991-2005	2.981	2.35	3.72	.240
lgNLMEpm	450	1991-2005	1.200	.56	2.05	.281
lgGDPpp	450	1991-2005	3.749	2.94	4.71	.341
lgFSTpthGDP	450	1991-2005	1.193	.05	2.18	.305
lgFTE_SEpm	450	1991-2005	3.084	2.35	4.26	.349
Emprate	450	1991-2005	.517	.35	.67	.060
lgFDIpthGDP	450	1991-2005	1.302	-.44	2.38	.524
lgEITpthGDP	450	1991-2005	2.202	1.50	3.36	.434
lgVDTCpthGDP	450	1991-2005	.556	-1.26	1.85	.477

Figure 5-1 shows there are great differences in patent output among regions, both for applications and granted patents. It is clear regions such as Beijing, Guangdong, Shanghai, Tianjin and Zhejiang have much better performance in terms of patent counts than regions such as Gansu and Xinjiang. With regard to independent variables, except employment rate, there are great differences among regions. Compared to the measures of innovation inputs and interactions, the differences in the measures of innovation actors are much smaller. For example, the logarithm scale of international trade ranges from 1.68 to 3.19, while the number of HEI is between 2.73 and 3.6 in logarithms.

Figure 5-1 Regional mean of dependent variables

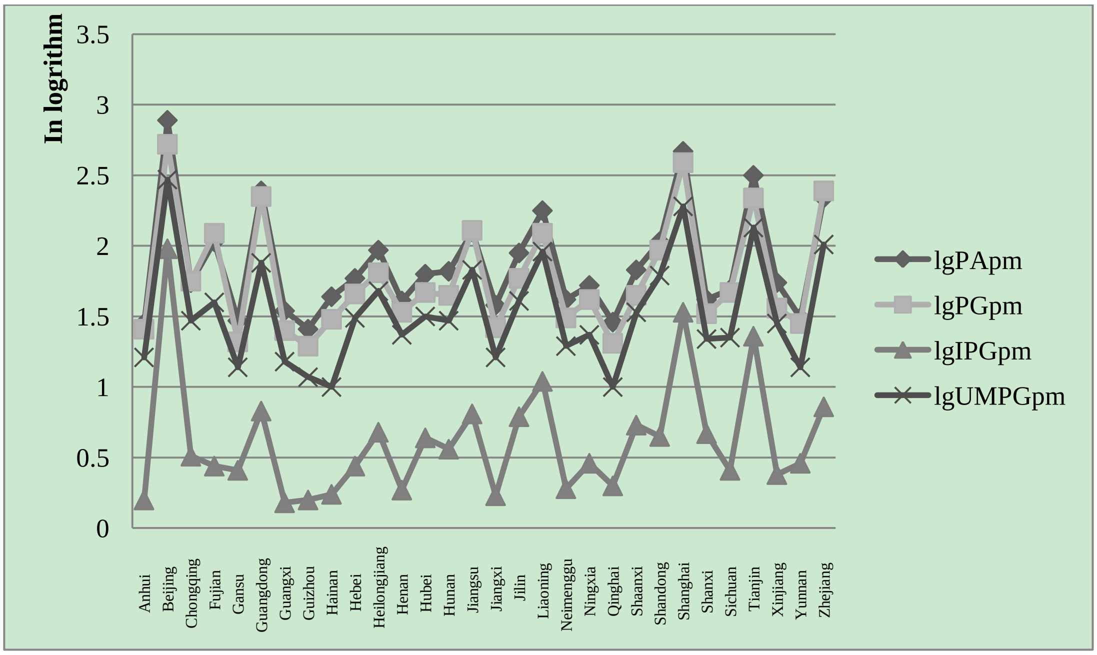
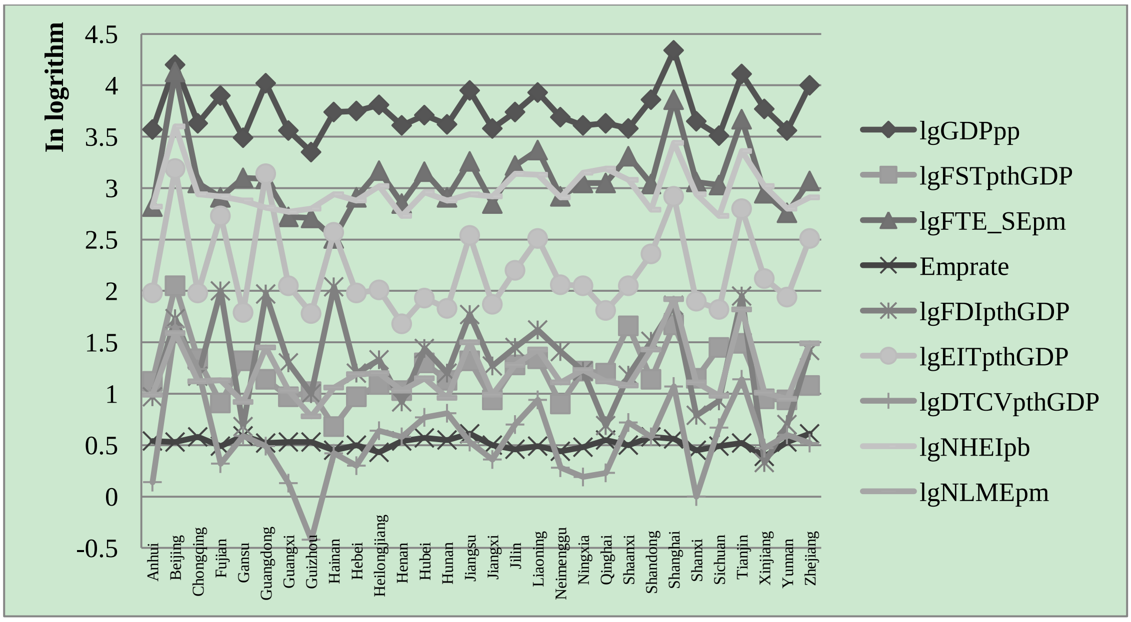


Figure 5-2 Regional mean of independent variables



Note: all variables are in logarithm, except Emprate, which is a ratio.

5.2 Estimation results

The following explains the estimated results from fixed effect models for different measures of patent counts covering all the regions. Taking the number of patent applications and granted patents as separate measures of innovation output, models for four dependent variables are estimated. Results are displayed in Table 5.2.

Before running the fixed effect model, the dependent variables are normalised to have the same mean as $lgPApm_{T+1}$ using the following equation:

$$Ny_{it} = y_{it} \times (\overline{lgPApm_{\imath,t+1}} \div \overline{y_{\imath t}}) \qquad i = 1, 2, \ldots, N, t = 1, 2, \ldots, T \qquad (5)$$

Where i represents the cross-sectional unit and t represents time; Ny_{it} is the normalised value of y_{it}; y_{it} refers to $lgPGpm_{i,t+4}$, $lgIPGpm_{i,t+4}$, and $lgUMPGpm_{i,t+4}$; and $\overline{lgPApm_{\imath,t+1}}$ is the mean of $lgIPApm_{i,t+1}$; $\overline{y_{\imath t}}$ is the mean of y_{it}.

The DV are normalised to have the same mean because once normalised, the estimated coefficients for each IV can be directly compared between equations, given the DV here are the same type of variable (patent counts). To test if there are significant differences in the coefficients of IV between models, in other words to see if the impact of explanatory variables on different dependent variables differ from each other, a standard z-test was applied (Paternoster, Brame, Mazerolie, & Piquero, 1998). Usually, a z score is used to test if a relationship estimated within two independent samples is equivalent (Paternoster, et al., 1998). Although in the literal sense the DV in this study are different, technically they can be treated as the same as they have similar meanings -- the measure of patent counts. Hence, z-test is applicable in this study.

According to Paternoster, et al. (1998), the correct formula for a z-score is:

$$z = \frac{b_1 - b_2}{\sqrt{SEb_1{}^2 - SEb_2{}^2}} \qquad (6)$$

Where b_1 is the coefficient of model 1; b_2 is the coefficient of model 2; SEb_1 is the standard error associated with b_1; and SEb_2 is the standard error associated with b_2. If z is significant, then the null hypothesis $b_1 = b_2$ can be rejected. In this study this means the IV has different impacts on different DVs. The results of coefficient comparison are listed in Table 5.3. With regard to the two categories of granted patents, invention patents represent radical innovations and utility model patents are incremental innovations, which is not totally new.

Table 5.2 Results with all the regions covering the whole period

Coef.			Overall applications (1)	Overall granted patents (2)	Granted invention patents (3)	Granted utility model patents (4)
Innovation actors	Number of higher education institutions	lgNHEIpb	.164**	.015	-.413	.258***
			(.075)	(.103)	(.386)	(.087)
	Number of large and medium-sized enterprises	lgNLMEpm	-.025	-.108	-.7443**	.0472
			(.062)	(.085)	(.319)	(.072)
Innovation input	GDP per capita	lgGDPpp	.644***	.964***	5.378***	.811***
			(.037)	(.051)	(.190)	(.043)
	Funding for scientific and technological activities	lgFSTpthGDP	.149***	.024	1.449***	.117*
			(.053)	(.074)	(.276)	(.062)
	Full time employed scientists and engineers	lgFTE_SEpm	.277***	.353***	1.317***	.289***
			(.079)	(.108)	(.407)	(.092)
	Employment rate	Emprate	-.225	-.051	-.996	.240
			(.202)	(.279)	(1.045)	(.236)
Interaction	FDI	lgFDIpthGDP	-.142***	-.078***	-.575***	-.157***
			(.020)	(.028)	(.106)	(.024)
	Import and export	lgEITpthGDP	.276***	.377***	-.453**	.423***
			(.043)	(.060)	(.224)	(.051)
	Value of domestic technology contract	lgVDTCpthGDP	.043**	.010	.244**	-.032
			(.021)	(.028)	(.106)	(.024)
		_cons	-2.367***	-3.483***	-19.832***	-3.861***
			(.188)	(.260)	(.973)	(.220)
		Within R-sq	.8138	.7991	.8799	.8360

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 5.3 Comparison of coefficient to different dependent variables

Z-score			Overall applications - Overall granted patents (5)	Overall granted patents - Granted invention patents (6)	Overall granted patents - Granted utility model patents (7)	Granted invention patents - Granted utility model patents (8)
Innovation actors	Number of higher education institutions	lgNHEIpb	1.17	1.07	-1.80*	-1.70
	Number of large and medium-sized enterprises	lgNLMEpm	0.80	1.93*	-1.40	-2.42**
Innovation input	GDP per capita	lgGDPpp	-5.10***	-22.40***	2.31**	23.40***
	Funding for scientific and technological activities	lgFSTpthGDP	1.37	-4.99***	-0.97	4.71***
	Full time employed scientists and engineers	lgFTE_SEpm	-0.57	-2.29**	0.45	2.47**
	Employment rate	Emprate	-0.50	0.87	-0.80	-1.15
Interaction	FDI	lgFDIpthGDP	-1.85*	4.54***	2.15**	-3.85***
	Import and export	lgEITpthGDP	-1.37	3.58***	-0.59	-3.82***
	Value of domestic technology contract	lgVDTCpthGDP	0.95	-2.13**	1.13	2.53**
		_cons	3.48***	16.22***	1.11	-15.99***

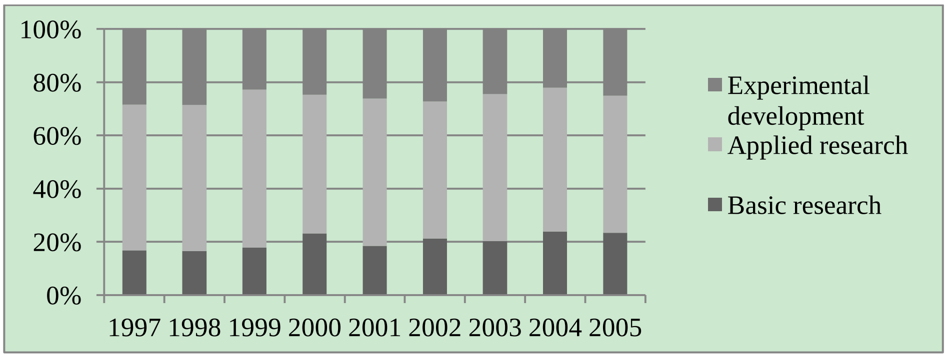
Note: ***p<0.01, **p<0.05, *p<0.1

5.2.1 Innovation actors

Higher education institutions: The estimated coefficient of HEI to overall patent applications is positively significant, which means more HEI will lead to more patent applications. When considering granted patents, no significant effect is found on overall granted patents. For different categories the impact is only positive and significant on granted utility model patents. However, the comparison of coefficients shows there is no strong difference between applications and granted patents and between the two categories of granted patents. Therefore we may infer that HEI is an important actor in China's innovation development and makes a contribution to both radical and incremental innovation.

The difference between the impact on granted invention and utility model patents may be explained by how R&D funding is distributed among different types of research (Zhong & Yang, 2007). Figure 5-3 shows between 1997 and 2005 less than 25 per cent of R&D funding was spent on basic research, more than 50 per cent was used on applied research, and the rest was allocated to experimental development in HEI. As basic research mainly leads to invention innovations and applied research mainly results in utility model innovations, it is not surprising HEI have a stronger impact on utility model patenting than on invention patenting.

Figure 5-3 Distribution of R&D fund on different types of research in HEI



Source: CSYST 1998 to CSYST 2006[17]

As innovation actors, there are several ways HEI make contributions to improving RIC in China, which may shed light on the explanation of the positive effect of HEI on patenting. First, HEI are crucial actors of innovation activity. Patent counts, used in this study, and published papers, which are not included, are two major proxies of the direct contributions HEI make to RIC development. Second, HEI are practitioners as well as educators in China. They created spin-off firms when conducting innovation activities, which facilitate firms' patenting activities (Hu & Mathews, 2005; Zhang & Rogers, 2009). Based on the results above, the study confirms the results from studies at the national level; HEI, as educators and practitioners, play an important role in improving IC in China (Chen & Guan, 2011; Hong, 2008; Hu & Mathews, 2005).

Large and medium-sized enterprises: Regarding the impact of LME on development of RIC, it is only negatively significant on granted invention patents. Z-tests show there are significant differences between the impact on the two categories of granted patents (z=-2.42, p<.05). Although Qi & Li (2008) stated that LME contribute most

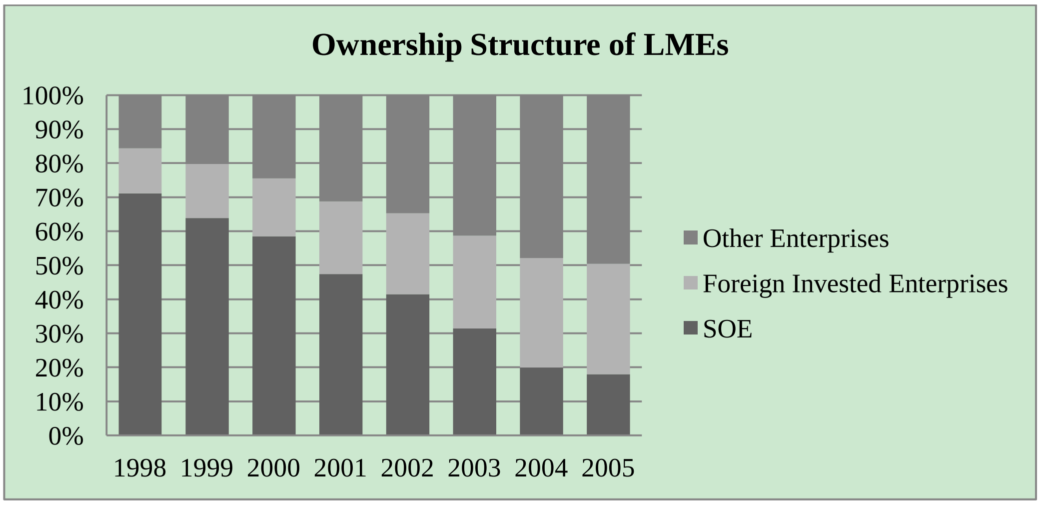
[17] The data from 1991 to 1996 are not available, but the data from 1997 to 2005 can provide enough information about the situation of how R&D funding was used on different types of research.

to China's patents, the results here show LME have no impact on incremental innovations and even hold back the increase of radical innovations.

The different effects of LME on granted invention and utility model patents may suggest domestic firms are more likely to file utility model and design than invention, as they are less radical and easier to be granted (Sun & Du, 2010).

The unexpected negative effect of LME on granted invention patents may be explained by the ownership structure of LME. Based on CSYST, LME is classified into three categories according ownership; (1) enterprises with funds from government are all called SOE here, which include state-owned, collective-owned, state joint ownership and collective joint ownership enterprises; (2) enterprises without government funds are called other enterprises, such as private enterprises, cooperative enterprises, limited liability corporations without government funds, and all other enterprises; (3) foreign invested enterprises (FIE), which include enterprises with funds from Hong Kong, Macau, and other countries. Although Hong Kong and Macau are two administrative divisions of China, they are under the Western economic system, which is different from socialism in Mainland China. The structure has been changing from 1998 to 2005 with the privatisation of SOE (see in Figure 5-4).

Figure 5-4 Ownership structure of LME



Source: CSY 1999-2006

Figure 5-4 shows the ratio of SOE kept decreasing from 71 per cent in 1998 to around 18 per cent in 2005. Meanwhile, FIE and other enterprises were increasing continuously from 12 per cent to 33 per cent and 16 per cent to 49 per cent respectively. With years of reform on the enterprise system, more than half of LME were FIE and SOE by the end of the study period, which may be the reason for the negative effect of LME on RIC.

Although it has been more than 30 years since the reform started in 1978, the reform is continuing and SOE lag behind the efficiency of China's economy (Sun, 2010). SOE may be less motivated to learn new knowledge and make innovations than other enterprises (Li, Liu, & Parker, 2001) because of government's soft budget constraints and some social responsibilities, such as, expansion of employment. SOE have low incentives to learn (Wang, 2003; Wang & Kafouros, 2009), unless it is the directive of the government. Although the economic benefits of SOE have been greatly improved, the R&D investment was only 1.5 per cent of annual sales revenue in

2007, which is much lower than 5 per cent in developed countries (Ye, 2009). Moreover, Wang and Kafouros (2009) stated with less involvement of SOE an industry may achieve higher innovation and develop better IC.

Other than SOE, the increasing number of FIE would lead to a negative effect as well. FIE prefer patenting outside China because of intellectual protection consideration (Zhou, 2006). This will be discussed in more detail in section 5.2.3.

5.2.2 Input factors

From Table 5.2 is can be seen that robust relationships exist between innovation inputs (except employment rate) and patent counts.

GDP per capita: Regarding GDP per capita, the estimated coefficients of all four DV are significantly positive. The impact of GDP per capita on overall applications and overall granted patents is comparable and significantly different at the level of $p<0.01$, as well as the impact on granted invention and utility model patents.

As GDP per capita reflects the potential to support knowledge accumulation (Hu & Mathews, 2005), it represents not only economic infrastructure but also knowledge stock of the region (Furman, et al., 2002). Hence, the positive effects of GDP per capita on patent counts suggests more accumulated knowledge stock and a better economic foundation greatly promotes the creation of new knowledge and facilitates the improvement of RIC.

S&T effort: Measuring R&D effort, the impact of funding for S&T (FST) is explored. On overall applications the impact of investment in S&T is positive and significant at the level of p<.01, which is consistent with Zhang and Rogers' (2009) findings that patent applications are strongly related to R&D effort. Although the impact on overall granted patents is not significant, it is positive and significant on granted invention patents at p<.01 and granted utility model patents at p<.1. The difference in the impact between the two categories is significant (z=4.71, p<.01), which means the impact of investment in S&T is greater on radical innovations than on incremental innovations. Overall, our results confirm the argument that capital investment effort contributes to technological progress (Chen, Sheng, Liu, & Zhang, 2010), and has a positive impact on domestic innovation performance (Girma, Gong, & Görg, 2008; Liu & Zou, 2008; Tsai & Wang, 2007; Wang & Kafouros, 2009).

Full time employed scientists and engineers: With full time employed scientists and engineers the estimated coefficients to overall applications and overall granted patents are almost the same, positive and significant at p<.01. Considering different categories, the impact on granted invention and utility model patents is comparable and significantly different. Ceteris paribus, 1 per cent increase of full time employed scientists and engineers will lead to greater increase of granted invention patents than granted utility model patents, 1.317 per cent and .289 per cent respectively.

The positive effects of S&T effort on patent counts confirm previous findings that skilled talents play an important role in RIC development. Bai and Li (2011) found a higher quality of labour force will lead to a higher innovation efficiency. Chi and Qian (2010) and Chi (2008) observed the education level of workers is significantly and positively related to regional innovation activities. These findings are all consistent with our results and Hervas-Oliver and his colleagues' study (2011) showing skilled labour is critical for improving RIC.

Employment rate: Another variable related to human resource is employment rate. The results show employment rate does not affect RIC, as none of the coefficients are significant. This may be explained by how the employment rate is calculated. In China, employment rate is the working population divided by the whole population. The working population includes people who are over fifteen years old and work for living. It includes employees of an organisation, self-employed persons, and farmers who works on the land to produce their own food (NBSC). Therefore, the employment rate used here over estimates the number of people who may make contributions to RIC.

In terms of innovation input, the results confirm the findings of previous studies; IC is largely related to innovation inputs (Hu & Mathews, 2005, 2008; Li, 2009; Ma, 2010a) and human capital and financial investment effort positively relate to improvement of RIC (Qi & Li, 2008; Schneider, 2005). Additionally, the results show the impact on different types of innovation differs.

5.2.3 Interactions

FDI Results displayed in Table 5.2 reveal that FDI has a negatively significant effect on domestic patenting at $p<.01$. This implies FDI retards the improvement of domestic technology change. With regards to different categories, the negative impact of FDI is greater on granted invention patents than on granted utility model patents and the coefficients are significantly different ($z=-3.85$, $p<.01$).

The effect of FDI on economic and innovation development has been discussed and examined in different contexts through the literature and the findings are mixed. There is evidence supporting both positive (Buckley, Clegg, & Wang, 2002; Chuang & Hsu, 2004; Hanousek, Kocenda, & Maurel, 2011; Li, et al., 2001; X. Liu & C. Wang, 2003; Tian, 2007) and negative effects (Hu & Jefferson, 2002; Hu, Jefferson, & Qian, 2005; Huang, 2004; Liu, 2002), as well as no significant effect (Chen, et al., 2007). Internationally, FDI is deemed as one of the main channels for diffusion of technological improvement (De Bondt, 1996; Wang & Kafouros, 2009). The host country can directly benefit from FDI, through new technologies, production processes, organisational methods, and advanced innovation management skills brought in by foreign enterprises (Buckley, Clegg, Wang, & Cross, 2002; Cheung & Lin, 2004; Fu, 2008; Zhou, 2006). The host country can also indirectly benefit through innovations developed by trading partners (Cheung & Lin, 2004), skilled labour turnover (Fu, 2008; Gorg & Strobl, 2001), and the adjustment of industrial structure as a result of a rise of overall industrial technology level (Zhou, 2006).

The possible positive spillovers are not adaptable to all circumstances. Fu (2008) pointed out that there are conditions for the significant spillovers from FDI. One is the absorptive capacity of domestic innovators (Cohen & Levinthal, 1989) and the other is the intensity of interactions between foreign and domestic economic activities (Balasubramanyam, Salisu, & Sapsford, 1996). Moreover, Meyer and Sinani (2009) found whether the host country can benefit from FDI depends on the specific context of the study and FDI spillovers have a curvilinear relation with the level of economic development.

The negativity of FDI observed in this study may be attributed to the following reasons. (1) FIE do not favour patenting in China, while FIE are the main pattern of foreign presence in China. A survey undertaken in Beijing, Shanghai, Suzhou, and Dongguan by the Chinese Academy of Social Sciences shows 91 per cent of FIE do not apply for patents in China and 13 per cent only apply for international patents (Zhou, 2006). (2) FIE may crowd out domestic organisations in terms of human capital and resources. FIE provide competitive payoffs to attract outstanding talent from the labour pool (Asheim & Vang, 2006; Huang, 2004; Sun, 2010), which reduces the accessibility of scientists and engineers and other skilled technicians to domestic organisations (Liu & Zou, 2008). Hence, FIE may lower the innovation capacity of domestic innovation actors and reduce knowledge spillover by keeping competent workers. Furthermore, FIE take up resources that may have helped domestic organisation in IC improvement. (3) Large inflows of FDI may redirect innovative activities, such as R&D, back to the parent company's home country (Girma, Gong, & Görg, 2006), consequently reducing innovative activities in the host country. (4) Usually, FIE would avoid unnecessary knowledge sharing with domestic firms, universities, and research institutes (Fu & Gong, 2011; Zhou, 2006) and only invest in employee training when in need of specific capabilities (Asheim & Vang, 2006). This weakens the effect of learning from FDI and spillovers from labour turnover. (5) Contrary to spillovers from FDI, domestic technology secrets may be disclosed to FIE through labour movement and cooperation with FIE (Zhou, 2006). (6) The final, but critical reason is domestic organisations are simply not capable of absorbing the advanced knowledge and technologies and benefiting from them. Although FDI inflow is abundant in China, domestic organisations lack sufficient funds and talents to take advantages from FIE (Chen, et al., 2010). Sufficient absorptive capacity is required for local organisations to benefit from FIE (Cohen & Levinthal, 1989; Fu & Gong, 2011).

The significant negative impact of FDI on patenting implies FDI brings pressure to bear on domestic organisations and the competitiveness of FIE may crowd low capacity organisations out of the market (Fu & Gong, 2011; Zhang & Rogers, 2009), as the loss of market share may lower the incentives of domestic organisations to innovate (Jiang & Xia, 2005). The negative impact also indicates increasing FDI alone will not improve the IC of a region. Policy makers should consider the conditions of benefiting from positive spillovers, as well as the way this may lead to a negative effect in order to make the best use of FDI for enhancing RIC.

Import and export: Different from FDI, international trade shows a positively significant effect on both overall applications and overall granted patents. For different categories, the impact is significantly positive on granted utility model patents, while it is significantly negative on granted invention patents. The comparison of coefficients confirms and reemphasises the different impact of international trade on radical innovations and incremental innovations ($z=-3.82$, $p<.01$).

The positive impact of EIT observed from the results is in line with findings from previous studies. Rivera-Batiz and Romer (1991), and Coe, Helpman and Hoffmaister (1997) have all pointed out that international trade may facilitate technology creation and diffusion, and Wang and Kafouros (2009) confirm this argument with empirical evidence from China.

Exports and imports bring benefits to domestic organisations in different ways. The positive spillovers of exports mainly come from the information gathered from the export market and by competing with foreign firms. On the international market exporters may access diverse knowledge and information on competing goods, which may help to improve their own products and lead to innovations, customer preferences which will encourage exporters to initiate innovative activities to maintain their market share, and market demands which will stimulate exporters' innovative activities as well (Cheung, 2010; Cheung & Lin, 2004; Salomon & Shaver, 2005; Zhang & Rogers, 2009).

Imports may improve RIC in three ways. Firstly, importing technologies may directly help build absorptive capacity and enhance innovation performance (Cheung, 2010; Cheung & Lin, 2004). Secondly, domestic organisations can take advantage of the advanced technologies and knowledge embedded in imported goods, which will upgrade the average technology level of the host country (Chuang & Hsu, 2004; Fu & Gong, 2011). Finally, imported goods will intensify the competition in the domestic market and reinforce the need for organisations to innovate in order to keep their position in the market (Lin & Lin, 2010). In summary, international trade can exert a positive effect on RIC through adopting new technologies and knowledge, interacting with international and domestic competitors and customers.

Although most evidence shows the positive effects of international trade on innovation performance (Chen, et al., 2010; Lin & Lin, 2010; Zhu & Jeon, 2007), this study found a negative and significant coefficient on granted invention patents. The negative effect may be from either export or import. In Li's (2009) work the impact of TSI[18], which is conducted with import and export, is ambiguous on granted invention patents. Lin and Lin (2010) found exports did not help in product innovation, while Sun (2000) found exports promote inventions, utility model, as well as designs, and excessive imports seem to paralyse domestic innovation. Moreover, studies show investing in foreign technologies has a negative impact on gross output value (Sun, 2010), and importing may substitute invention in domestic organisations (Sun, et al., 2009). To some extent this study's negative result is consistent with these findings. Another possible reason for the negative effect on radical innovation may be the insufficient absorptive capacity of domestic organisations who are incapable of assimilating and fully utilising the imported foreign technologies, knowledge, and information from the export market. This is similar to one of the reasons for the negative effect of FDI. To verify whether the negative effect is mainly from export or import, further studies are needed to analyse the impact of import and export separately.

Value of domestic technology contracts: With domestic technology transfer, measured as technology contract value per thousand GDP, the estimated coefficient of overall applications is positive and significant. For overall granted patents no significant effect is found, but Z-test shows there is no difference between the coefficients of overall applications and overall granted patents. Considering the two categories of granted patents, it is positive and significant on granted invention patents, but insignificant on granted utility model patents. This implies domestic technology transfer enhances improvement on radical innovations, but has no effect

[18] $TSI = \frac{total\ amount\ of\ export - total\ amount\ of\ import}{total\ amount\ of\ export + total\ amount\ of\ import}$

on incremental innovations. Z-tests confirm the different impact between the two categories of innovations.

The positive and significant coefficient of domestic technology transfer on granted invention patents aligns with what innovation system theory predicts and suggests domestic technology transfer helps in generating radical innovations. On the contrary, domestic technology interaction through technology market does not help in developing overall patents and utility model patents. This is consistent with findings of some previous studies (Hu, et al., 2005; Sun & Du, 2010) at the firm level that suggests the domestic technology market is insignificant and domestic technology transfer has a negative impact firms' productivity. Some researchers stress t technology transfer would increase patents in the long run (Sun, et al., 2009). Perhaps the time lag between technology transfer and patent output is not long enough, or the insignificance is mainly due to some specific transfer mechanism. The exact reason for the insignificance of overall patent output needs further investigation. Overall, the significant coefficients indicate the technology market plays a critical role in RIC improvement (Liu, 2006), while the insignificance of domestic technology market implies the linkages between firms and universities and research institutes are weak and the innovation actors have not yet been well integrated (Liu & White, 2001a; Sun, 2002).

5.2.4 Interactive effects

In discussion of the effect of FDI and international trade on RIC, absorptive capacity was frequently mentioned in the literature as one reason for the negative impact (Cohen & Levinthal, 1989; Fu & Gong, 2011). In studies at the firm level it has been found that absorptive capacity affects the relationship between knowledge acquisition and innovation capacity (Bosch, Volberda, & Boer, 1999; Liao, et al., 2010). R&D investment is widely used as the measure of absorptive capacity (Cohen & Levinthal, 1989, 1990; Kinoshita, 2000; Kostopoulos, et al., 2010; Lai, et al., 2006) as it will enhance learning capability (Liu & Zou, 2008) and the ability to exploit outside knowledge (Hervas-Oliver, et al., 2011). Since absorptive capacity is commonly used at the firm level and this study uses S&T investment rather than R&D investment, this thesis will explore whether S&T investment helps in benefiting from international and domestic interactions and whether S&T investment influences the relationships between interactions and RIC at the regional level.

The interactive effects on overall applications and overall granted patents are displayed in Table 5.4 and effects on different categories of granted patents are in Table 5.5.

Table 5.4 Interactive effects on overall applications and granted patents

Coef.			Overall applications				Overall granted patents			
			(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Innovation actors	Number of higher education institutions	lgNHEIpb	.163**	.162**	.164**	.163**	.014	.014	.016	.011
			(.075)	(.072)	(.075)	(.075)	(.103)	(.102)	(.103)	(.102)
	Number of large and medium-sized enterprises	lgNLMEpm	-.026	-.097	-.017	-.027	-.110	-.150*	-.128	-.133
			(.062)	(.061)	(.062)	(.062)	(.085)	(.086)	(.086)	(.085)
Innovation input	GDP per capita	lgGDPpp	.644***	.640***	.645***	.645***	.964***	.962***	.960***	.972***
			(.037)	(.035)	(.037)	(.037)	(.051)	(.050)	(.051)	(.051)
	Funding for scientific and technological activities	lgFSTpthGDP	.148***	.168***	.144***	.149***	.023	.034	.029	.035
			(.054)	(.051)	(.053)	(.053)	(.074)	(.073)	(.073)	(.073)
	Full time employed scientists and engineers	lgFTE_SEpm	.275***	.186**	.279***	.275***	.352***	.300***	.356***	.328***
			(.081)	(.077)	(.079)	(.079)	(.111)	(.110)	(.108)	(.108)
	Employment rate	Emprate	-.220	-.078	-.194	-.224	-.048	.035	-.131	-.049
			(.203)	(.196)	(.205)	(.202)	(.280)	(.280)	(.282)	(.277)
Interaction	FDI	lgFDIpthGDP	-.142***	-.133***	-.142***	-.141***	-.078***	-.072**	-.077***	-.073**
			(.020)	(.020)	(.020)	(.021)	(.028)	(.028)	(.028)	(.028)
	Import and export	lgEITpthGDP	.277***	.271***	.267***	.276***	.377***	.373***	.400***	.384***
			(.043)	(.042)	(.044)	(.043)	(.060)	(.059)	(.061)	(.059)
	Value of domestic technology contract	lgVDTCpthGDP	.043**	.040**	.050**	.043**	.010	.008	-.008	.009
			(.206)	(.020)	(.022)	(.021)	(.028)	(.028)	(.030)	(.028)
Interactive effects		lgFST_lgFDI	.012				.009			
			(.052)				(.071)			
		lgFST_lgEIT		.432***				.254**		
				(.075)				(.107)		
		lgFST_lgVDTC			.054				-.137*	
					(.058)				(.079)	
		lgFDI_lgVDTC				.007				.096**
						(.027)				(.037)
		_cons	-2.366***	-1.300***	-2.182***	-2.524***	-3.552***	-2.462***	-3.423***	-3.525***
			(.221)	(.207)	(.219)	(.186)	(.305)	(.295)	(.301)	(.255)
		Within R-sq	.8137	.8278	.8141	.8138	.7991	.8018	.8005	.8023

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 5.5 Interactive effects on two categories of granted patents

Coef.			Granted invention patents				Granted utility model patents			
			(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.462	-.423	-.421	-.411	.252***	.255***	.258***	.254***
			(.379)	(.373)	(.386)	(.387)	(.087)	(.086)	(.087)	(.086)
	Number of large and medium-sized enterprises	lgNLMEpm	-.846***	-1.109***	-.685**	-.734**	.037	-.014	.025	.022
			(.314)	(.315)	(.321)	(.321)	(.072)	(.072)	(.072)	(.072)
Innovation input	GDP per capita	lgGDPpp	5.404***	5.356***	5.387***	5.373***	.814***	.808***	.807***	.819***
			(.187)	(.184)	(.190)	(.191)	(.043)	(.042)	(.043)	(.043)
	Funding for scientific and technological activities	lgFSTpthGDP	1.548***	1.558***	1.430***	1.444***	.129**	.137**	.127**	.128**
			(.271)	(.267)	(.276)	(.277)	(.062)	(.061)	(.062)	(.062)
	Full time employed scientists and engineers	lgFTE_SEpm	.952**	.854**	1.315***	1.329***	.252***	.207**	.289***	.265***
			(.408)	(.401)	(.406)	(.409)	(.094)	(.092)	(.091)	(.091)
	Employment rate	Emprate	-.580	-.252	-.744	-.998	.282	.370	.151	.242
			(1.030)	(1.018)	(1.058)	(1.047)	(.237)	(.233)	(.238)	(.234)
Interaction	FDI	lgFDIpthGDP	-.579***	-.528***	-.574***	-.575***	-.157***	-.149***	-.157***	-.152***
			(.104)	(.103)	(.106)	(.106)	(.024)	(.024)	(.024)	(.024)
	Import and export	lgEITpthGDP	-.402*	-.487**	-.527**	-.457**	.428***	.417***	.450***	.430***
			(.220)	(.216)	(.229)	(.224)	(.050)	(.050)	(.082)	(.050)
	Value of domestic technology contract	lgVDTCpthGDP	.268**	.234**	.298***	.242**	-.030	-.035	-.052**	-.033
			(.102)	(.103)	(.113)	(.106)	(.024)	(.024)	(.025)	(.024)
Interactive effects		lgFST_lgFDI	1.088***				.107*			
			(.262)				(.060)			
		lgFST_lgEIT		2.162***				.376***		
				(.390)				(.089)		
		lgFST_lgVDTC			.424				-.157**	
					(.298)				(.067)	
		lgFDI_lgVDTC				-.042				.094***
						(.140)				(.031)
		_cons	-17.910***	-17.668***	-18.050***	-20.467***	-3.828***	-2.538***	-3.698***	-4.029***
			(1.120)	(1.076)	(1.130)	(.964)	(.257)	(.247)	(.254)	(.215)
		Within R-sq	.8847	.8883	.8805	.8799	.8373	.8429	.8382	.8359

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

*S&T effort*FDI:* The interactive effect of S&T effort and FDI is positive on all four DV, but it is only significant on granted invention patents and utility model patents at $p<0.01$ and $p<.1$ respectively. The significance level on granted invention patents is much higher than on granted utility model patents, which means the interactive effect of S&T effort and FDI is much stronger on radical innovations than on incremental innovations.

To explore how S&T effort influences the relationship between FDI and RIC, simple slope analysis (Aiken & West, 1991) is employed. The analysis confirms the interactive effect between S&T effort and FDI on granted invention patents and granted utility model patents. Figure 5-5 shows high funding for S&T slightly buffers the negative effect of FDI on granted invention patents, but low funding for S&T exacerbates the negative effect of FDI. This means increase of investment in S&T will help regions benefit from FDI in improving invention patenting. Figure 5-6 shows both high and low levels of S&T effort exacerbates the negative effect of FDI on granted utility model patents.

Figure 5-5 Interactive effects between S&T effort and FDI on granted invention patents

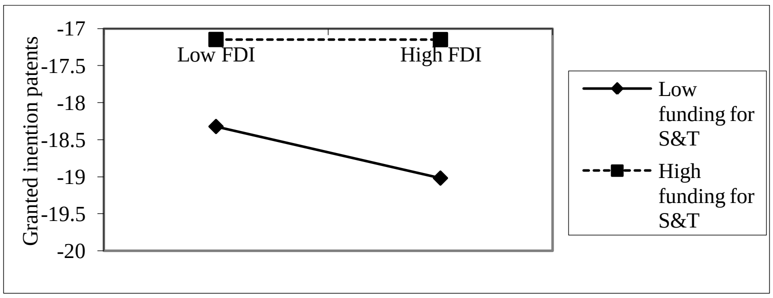
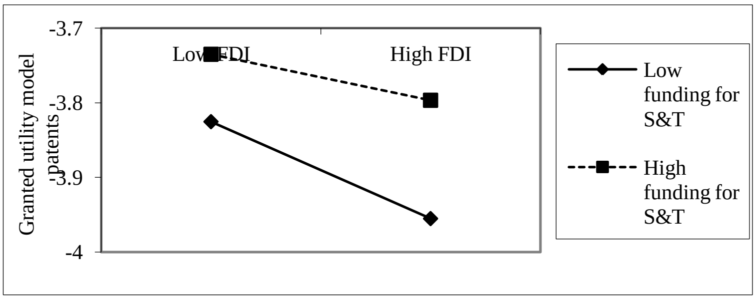


Figure 5-6 Interactive effects between S&T effort and FDI on granted utility model patents



The results corroborate findings from previous studies. They confirm the argument S&T investment is one condition of positive spillovers of FDI (Crespo & Fontoura, 2007) and the strength of positive effect of FDI relies on the availability of S&T investment (Fu, 2008). Moreover, FDI brings about financial access and as stated in previous sections, financial input is an important factor for innovation performance, , which helps to benefit from FDI as well (Girma, et al., 2008). This forms a beneficial cycle.

The positive interactive effects imply FDI has a more prominent effect on RIC where there are significant S&T activities. They also indicate absorptive capacity is one condition for domestic organisations to enjoy spillovers from FDI and create improvement in RIC. Moreover, the positive effect stresses S&T activities are not only the source of innovation, but also a moderator of the relationship between FDI and RIC. The interactive effect reveals the importance of in-house innovative effort in helping domestic organisations capture positive spillovers from FDI (Sun, 2010).

*S&T effort*international trade:* The interactive effects of S&T effort and international trade are positive and significant on all four DV and the impact on granted invention patents is much greater than on granted utility model patents.

Simple slope analysis shows both low and high S&T efforts enhance the positive effect of international trade on overall applications, overall granted patents, and granted utility model patents (see Figure 5-7, Figure 5-8, and Figure 5-10). While in Figure 5-9, it shows low funding for S&T exacerbates the negative effect of international trade on invention patenting, while high funding for S&T buffers the negative effect. Overall, S&T effort moderates the relationship between international trade and RIC. In other words, regions can improve how they benefit from international trade by increasing S&T investment.

Figure 5-7 Interactive effects between S&T effort and international trade on overall applications

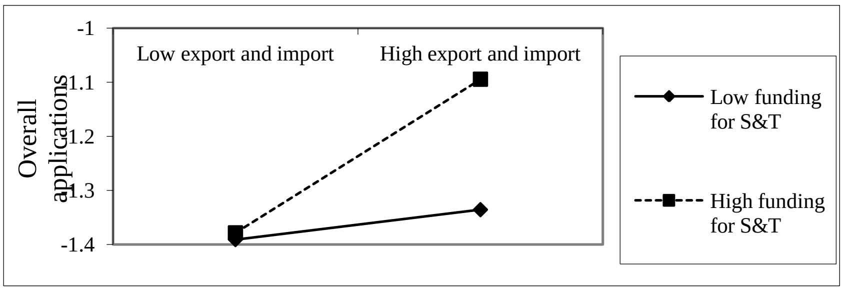


Figure 5-8 Interactive effects between S&T effort and international trade on overall granted patents

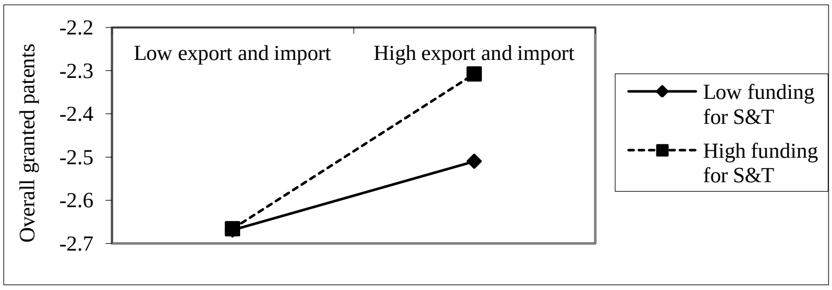


Figure 5-9 Interactive effects between S&T effort and international trade on granted invention patents

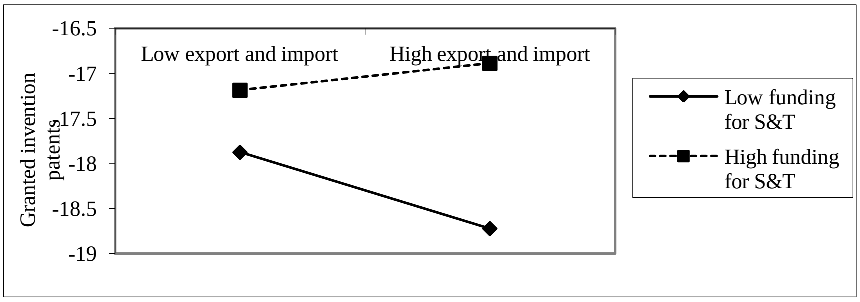
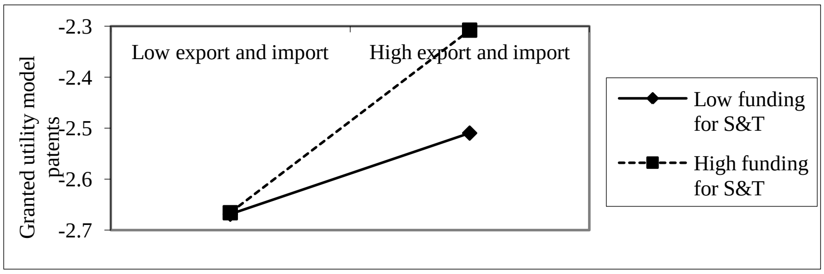


Figure 5-10 Interactive effects between S&T effort and international trade on granted utility model patents



S&T effort could enhance the absorptive capacity of domestic organisations (Cohen & Levinthal, 1989; Rosenberg, 1990) and subsequently promote the development of RIC by absorbing and effectively utilising the knowledge and advanced technologies embodied in imported or competing goods (Kumar & Aggarwal, 2005; Sun, 2010; Wang & Kafouros, 2009). The results obtained from this part of the analysis confirm the positive role of S&T effort in the relationship between international trade and RIC.

*S&T effort*domestic technology transfer:* The interactive effect between S&T effort and domestic technology transfer is more complicated and ambiguous than that between S&T effort and FD, and between S&T effort and international trade. The estimated coefficient is negative and significant on overall granted patents at $p<.1$, and it is significant and negative on granted utility model patents at $p<.05$.

Simple slope analysis of the two significant interactive effects show low S&T effort enhances the positive effect of domestic technology transfer on overall granted patents and buffers the negative effect on granted utility model patents. Meanwhile, high S&T efforts affect the relationship between domestic technology transfer and patenting in the opposite way (see Figure 5-11 and Figure 5-12). The graphs confirm the moderating role of S&T effort between domestic technology transfer and overall granted patents, and between domestic technology transfer and granted utility model patents. Hence, to some extent, S&T investment negatively affects the relationship between domestic technology transfer and RIC.

In previous research the findings have been mixed. Hu and his colleagues (2005) found S&T efforts assist in taking advantage of domestic technology transfer in China’s LME, while research on high-tech industries reveal S&T effort is not important in assimilation and utilisation of domestic technology (Li, 2011; Li & Wu, 2010). However, the results in this research indicate S&T effort retards the ability to benefit from domestic technology transfer. Therefore, how S&T effort influences the impact of domestic technology transfer on RIC needs further investigation.

Figure 5-11 Interactive effects between funding for S&T and domestic technology transfer on overall granted patents

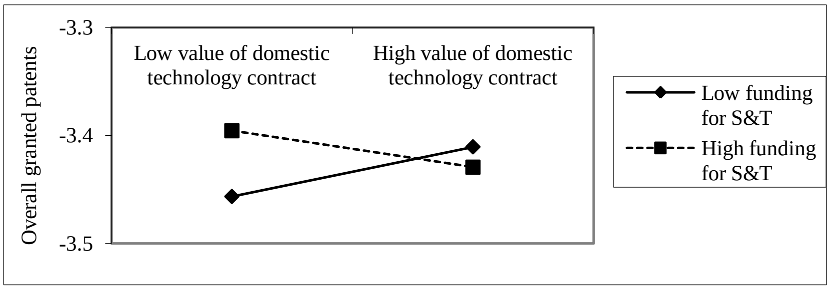
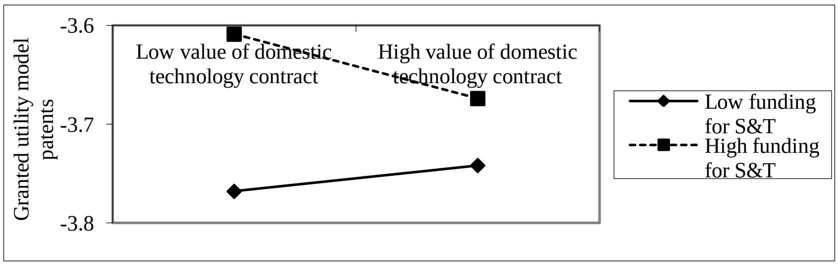


Figure 5-12 Interactive effects between funding for S&T and domestic technology transfer on granted utility model patents



*FDI*domestic technology transfer:* To see if foreign capital affects the impact of domestic technology transfer on RIC or domestic technology transfer influences the effect of FDI on RIC, the study explores whether an interactive effect on patenting exists between them. The results in Table 5.4 and Table 5.5 show FDI, coupled with domestic technology transfer, have a positive and significant impact on overall granted patents and granted utility model patents. A simple slope analysis, taking domestic technology and FDI as the moderator respectively, explores how they influence each other's impact on RIC. Figure 5-13 indicates domestic technology transfer moderates the relationship between FDI and overall patenting negatively, while Figure 5-14 shows it helps regions to benefit from FDI by improving utility model patenting. Meanwhile, Figure 5-15 and Figure 5-16 both reveal FDI improves the impact of domestic technology transfer on RIC. Hence, it can be argued FDI and domestic technology transfer do have interactive effect on RIC. FDI positively affects the relationship between domestic technology transfer and RIC, while the impact of domestic technology transfer on the relationship between FDI and RIC depends on the type of innovation.

Figure 5-13 Interactive effects between FDI and domestic technology transfer on overall granted patents – domestic technology transfer as the moderator

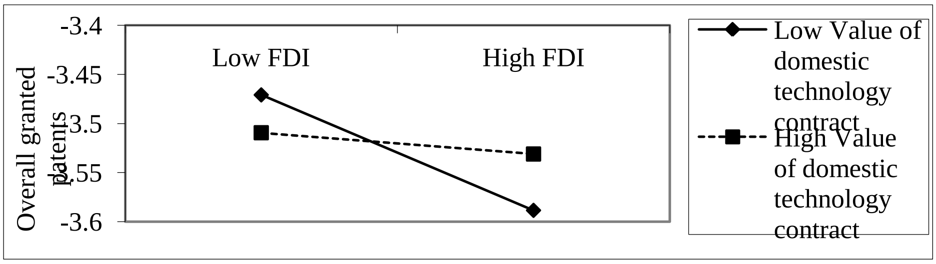


Figure 5-14 Interactive effects between FDI and domestic technology transfer on granted utility model patents – domestic technology transfer as the moderator

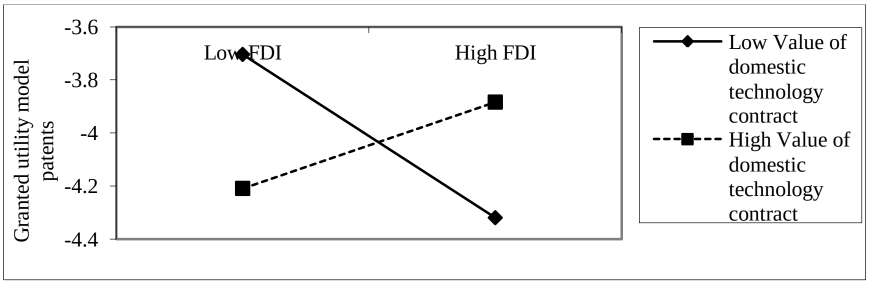


Figure 5-15 Interactive effects between FDI and domestic technology transfer on overall granted patents – FDI as the moderator

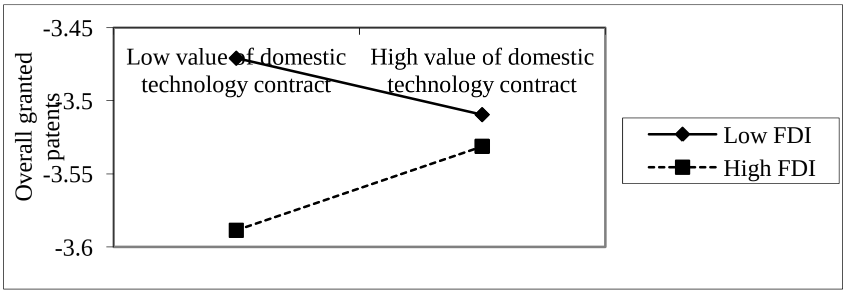
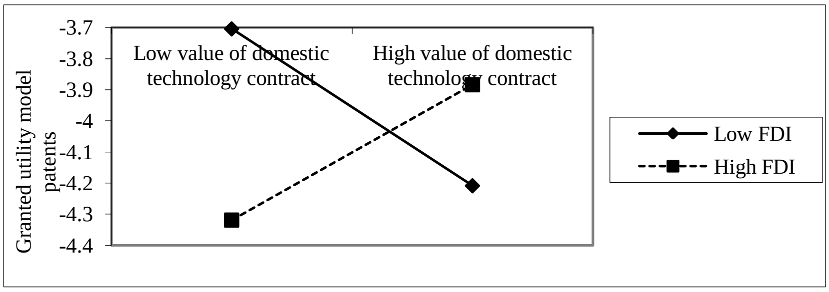


Figure 5-16 Interactive effects between FDI and domestic technology transfer on overall granted patents – FDI as the moderator

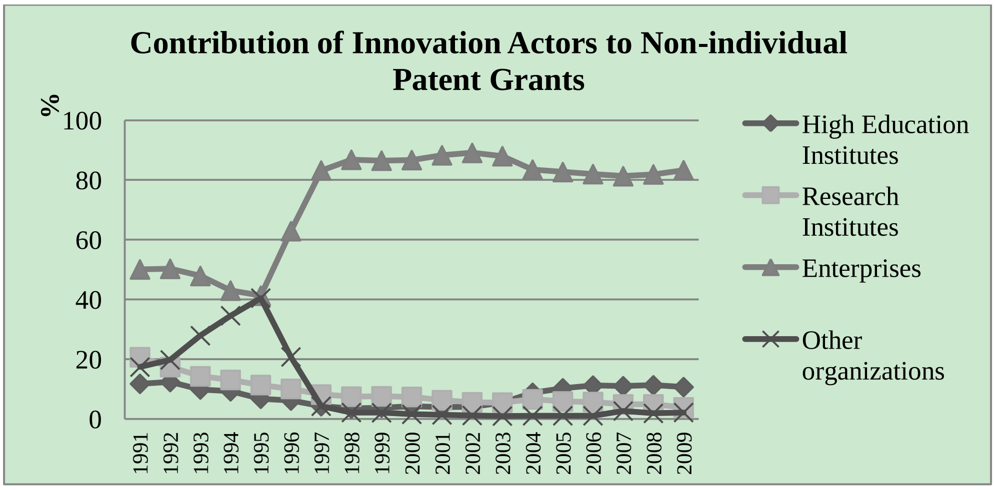


5.3 Summary

This chapter elaborated on the impact of drivers on RIC in the long-term, across all regions. The results answered the first main research question, showing knowledge stock and economic infrastructure, financial and human capital were the core drivers and interactions with international innovation actors measured by FDI and international trade were important factors as well. Other than direct impact, the interactions between financial investment in S&T and interactions between innovation actors also significantly influenced RIC. Moreover, the results showed in China domestic technology transfer influenced RIC less than international interactions, and HEI played a more important role than LME in innovation development. Furthermore, the results reveal the impact of a factor may differ in different types of innovations.

Innovation actors are direct contributors of RIC and two of the major actors, investigated in this study, HEI and LME, played different roles in RIC development. HEI improved RIC in China, not only as educators, but also as innovation creators. In contrast, LME, of which by the end of 2005 more than 50 per cent were composed of SOE and FIE, impeded the improvement of RIC. This does not mean enterprises are not important in developing RIC. In fact, enterprises make the most contribution to non-individual granted patents. As shown in Figure 5-17, since 1997, over 80 per cent of non-individual grants were from enterprises. From another point of view, the negative effect of LME revealed the important role of small and medium-sized enterprises (SME) in RIC development. As Zhu (2010) and Li and Zhu (2007) observe, the relationship between small and medium sized enterprises (SME) and RIC is stronger than between LME and RIC

Figure 5-17 Contribution of innovation actors to non-individual patent grants



The results suggested development of RIC depended not only on direct financial and human capital inputs, but also on international and domestic interactions between innovation actors and the interactive effect between S&T effort and interactions. This study found financial investment in S&T and skilled human capital greatly contributed to the establishment of RIC. However, the effects of international and domestic interactions were complicated. FDI alone did not help the development of RIC, and it even retarded the improvement of RIC, which was unexpected. International trade, which was measured as total amount of imports and exports, played a positive role in overall patenting, but it had a negative effect on invention patenting. The effect of domestic interactions on RIC was positive, but it was not as strong as international interactions. The impact of interactions demonstrated interactions with international innovation actors played a more important role than domestic technological interactions in RIC development in China.

S&T effort was a special factor in RIC development as it is a direct driver of RIC, as well as a moderator between interactions and RIC. Tsai & Wang (2007) stated in-house S&T effort contributes to external knowledge acquisition, which enhances organisations' innovation performance. The results in this study on the moderating role of S&T investment confirmed the argument. S&T effort was important for seizing positive spillovers from international trade and FDI. The more investment in S&T activities, the more positive spillovers domestic innovators got from international trade and FDI. However, the interactive effect of S&T effort was much stronger on international trade than on FDI. The positive moderating role of S&T effort between international interactions and RIC indicated they were highly complementary in improving RIC (Hu, et al., 2005).

In terms of domestic interactions, it seemed S&T effort was much less important. The regional technology market is essential to enhancing innovation activities (Johnson & Liu, 2011), which was confirmed by the impact of domestic technology transfer on RIC. However, when coupled with S&T effort, the results showed an increase in S&T investment impeded taking advantage of domestic technologies to improve overall patenting and utility model patenting. Hence, to some extent, S&T

effort negatively affected the relationship between domestic technology transfer and overall RIC, which was not expected.

Domestic and international interactions also had an influence on each other. Results showed FDI positively moderated the impact of domestic technology transfer on RIC, while the impact of domestic technology transfer on the relationship between FDI and RIC was associated with innovation types.

The existence of interactive effects implied the impact of a factor on RIC may be affected by other factors. This finding expanded the scale of interaction in RIS. Interactions in RIS were not only the interactive activities among RIS components, but also the interactive effects between the drivers of RIC. Moreover, the existence of interactive effects provided new insights for RIC studies.

Other than theoretical contributions, the findings of interactive effects suggested to improve RIC and make best use of the positive effect of each factor on RIC, policies makers should consider how a factor influences RIC as well as the possible interactive effect with other factors.

Chapter 6 PHASE COMPARISON

China has been changing over time since its foundation, as well as innovation development. During the time period of this study, there are two phases; 1991 to 1998; and 1999 to 2005. So then, *what are the differences in the main drivers of China's RIC between different transitional phases?* By answering this question this chapter will help to better understand the transitional path and the trajectory of innovation development in China. This chapter first describes the descriptive statistics of the two phases, and then explains the results in detail.

6.1 Data Summary

As discussed in section 2.3, the time frame of this study can be divided into two phases according to the reform process of innovation system. Phase One is 1991 to 1998 and Phase Two is 1999 to 2005. To explore whether there are any differences in RIC drivers between the two stages, the two stages were analysed separately using panel data regression with fixed effect models. The descriptive statistics from the two phases are listed in Table 6.1 and Table 6.2. The comparison of means between the two phases is graphed in Figure 6.1.

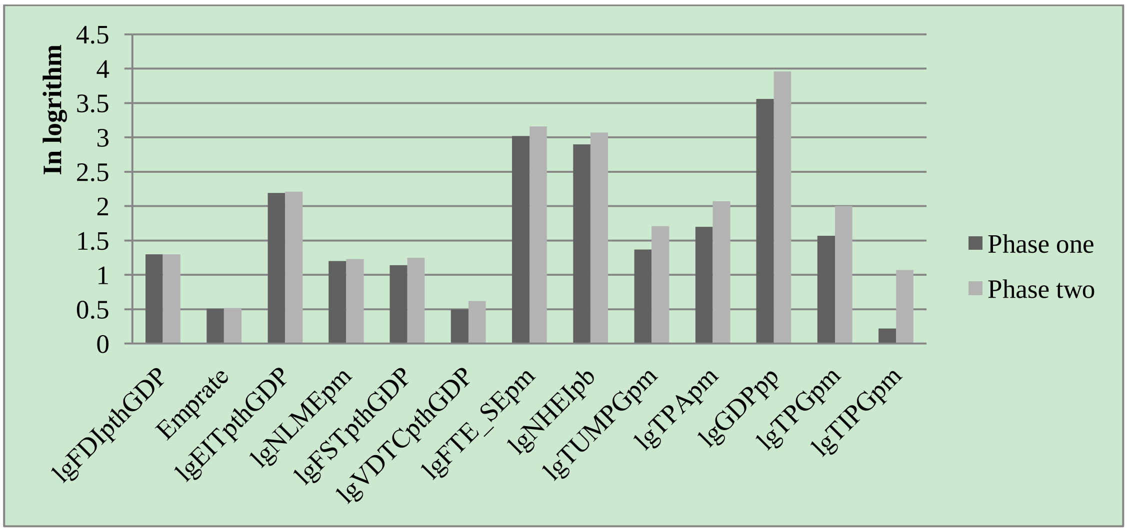
Table 6.1 Descriptive Statistics of stage one

	N	Period	Min	Max	Mean	Std. Dev
lgTPApm	240	1992-1999	1.01	2.80	1.70	.35
lgTPGpm	240	1995-2002	.83	2.67	1.57	.39
lgTIPGpm	240	1995-2002	-1.01	1.89	.22	.49
lgTUMPGpm	240	1995-2002	.56	2.50	1.37	.37
lgNHEIpb	240	1991-1998	2.35	3.72	2.90	.23
lgNLMEpm	240	1991-1998	.56	1.98	1.20	.28
lgGDPpp	240	1991-1998	2.94	4.40	3.56	.29
lgFSTpthGDP	240	1991-1998	.44	2.12	1.14	.32
lgFTE_SEpm	240	1991-1998	2.35	4.17	3.02	.35
Emprate	240	1991-1998	.39	.67	.51	.06
lgFDIpthGDP	240	1991-1998	-.44	2.38	1.30	.57
lgEITpthGDP	240	1991-1998	1.52	3.36	2.19	.41
lgVDTCpthGDP	240	1991-1998	-1.11	1.64	.50	.48

Table 6.2 Descriptive Statistics of stage two

	N	Period	Min	Max	Mean	Std. Dev
lgTPApm	210	2000-2006	1.36	3.30	2.07	.46
lgTPGpm	210	2003-2009	1.11	3.26	2.00	.49
lgTIPGpm	210	2003-2009	.23	2.72	1.07	.50
lgTUMPGpm	210	2003-2009	.75	2.84	1.71	.45
lgNHEIpb	210	1999-2005	2.70	3.71	3.07	.22
lgNLMEpm	210	1999-2005	.70	2.05	1.23	.28
lgGDPpp	210	1999-2005	3.39	4.71	3.96	.26
lgFSTpthGDP	210	1999-2005	.05	2.18	1.25	.28
lgFTE_SEpm	210	1999-2005	2.42	4.26	3.16	.33
Emprate	210	1999-2005	.35	.63	.52	.06
lgFDIpthGDP	210	1999-2005	-.06	2.17	1.30	.47
lgEITpthGDP	210	1999-2005	1.50	3.22	2.21	.46
lgVDTCpthGDP	210	1999-2005	-1.26	1.85	.62	.47

Figure 6-1 Comparison of means between two phases



Note: all variables are in logarithm, except Emprate, which is a ratio

Figure 6-1 shows the mean of each variable was higher in Phase Two than in Phase One, except for FDI. FDI per thousand GDP was almost the same between the two phases, which means the inflow of FDI was growing at the same speed as GDP. For other variables, the difference between means differed. Granted invention patents increased dramatically and grew faster than granted utility model patents. Considering IV, the difference between GDP per capital was the greatest, followed by number of HEI, skilled labor, domestic technology, and financial input. The differences in the rest of the variables were all quite similar.

6.2 Estimated results

In the following, the estimated results from fixed effect models for the two phases are elaborated. The estimated main effects are shown in Table 6.3 and a comparison of coefficients is listed in Table 6.4. Interactive effects are displayed in Table 6.5, Table 6.6, Table 6.7 and Table 6.8.

Table 6.3 Main effects of two phase

Coef.			Overall applications		Overall granted patents		Granted invention patents		Granted utility model patents	
			P1(25)	P2(26)	P1(27)	P2(28)	P1(29)	P2(30)	P1(31)	P2(32)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.046	-.117	-.378***	.050	-3.466**	-.103	-.325***	.487***
			(.090)	(.104)	(.140)	(.184)	(1.704)	(.268)	(.120)	(.117)
	Number of large and medium-sized enterprises	lgNLMEpm	-.167	.202***	-.132	-.263**	-3.669*	.207	-.053	-.050
			(.107)	(.064)	(.165)	(.113)	(2.017)	(.164)	(.142)	(.072)
Innovation input	GDP per capita	lgGDPpp	.492***	.918***	.989***	1.128***	13.747***	1.962***	.815***	1.019***
			(.060)	(.105)	(.093)	(.185)	(1.132)	(.269)	(.079)	(.118)
	Funding for scientific and technological activities	lgFSTpthGDP	.048	.083	-.113	-.038	3.465**	.224	-.074	.023
			(.076)	(.066)	(.118)	(.116)	(1.434)	(.169)	(.101)	(.074)
	Full time employed scientists and engineers	lgFTE_SEpm	.117	.126	.436**	-.012	2.173	1.152***	.426***	-.043
			(.117)	(.091)	(.182)	(.162)	(2.218)	(.236)	(.156)	(.103)
	Employment rate	Emprate	.017	.093	-.753*	.050	-.921	.955	-.436	.656*
			(.246)	(.349)	(.381)	(.618)	(4.65)	(.899)	(.326)	(.394)
Interaction	FDI	lgFDIpthGDP	-.112***	.028	-.141***	.135**	-2.069***	-.021	-.167***	.054
			(.023)	(.035)	(.036)	(.062)	(.438)	(.090)	(.031)	(.039)
	Import and export	lgEITpthGDP	-.034	.319***	.135	.411***	-2.804***	.603***	.238***	.467***
			(.053)	(.080)	(.083)	(.141)	(1.012)	(.205)	(.071)	(.090)
	Value of domestic technology contract	lgVDTCpthGDP	.040*	.037	-.034	.108**	.890**	-.029	-.049*	.082**
			(.021)	(.028)	(.033)	(.050)	(.399)	(.073)	(.028)	(.032)
		_cons	.059	-2.770***	-1.470**	-3.330***	-34.514***	-11.343***	-1.459**	-4.792***
			(.422)	(.251)	(.655)	(.445)	(7.990)	(.647)	(.561)	(.283)
		Within R-sq	.4892	.7883	.6983	.6291	.6799	.7938	.6711	.8645

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 6.4 Coefficient comparison between Phase One and Phase Two

Z-score			Overall applications P1-P2(33)	Overall granted patents P1-P2 (34)	Granted invention patents P1-P2 (35)	Granted Utility model patents P1-P2 (36)
Innovation actors	Number of higher education institutions	lgNHEIpb	0.52	-1.85*	-1.95*	-4.84***
	Number of large and medium-sized enterprises	lgNLMEpm	-2.97***	0.66	-1.92*	-0.02
Innovation input	GDP per capita	lgGDPpp	-3.54***	-0.67	10.13	-1.44
	Funding for scientific and technological activities	lgFSTpthGDP	-0.35	-0.45	2.24**	-0.78
	Full time employed scientists and engineers	lgFTE_SEpm	-0.06	1.84*	0.46	2.51**
	Employment rate	Emprate	-0.18	-1.12	-0.40	-2.13**
Interaction	FDI	lgFDIpthGDP	-3.37***	-3.87***	-4.58***	-4.42***
	Import and export	lgEITpthGDP	-3.68***	-1.69*	-3.30***	-2.00**
	Value of domestic technology contract	lgVDTCpthGDP	0.06	-2.35**	2.27**	-3.08***
		_cons	5.76***	2.35**	-2.89***	5.31***

Note: ***p<0.01, **p<0.05, *p<0.1

6.2.1 Innovation actors

Higher education institutions: The estimated results showed the impact of HEI differed between Phase One and Phase Two. In Phase One the impact was negative and significant on overall granted patents, granted invention and utility model patents, while in Phase Two it was positively significant on granted utility model patents. The comparison of coefficients confirmed the difference in impact between the two phases. Hence the positive impact during the whole period may be mainly influenced by the effect in Phase Two.

The different impact between the two phases may be explained by the reform of HEI in China. The reform of HEI started with the open door policy in 1978. With the reform of S&T system, the importance of HEI in S&T development was re-emphasised. The progress of the reform led to HEI having different impacts on RIC, as shown in the analysis. In Phase One the national government asserted other than the responsibility of educating, HEI should expand their role in improving S&T by putting more effort into applied research (Zhou, 2009). Although they made great achievements in technology innovation during 1991 and 1998, most achievements were in theoretical research, which largely resulted in published papers rather than patent counts. Therefore, analysing the impact on patent counts would impair the impact of HEI on the improvement of overall RIC. However, with the progress of reform, HEI engaged more in technology innovation and industry development in Phase Two than in Phase One (Zhou, 2009), which makes patent counts a better proxy of IC than in Phase One. Hence, the impact of high education of institutes on patent counts better reflects the impact of high education institutions on RIC in Phase Two.

Large and medium sized enterprises: The impact of LME differed between the two phases as well. In Phase One, the estimated coefficient was only negatively significant on granted invention patents at $p>.1$. In Phase Two, it was positively significant on overall applications at $p<.01$, but negatively significant on overall granted patents. Comparing its effect during the whole period, the significantly negative impact on granted invention patents was mainly from the impact in Phase One, while the positive impact on overall applications and negative impact on overall granted patents in Phase Two were weakened in the long term.

The different impact of LME between the two phases was closely related to the progress of enterprise system reform, especially the reform on SOE. As shown in Figure 5-4, more than 70 per cent of LME were SOE by the end of Phase One. Although SOE were given more autonomy for operations, to a great extent they still relied on the order of government directive (Zheng, 2004) and had low incentives to initiate innovation activities. With the deepening of reform, the ownership structure of SOE has been changing and most small and medium sized SOE have been privatised (Zheng, 2004). With the change of ownership structure, SOE may have improved their incentives to innovate (Li & Zhou, 2008), and the IC of LME has improved (Ye, 2009), which can be seen from the positive impact on overall applications in Phase Two. Although the impact of LME on overall granted patents was significantly negative, the change of the impact between the two phases showed signs of improvement of contribution of LME to RIC development.

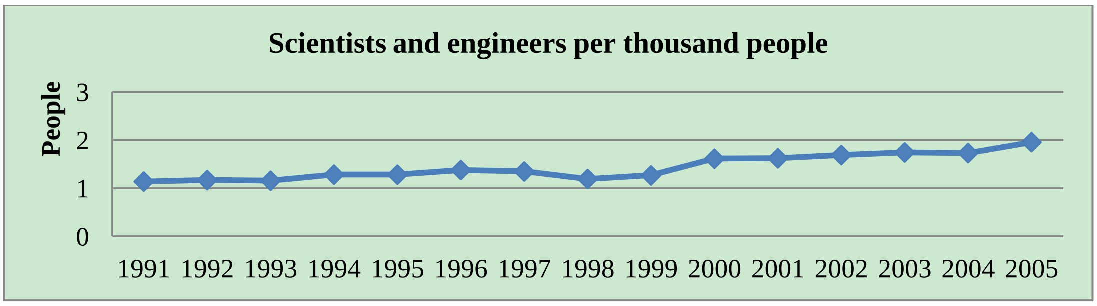
6.2.2 Input factors

GDP per capita: GDP per capita was positively significant on all DV in both phases. Considering the impact of GDP per capita in the long run, it can be concluded no matter under what circumstances, knowledge stock and economic structure were critical in improving RIC.

S&T effort: The estimated results show S&T effort was only significant and positive on granted invention patents in Phase One and none of the effects were significant in Phase Two. However, during the whole period, S&T showed a positive and significant effect on RIC. Hence, it can be inferred the improvement of RIC benefited more from the accumulated effect of S&T effort in a long term.

Scientists and engineers employed full time: According to the results shown in Table 6.3 and Table 6.4, differences exist in the impact of scientists and engineers employed full time. In Phase One, all the coefficients were positive and it was significant on overall granted patents and granted utility model patents. In Phase Two, it was only positively significant on granted invention patents. The results indicated skilled labour drove incremental innovations in Phase One, but radical innovations in Phase Two. Besides, the impact on RIC was greater in Phase One than in Phase Two, which is consistent with what Chi and Qian (2010) found; the impact of skilled labour decreased on innovation over time. Since the number of skilled labourers per million people had been increasing as shown in Figure 6-2, theoretically, the impact should have been greater in Phase Two. However, it was not the case in reality. Less impact with more skilled labour was probably because there were problems in taking advantage of human capital (Wang & Jia, 2009). This needs verification in further research.

Figure 6-2 Scientists and engineers per thousand people



Source: data is calculated by the author according to China Compendium of Statistics 1949-2008

Employment rate: The estimated coefficients of employment were only negatively significant on overall granted patents in Phase One and were positively significant on granted utility model patents in Phase Two, both at the level of $p<.01$. The comparison of coefficients only showed a significant difference on granted utility model patents between the two phases. Hence, it can be inferred employment rate had no effect on RIC in any regions.

6.2.3 Interactions

FDI: The impact of FDI was quite different between the two phases. In Phase One, FDI was significantly and negatively related to all four DV. In Phase Two, the effect became significantly positive on overall granted patents. Therefore, the strong negative impact over the whole period was mainly because of Phase One.

The change of impact indicated the positive effect of spillovers from FDI were gradually appearing. It took time for domestic innovators to benefit from accumulated spillovers of FDI, or the strategy of introducing foreign capital works in the long-term in China.

Import and export: The impact of international trade was greater in Phase Two than in Phase One. The estimated results showed the impact of international trade was negative and significant on granted invention patents, but was positive and significant on granted utility model patents in Phase One. In Phase Two, the coefficients were positive and significant on overall patenting and both the two categories of granted patents. This indicate the negative effect of international trade on granted invention patents over the whole period was mainly during Phase One, and the strategy of enhancing international trade worked better in Phase Two than in Phase One.

One possible reason the impact of international trade is stronger in Phase Two than that in Phase One is because of the adjustment in the international trade strategy. Earlier in Phase One, the government encouraged firms to import advanced technologies and digest and absorb embedded knowledge to re-innovate, with digestion and absorption the focus (NDRC, 1991). Later in Phase One, re-innovation was emphasised and facilitated by the government to export intensive processed goods (NDRC, 1996), which need better technologies and may stimulate domestic organisation to initiate more innovation activities. In Phase Two, organisations were encouraged to export goods which contain high technology content and import the most advanced and urgently needed equipment to facilitate the improvement of NIC (NDRC, 2001). The shift in international trade strategy helped domestic organisations benefit from international trade and made international trade serve the development of IC better in recent years.

Value of domestic technology transfer: The impact of domestic technology transfer was weaker than the impact of international interactions in both phases. In Phase One the estimated coefficients were positive and significant on overall applications ($p<.1$) and overall granted patents ($p<.05$), but are negatively significant on granted utility model patents at $p<.1$. However, in Phase Two, they ere positive and significant on overall granted patents and granted utility model patents at $p<.05$.

The different impact across the two phases may be explained by the shift in the tasks of technology markets. In Phase One the main tasks of the technology markets were academic research and technology import, while in Phase Two, technology markets were to help enhance independent innovation capacity and accelerate transformation of S&T achievements (Zhang, 2010). Clearly, the contribution of technology markets will be reflected more by patent counts in Phase Two than in Phase One. Since it exerted a negative impact in Phase One, it can be argue domestic innovators benefited more from domestic technology transfer in Phase Two than in Phase One.

6.2.4 Interactive effects

In line with the main effects of the possible drivers, the interactive effects of S&T effort and interactions differed between the two phases. Estimated results are displayed in Table 6.5, Table 6.6, Table 6.7, and Table 6.8.

Table 6.5 Interactive effects on overall applications

Coef.			P1				P2			
			(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.054	-.046	-.045	-.051	-.133	-.063	-.113	-.107
			(.087)	(.090)	(-.045)	(-.051)	(.104)	(.099)	(.104)	(.103)
	Number of large and medium sized enterprises	lgNLMEpm	-.201*	-.164	-.165	-.165	.182***	.141**	.211***	.178***
			(.103)	(.107)	(-.165)	(-.165)	(.064)	(.062)	(.064)	(.065)
Innovation input	GDP per capita	lgGDPpp	.481***	.487***	.483***	.477***	.952***	.899***	.908***	.936***
			(.058)	(.061)	(.483)	(.477)	(.105)	(.099)	(.104)	(.104)
	Funding for scientific and technological activities	lgFSTpthGDP	.003	.038	.044	.005	.139*	.156**	.066	.076
			(.074)	(.079)	(.044)	(.005)	(.072)	(.064)	(.066)	(.065)
	Full time employed scientists and engineers	lgFTE_SEpm	.118	.120	.124	.175	.040	.025	.140	.123
			(.113)	(.117)	(.124)	(.175)	(.102)	(.089)	(.092)	(.091)
	Employment rate	Emprate	.023	.021	.017	-.032	.172	.345	.165	.039
			(.237)	(.251)	(.017)	(-.032)	(.349)	(.334)	(.352)	(.348)
Interaction	FDI	lgFDIpthGDP	-.096***	-.112***	-.111***	-.110***	.036	.032	.033	.026
			(.023)	(.023)	(-.111)	(-.110)	(.035)	(.033)	(.035)	(.035)
	Import and export	lgEITpthGDP	-.022	-.034	-.028	-.056	.301***	.283***	.311***	.321***
			(.052)	(.054)	(-.028)	(-.056)	(.080)	(.076)	(.080)	(.079)
	Value of domestic technology contract	lgVDTCpthGDP	.035*	.040*	.038*	.046**	.044	.036	.071*	.021
			(.020)	(.021)	(.038)	(.046)	(.028)	(.027)	(.037)	(.030)
		lgFST_lgFDI	-.196***				.173*			
			(.049)				(.091)			
		lgFST_lgEIT		-.015				.456***		
				(.125)				(.098)		
		lgFST_lgVDTC			-.037				.135	
					(-.037)				(.095)	
		lgFDI_lgVDTC				-.085***				.103*
						(-.085)				(.056)
		_cons	.041	.047	.133	-.048	-2.428***	-1.820***	-2.699***	-2.744***
			(.391)	(.380)	(.133)	(-.048)	(.302)	(.314)	(.291)	(.243)
		Within R-sq	.5267	.4889	.4904	.5217	.7925	.8123	.79707	.7923

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 6.6 Interactive effects on overall granted patents

Coef.			P1				P2			
			(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.384***	-.393***	-.370***	-.378***	.017	.097	.048	.065
			(.138)	(.139)	(.137)	(.140)	(.183)	(.184)	(.185)	(.184)
	Number of large and medium sized enterprises	lgNLMEpm	-.165	-.095	-.123	-.132	-.302***	-.312***	-.270**	-.299**
			(.164)	(.165)	(.163)	(.166)	(.113)	(.115)	(.114)	(.115)
Innovation input	GDP per capita	lgGDPpp	.984***	.960***	.959***	.991***	1.198***	1.119***	1.136***	1.159***
			(.092)	(.093)	(.092)	(.093)	(.186)	(.184)	(.186)	(.185)
	Funding for scientific and technological activities	lgFSTpthGDP	-.142	-.177	-.084	-.107	.065	.018	-.037	-.050
			(.117)	(.121)	(.116)	(.119)	(.127)	(.119)	(.118)	(.116)
	Full time employed scientists and engineers	lgFTE_SEpm	.432**	.450**	.458**	.428**	-.176	-.091	-.013	-.018
			(.180)	(.181)	(.179)	(.184)	(.180)	(.166)	(.163)	(.161)
	Employment rate	Emprate	-.745*	-.607	-.749**	-.746*	.200	.245	-.011	-.038
			(.378)	(.385)	(.375)	(.383)	(.616)	(.622)	(.626)	(.617)
Interaction	FDI	lgFDIpthGDP	-.127***	-.135***	-.135***	-.141***	.154**	.139**	.133**	.135**
			(.036)	(.036)	(.035)	(.036)	(.062)	(.061)	(.062)	(.061)
	Import and export	lgEITpthGDP	.145*	.115	.169**	.138	.374***	.368**	.420***	.413***
			(.082)	(.083)	(.082)	(.084)	(.141)	(.142)	(.142)	(.140)
	Value of domestic technology contract	lgVDTCpthGDP	-.038	-.033	-.053	-.034	.120**	.106**	.085	.081
			(.032)	(.032)	(.033)	(.033)	(.050)	(.050)	(.066)	(.053)
		lgFST_lgFDI	-.171**				.336**			
			(.078)				(.160)			
		lgFST_lgEIT		-.383**				.374**		
				(.192)				(.183)		
		lgFST_lgVDTC			-.233***				-.093	
					(.082)				(.170)	
		lgFDI_lgVDTC				.011				.163
						(.037)				(.100)
		_cons	-1.730***	-1.321**	-1.678***	-1.672**	-2.827***	-2.395***	-3.300***	-3.143***
			(.623)	(.584)	(.611)	(.664)	(.533)	(.584)	(.519)	(.431)
		Within R-sq	.7053	.7041	.7100	.6985	.6386	.6369	.6298	.6349

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 6.7 Interactive effects on granted invention patents

Coef.			P1				P2			
			(53)	(54)	(55)	(56)	(57)	(58)	(59)	(60)
Innovation actors	Number of higher education institutions	lgNHEIpb	-3.433** (1.696)	-3.334* (1.699)	-3.528** (1.703)	-3.542** (1.678)	-.159 (.265)	.001 (.262)	-.102 (.269)	-.092 (.269)
	Number of large and medium sized enterprises	lgNLMEpm	-3.341* (2.013)	-4.014** (2.022)	-3.714* (2.016)	-3.639* (1.987)	.141 (.164)	.092 (.163)	.207 (.166)	.178 (.168)
Innovation input	GDP per capita	lgGDPpp	13.808*** (1.125)	14.038*** (1.142)	13.889*** (1.138)	13.539*** (1.117)	2.078*** (.269)	1.921*** (.262)	1.96*** (.271)	1.984*** (.271)
	Funding for scientific and technological activities	lgFSTpthGDP	3.795*** (1.438)	4.119*** (1.487)	3.350** (1.436)	2.859** (1.429)	.426** (.183)	.372** (.169)	.230 (.172)	.215 (.169)
	Full time employed scientists and engineers	lgFTE_SEpm	2.209 (2.205)	2.046 (2.210)	2.097 (2.218)	2.986 (2.204)	.848*** (.260)	.952*** (.236)	1.148*** (.237)	1.148*** (.236)
	Employment rate	Emprate	-.967 (4.627)	-2.299 (4.718)	-.929 (4.649)	-1.621 (4.587)	1.234 (.891)	1.449 (.884)	.950 (.912)	.887 (.903)
Interaction	FDI	lgFDIpthGDP	-2.210*** (.443)	-2.127*** (.438)	-2.097*** (.438)	-2.036*** (.431)	.008 (.089)	-.015 (.087)	-.022 (.090)	-.025 (.090)
	Import and export	lgEITpthGDP	-2.908*** (1.008)	-2.623** (1.014)	-2.969*** (1.022)	-3.119*** (1.003)	.536*** (.203)	.537*** (.201)	.604*** (.206)	.606*** (.205)
	Value of domestic technology contract	lgVDTCpthGDP	.939** (.397)	.883** (.397)	.995** (.408)	.980** (.395)	-.008 (.073)	-.032 (.071)	-.034 (.096)	-.053 (.077)
		lgFST_lgFDI	1.669* (.961)				.593** (.232)			
		lgFST_lgEIT		3. 638 (2.345)				.876*** (.260)		
		lgFST_lgVDTC			1.087 (1.017)				-.010 (.248)	
		lgFDI_lgVDTC				-1.206*** (.445)				.131 (.146)
		_cons	-33.632*** (7.627)	-36.438*** (7.147)	-29.676*** 7.577 ()	-36.468*** (7.955)	-10.369*** (.771)	-9.431*** (.830)	-11.063*** (.755)	-11.430*** (.630)
		Within R-sq	.6847		.6819	.6914	.8015	.8070	.7939	.7948

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 6.8 Interactive effects on granted utility model patents

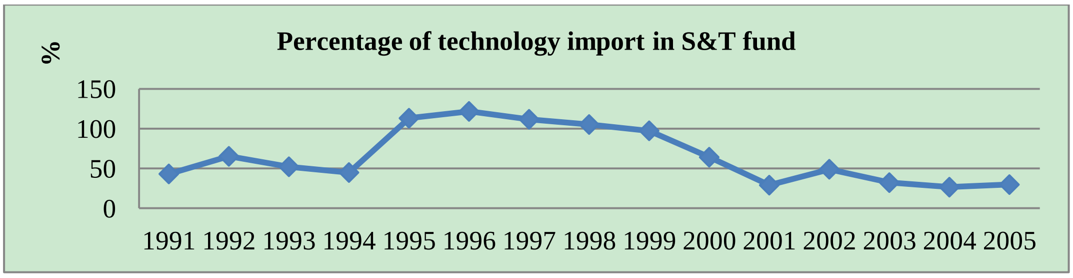
Coef.			P1				P2			
			(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.327***	-.329***	-.316***	-.323***	.471***	.528***	.118***	.490***
			(.120)	(.120)	(.116)	(.120)	(.117)	(.116)	(.118)	(.118)
	Number of large and medium sized enterprises	lgNLMEpm	-.070	-.045	-.045	-.054	-.070	-.091	.072	-.055
			(.142)	(.143)	(.138)	(.141)	(.072)	(.072)	(.072)	(.073)
Innovation input	GDP per capita	lgGDPpp	.817***	.811***	.786***	.821***	1.054***	1.007***	.118***	1.022***
			(.079)	(.081)	(.078)	(.080)	(.119)	(.116)	(.118)	(.119)
	Funding for scientific and technological activities	lgFSTpthGDP	-.078	-.084	-.037	-.056	.077	.074	.075	.022
			(.101)	(.105)	(.098)	(.102)	(.081)	(.075)	(.075)	(.074)
	Full time employed scientists and engineers	lgFTE_SEpm	.422***	.429***	.450***	.401**	-.128	-.114	.104	-.044
			(.155)	(.156)	(.151)	(.157)	(.115)	(.105)	(.104)	(.103)
	Employment rate	Emprate	-.429	-.391	-.430	-.412	.734*	.827**	.398*	.644
			(.326)	(.333)	(.317)	(.327)	(.394)	(.392)	(.398)	(.396)
Interaction	FDI	lgFDIpthGDP	-.161***	-.166***	-.161***	-.168***	.061	.056	.040	.052
			(.031)	(.030)	(.030)	(.031)	(.039)	(.039)	(.040)	(.039)
	Import and export	lgEITpthGDP	.241***	.231***	.273***	.247***	.448***	.437***	.090***	.468***
			(.071)	(.070)	(.070)	(.071)	(.090)	(.089)	(.090)	(.090)
	Value of domestic technology contract	lgVDTCpthGDP	-.052*	-.049*	-.071**	-.052*	.088***	.080**	.042**	.079**
			(.028)	(.028)	(.028)	(.028)	(.032)	(.032)	(.042)	(.034)
		lgFST_lgFDI	-.074				.174*			
			(.068)				(.103)			
		lgFST_lgEIT		-.110				.320***		
				(.165)				(.115)		
		lgFST_lgVDTC			-.252***				.108	
					(.069)				(.108)	
		lgFDI_lgVDTC				.037				.024
						(.032)				(.064)
		_cons	-1.746***	-1.039**	-1.639***	-1.708***	-4.498***	-3.645***	.330***	-4.680***
			(.538)	(.504)	(.517)	(.567)	(.341)	(.368)	(.330)	(.276)
		Within R-sq	.6729	.6716	.6912	..6733	.8667	.8698	.8651	.8647

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

*S&T effort*FDI:* The interactive effect of S&T effort and FDI was quite different between the two phases. The regression results showed S&T effort had a significantly negative effect on overall patenting, both in applications and granted patents, but a significantly positive effect on granted invention patents in Phase One. In Phase Two, the interactive effects were positively significant both on overall patenting and the two categories of granted patents.

To confirm these results, simple slope analysis was conducted. Figures 6-4, 6-5 and 6-6 confirm the negative moderating role of S&T effort in the relationship between FDI and overall applications, overall granted patents, and granted invention patent in Phase One. However, Figure 6-7 to Figure 6-10 showed low S&T effort buffered the positive effect of FDI on all four DV and high S&T exacerbated the positive effect in Phase Two, which means S&T effort moderates the relationship between FDI and RIC positively.

Figure 6-3 Percentage of technology import in S&T fund



Source: the percentage was calculated by the author according to CSYST 2001 and CSYST 2006

The effect of resource input relies not only on the amount, but also on how it is used (Yu & Xie, 2007). As shown in Figure 6-3, in Phase One, more and more S&T funds were used in importing foreign technologies. The money used for technology import was even more than the total S&T funds between 1995 and 1998. Although the absolute amount of S&T fund was increasing, the ratio spent on innovation activities was decreasing, which means an increase of S&T effort increased imported technologies, but not domestic innovation activities. To some extent this explains the negativity of the interactive effects of S&T effort and FDI in Phase One.

In Phase Two money spent on technology import in S&T funds was decreasing, which means more funds were used on self-innovation activities. Consequently, absorptive capacity was enhanced, causing the capability of domestic organisations to benefit from FDI to improve, which shows signs of a positive moderating effect of S&T effort between FDI and RIC.

Figure 6-4 Interactive effects between FDI and S&T effort on overall applications in Phase One

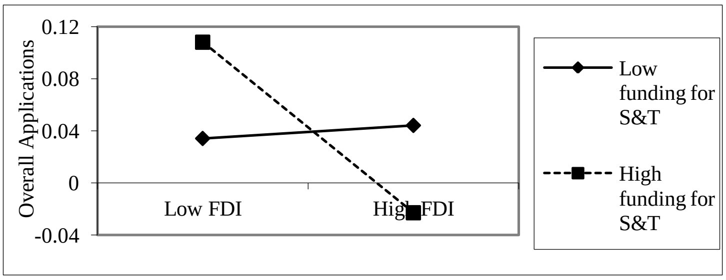


Figure 6-5 Interactive effects between FDI and S&T effort on overall granted patents in Phase One

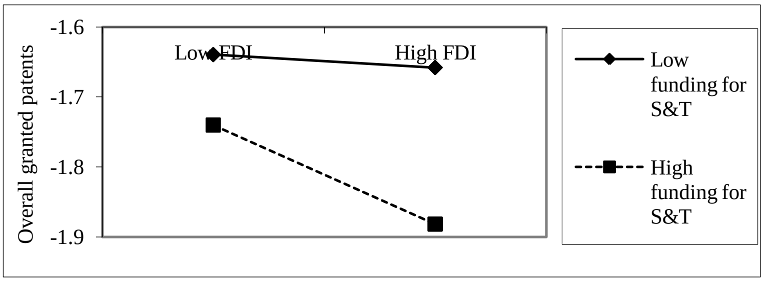


Figure 6-6 Interactive effects between FDI and S&T effort on granted invention patents in Phase One

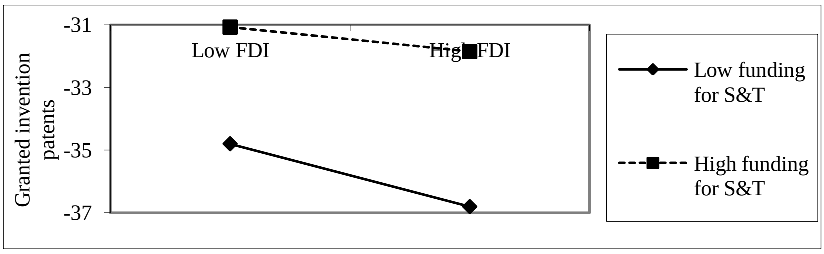


Figure 6-7 Interactive effects between FDI and S&T effort on overall applications in Phase Two

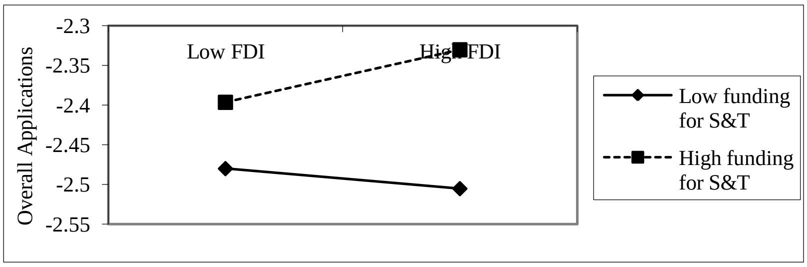


Figure 6-8 Interactive effects between FDI and S&T effort on overall granted patents in Phase Two

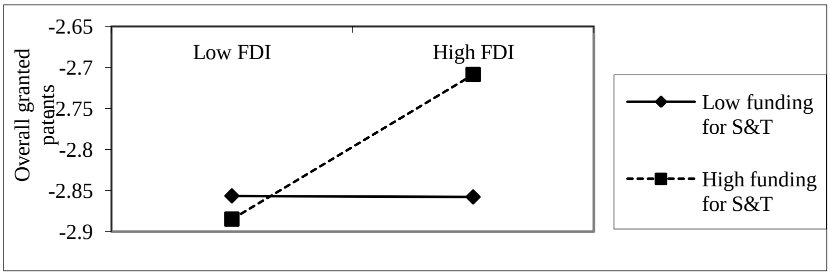


Figure 6-9 Interactive effects between FDI and S&T effort on granted invention patents in Phase Two

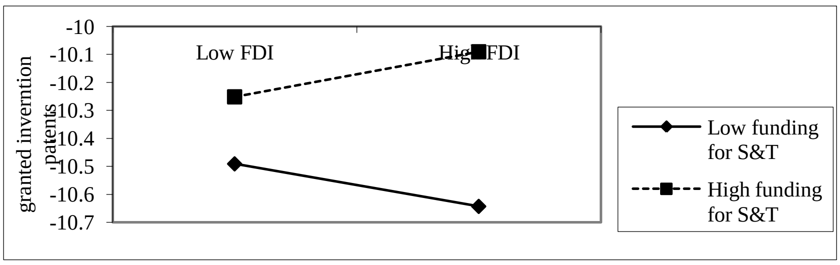
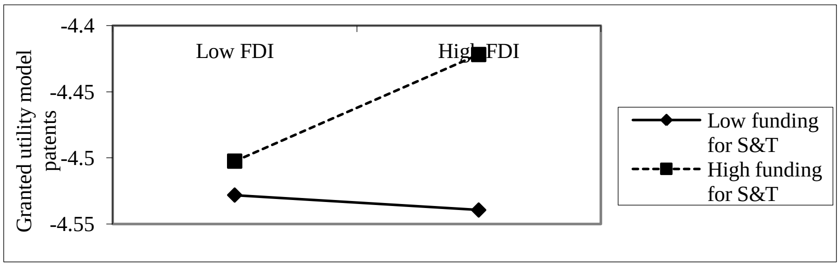


Figure 6-10 Interactive effects between FDI and S&T effort on granted utility model patents at Phase Two



*S&T effort*international trade:* Differences exist in interactive effects between S&T effort and international trade between two phases, and it is similar to that between S&T effort and FDI. The estimated coefficients show interactive effect was only negatively significant on overall granted patents in Phase One, and the simple slope analysis confirmed the moderating role of S&T effort between international trade and overall patenting (see Figure 6-11). In terms of Phase Two, the interactive effects were significantly positive on all four DV at $p<.01$. Figures 6-12 to 6-15 show both increasing and reducing S&T effort enhanced the positive effect between international trade and RIC, and the effect with high S&T effort was greater than with low S&T effort. This implies an increase of S&T effort will enhance the ability of domestic innovators to benefit from international trade and improve RIC. The different effects of S&T effort between the two phases could be explained by the reason discussed in its effect on the relationship between FDI and RIC.

Overall, with the shift of technology import strategy, S&T effort plays an important role in benefiting from international trade in the long term.

Figure 6-11 Interactive effects between international trade and S&T effort on overall granted patents in Phase One

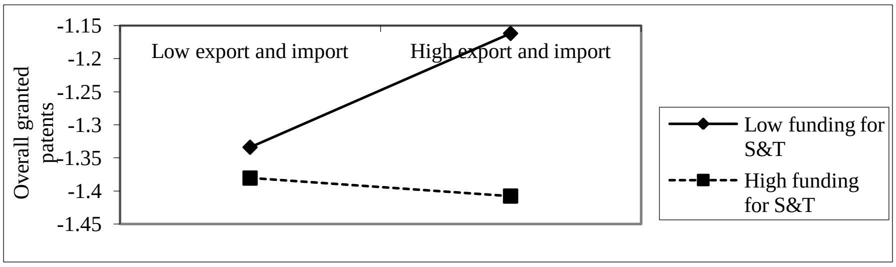


Figure 6-12 Interactive effects between international trade and S&T effort on overall applications in Phase Two

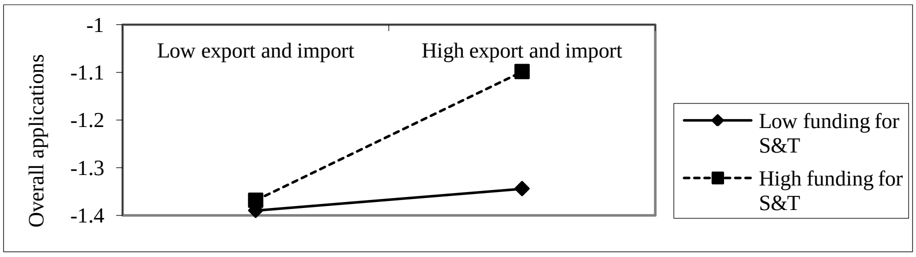


Figure 6-13 Interactive effects between international trade and S&T effort on overall granted patents in Phase Two

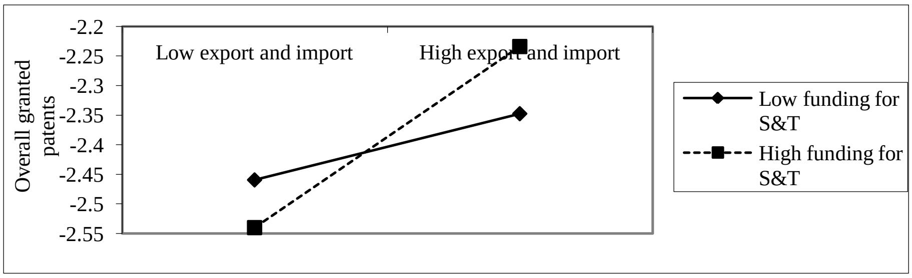


Figure 6-14 Interactive effects between international trade and S&T effort on granted invention patents in Phase Two

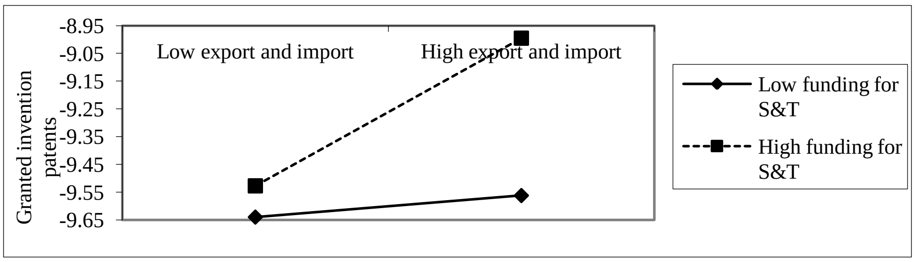
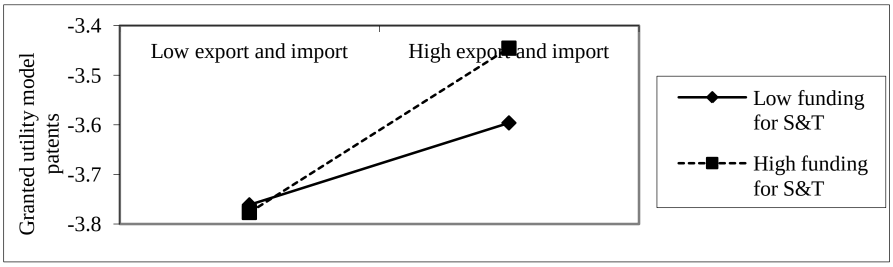


Figure 6-15 Interactive effects between international trade and S&T effort on granted utility model patents in Phase Two



*S&T effort*domestic technology transfer:* In terms of the interactive effect between S&T effort and domestic technology transfer on RIC, the regression results showed only the effect on overall granted patents and granted utility model patents in Phase One was negatively significant. As shown in Figure 6-16 and Figure 6-17, low S&T effort buffered the negative effect, while high S&T effort exacerbated the negative effect on both overall granted patents and granted utility model patents. This indicates an increase in S&T effort will impede domestic organisations in taking advantage of domestic technologies in Phase One. Since S&T effort did not display a moderating role in Phase Two, the negative interactive effect on overall granted patents and granted utility model patents shown during the whole period may be attributed to the effect in Phase One.

As discussed in section 5.3.3, the main tasks of the technology market in Phase One were academic research and technology import, while in Phase Two they were development of IC and transformation of S&T achievement. Hence, increase of S&T effort in Phase One would increase the effort on technology transfer, but not on taking advantage of transferred technologies as the effort that on self-innovation was not enough. With the improvement of IC and the technology market, the negative effect of S&T effort on the relationship between domestic technology transfer and RIC disappeared in Phase Two.

Figure 6-16 Interactive effects between domestic technology transfer and S&T effort on overall granted patents in Phase One

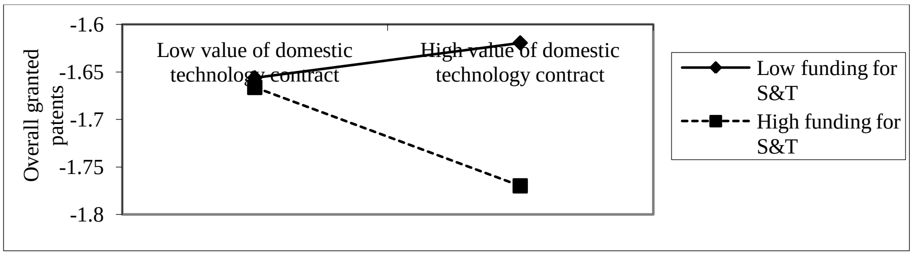
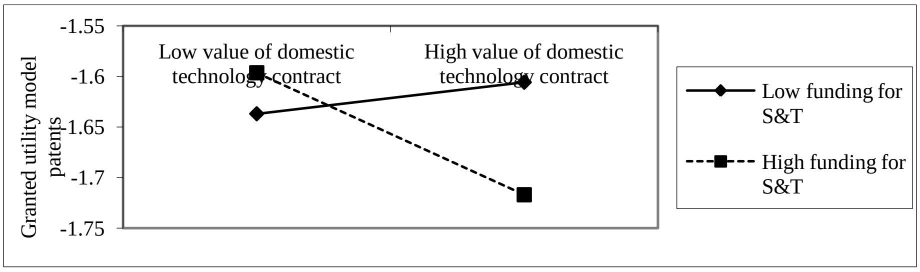


Figure 6-17 Interactive effects between domestic technology transfer and S&T effort on granted utility model patents in Phase One



*FDI*domestic technology transfer*: Estimated results show there were negative interactive effects between FDI and domestic technology transfer, on both overall applications and granted invention patents in Phase One and significantly positive interactive effect only on overall applications in Phase Two. Figures 6-18 to 6-21 indicate domestic technology transfer affects the relationship between FDI and RIC negatively, while FDI influences the relationship between domestic technology transfer and RIC positively in Phase One.

From Figures 6-22 and 6-23, it can be seen that both FDI and domestic technology transfer can be treated as a moderator in Phase Two in terms of patent applications.

Low FDI buffered the positive effect of domestic technology transfer on overall applications, while high FDI increased the benefits domestic innovators gain through domestic technology transfer. Meanwhile, increase of domestic technology transfer helped in taking advantage of FDI.

The difference between the two phases is probably because of the development of the technology market, which helps in attracting more FDI, and the increase of positive spillovers from FDI, which may lead to more innovations in the technology market. How FDI and domestic technology transfer influence each other's impact on RIC needs further verification.

Figure 6-18 Interactive effects between FDI and domestic technology transfer on overall applications in Phase One – domestic technology transfer as the moderator

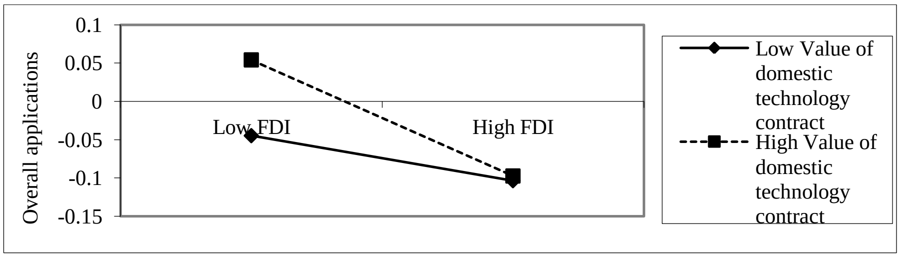


Figure 6-19 Interactive effects between FDI and domestic technology transfer on granted invention patents in Phase One – domestic technology transfer as the moderator

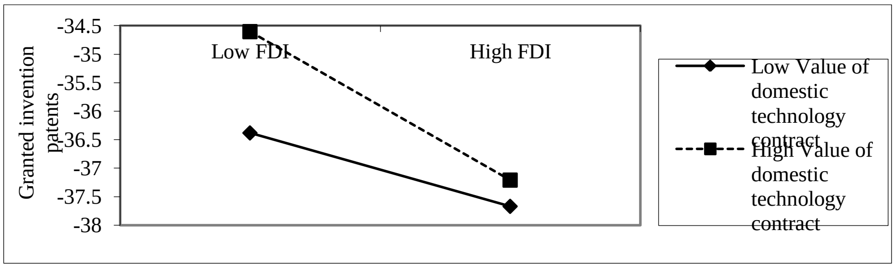


Figure 6-20 Interactive effects between FDI and domestic technology transfer on overall applications in Phase One – FDI as the moderator

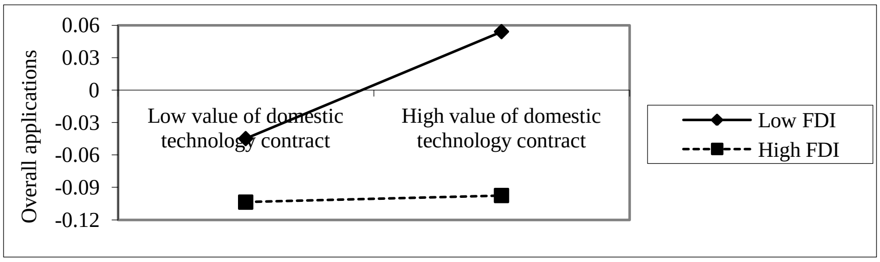


Figure 6-21 Interactive effects between FDI and domestic technology transfer on granted invention patents in Phase One – FDI as the moderator

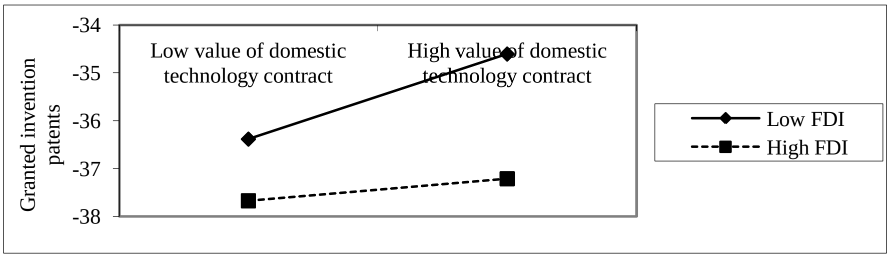


Figure 6-22 Interactive effects between FDI and domestic technology transfer on overall applications in Phase Two – domestic technology transfer as the moderator

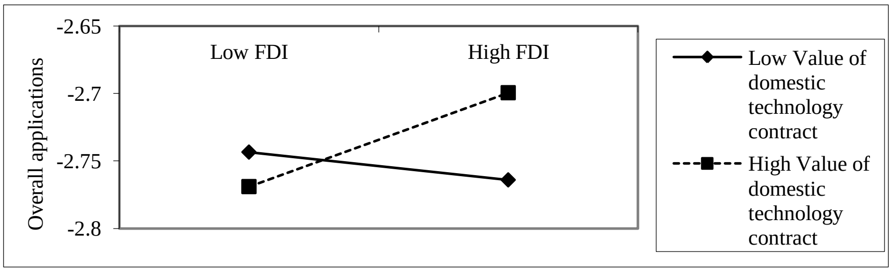
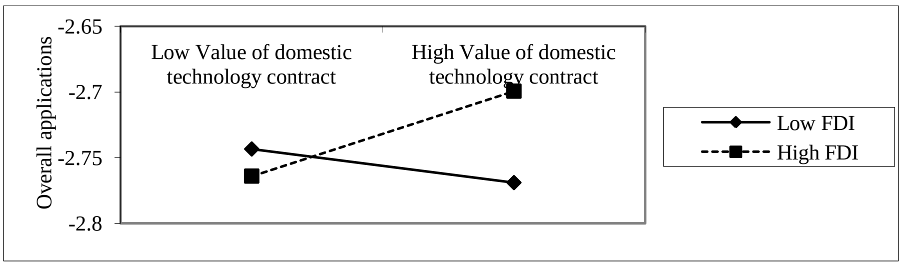


Figure 6-23 Interactive effects between FDI and domestic technology transfer on overall applications in Phase Two – FDI as the moderator



6.3 Summary

This chapter elaborates on the impact of drivers on RIC with fixed effect panel data modeled in two phases. The results in this part revealed the impacts of the drivers changed over time, as did the interactive effects between S&T investment and interactions.

Specifically in terms of innovation actors, both HEI and LME showed a negative impact in Phase One, while in Phase Two HEI exerted a positive effect on incremental innovations and LME exerted a positive effect on applications but a negative impact on overall granted patents. The difference in the impact of the two innovation actors between the two phases can be attributed to their reform as discussed above. The difference of the impact and the positive effect observed in Phase Two indicate reform of both HEI and LME leads to improvement of RIC. In other words, the reform of HEI and LME works effectively in the long run in China.

In terms of innovation inputs, the results show GDP per capita, representing knowledge stock and economic infrastructure, was an important factor of RIC, no matter in what phase of reform and under what situation. However, financial capital and human capital did not display a great impact on overall RIC in either phase. Considering the strong effect across the whole period, it suggests financial and human capital have an accumulated effect in the long term.

Concerning interactions, the impact of domestic interactions is more complicated than of international interactions. FDI negatively influenced RIC in Phase One and exerted a positive effect in Phase Two, while the impact of international trade depended on the type of innovations in Phase One and it was positive on overall RIC in Phase Two. These results imply with the improvement of RIC, domestic innovators benefit more from international interactions, and the positive effect of the strategies to attract FDI and enhance international trade emerges. Domestic technology transfer affected radical innovations positively, but influenced incremental innovations negatively in Phase One. However, it only exerted a positive impact on incremental innovations in Phase Two. On the whole, the contribution of international interactions increased in Phase Two, but it is hard to tell if the impact of domestic interactions improved in the second phase.

The interactive effects differ as well. So much was spent on S&T funding to import technologies and equipment, S&T effort negatively moderated the relationship between FDI and RIC and between international trade and RIC in Phase One. In Phase Two S&T effort moderated the relationship between FDI and RIC in a positive way, as well as the impact of international trade on RIC. For domestic interactions, S&T effort negatively moderated its influence on RIC in Phase One, but no moderating effect as found in Phase Two. Meanwhile, domestic technology transfer moderated the impact of FDI negatively in Phase One, but positively in Phase Two. On the contrary, FDI influenced the relationship between domestic technology transfer and RIC positively in both phases. Overall, investment in S&T activities influenced the impact of interactions on RIC, and FDI and domestic technology transfer influenced each other’s relationship with RIC.

All in all, the differences found between the two phases reveal with the proceeding of IS reform the innovation environment has been changed and consequently changed the impact of drivers on RIC. The change of impact provides indications of which strategies or innovations worked better during a specific period, which in turn helps better understanding the effect of IS reform in each phase in China.

Chapter 7 CLUSTER ANALYSIS

Regions in China are unevenly developed and RIC is also uneven. To better understand the variations of RIC Chapter 7 and Chapter 8 try to address the following research question "*What are the differences in the drivers of RIC among regions at different innovation levels in China?"* The purpose of this chapter is to classify the 30 regions into different groups in terms of their innovation level in preparation for group comparison. Hierarchical cluster analysis is conducted with the variables from the research model developed. Ultimately, three groups are formed; high, medium and low innovative groups.

As described in section 2.3, differences exist in economic infrastructure, S&T financial input, and innovation performance among regions. Take Beijing and Shaanxi as examples. The S&T intensity of Beijing is much higher than other regions, and Shaanxi is in the top tier of S&T intensity. However, since 2002 the number of patents owned per million people is lower in Beijing than in Shanghai, and Shaanxi is always in the bottom tier in terms of patent counts. The region with the highest S&T intensity is not always the one with the most innovation output, which implies the relationship between financial input and innovation output is quite different between these two regions. It can be inferred the impact of the drivers vary among regions. Therefore, investigating the differences in the impact of drivers among regions is important. It will deepen the understanding of RIC in China, as well as provide insights for regions on improving RIC.

In previous literature on China's IS, researchers focus on a part of China, such as Shanghai (Wu, 2007), Beijing (Guan, et al., 2005; Yam, Guan, Pun, & Tang, 2004), Central China (Ren, Zeng, & Krabbendam, 2010), Southern China (Barbieri, et al., 2010), or the Yangtze River Delta (Lee, Liu, & Pan, 2009). In terms of RIC only a few Chinese studies look into different areas (Ji & Zhao, 2008).

In terms of geography and economic development level China is traditionally divided into three parts; East China, Central (or Mid) China, and West China. . According to CSY, East China consists of 11 regions: Beijing, Shanghai, Jiangsu, Guangdong, Tianjin, Liaoning, Zhejiang, Fujian, Shandong, Hebei, and Hainan; Central/Mid China covers eight regions: Hubei, Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, and Hunan; and West China covers 12 regions: Neimenggu, Guangxi, Chongqing, Guizhou, Yunnan, Tibet, Gansu, Qinghai, Ningxia, Xinjiang, Shaanxi, and Sichuan. Since this classification mainly considers geographical differences and economic development, it is not directly applicable to this study.

As the existing classifications are not suitable for this research, hierarchical cluster analysis is conducted to classify the regions considering both IC and explanatory factors in the research model developed in Chapter 4. The results are detailed below.

7.1 Cluster Results

According to the transitional process of China's NIS, the study period (1991-2009) of the thesis can be divided into three phases. Phase One from 1991 to 1998, Phase Two from 1999 to 2005, and Phase Three from 2006 to 2009. Considering the time lag between input and output, data from 1991 to 2005 was used for IV, data from

1992 to 2006 was used for overall applications, and data from 1995 to 2009 was used for overall granted patents. Hence, the analysis covers the first two phases in terms of the time frame for IV.

To be more accurate, cluster analysis was conducted for the whole period as well as each stage. For each period, group means were calculated by region for clustering. Correspondingly, there are 30 observations of each analysis, namely the 30 regions. During the clustering procedure variables are converted to standard scores, which eliminates the effects of scale differences (Hair, et al., 2010). All independent variables, plus overall applications and granted patents, are included for similarity calculation. The dendrograms of each period are shown in Figures 6-1, 6-2, and 6-3.

Figure 7-1 Results for the whole period (1991-2005)

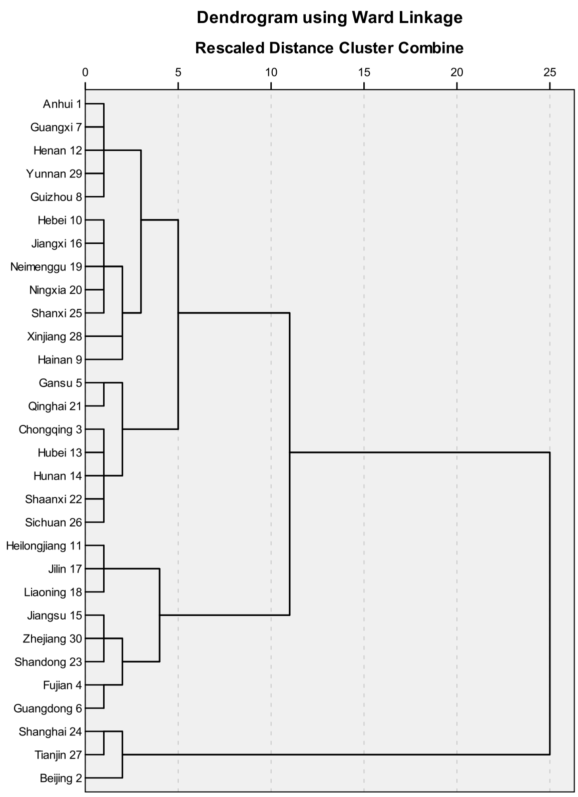


Figure 7-2 Results for Phase One (1991-1998)

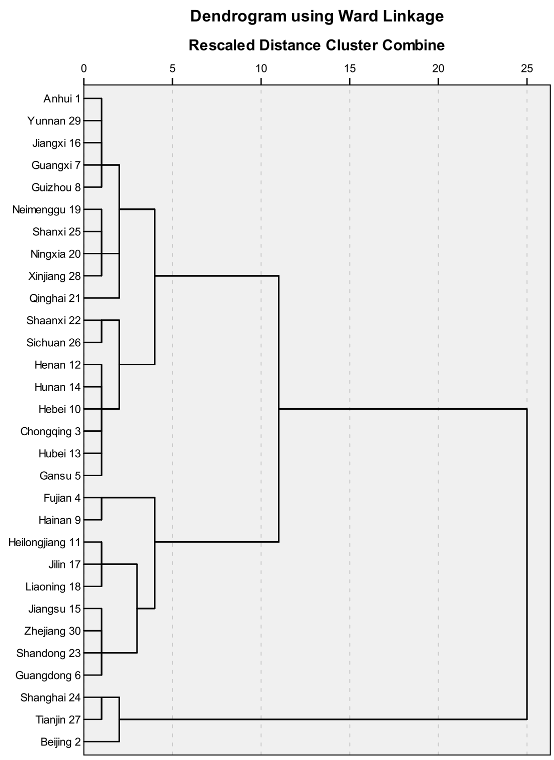
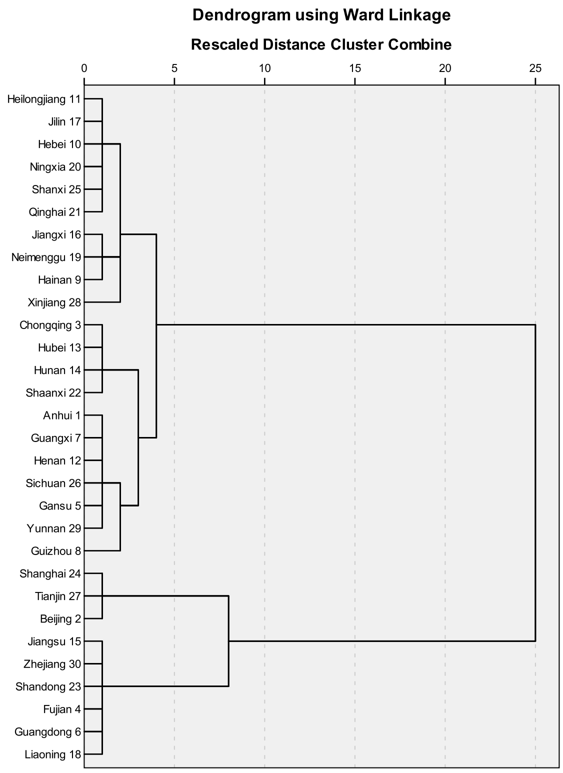


Figure 7-3 Results for Phase Two (1999-2005)



The results show three clusters are the most appropriate for the 30 regions in China. The clusters can be described as high innovation regions, medium innovation regions, and low innovation regions. The members of each cluster for each stage are summarised in Table 6.1. There is no doubt cluster 1 consists of Beijing, Shanghai, and Tianjin, but in cluster 2 and cluster 3 there are three marginal regions; Hainan, Heilongjiang, and Jilin. To confirm which cluster is more suitable for the marginal regions, panel data regression was conducted for each possible group.

Table 7.1 Results of cluster analysis

	Cluster 1	Cluster 2	Cluster 3
Whole period: 1991-2008	Beijing, Shanghai, Tianjin	Fujian, Guangdong, Heilongjiang, Jilin, Jiangsu, Liaoning, Shandong, Zhejiang	The rest
Phase One: 1991-1998	Beijing, Shanghai, Tianjin	Fujian, Guangdong, Hainan, Heilongjiang, Jilin, Jiangsu, Liaoning, Shandong, Zhejiang,	The rest
Phase Two: 1999-2005	Beijing, Shanghai, Tianjin	Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Zhejiang	The rest

Table 7.2 R-square comparison of each possible group

	Cluster 2				Cluster 3			
Dependent Variable	Overall applications		Overall granted patents		Overall applications		Overall granted patents	
	G2	G3	G2	G3	G4	G5	G4	G5
Within R-sq	.9605	.9280	.8553	.8398	.7544	.7564	.7887	.7927

Note: G1: Beijing, Shanghai, Tianjin

G2: Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Zhejiang

G3: Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Zhejiang, Heilongjiang, Jilin

G4: all regions – G1 – G2

G5: all regions – G1 – G3

From Table 6.2 it can be seen that the explanatory variables show more variances without the marginal regions both for overall applications and granted patents in cluster 2, the same as in cluster 3. However, the differences of R-square between groups with and without marginal regions are greater in the second cluster (0.0325 for overall applications, and 0.0155 for overall granted patents) than in the third cluster (0.002 for overall applications, and 0.004 for overall granted patents). Therefore, it was decided to put Hainan, Heilongjiang, and Jilin into cluster 3.

The final members of the three groups are listed in Table 6.3. Group 1 represents the high innovation regions, Group 2 are medium innovation regions, and Group 3 consists of low innovation regions.

Table 7.3 Final group members

Group No.	Group Member
Group 1: high innovation regions	Beijing, Shanghai, Tianjin
Group 2: medium innovation regions	Fujian, Guangdong, Jiangsu, Liaoning, Shandong, Zhejiang
Group 3: low innovation regions	Anhui, Chongqing, Gansu, Guangxi, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangxi, Jilin, Neimenggu, Ningxia, Qinghai, Shaanxi, Shanxi, Sichuan, Xinjiang, Yunnan

The results from the cluster analysis are different from the existing ones: regions in groups 1 and 2 are located in East China, and regions in Group 3 are in Central and West China, except for Jiangxi and Hainan. Figure 6-5 displays the locations of each region.

Figure 7-4 Map of China

The results are different to Ji and Zhao's (2008) work, as well, though the regions are both divided into three groups. According to Ji and Zhao the advanced group includes Beijing, Shanghai, Jiangsu, Guangdong, the developed group includes Tianjin, Liaoning, Zhejiang, Fujian, Shandong, Shanxi, Hubei, Sichuan. The rest of the regions belong to the under-developed group. Since the criteria and measures are different, the difference in results is reasonable.

This study's results are consistent with the findings of Liu and Chen (2003). They observe obvious differentiation exists between metropolitan cities and provincial regions, as well as between eastern and western provincial regions. In this study's classification, the high innovation group consists of three municipal regions, which are metropolitan cities as well. The high and medium innovation groups include regions from East China, while low innovation regions are mainly located in Central and West China.

7.2 Group Data Summary

According to cluster analysis, the 30 regions can be classified into three groups. The descriptive statistics of each group are displayed in Table 7.4, Table 7.5 and Table 7.6, and the comparison of group mean is graphed in Figure 7-5.

Table 7.4 Descriptive statistics of Group 1 – high innovation regions

	N	Period T	Mean	Min	Max	Std. Dev
$lgPApm_{T+1}$	45	1992-2006	2.688	2.19	3.3	.355
$lgPGpm_{T+4}$	45	1995-2009	2.546	1.8	3.26	.366
$lgIPGpm_{T+4}$	45	1995-2009	1.622	.65	2.72	.614
$lgUMPGpm_{T+4}$	45	1995-2009	2.292	1.82	2.84	.284
lgNHEIpb	45	1991-2005	3.468	3.17	3.72	.155
lgNLMEpm	45	1991-2005	1.778	1.47	2.05	.159
lgGDPpp	45	1991-2005	4.216	3.57	4.71	.292
lgFSTpthGDP	45	1991-2005	1.739	1.31	2.18	.246
lgFTE_SEpm	45	1991-2005	3.884	3.58	4.26	.199
Emprate	45	1991-2005	.535	.45	.6	.040
lgFDIpthGDP	45	1991-2005	1.846	1.04	2.23	.272
lgEITpthGDP	45	1991-2005	2.970	2.47	3.36	.235
lgVDTCpthGDP	45	1991-2005	1.287	-.07	1.85	.339

Table 7.5 Descriptive statistics of Group 2 – medium innovation regions

	N	Period T	Mean	Min	Max	Std. Dev
$lgPApm_{T+1}$	90	1992-2006	2.191	1.47	3.03	.345
$lgPGpm_{T+4}$	90	1995-2009	2.165	.83	3.19	.426
$lgIPGpm_{T+4}$	90	1995-2009	.771	-.34	2.07	.609
$lgUMPGpm_{T+4}$	90	1995-2009	1.845	1.13	2.69	.349
lgNHEIpb	90	1991-2005	2.919	2.35	3.26	.182
lgNLMEpm	90	1991-2005	1.405	.89	1.82	.190
lgGDPpp	90	1991-2005	3.943	3.3	4.44	.282
lgFSTpthGDP	90	1991-2005	1.154	.64	1.54	.226
lgFTE_SEpm	90	1991-2005	3.124	2.71	3.52	.242
Emprate	90	1991-2005	.550	.45	.67	.059
lgFDIpthGDP	90	1991-2005	1.715	.7	2.29	.308
lgEITpthGDP	90	1991-2005	2.629	1.94	3.2	.292
lgVDTCpthGDP	90	1991-2005	.564	-.47	1.05	.270

Table 7.6 Descriptive statistics of Group 3 – low innovation regions

	N	Period T	Mean	Min	Max	Std. Dev
$lgPApm_{T+1}$	315	1992-2006	1.663	1.01	2.41	.253
$lgPGpm_{T+4}$	315	1995-2009	1.544	.86	2.42	.302
$lgIPGpm_{T+4}$	315	1995-2009	.430	-1.01	1.55	.514
$lgUMPGpm_{T+4}$	315	1995-2009	1.327	.56	2.06	.287
lgNHEIpb	315	1991-2005	2.929	2.56	3.35	.178
lgNLMEpm	315	1991-2005	1.061	.56	1.41	.140
lgGDPpp	315	1991-2005	3.627	2.94	4.21	.273
lgFSTpthGDP	315	1991-2005	1.126	.05	1.75	.251
lgFTE_SEpm	315	1991-2005	2.959	2.35	3.38	.209
Emprate	315	1991-2005	.505	.35	.63	.058
lgFDIpthGDP	315	1991-2005	1.106	-.44	2.38	.474
lgEITpthGDP	315	1991-2005	1.970	1.5	2.85	.215
lgVDTCpthGDP	315	1991-2005	.449	-1.26	1.64	.448

Figure 7-5 Group mean comparison

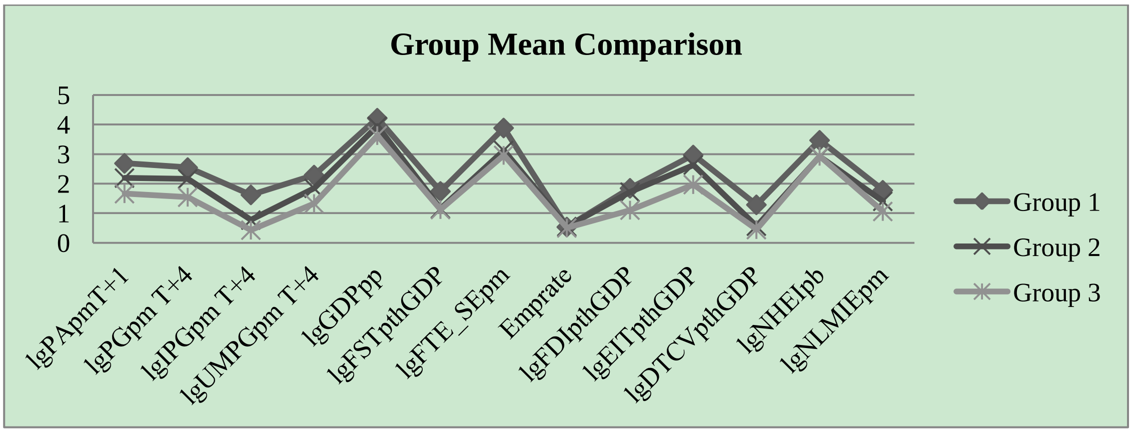


Figure 7-5 clearly shows for most variables the mean was higher in Group 1 than in Group 2, and higher in Group 2 than in Group 3. However, for employment rate the mean was the highest in Group 2 and the lowest in Group 3 and for HEI Group 1 was the highest and Group 2 was the lowest. Although Figure 7-1 shows higher RIC comes with more innovation input and more international and domestic interactions, the differences of means among groups differ from each variable, which indicates the impact of each variable may vary among groups. For some variables, such as granted invention patents, S&T effort, human capital, domestic technology transfer, and number of HEI, the differences in mean was greater between Group 1 and Group 2 than between Group 2 and Group 3. For others, such as overall granted patents, granted utility model patents, FDI, and international trade, it was greater between Group 2 and Group 3,. For the rest of the variables the differences between Group 1 and Group 2 were quite similar to the differences between Group 2 and Group 3.

7.3 Summary

This chapter classified the 30 regions in China into three groups using hierarchical cluster analysis. Group 1 was high innovation level regions, including three municipal cities. Group two was at medium innovation level, including six regions in East China, while group three was low innovation regions, which were mostly located in West and Mid China.

The descriptive statistics of each group showed the differences in DV between groups are not consistent with the differences in IV between groups. This indicates the impact of IV on DV may vary between groups with different innovation levels.

Chapter 8 GROUP COMPARISON

Cluster analysis in the previous chapter indicated regions in China are at different innovation levels and there are differences in both explanatory variables and IC indicators. However, it did not answer the question "*What are the differences in the drivers of RIC among regions at different innovation levels in China?*" This chapter will conduct panel data analysis for each group and compare in detail the differences in the impact of drivers. By investigating the variations of drivers among groups it will become clear which factor is more important in the region and strategies can be developed for improving RIC for a regions each specific innovation level.

The estimated results are specified in the following section.

8.1 Estimation Results

The effect of possible drivers in each group was estimated using fixed effect model with panel data. The impact on overall applications and granted patents is listed in Table 8.1 and the impact on different categories of granted patents is listed in Table 8.2. The comparison of coefficients between groups is displayed in Tables 8.3 and 8.4.

Table 8.1 Main effects on overall applications and granted patents

Coef.			Overall applications			Overall granted patents		
			G1(69)	G2(70)	G3(71)	G1(72)	G2(73)	G3(74)
Innovation actors	Number of higher education institutions	lgNHEIpb	.002	.200**	.159*	.003	-.145	.111
			(.182)	(.093)	(.095)	(.262)	(.238)	(.123)
	Number of large and medium-sized enterprises	lgNLMEpm	-.027	-.067	-.099	-.198	-.286	-.156
			(.243)	(.069)	(.083)	(.349)	(.179)	(.107)
Innovation input	GDP per capita	lgGDPpp	.868***	.835***	.564***	.931***	1.252***	.872***
			(.119)	(.066)	(.044)	(.171)	(.171)	(.057)
	Funding for scientific and technological activities	lgFSTpthGDP	.828**	.322***	.078	-.175	.300	-.048
			(.322)	(.114)	(.057)	(.462)	(.293)	(.073)
	Full time employed scientists and engineers	lgFTE_SEpm	-1.052**	.163	.211**	-1.081	.230	.226*
			(.460)	(.142)	(.097)	(.660)	(.366)	(.125)
	Employment rate	Emprate	-.086	-.702**	.510*	-1.167	-.767	.787**
			(.583)	(.298)	(.262)	(.837)	(.768)	(.338)
Interaction	FDI	lgFDIpthGDP	-.441***	-.225***	-.112***	-.423***	-.086	-.059**
			(.073)	(.048)	(.022)	(.105)	(.124)	(.028)
	Import and export	lgEITpthGDP	.617***	.325***	.101*	.747***	.167	.278***
			(.118)	(.079)	(.053)	(.169)	(.203)	(.068)
	Value of domestic technology contract	lgVDTCpthGDP	.212***	-.122**	.046**	.062	.116	.003
			(.077)	(.053)	(.021)	(.110)	(.137)	(.028)
		_cons	.470	-2.487***	-1.807***	2.719	-2.823***	-3.186***
			(1.453)	(.235.)	(.252)	(2.086)	(.605)	(.326)
		Within R-sq	.9365	.9605	.7544	.8919	.8553	.7887

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 8.2 Main effects on granted invention and utility model patents

Coef.			Granted invention patents			Granted utility model patents		
			G1(75)	G2(76)	G3(77)	G1(78)	G2(79)	G3(80)
Innovation actors	Number of higher education institutions	lgNHEIpb	-.278	.833	-1.582***	-.267*	.100	.455***
			(.693)	(.510)	(.511)	(.143)	(.135)	(.120)
	Number of large and medium-sized enterprises	lgNLMEpm	-.255	-.739*	-1.405***	-.276	.122	-.112
			(.924)	(.382)	(.445)	(.192)	(.101)	(.104)
Innovation input	GDP per capita	lgGDPpp	5.335***	4.948***	5.507***	.979***	1.054***	.726***
			(.454)	(.366)	(.238)	(.094)	(.097)	(.056)
	Funding for scientific and technological activities	lgFSTpthGDP	3.182**	.869	1.350***	.256	.142	.032
			(1.223)	(.627)	(.305)	(.254)	(.133)	(.071)
	Full time employed scientists and engineers	lgFTE_SEpm	-4.285**	2.181***	1.378***	-1.325***	.323	.122
			(1.748)	(.784)	(.517)	(.353)	(.208)	(.121)
	Employment rate	Emprate	-5.648**	-5.174***	3.741***	.610	-.449	.500
			(2.216)	(10643)	(1.405)	(.460)	(.435)	(.329)
Interaction	FDI	lgFDIpthGDP	-1.384***	-1.470***	-.524***	-.388***	-.259***	-.131***
			(.277)	(.265)	(.116)	(.058)	(.070)	(.027)
	Import and export	lgEITpthGDP	1.430***	.741*	-1.211***	.761***	.377***	.309***
			(.449)	(.435)	(.282)	(.093)	(.115)	(.066)
	Value of domestic technology contract	lgVDTCpthGDP	.731**	-.411	.297**	.106*	-.087	-.031
			(.292)	(.294)	(.115)	(.061)	(.078)	(.027)
		_cons	-4.661	-22.739***	-17.203***	2.791**	-3.785***	-3.316***
			(5.523)	(1.295)	(1.353)	(1.148)	(.343)	(.317)
		Within R-sq	.9671	.9619	.8678	.9563	.9471	.7801

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 8.3 Main effects comparison on overall applications and overall granted patents

Z-score			Overall applications			Overall granted patents		
			G1-G2(81)	G1-G3(82)	G2-G3(83)	G1-G2(84)	G1-G3(85)	G2-G3(86)
Innovation actors	Number of higher education institutions	lgNHEIpb	-0.97	-0.76	0.30	0.42	-0.37	-0.95
	Number of large and medium-sized enterprises	lgNLMEpm	0.16	0.28	0.30	0.23	-0.11	-0.62
Innovation input	GDP per capita	lgGDPpp	0.24	2.39**	3.40***	-1.33	0.33	2.11**
	Funding for scientific and technological activities	lgFSTpthGDP	1.48	2.29**	1.91*	-0.87	-0.27	1.15
	Full time employed scientists and engineers	lgFTE_SEpm	-2.52**	-2.69***	-0.28	-1.74*	-1.95*	0.01
	Employment rate	Emprate	0.94	-0.93	-3.04***	-0.35	-2.16**	-1.85*
Interaction	FDI	lgFDIpthGDP	-2.48**	-4.33***	-2.14**	-2.08**	-3.37***	-0.22
	Import and export	lgEITpthGDP	2.05**	3.99***	2.35**	2.19**	2.57**	-0.52
	Value of domestic technology contract	lgVDTCpthGDP	3.57***	2.08**	-2.93***	-0.31	0.52	0.81
		_cons	2.01**	1.54	-1.97**	2.55***	2.80***	0.53

Note: ***p<0.01, **p<0.05, *p<0.1

Table 8.4 Main effects comparison on two categories of granted patents

Z-score			Granted invention patents			Granted utility model patents		
			G1-G2(87)	G1-G3(88)	G2-G3(89)	G1-G2(90)	G1-G3(91)	G2-G3(92)
Innovation actors	Number of higher education institutions	lgNHEIpb	-1.29	1.51	3.35***	-1.86*	-3.85***	-1.96*
	Number of large and medium-sized enterprises	lgNLMEpm	0.48	1.12	1.14	-1.83*	-0.75	1.60
Innovation input	GDP per capita	lgGDPpp	0.66	-0.34	-1.28	-0.56	2.31**	2.94***
	Funding for scientific and technological activities	lgFSTpthGDP	1.68*	1.45	-0.69	0.38	0.85	0.61
	Full time employed scientists and engineers	lgFTE_SEpm	-3.38***	-3.11***	0.86	-3.94***	-3.78***	0.84
	Employment rate	Emprate	-0.17	-3.58***	-4.12***	1.67*	0.20	-1.73*
Interaction	FDI	lgFDIpthGDP	0.22	-2.86***	-3.27***	-1.43	-4.04***	-1.69*
	Import and export	lgEITpthGDP	1.10	4.98***	3.76***	2.59**	3.95***	0.51
	Value of domestic technology contract	lgVDTCpthGDP	2.75***	1.38	-2.24**	1.96**	2.07**	-0.68
		_cons	3.19***	2.21**	-2.96***	5.49***	5.13***	-1.00

Note: ***p<0.01, **p<0.05, *p<0.1

8.1.1 Innovation actors

The results showed innovation actors influenced RIC differently across the three groups.

Higher education institutions: The impact of HEI differs among groups. In Group 1 the impact was only negatively significant on granted utility model patents at $p<.1$, which means HEI was not a significant driver of RIC improvement in high innovation regions. In Group 2 the impact was positive and significant on overall applications, but no significant effect was found on granted patents. It seems an increase in HEI increased patent applications, which indicates HEI do increase innovation activities in medium innovation regions. In Group 3 the impact was much more complicated than in the former two groups, but similar in the impact on overall regions. Impact was positive and significant on overall applications, but no significance as found on overall granted patents. Impact was negative and significant on granted invention patents, but positive and significant on granted utility model patents.

Comparing the effects of HEI to overall regions, it seems HEI did not greatly affect the development of RIC in separate groups. In low innovation regions there even existed a negative impact. Since HEI are educators as well as innovation practitioners (Li, Wang, & Zhang, 2010), strategies for S&T activities should be adjusted in order to increase HEI's contribution to RIC development.

Large and medium-sized enterprises: Compared with HEI, there were fewer differences in the impact of LME on patenting among groups. The coefficients were only negatively significant on granted invention patents in Group 2 and Group 3 at $p<.1$ and $p<.01$ respectively. Visually, the impacts were different among groups, but no strong significance showed up in the z-test. Therefore, considering regions at different innovation levels separately, LME did not significantly contribute to the development of overall RIC. In medium and low innovation regions, to some degree, LME impeded the improvement of RIC, as shown in the results.

8.1.2 Input factors

Among groups differences existed in the impact of input factors, and the differences were greater than seen in innovation actors.

GDP per capita: Measuring knowledge stock and economic infrastructure, the estimated coefficients of GDP per capita were positive and significant at $p<.01$ on all four DV in the three groups,. This is consistent with the results in overall regions. The positive effect implies knowledge stock and economic infrastructure play an important role in RIC no matter what innovation level of the region is.

S&T effort: In all the regions S&T effort greatly affected patenting in a positive way, but the effect was not so strong within the groups. In Group 1 the impact of S&T effort was positive and significant on overall applications, but had no significant effect on overall granted patents. Between categories the effects were both positive, but only significant on granted invention patents. In Group 2 positive significance only existed on overall applications, while in Group 3 the effect was only positively significant on granted invention patents. Although S&T effort was significant on specific type of innovations in each group and the significant effect were all positive, the impact of S&T effort is greater in Group 1 than in Group 2 and Group 3. This confirms the findings in Chen and his colleagues' work (2010) and indicates S&T funding is more efficiently used in high innovation regions than in medium and low innovation regions. Moreover, S&T effort contributed more to radical innovations than to incremental innovations in all groups, as the impact on invention patents was greater and stronger than on utility model patents in all groups.

Full time employed scientists and engineers: Human capital invested in S&T activities was found to be a crucial factor in improving RIC in all the regions. However there are great differences between groups. In Group 1 the impact of full time employed scientists and engineers were negative on all four DV and significant on overall applications and the two categories of granted patents. In Group 2 the effects were all positive, but only significant on granted invention patents. In Group 3 the effects were positive and significant on overall applications, overall granted patents, and granted invention patents. The Z-test showed there were no differences between Group 2 and Group 3 in the same DV. Therefore the results suggest human capital played a more important role in Group 2 and Group 3 than in Group 1. In other words, the development of RIC relies more on human capital in lower innovation regions. In Group 2 and Group 3, human capital influenced invention patenting, but not utility model patenting. This suggests skilled labour is more important to radical innovations than to incremental innovations. This finding is in line with the results in overall regions, as the impact is greater on invention patents than on utility model patents.

In China skilled labourers prefer working in developed regions because of higher salaries and better working environments (Zhou & Du, 2005). As shown in Figure 7-1, there were more scientists and engineers in Group 1 than in Group 2 and Group 3. However, an increase of skilled labour reduces the marginal efficiency when the number is over some point, which leads to problems associated with fully utilising skilled labour in high innovation regions (Wang & Jia, 2009). This may partially explain the negative effect shown in high innovation regions.

Employment rate: In all the regions employment rate was not found to have a significant effect on patenting, but the impacts were quite different among groups. In Group 1 the impact was negative and significant on granted invention patents. In Group 2 the coefficients were negative and significant on overall applications and granted invention patents. The Z-test showed there was no real difference in impact on the same DV between Group 1 and Group 2. The impact in Group 3 was positive and significant on overall applications, overall granted patents, and granted invention patents. The results suggest employment rate is an important factor of RIC in low innovation regions, while in high and medium innovation regions it retards the improvement of RIC to some extent. Employment rate influences radical innovations, but does not influence incremental innovations, either positively or negatively.

The impact of full time employed scientists and engineers show the lower innovation level the region, the more important human capital is. Moreover, in medium and low innovation regions, human capital influences radical innovations but not incremental innovations.

8.1.3 Interactions

Interactions among groups showed less of a difference in impact than innovation inputs.

FDI: The impact of FDI was negative on all four DV across the three groups. It was only insignificant on overall granted patents in Group 2, which was consistent with the results found in overall regions. The negative impact of FDI was greater in Group 1 than in Group 2, and greater in Group 2 than in Group 3. This means the more innovative the region, the greater the negative impact of FDI, especially for incremental innovations. The reasons for the negative impact were explained in section 5.3.3, and the reason for the differing degree of impact may be explained by the amount of FDI inflows each group received. From 1991 to 2005, the average FDI inflow in Group 3 was 1.3 per cent of GDP, in Group 2 5.2 per cent and in Group 1 7.0 per cent. As stated in section 5.3.3, FIE take all kinds of resources away from local markets, including skilled labour, financial capital, and materials. Furthermore, more incoming FDI occupies more resources. However, the contribution made by these resources did not appear in China's patenting. Therefore, the more FDI a region receives, the greater the negative impact is on RIC. Another reason may be that the conductive mechanism of FDI spillovers varies under different innovation levels (Qiu, Yang, Xin, & Kirkuklak, 2009). However, this needs further investigation.

Import and export: The impact of international trade in Group 1 and Group 2 was similar, but it was different from the impact in overall regions. The coefficients were positive and significant on all DV in these two groups, except on overall granted patents in Group 2. The impact was greater in Group 1 than in Group 2 on the same

DV. In Group 3 the impact was quite similar to the overall regions. It was significantly positive on overall applications, overall granted patents, and granted utility model patents, but was significantly negative on granted invention patents. Regardless of the insignificant impact on overall granted patents in Group 2 and the negative impact on granted invention patents in Group 3, the impact on Group 2 was greater than on Group 3 on the same DV. Hence, to some degree, the more innovative the region, the greater the positive impact of international trade on RIC would be.

Similar to the impact of FDI, evidence showed the more EIT takes up in GDP, the greater the positive effect will be. From 1991 to 2005 the average level of import and export was around 93.3 per cent of GDP in Group 1, 42.6 per cent in Group 2, and 9.3 percent in Group 3. Therefore, the results suggest the impact of FDI and international trade relates to the ratio of FDI and international trade that takes in regional GDP.

Value of domestic technology contract: Consistent with Zhao and his colleague's (2011) findings, the results from this study indicate technology transfer has different impacts in regions at different innovation levels. In Group 1, the effect was positive and significant on overall applications and the two categories of granted patents. In Group 2 the impact was only negatively significant on overall applications. However, in Group 3 the impact on overall applications and granted invention patents became positive and significant again as it was in Group 1. From these results it can be seen that domestic technology transfer impacts regions at both high and low innovation levels, but not at the medium level. It seems there is a U-shape relationship between domestic technology transfer and innovation level.

8.1.4 Interactive effects

In Chapter 5 and Chapter 6, it was demonstrated that there are interactive effects between S&T effort and interactions and international and domestic interactions. It was also shown the effects vary at different transitional stages. This section will investigate if the moderating role remains consist across groups. The results of interactive effects on each DV are displayed in Tables 8.5, 8.6, 8.7, and 8.8.

Table 8.5 Interactive effects of groups on overall applications

Coef.	G1				G2				G3			
	(93)	(94)	(95)	(96)	(97)	(98)	(99)	(100)	(101)	(102)	(103)	(104)
lgNHEIpb	.025	.226	-.000	.023	.229**	.186**	.241***	.210**	.161*	.170*	.147	.135
	(.183)	(.198)	(.187)	(.187)	(.088)	(.092)	(.087)	(.093)	(.095)	(.096)	(.097)	(.098)
lgNLMEpm	.259	-.081	-.010	-.110	-.020	-.091	.065	-.076	-.109	-.092	-.016	-.050
	(.333)	(.231)	(.262)	(.276)	(.068)	(.070)	(.075)	(.070)	(.084)	(.084)	(.083)	(.083)
lgGDPpp	.840***	.944***	.871***	.850***	.875***	.817***	.833***	.852***	.561***	.564***	.521***	.550***
	(.121)	(.116)	(.124)	(.125)	(.064)	(.068)	(.061)	(.067)	(.044)	(.044)	(.050)	(.050)
lgFSTpthGDP	.529	.741**	.830**	.891**	.384***	.340***	.381***	.346***	.070	.080	.091	.076
	(.406)	(.305)	(.326)	(.336)	(.108)	(.112)	(.105)	(.115)	(.057)	(.057)	(.059)	(.059)
lgFTE_SEpm	-.641	-1.028**	-1.031**	-1.218**	.087	.156	.187	.143	.228**	.207**	.298***	.207**
	(.559)	(.429)	(.474)	(.524)	(.135)	(.139)	(.130)	(.143)	(.098)	(.097)	(.103)	(.098)
Emprate	-.159	-.306	-.100	-.129	-.830***	-.558*	-.806***	-.737**	.525**	.497*	.435*	.408
	(.580)	(.556)	(.595)	(.594)	(.285)	(.312)	(.278)	(.299)	(.263)	(.263)	(.258)	(.262)
lgFDIpthGDP	-.461***	-.441***	-.443***	-.446***	-.244***	-.197***	-.202***	-.242***	-.110***	-.113***	-.108***	-.113***
	(.074)	(.069)	(.076)	(.074)	(.046)	(.051)	(.045)	(.050)	(.022)	(.022)	(.022)	(.022)
lgEITpthGDP	.662***	.579***	.611***	.616***	.258***	.321***	.110	.303***	.094*	.090	.088*	.090
	(.125)	(.112)	(.124)	(.119)	(.078)	(.079)	(.094)	(.082)	(.053)	(.055)	(.053)	(.054)
lgVDTCpthGDP	.221***	.213***	.204**	.216**	-.098*	-.142**	-.153***	-.124**	.045**	.045**	.062*	.042
	(.077)	(.072)	(.090)	(.079)	(.051)	(.051)	(.050)	(.053)	(.021)	(.021)	(.037)	(.037)
lgFST_lgFDI	.505				-.430***				-.063			
	(.419)				(.142)				(.064)			
lgFST_lgEIT		1.587**				.294				-.124		
		(.676)				(.195)				(.148)		
lgFST_lgVDTC			-.048				.773***				-.209**	
			(.418)				(.214)				(.081)	
lgFDI_lgVDTC				-.209				-.143				-.020
				(.309)				(.132)				(.030)
_cons	-1.065	2.699	2.098	.636	-2.342***	-1.208***	-2.002***	-2.913***	-1.876***	-1.540***	-1.882***	-1.814***
	(2.434)	(1.600)	(1.800)	(1.817)	(.318)	(.343)	(.305)	(.252)	(.268)	(.253)	(.295)	(.264)
Within R-sq	.9394	.9453	.9364	.9372	.9651	.9617	.9665	.9614	.7552	.7549	.7570	.7520

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 8.6 Interactive effects of groups on overall granted patents

Coef.	G1				G2				G3			
	(105)	(106)	(107)	(108)	(109)	(110)	(111)	(112)	(113)	(114)	(115)	(116)
lgNHEIpb	.037	.334	.034	.005	-.106	-.156	-.168	-.129	.114	.131	.038	.013
	(.265)	(.282)	(.265)	(.271)	(.240)	(.241)	(.241)	(.241)	(.123)	(.124)	(.116)	(.121)
lgNLMEpm	.146	-.290	-.306	-.210	-.234	-.311*	-.365*	-.295	-.162	-.140	-.033	-.183*
	(.494)	(.329)	(.372)	(.399)	(.184)	(.184)	(.208)	(.181)	(.108)	(.108)	(.099)	(.103)
lgGDPpp	.895***	1.041***	.901***	.931***	1.287***	1.229***	1.249***	1.267***	.870***	.873***	.675***	.776***
	(.176)	(.166)	(.175)	(.180)	(.174)	(.174)	(.172)	(.175)	(.057)	(.057)	(.060)	(.062)
lgFSTpthGDP	-.547	-.305	-.147	-.162	.352	.302	.240	.332	-.052	-.038	-.084	-.118
	(.589)	(.435)	(.463)	(.487)	(.293)	(.292)	(.293)	(.300)	(.074)	(.074)	(.070)	(.073)
lgFTE_SEpm	-.589	-1.069*	-1.220*	-1.105	.165	.241	.246	.205	.237*	.214*	.530***	.274**
	(.811)	(.611)	(.672)	(.759)	(.367)	(.363)	(.362)	(.371)	(.126)	(.125)	(.124)	(.121)
Emprate	-1.250	-1.486**	-1.067	-1.156	-.915	-.634	-.729	-.797	.796**	.762**	.815***	.601*
	(.842)	(.792)	(.843)	(.860)	(.773)	(.814)	(.775)	(.775)	(.340)	(.338)	(.309)	(.325)
lgFDIpthGDP	-.444***	-.423***	-.400***	-.420***	-.103	-.059	-.102	-.102	-.056**	-.062**	-.028	-.038
	(.107)	(.098)	(.108)	(.107)	(.125)	(.134)	(.126)	(.129)	(.028)	(.028)	(.026)	(.027)
lgEITpthGDP	.807***	.698***	.781***	.741***	.092	.163	.290	.139	.273***	.253***	.221***	.268***
	(.181)	(.460)	(.175)	(.173)	(.212)	(.205)	(.262)	(.212)	(.069)	(.070)	(.064)	(.067)
lgVDTCpthGDP	.077	.065	.119	.063	.145	.097	.130	.114	.003	.001	.246***	.185***
	(.112)	(.103)	(.127)	(.114)	(.139)	(.142)	(.140)	(.139)	(.028)	(.028)	(.045)	(.046)
lgFST_lgFDI	.634				-.470				-.042			
	(.608)				(.385)				(.083)			
lgFST_lgEIT		2.317**				.301				-.262		
		(.964)				(.508)				(.190)		
lgFST_lgVDTC			.512				-.439				-.534***	
			(.593)				(.595)				(.097)	
lgFDI_lgVDTC				-.025				-.176				.073*
				(.447)				(.342)				(.037)
_cons	-.988	3.207	3.019	2.113	-2.486***	-2.022**	-2.570***	-2.868***	-3.325***	-2.722***	-3.624***	-2.800***
	(3.531)	(2.281)	(2.550)	(2.631)	(.862)	(.894)	(.850)	(.654)	(.347)	(.326)	(.354)	(.327)
Within R-sq	.8947	.9082	.8944	.8913				.8557	.7888	.7900	.8198	.8033

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 8.7 Interactive effects of groups on granted invention patents

Coef.	G1				G2				G3			
	(117)	(118)	(119)	(120)	(121)	(122)	(123)	(124)	(125)	(126)	(127)	(128)
lgNHEIpb	-.186	-.176	-.292	-.372	.828	.720	.863	.762	-1.612***	-1.634***	-2.135***	-2.164***
	(.689)	(.805)	(.707)	(.708)	(.517)	(.493)	(.518)	(.513)	(.504)	(.514)	(.496)	(.496)
lgNLMEpm	.927	-.261	-.201	.107	-.751*	-.950**	-.653	-.700*	-1.261***	-1.439***	-.943**	-.976**
	(1.257)	(.940)	(.992)	(1.043)	(.397)	(.376)	(.445)	(.384)	(.441)	(.448)	(.423)	(.420)
lgGDPpp	5.226***	5.387***	5.353***	5.436***	4.948***	4.773***	4.943***	4.890***	5.543***	5.505***	4.818***	4.866***
	(.457)	(.474)	(.468)	(.472)	(.374)	(.357)	(.367)	(.372)	(.235)	(.238)	(.258)	(.253)
lgFSTpthGDP	1.990	3.186**	3.246**	2.959**	.850	1.080*	.892	.750	1.420***	1.328***	1.075***	.973***
	(1.532)	(1.242)	(1.234)	(1.272)	(.0632)	(.599)	(.628)	(.637)	(.302)	(.307)	(.299)	(.298)
lgFTE_SEpm	-2.636	-4.278**	-4.285**	-3.627*	2.213***	2.067***	2.224***	2.286***	1.136**	1.408***	1.971***	1.687***
	(2.108)	(1.746)	(1.791)	(1.984)	(.792)	(.744)	(.776)	(.789)	(.516)	(.519)	(.527)	(.495)
Emprate	-5.907**	-5.716**	-5.613**	-5.382**	-5.230***	-3.771**	-5.269***	-5.116***	3.483**	3.813***	2.715**	2.833**
	(20189)	(2.264)	(2.248)	(2.247)	(1.669)	(1.669)	(1.662)	(1.648)	(1.388)	(1.407)	(1.320)	(1.327)
lgFDIpthGDP	-1.465***	-1.384***	-1.387***	-1.357***	-1.476***	-1.197***	-1.455***	-1.400***	-.559***	-.515***	-.421***	-.433***
	(.279)	(.280)	(.289)	(.280)	(.269)	(.275)	(.269)	(.275)	(.115)	(.116)	(.112)	(.112)
lgEITpthGDP	1.617***	1.399***	1.402***	1.390***	.746	.691	.590	.868*	-1.097***	-1.147***	-1.424***	-1.495***
	(.471)	(.458)	(.468)	(.452)	(.457)	(.420)	(.562)	(.450)	(.291)	(.292)	(.271)	(.276)
lgVDTCpthGDP	.771**	.729**	.718**	.694**	-.420	-.588**	-.435	-.420	.306***	.301**	1.185***	1.130***
	(.290)	(.295)	(.339)	(.298)	(.300)	(.291)	(.301)	(.295)	(.113)	(.115)	(.192)	(.187)
lgFST_lgFDI	2.087				.031				1.032***			
	(1.582)				(.831)				(.340)			
lgFST_lgEIT		.854				2.781***				.647		
		(2.755)				(1.042)				(.792)		
lgFST_lgVDTC			-.104				.538				-.799*	
			(1.580)				(1.276)				(.415)	
lgFDI_lgVDTC				.876				.771				-.292**
				(1.168)				(.727)				(.151)
_cons	-10.457	4.534	1.764	-9.190	-24.298***	-19.261***	-21.881***	-25.654***	-15.814***	-17.998***	-14.540***	-15.164***
	(9.181)	(6.517)	(6.796)	(6.878)	(1.861)	(1.832)	(1.822)	(1.390)	(1.417)	(1.356)	(1.509)	(1.337)
Within R-sq	.9691	.9675	.9675	.9678				.9625	.8728	.8619	.8818	.8816

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

Table 8.8 Interactive effects of groups on granted utility model patents

Coef.	G1				G2				G3			
	(129)	(130)	(131)	(132)	(133)	(134)	(135)	(136)	(137)	(138)	(139)	(140)
lgNHEIpb	-.261*	-.169	-.280*	-.245	.112	.084	.138	.085	.452***	.433***	.318***	.288**
	(.147)	(.165)	(.147)	(.147)	(.136)	(.135)	(.133)	(.136)	(.120)	(.120)	(.103)	(.111)
lgNLMEpm	-.188	-.303	-.228	-.363	.143	.091	.241**	.128	-.099	-.132	.007	-.160*
	(.269)	(.193)	(.206)	(.217)	(.104)	(.103)	(.115)	(.102)	(.105)	(.105)	(.088)	(.094)
lgGDPpp	.973***	1.014***	.994***	.960***	1.076***	1.030***	1.053***	1.045***	.729***	.724***	.424***	.537***
	(.098)	(.097)	(.097)	(.098)	(.098)	(.098)	(.095)	(.099)	(.056)	(.056)	(.053)	(.056)
lgFSTpthGDP	.170	.219	.253	.320	.173	.175	.203	.118	.037	.018	-.063	-.104
	(.328)	(.255)	(.256)	(.264)	(.166)	(.164)	(.162)	(.169)	(.072)	(.072)	(.062)	(.066)
lgFTE_SEpm	-1.201**	-1.322***	-1.276***	-1.496***	.284	.305	.338*	.343	.100	.137	.528***	.234**
	(.451)	(.358)	(.371)	(.412)	(.208)	(.204)	(.200)	(.209)	(.123)	(.121)	(.109)	(.111)
Emprate	.599	.521	.578	.569	-.514	-.248	-.538	-.440	.472	.524	.557**	.327
	(.469)	(.464)	(.466)	(.467)	(.439)	(.458)	(.428)	(.437)	(.330)	(.329)	(.273)	(.296)
lgFDIpthGDP	-.393***	-.388***	-.398***	-.393***	-.270***	-.218***	-.237***	-.249***	-.135***	-.127***	-.081***	-.092***
	(.060)	(.087)	(.060)	(.058)	(.071)	(.076)	(.069)	(.073)	(.027)	(.027)	(.023)	(.025)
lgEITpthGDP	.771***	.744***	.743***	.760***	.348***	.364***	.184	.402***	.319***	.339***	.222***	.271***
	(.101)	(.094)	(.097)	(.094)	(.120)	(.115)	(.145)	(.119)	(.067)	(.068)	(.056)	(.062)
lgVDTCpthGDP	.108*	.108*	.083	.113*	-.077	-.112	-.113	-.089	-.031	-.030	.390***	.320***
	(.062)	(.060)	(.070)	(.062)	(.079)	(.080)	(.077)	(.078)	(.027)	(.027)	(.040)	(.042)
lgFST_lgFDI	.155				-.196				.095			
	(.339)				(.218)				(.081)			
lgFST_lgEIT		.707				.401				.316*		
		(.564)				(.285)				(.185)		
lgFST_lgVDTC			-.217				.692**				-.621***	
			(.327)				(.329)				(.086)	
lgFDI_lgVDTC				-.215				.145				.068**
				(.243)				(.193)				(.034)
_cons	1.866	5.058***	3.181	2.941**	-3.987***	-2.555***	-3.494***	-4.311***	-3.385***	-2.639***	-3.593***	-2.729***
	(1.966)	(1.335)	(1.409)	(1.430)	(.189)	(.502)	(.469)	(.369)	(.337)	(.317)	(.312)	(.299)
Within R-sq	.9564	.9580	.9570	.9571	.9480	.9482	.9501	.9478	.7815	.7823	.8460	.8202

Note: Standard errors are in the parentheses, ***p<0.01, **p<0.05, *p<0.1

*S&T effort*FDI*: In the overall regions the interactive effect was positive and significant on granted invention and utility model patents, while the impact among groups was quite different. Only the effect in Group 3 was similar to the overall regions. In Group 1 no interactive effect was found. In Group 2 the interactive effect was negative and significant on overall applications, but no significance was found on granted patents. In Group 3 the impact was only positively significant on granted invention patents.

Simple slope analysis confirmed the significance of interactive effects found in Group 2 and Group 3. Figure 8-1 and Figure 8-2 show both low and high S&T effort exacerbated the negative effect of FDI on overall applications in Group 2 and on granted invention patents in Group 3. The impact was greater in Group 3 than in Group 2. The results suggest increasing investment in S&T does assist in benefiting from FDI, and even has the opposite effect.

Figure 8-1 Interactive effects between funding for S&T and FDI on overall applications in Group 2

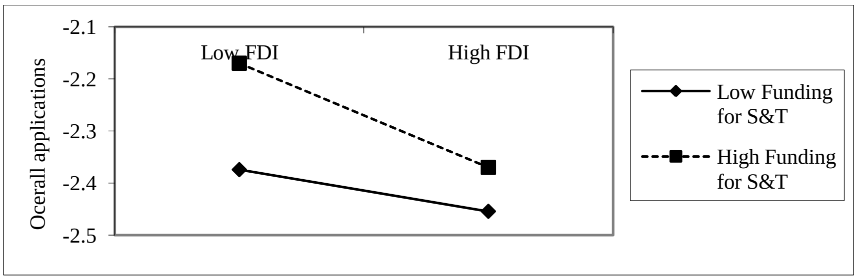
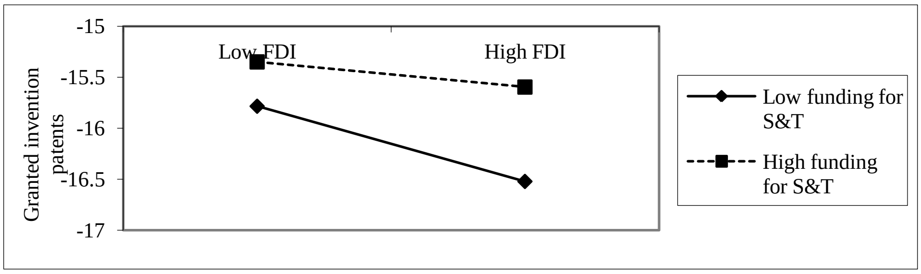


Figure 8-2 Interactive effects between funding for S&T and FDI on granted invention patents in Group 3



*S&T effort*international trade*: The effect of international trade coupled with S&T effort was quite different among groups. In Group 1 the effect was positive on all DV, but only significant on overall applications and overall granted patents at p<.05. In Group 2 the effect was positive on all Ds as well, but it is only significant on granted invention patents at p<.01. However, in Group 3 the coefficient was only found to be positively significant on granted utility model patents at p<.1.

For those significant interactive effects the simple slope analysis showed both low and high S&T effort enhanced the positive effect of international trade on overall applications and granted patents in Group 1, on granted invention patents in Group 2, and on granted utility model patents in Group 3 (see Figure 8-3, Figure 8-4, Figure 8-5, and Figure 8-6). From all these figures it can be seen the influence of increasing investment in S&T was greater than decreasing the same amount of investment in S&T. The influence was greater in high and medium innovation regions than in low innovation regions. It seems the more innovation the regions is, the more benefit it will get from international trade.

Figure 8-3 Interactive effects between funding for S&T and international trade on overall applications in Group 1

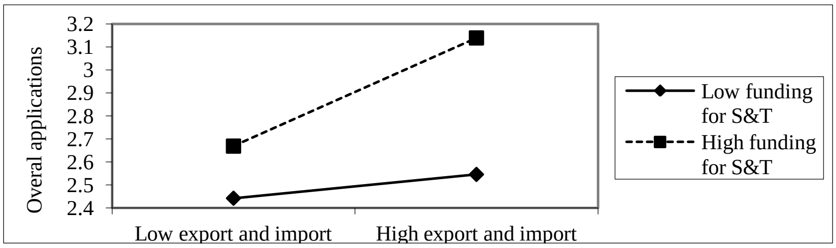


Figure 8-4 Interactive effects between funding for S&T and international trade on overall granted patents in Group 1

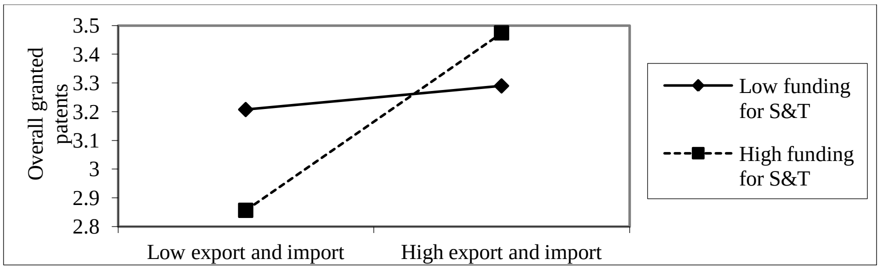


Figure 8-5 Interactive effects between funding for S&T and international trade on granted invention patents in Group 2

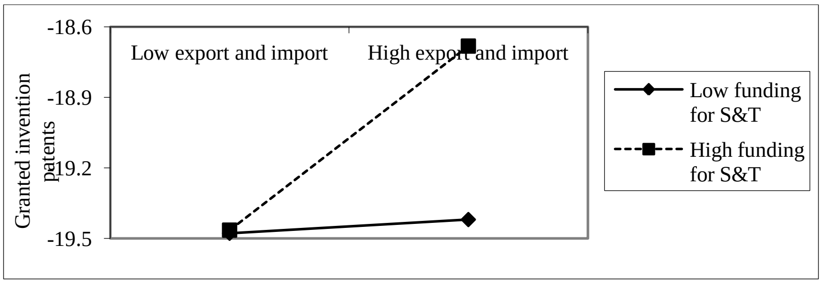
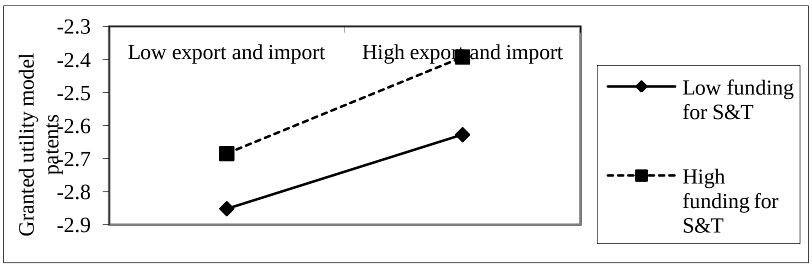


Figure 8-6 Interactive effects between funding for S&T and international trade on granted utility model patents in Group 3



*S&T effort*domestic technology transfer*: The differences in the interactive effect between S&T effort and domestic technology transfer among groups were greater than between S&T effort and international interactions. In Group 1 no interactive effect was found. In Group 2 the interactive effect was positive and significant on overall applications and granted utility model patents. In Group 3 the coefficients were all negative and significant, but with different significant levels.

The simple slope analysis in Group 2 showed high funding for S&T buffered the negative effect of domestic technology transfer, both on overall applications and granted utility model patents. Meanwhile low S&T effort exacerbated the negative effect of domestic technology (see Figure 8-7 and Figure 8-8). The results indicate S&T effort moderates the relationship between domestic technology transfer and RIC positively in medium innovation regions.

In Group 3, Figure 8-9, Figure 8-10 and Figure 8-11 show both high and low S&T efforts enhanced the positive effect of domestic technology transfer on overall applications, overall granted patents, and granted invention patents. Figure 8-12 shows both high and low S&T efforts buffered the negative effect of domestic technology transfer on granted utility model patents. The figures also indicate the effect of reducing S&T effort is greater than increasing S&T effort. Overall, S&T effort plays a positive role in the relationship between domestic technology transfer and RIC in low innovation regions.

Figure 8-7 Interactive effects between funding for S&T and domestic technology transfer on overall applications in Group 2

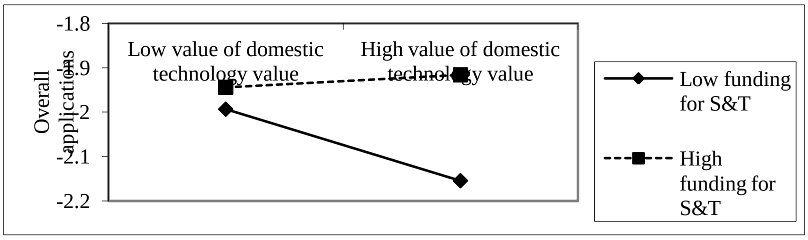


Figure 8-8 Interactive effects between funding for S&T and domestic technology transfer on granted utility model patents in Group 2

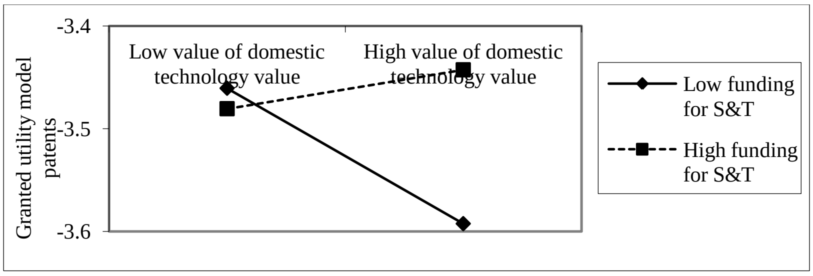


Figure 8-9 Interactive effects between funding for S&T and domestic technology transfer on overall applications in Group 3

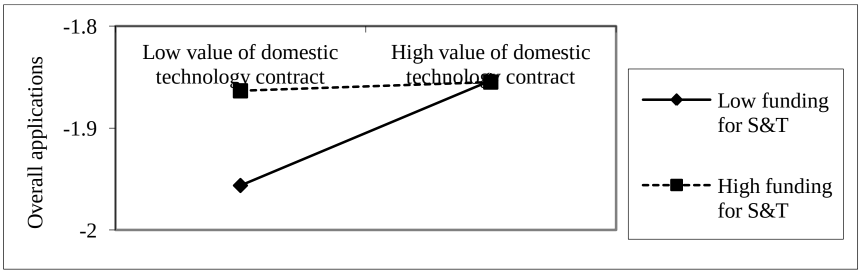


Figure 8-10 Interactive effects between funding for S&T and domestic technology transfer on overall granted patents in Group 3

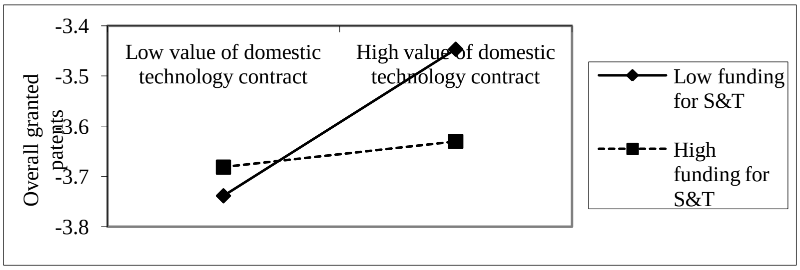


Figure 8-11 Interactive effects between funding for S&T and domestic technology transfer on granted invention patents in Group 3

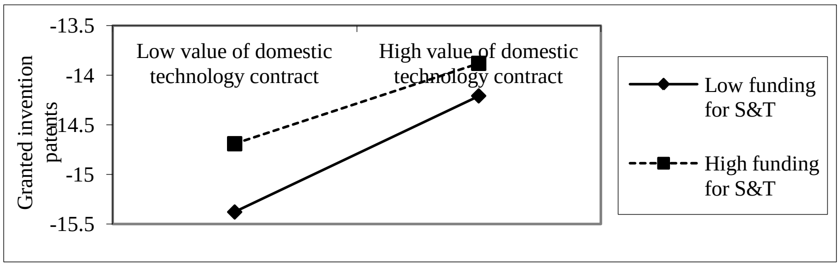
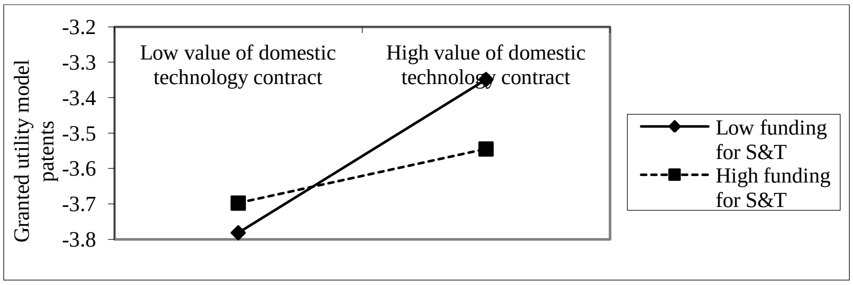


Figure 8-12 Interactive effects between funding for S&T and domestic technology transfer on granted utility model patents in Group 3



The reason for the differences among groups is probably the technology gap between buyer-region and seller-region, which can be inferred from Crespo and Fontoura (2007) and Sun and Du's (2010) argument on the impact of FDI. They argue the impact of FDI is contingent on the technology gap between the host and foreign countries. Since FDI is considered one means of technology transfer with international organisations, a similar argument can be made about domestic technology transfer among regions. High innovation regions in this study had the highest RIC on China, which means the gap between their technologies and technologies transferred from other regions was small. Hence there was not much they could get from transferred technologies to help them improve RIC. In medium innovation regions there was a gap between their own technologies and the advanced technologies transferred from other regions. By increasing their investment in S&T activities and employing more advanced technologies with more S&T funding, the regions could benefit a lot to develop RIC. However, there may be a big technology gap between what low innovation regions own and the technologies transferred from other regions. Consequently, the imported advanced technologies greatly improved the technology level of the region, but did not improve RIC. The reason may be the regions focused too much on importing from other regions, rather than innovation activities within the region. Whether the moderating role of S&T effort between domestic interactions and RIC relates to the innovation level of a region needs further verification.

*FDI*domestic technology transfer:* The interactive effect between FDI and domestic technology transfer was quite different between groups. In Group 1 and Group 2 no interactive effects existed between the two interaction variables. In Group 3 it was positive and significant on overall granted patents but only at $p<.1$. It was negative and significant on granted invention patents, but positive and significant on granted utility model patents. So it is difficult to tell how exactly the interactive effect will influence RIC in Group 3 according to regression results.

Taking FDI as a moderator, the simple slope analysis shows both low and high FDI enhanced the positive effect of domestic technology transfer on overall granted patents and granted invention patents. In Group 3 both an increase and decrease of FDI buffered the negative effect on domestic technology transfer on granted utility model patents (see Figure 8-13, Figure 8-14, and Figure 8-15). When considering domestic technology transfer as a moderator (see Figure 8-16, Figure 8-17, and

Figure 8-18), both an increase and decrease of domestic technology transfer exacerbated the negative impact of FDI, which means domestic technology transfer does not help low innovation regions to benefit from FDI.

All in all, FDI and domestic technology transfer have no influence on each other's relationship with RIC in high and medium innovation regions. In low innovation regions FDI helps regions take advantage of domestic technology transfer. Domestic technology transfer does not influence the impact of FDI on RIC in the same way.

Figure 8-13 Interactive effects between FDI and domestic technology transfer on overall granted patents in Group 3 – FDI as the moderator

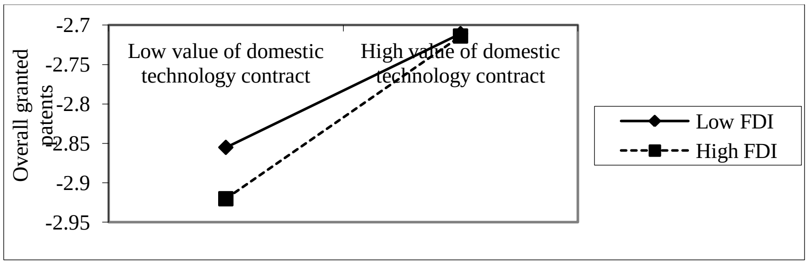


Figure 8-14 Interactive effects between FDI and domestic technology transfer on granted invention patents in Group 3 -- – FDI as the moderator

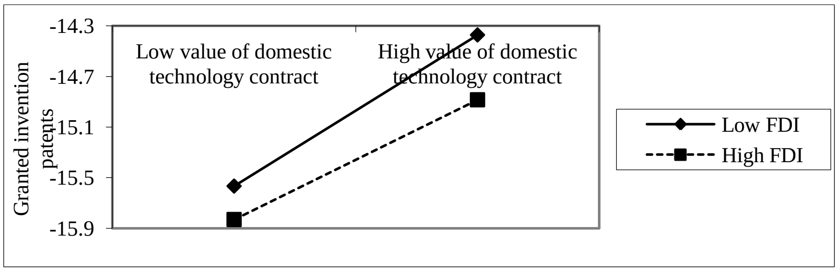


Figure 8-15 Interactive effects between FDI and domestic technology transfer on granted utility model patents in Group 3 -- – FDI as the moderator

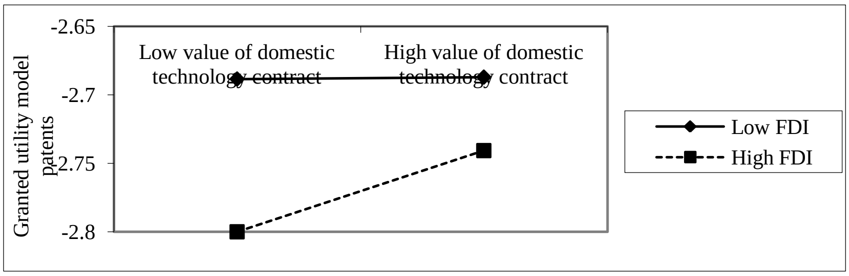


Figure 8-16 Interactive effects between FDI and domestic technology transfer on overall granted patents in Group 3 – domestic technology transfer as the moderator

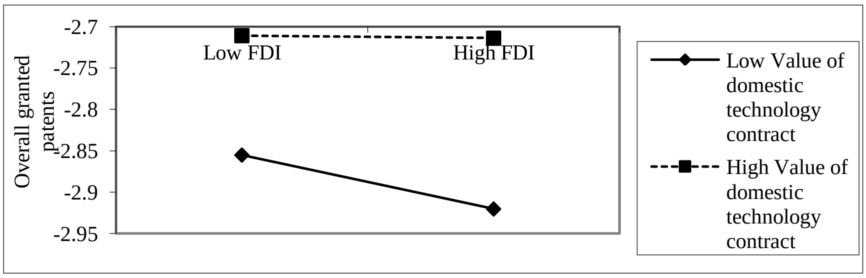


Figure 8-17 Interactive effects between FDI and domestic technology transfer on granted invention patents in Group 3 -- – domestic technology transfer as the moderator

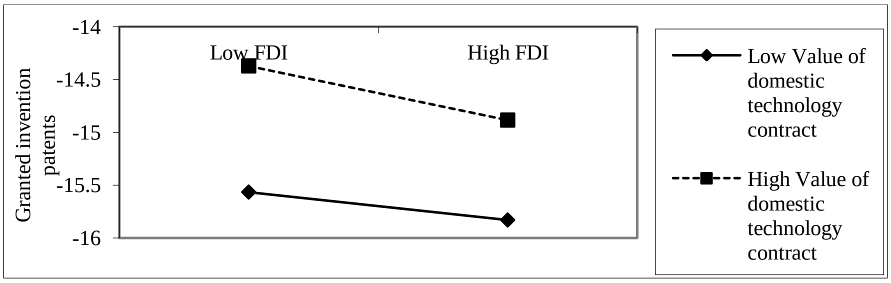
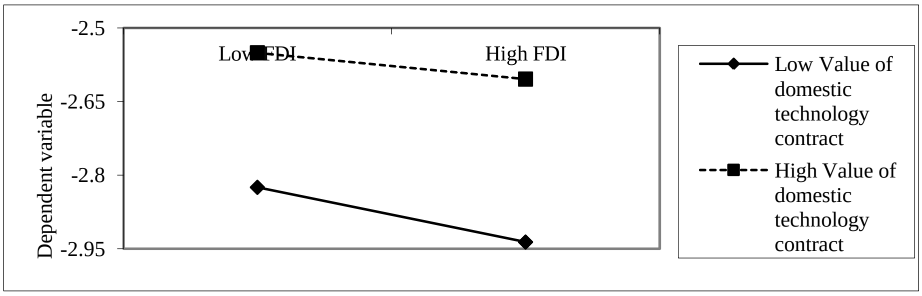


Figure 8-18 Interactive effects between FDI and domestic technology transfer on granted utility model patents in Group 3 -- – domestic technology transfer as the moderator



8.2 Summary

The estimated results showed there were great differences in the impact of drivers on RIC among groups at different innovation levels. The innovation actors played different roles among groups and the core drivers of RIC changed as well.

HEI made different contributions among groups, while there was no significant difference in the impact of LME between groups. Negative and positive effects existed in high and medium innovation regions respectively, and both negative and positive effects were observed in low innovation regions. According to the results HEI are more important in medium and low innovation regions than in high innovation regions.

Impact of input factors varies across different groups. The results again confirmed the importance of knowledge stock and economic infrastructure in RIC development. GDP per capita positively influenced RIC in all groups, though the degree of effect was different across groups. S&T effort was a critical factor of RIC as well. To some extent, investment in S&T enhanced RIC in all groups, though the impact was greater in high innovation regions than in medium and low innovation regions.

The differences in the impact of human capital were greater than GDP per capita and S&T effort. In high innovation regions, skilled labour negatively affected RIC. The more scientists and engineers per million people there were, the fewer the patents there were. The impact of skilled labour was positive in both medium and low innovation regions, but was greater in low innovation regions than in medium ones. In terms of employment rate, it is negative in high and medium innovation regions, while it is positive in low innovation regions. Hence, human capital drives the development of RIC more in lower innovation regions.

Among groups, the effect of interactions on RIC is complicated. FDI was a negative factor of RIC no matter what innovation level the region was, which is consistent with the findings in overall regions. However, the degree of the effect differs among groups. In high innovation regions with the highest inflow of FDI, measured as the percentage of GDP, the negative effect was greater than in low innovation regions, which had the lowest inflow. This indicates attracting more FDI alone is not a good strategy for improving RIC.

In contrast to FDI, international trade, measured as the total amount of import and export, greatly enhanced RIC in most regions, with the exception of low innovation regions. The results showed the degree of effect relates to the ratio of import and export in GDP. The more exports and imports a region received, the more it benefited from international trade. The more innovative the regions was, the greater the impact would be. This implies the international trade-oriented strategy works in improving RIC, and the degree of effect is related to the innovation level of the region. Whether export or import has greater influence needs to be examined separately.

The impact of domestic technology transfer on RIC differs in terms of the innovation level of the region. This study's results revealed that in both high and low innovation regions domestic technology transfer helps to improve RIC, whereas in medium innovation regions it retards the development of RIC. This suggests a U-shape relationship between the impact of domestic technology transfer and the innovation level of the region. This implication needs further investigation.

Similar to the impact of interactions, the interactive effect between S&T effort and interactions on RIC is complex. Results showed S&T effort moderated the relationship between FDI and RIC negatively in medium and low innovation regions, which is consistent with what has been found in overall regions. The results suggest that simply increasing S&T effort is not an effective way to gain positive spillover effects from FDI.

The impact of S&T effort on the relationship between international trade and RIC was quite different from the relationship between FDI and RIC. Both an increase and decrease of S&T effort enhanced the positive effect of international trade on RIC, with the impact of an increase greater than the impact of a decrease. The impact was greater and stronger in high and medium innovation regions than in low innovation regions, which implies the moderating role of S&T effort in the impact of international trade on RIC may be related to the innovation level of a region.

A positive moderating role was observed in the effect of S&T effort and domestic technology transfer in medium and low innovation regions, while in high innovation regions no interactive effect was found. Therefore it is proposed that the impact of S&T effort on the relationship between domestic technology transfer and RIC may relate to the innovation level of a region. This, however, needs further investigation and verification.

When considering interactive effect between domestic and international interactions, significance was only observed in low innovation regions. FDI helped regions to benefit from domestic technology transfer to improve RIC, while domestic technology transfer influenced the relationship between FDI and RIC negatively. Therefore, the moderating role shown in overall regions may be due to the interactive effect in low innovation regions.

The results from groups at different innovation levels suggest the impact of the factors vary among groups, and to some extent, the impact of drivers relates to the innovation level of the region. Hence, the findings re-affirm the importance of studying IC at the regional level in a big country that is unevenly developed. They also re-emphasise that exploring the phenomenon of RIC will greatly help to improve innovation capacity of the nation.

Moreover, the results suggest the successful experiences from other regions may not be compatible with the situation in a specific region and a region should not blindly follow the successful strategies of other regions. The varied impact of a factor in regions at different innovation levels and the interactive effect between factors warn a region that when activating a strategy to improve RIC, it should consider its innovation level, the impact of a factor on RIC alone, and the interactive impact between factors as well.

Chapter 9 DISCUSSION AND CONCLUSION

The previous chapters present why and how the research was conducted, and what has been found through the analysis. In this final chapter, the main arguments and research objectives will be reviewed, and then this chapter will summarise and provide an overview of the main empirical findings in relation to the objectives and discuss the theoretical contributions and practical implications of the research. Finally, some concluding remarks will be provided, discussing the limitations of the thesis and directions for future research.

9.1 Review of Objectives

This research was concerned with understanding and investigating the determinants of RIC in China. It addressed three main research questions:

RQ 1: What are the core drivers of RIC in China?

RQ 2: What are the differences in the main drivers of China's RIC between different transitional stages?

RQ 3: What are the differences in the drivers of RIC among regions at different innovation level in China?

The three questions focused on different aspects. RQ1 aimed to understand the main drivers of RIC and how the selected factors influenced RIC in terms of patent counts in the long term across China. It also strived to gain more insights into the research context. RQ2 was to identify the different impacts of drivers across two transitional stages and to obtain insights on how to adjust the effort spent on each factor. RQ3 was to investigate the differences in the impact of drivers among groups at different innovation levels and consequently to provide references for regional government or policy makers to make effective policies and strategies in improving RIC.

To answer these questions and reach the aims, a simplified framework of RIC was developed based on the research of NIS/RIS and NIC. Following the framework, three steps of analysis were conducted employing a quantitative approach. Fixed effect panel data models were imported to examine the relationship between possible drivers and RIC, covering the whole time period and overall regions, concerning all regions in two phases, and regarding different groups over the whole frame respectively. Hierarchical cluster analysis was conducted to classify regions into groups according to RIC before investigating the variations among regions at different innovation levels.

9.2 Main Findings

This thesis is based on the context of China, covering 30 administrative regions in Mainland China. The analysis reveals that in China HEI and LME play different roles in innovation. Financial and human capital in S&T activities and interactions between innovation actors are the main direct influencers of RIC development in China. This finding answers the first research question.

The results in step two indicate the impact of the main drivers change over time with the process of IS reform in China, which provides an answer to the second research question. The final portion of analysis confirms variations in the impact of drivers among regions at different innovation levels in China, which addresses the third research question. Meanwhile, some additional findings emerged during the three steps of analysis. The main findings from the research are summarised below.

Firstly, the impact of a driver varies according to the type of innovation.The results from step one show the input factors, as well as FDI, all have greater impact on radical innovation than on incremental innovations. These results were consistent across the overall regions throughout the period of the study. However, international trade has a negative impact on radical innovation and a positive impact on incremental innovation, while domestic technology transfer only influences radical innovations. The differences in the impact of drivers between two categories of innovation imply different resources and knowledge are required to produce radical and incremental innovations.

Secondly, RIC is directly affected by drivers, as well as indirectly affected by the interactive effects between drivers. Outside of direct impact from other factors, absorptive capacity is commonly considered as one condition required to obtain positive spillovers from FDI and international trade (Cohen & Levinthal, 1989; Fu & Gong, 2011). In this study, the results suggest S&T effort, FDI, and international trade all greatly influence the development of RIC. When coupling S&T effort with FDI, and S&T effort with international trade, significant effects are presented. The impact is greater and stronger on radical innovations than on incremental innovations in overall regions. An interactive effect emerges between S&T effort and domestic technology transfer as well, but only in incremental innovations. On the whole, drivers can affect RIC directly and also indirectly by influencing the impact another driver has on RIC.

Thirdly, with the economic development and progressing of IS reform, the impacts of drivers change over time. The impacts of HEI and LME both improve in the second phase, as does the impact of economic infrastructure. However, financial capital and human capital seem to be more important in Phase One than in Phase Two. Since they show significant impact in the long term, it can be argued that input factors have an accumulative impact on RIC, it takes time for them to work. The impact of international interactions improves in the second phase, but there is not much improvement in the impact of domestic technology transfer in Phase Two. This suggests export-oriented strategies work better than strategies designed to enhance technology transfer domestically. As for the interactive effects, evidence shows most of them are improved. Therefore, with the economic development and the progressing of IS reform, RIC has been improving, as have the impact of drivers on RIC. The change in impact is in line with the reform, which indicates the reform works to improve RIC and the reform results in a change in impacts. For instance, since mid 1990s the national government encouraged innovation actors to increase innovation activities (*The Outline of the Ninth Five-Year Plan of the National Economy and Social Development (1996-2000)*, 1996). This improved the absorptive capacity and consequently enhanced benefits from FDI and international trade.

Finally, the impact of drivers on RIC differs among regions at different innovation levels. HEI make more contributions in low innovation regions than in high and medium innovation regions, while LME make more contributions in higher innovation regions. Hence, it may be argued the lower the innovation level of the region, the less enterprise-oriented its RIS is.

In regards to innovation inputs, financial investment has a greater influence in high innovation regions than in medium and low innovation regions. There are signs that the higher the innovation level of the region, the greater the impact of financial capital would be. On the contrary, the higher the innovation level of the region, the lower the impact of human capital. This indicates skilled talents are not well utilised in high innovation regions, as they have more skilled labour.

The impact of interactions appears to be more closely related to the innovation level of the region. The evidence shows the higher the innovation level of the region, the greater the impact of FDI and international trade. As for domestic interactions, there seems to be a U-shape relationship between the impact of domestic technology transfer and the innovation level of the region.

In terms of the results got from the analysis in previous chapters, the following conclusions can be made. HEI are critical innovation actors and enterprises are making more contributions to the improvement of RIC. The pivotal role of GDP suggests the phenomenon of "standing on the shoulders of others" exists in transitional countries. This means economic base and knowledge stock are critical in improving RIC. In the long term, the critical impacts of S&T effort and skilled labour indicate innovation resources are important in for developing countries to improve RIC. In addition, the different impact among groups suggests the impact of innovation resources depends on the efficiency of utilisation, not just the amount. The change in the impact of international interaction over the study period implies it takes time to take advantage of international interactions and particular conditions are needed to ensure positive spillovers from international interactions. The weak positive impact of domestic technology transfer suggests the technology market is important in RIC improvement, but it is not well developed in China. Moreover, the interactive effects between S&T effort and interactions display that factors in RIS may affect RIC both directly and indirectly, and its impact may be influenced by other factors.

9.3 Contributions and Implications

The research undertaken in this thesis provides a better understanding of China's RIS and RIC development. The findings and knowledge obtained in this thesis contribute to the literature of NIS/RIS and NIC/RIC in three ways.

Firstly, the interactive effects between the drivers explored in China enrich the literature of NIS/RIS and NIC/RIC. Previous studies based on the NIS/RIS approach mainly focused on the impact of the factors alone, while this research finds RIC is also influenced by the interactive effects between factors. The findings on interactive effects between S&T investment and international and domestic interaction suggest S&T investment moderates the relationship between interactions among innovation actors and innovation capacity, which confirms the importance of absorptive capacity in benefiting from advanced technologies and knowledge. Moreover, the findings broaden the definition of interactions in the IS approach. In the traditional IS approach, interaction is acknowledged as the key activity between innovation actors (Cooke & Memedovic, 2003; Edquist, 2004). The findings from this thesis indicate interactions between the direct influential drivers, such as financial investment and FDI, FDI and domestic technology transfer, should also be included in the definition of interaction.

Secondly, a qualitative comparison of RIC drivers between two transitional phases improves the understanding of the transitional process and the changes that resulted from the reform in China. As a transitional country, many researchers have studied the transitional process and the changes using qualitative approaches. This thesis examines the changes in the impact of drivers on RIC using a quantitative approach, which provides insights from another perspective. Findings show the impact of drivers changes over time and most of the impact improved in the second phase. This affirms the differences between these two phases. The improvement also provides evidence of the effectiveness of the policies and strategies implemented by the government this period.

For example, the stronger and greater impact of international trade in the second phase suggests the strategy of enhancing international trade works in the later stage of reform. Considering the impact during the whole period, it shows it takes time to take advantage from imported technologies and to reflect international customers' needs in the exported products.

Finally, the comparison among groups at different innovation levels enriches the literature of RIS and RIC, and re-emphasises the importance of conducting IS research at the regional level, especially in countries that are unevenly developed on a national scale. Although studies at the national level enrich the bigger picture of the innovation phenomenon of the country, studies at the regional level uncover the story behind the big picture and provide a broader view. Moreover, the findings add knowledge to the study of RIS/RIC, detailing how the impact of drivers may relate to the innovation level of a region. Hence, findings based on regions with different innovation levels may not be generalisable.

For instance, domestic technology transfer exerts a positive impact on RIC across all the regions. However, according to the results from separate groups, in terms of granted patents it influences RIC positively in high and low innovation regions and has no effect in medium innovation regions. Therefore, in this case, the finding across overall regions is not generalisable in medium innovation regions.

Other than the theoretical contributions discussed above, the findings provide policy implications for both national and regional governments and policy makers.

Firstly, the existence of interactive effects between drivers suggests both national and regional governments need to pay attention to the effect of a single factor, as well as its interactive effect with other factors, when developing strategies or policies to improve RIC in China.

Secondly, the changing impact of drivers over time implies both national and regional governments need to know the recent affect of a factor on RIC and how the strategies related to that factor worked in the past prior to developing new strategies or adjusting policies to improve RIC. The changing impact also indicates governments should modulate innovation strategies and policies in terms of the change of the impact.

Specifically, the impact of innovation actors in the two phases suggests it is good for governments to continue encouraging HEI to take advantage of the research resources they have and exert spin-offs to serve the development of industries.

Developing further incentives for enterprises to put more effort into innovation activities will help achieve the objective of developing an enterprise-oriented NIS/RIS.

The accumulative impact of innovation input implies that to improve RIC, financial inputs need to be increased and human capital investment is also required. The improved impact of FDI in the second stage suggests that, in addition to putting effort into enhancing inward FDI, governments also need to improve absorptive capacity and other conditions to gain more positive spillovers. For domestic interactions, although the technology market has improved, the impact did not show much improvement. Therefore, technology markets need to be further developed and specialised in order to better play their role in RIC development.

Thirdly, the findings from the comparison of groups show successful strategies and policies may not be adaptable to regions at different innovation levels, and regional governments should not blindly follow the successful experiences of other regions. The national government should give more autonomy to the regional governments, so they can create more effective strategies and policies suitable to their own situations.

In regards to innovation actors, governments in low innovation regions need to accelerate the reform of enterprise systems and HEI and provide more incentives for them to initiate innovation activities. In terms of input factors, all regions need to enhance the efficiency of resources utilisations and low innovation regions need to make policies designed to attract more skilled talent. For FDI and international trade, high innovation regions need to place more focus on how to gain positive spillovers, as they already have a large inflow of FDI and international trade. Meanwhile low innovation regions need to develop conditions for positive spillovers and attracting more FDI inflow.

Overall, the thesis makes both theoretical and practical contributions to NIS/RIS and NIC/RIC through three key findings: interactive effects, impact changes over time, and differences in impact of drivers on RIC among different innovation regions in China.

9.4 Limitations

Even though the research is carefully designed, there are some inevitable limitations.

The first limitation relates to the data source. When using secondary data the quality of the data can not be controlled (Bryman & Bell, 2003), and measures of the variables have to be adjusted if the information available does not meet the requirements of the study (Emory & Cooper, 1991). This being said, the fit of the data to the research question is a common concern (Saunders, et al., 2003).

The second limitation concerns the variables included in the research framework. RIS is a complicated system that consists of many elements. However, it is impossible to include every factor and tell the whole story in one study. Hence, the omitted variables in the study may lead to some biases in the results.

The third limitation refers to the measures of the variables. To measure RIC, patent counts are employed. However, not all innovations are patentable (Griliches, 1990) and patents are not the ultimate goal of enterprise and HEI (Bai & Li, 2011). Besides, a large amount of patents are applied for and granted to individuals in China, which measures the RIC of individual residents within a region, but the financial and human resource inputs to those activities are unknown. This study did not consider the ownership of patents, which may lead to some biases in the results.

For innovation actors, the number of HEI and LME cannot well represent the innovation activities they conduct. Consequently, it is not a good proxy to measure the impact of HEI and LME on RIC and this needs to be improved. Besides, another important innovation actor, research institutes, is missing due to data availability. Research institutes play an important role in China's NIS and the reform of research institutes is part of the reform of NIS, which in turn leads to changes in the innovation environment in China. Hence it is not possible to ignore research institutes when studying NIS/RIS in China. The findings regarding the impact of innovation actors on RIC are limited in this study.

In terms of international interactions, there is also a limitation on the measure of international trade. To measure international trade the total value of imports and exports is employed, which combines the separate impact of import and export. Hence, it is hard to tell from the results which one leads to the overall effect and provide insights on import and exportseparately.

The final limitation is the time lag between IV and DV. In this study it is assumed the time lags are the same between IV and granted invention patents, and between IV and granted utility model patents. But according to China's Patent Law the granting process is simpler for utility model patents than for invention patents and it takes less time as well. Therefore, employing the same time lag for different categories of patents may lead to biases in the impacts of drivers on these two categories.

9.5 Future Research

In terms of the findings and limitations, this thesis makes several recommendations for future research. To overcome the disadvantages of secondary data, researchers can design studies, collecting primary data to meet their specific needs and controlling the quality of the data. To reduce the biases from the omitted variables the framework of RIC can be expanded with more variables. To better measure RIC alternative indicators can be employed in future research, such as the number of new products (Fritsch, 2002), new product sales (Liu & White, 1997), and literature-based innovation counts (Acs, et al., 2002). To cover the biases resulted from time lag, different time lags may be applied according to the type of innovations.

Regarding the measures of the variables and the differences in the impact of drivers on RIC, studies can be undertaken in the following directions in the future. To better investigate the impact of enterprises, enterprises in all sizes should be considered, and measures such as the ration of R&D fund spent on each actor can be employed in future research. Since the effect of the resource depends on the amount invested, in addition to how it is used (Yu & Xie, 2007), to further understand the reasons for the differences in S&T effort among regions at different innovation levels, researchers can explore the impact of different ways S&T effort is used on RIC. This kind of research can also determine which is the most efficient way to use S&T effort to improving RIC.

With regard to international interactions, the impact of imports and exports can be investigated separately to see which strategy works better. For FDI, alternative indicators, such as the assets of foreign invested enterprises (Xian & Yan, 2005), rather than the annual inflow of FDI, could be considered. Besides, how the FDI is used could provide more insights into how FDI influences RIC (Fu, 2008) and how different types of FDI generate different spillovers (Driffield & Love, 2007). It could also provide a better understanding of the ways FDI is spent and the types of FDI that should be the focus of future research based in the context of China. In terms of the possible U-shape relationship between the impact of domestic technology transfer on RIC and the innovation level of the region, future research can test if technology gap between importer and exporter within the country affects the spillovers of transferred technology.

Finally, the role of S&T investment between domestic and international interactions and RIC, S&T effort does not fully represent absorptive capacity, though it is commonly used. As the quality of labour force will influence the capability to absorb advanced technologies (Anwar & Nguyen, 2010; Chi, Yu, & Li, 2008), skilled labour should be considered when measuring absorptive capacity in the future. Moreover, the unexpected negative effect of S&T effort on the impact of domestic technology transfer and FDI in different phases and in different groups calls for further verification.

In the future, these are the potential directions the author plans to explore.

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Appendix I Time lag verification of DVs

	Time lag	0	1	2	3	4	5
Within R-sq	Overall applications	.6481	.6338	.6393	.6214	.6225	.6213
	Overall granted patents	.7051	.7115	.7525	.7772	.7801	.7783
	Granted invention patents	.8691	.8376	.8373	.8557	.8774	.8781
	Granted utility model patents	.7451	.7473	.7857	.8063	.8179	.8194

Appendix II Correlations of variables

Appendix II-1 Correlations with data from all the regions between 1991 and 2005

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1												
lgTPGpm	.946**	1											
lgTIPGpm	.858**	.846**	1										
lgTUMPGpm	.955**	.947**	.853**	1									
lgNHEIpb	.689**	.610**	.723**	.662**	1								
lgNLMEpm	.762**	.717**	.563**	.752**	.563**	1							
lgGDPpp	.853**	.882**	.878**	.846**	.645**	.650**	1						
lgSTFpthGDP	.559**	.480**	.563**	.573**	.631**	.459**	.311**	1					
lgFTE_SEpm	.782**	.706**	.732**	.794**	.799**	.734**	.603**	.846**	1				
Emprate	.170**	.234**	.176**	.215**	-.011	.220**	.164**	.233**	.179**	1			
lgEITpthGDP	.760**	.724**	.487**	.684**	.478**	.731**	.596**	.351**	.563**	.059	.657**	1	
lgTCVpthGDP	.559**	.496**	.497**	.537**	.459**	.482**	.402**	.555**	.609**	.121**	.226**	.399**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix II-2 Correlations with data from all the regions between 1991 and 1998

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1												
lgTPGpm	.919**	1											
lgTIPGpm	.777**	.789**	1										
lgTUMPGpm	.931**	.929**	.829**	1									
lgNHEIpb	.639**	.524**	.632**	.614**	1								
lgNLMEpm	.830**	.801**	.708**	.842**	.640**	1							
lgGDPpp	.759**	.857**	.776**	.778**	.469**	.768**	1						
lgSTFpthGDP	.452**	.316**	.458**	.486**	.600**	.440**	.072	1					
lgFTE_SEpm	.756**	.651**	.731**	.790**	.835**	.753**	.500**	.826**	1				
Emprate	.210**	.247**	.255**	.250**	.077	.331**	.266**	.259**	.251**	1			
lgFDIpthGDP	.518**	.590**	.368**	.446**	.170**	.494**	.638**	-.026	.215**	.151*	1		
lgEITpthGDP	.768**	.743**	.467**	.639**	.446**	.644**	.599**	.235**	.476**	.147*	.671**	1	
lgTCVpthGDP	.534**	.457**	.525**	.522**	.415**	.475**	.321**	.587**	.572**	.157*	.211**	.320**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix II-3 Correlations with data from all the regions between 1999 and 2005

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1	.946**	.927**	.959**	.644**	.844**	.923**	.645**	.825**	.120	.596**	.874**	.602**
lgTPGpm	.946**	1	.860**	.946**	.560**	.788**	.887**	.604**	.760**	.221**	.584**	.837**	.540**
lgTIPGpm	.927**	.860**	1	.897**	.749**	.754**	.857**	.773**	.896**	.106	.494**	.775**	.593**
lgTUMPGpm	.959**	.946**	.897**	1	.609**	.785**	.905**	.641**	.805**	.173*	.520**	.810**	.556**
lgNHEIpb	.644**	.560**	.749**	.609**	1	.552**	.709**	.640**	.746**	-.162*	.372**	.570**	.491**
lgNLMEpm	.844**	.788**	.754**	.785**	.552**	1	.818**	.495**	.739**	.100	.621**	.820**	.494**
lgGDPpp	.923**	.887**	.857**	.905**	.709**	.818**	1	.528**	.757**	.030	.569**	.861**	.533**
lgSTFpthGDP	.645**	.604**	.773**	.641**	.640**	.495**	.528**	1	.861**	.190**	.271**	.491**	.495**
lgFTE_SEpm	.825**	.760**	.896**	.805**	.746**	.739**	.757**	.861**	1	.081	.412**	.675**	.638**
Emprate	.120	.221**	.106	.173*	-.162*	.100	.030	.190**	.081	1	.074	-.029	.071
lgFDIpthGDP	.596**	.584**	.494**	.520**	.372**	.621**	.569**	.271**	.412**	.074	1	.657**	.253**
lgEITpthGDP	.874**	.837**	.775**	.810**	.570**	.820**	.861**	.491**	.675**	-.029	.657**	1	.484**
lgTCVpthGDP	.602**	.540**	.593**	.556**	.491**	.494**	.533**	.495**	.638**	.071	.253**	.484**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix II-4 Correlations with data from high innovation regions between 1991 and 2005

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1	.924**	.943**	.947**	.749**	-.411**	.724**	.522**	.395**	-.418**	-.233	.746**	.567**
lgTPGpm	.924**	1	.913**	.942**	.700**	-.293	.804**	.413**	.423**	-.404**	-.098	.699**	.435**
lgTIPGpm	.943**	.913**	1	.937**	.756**	-.425**	.799**	.476**	.339*	-.544**	-.087	.693**	.565**
lgTUMPGpm	.947**	.942**	.937**	1	.724**	-.417**	.757**	.504**	.431**	-.342*	-.134	.799**	.535**
lgNHEIpb	.749**	.700**	.756**	.724**	1	-.572**	.526**	.684**	.536**	-.271	-.265	.652**	.575**
lgNLMEpm	-.411**	-.293	-.425**	-.417**	-.572**	1	.060	-.731**	-.262	.233	.410**	-.510**	-.732**
lgGDPpp	.724**	.804**	.799**	.757**	.526**	.060	1	.060	.263	-.310*	.230	.390**	.125
lgSTFpthGDP	.522**	.413**	.476**	.504**	.684**	-.731**	.060	1	.758**	-.094	-.425**	.724**	.713**
lgFTE_SEpm	.395**	.423**	.339*	.431**	.536**	-.262	.263	.758**	1	.203	-.291	.548**	.358*
Emprate	-.418**	-.404**	-.544**	-.342*	-.271	.233	-.310*	-.094	.203	1	-.094	-.174	-.322*
lgFDIpthGDP	-.233	-.098	-.087	-.134	-.265	.410**	.230	-.425**	-.291	-.094	1	-.066	-.260
lgEITpthGDP	.746**	.699**	.693**	.799**	.652**	-.510**	.390**	.724**	.548**	-.174	-.066	1	.630**
lgTCVpthGDP	.567**	.435**	.565**	.535**	.575**	-.732**	.125	.713**	.358*	-.322*	-.260	.630**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix II-5 Correlations with data from mid innovation regions between 1991 and 2005

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1	.902**	.927**	.942**	.619**	.540**	.891**	.577**	.703**	.151	.100	.499**	.454**
lgTPGpm	.902**	1	.824**	.861**	.483**	.432**	.893**	.407**	.557**	.197	.217*	.478**	.364**
lgTIPGpm	.927**	.824**	1	.955**	.714**	.566**	.890**	.698**	.826**	.188	.028	.292**	.571**
lgTUMPGpm	.942**	.861**	.955**	1	.642**	.653**	.891**	.636**	.775**	.288**	-.018	.280**	.558**
lgNHEIpb	.619**	.483**	.714**	.642**	1	.258*	.554**	.607**	.743**	-.087	-.012	.080	.533**
lgNLMEpm	.540**	.432**	.566**	.653**	.258*	1	.503**	.581**	.612**	.518**	-.208*	.051	.405**
lgGDPpp	.891**	.893**	.890**	.891**	.554**	.503**	1	.417**	.620**	.230*	.314**	.426**	.404**
lgSTFpthGDP	.577**	.407**	.698**	.636**	.607**	.581**	.417**	1	.910**	.185	-.199	.045	.585**
lgFTE_SEpm	.703**	.557**	.826**	.775**	.743**	.612**	.620**	.910**	1	.168	-.053	.118	.667**
Emprate	.151	.197	.188	.288**	-.087	.518**	.230*	.185	.168	1	-.321**	-.255*	-.118
lgFDIpthGDP	.100	.217*	.028	-.018	-.012	-.208*	.314**	-.199	-.053	-.321**	1	.619**	-.141
lgEITpthGDP	.499**	.478**	.292**	.280**	.080	.051	.426**	.045	.118	-.255*	.619**	1	.007
lgTCVpthGDP	.454**	.364**	.571**	.558**	.533**	.405**	.404**	.585**	.667**	-.118	-.141	.007	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix II-6 Correlations with data from low innovation regions between 1991 and 2005

	lgTPApm	lgTPGpm	lgTIPGpm	lgTUMPGpm	lgNHEIpb	lgNLMEpm	lgGDPpp	lgSTFpthGDP	lgFTE_SEpm	Emprate	lgFDIpthGDP	lgEITpthGDP	lgTCVpthGDP
lgTPApm	1	.875**	.785**	.878**	.584**	.394**	.753**	.240**	.537**	-.082	.184**	.175**	.353**
lgTPGpm	.875**	1	.813**	.900**	.511**	.343**	.810**	.196**	.471**	.044	.221**	.128*	.296**
lgTIPGpm	.785**	.813**	1	.752**	.569**	.228**	.834**	.261**	.510**	.117*	.096	-.044	.229**
lgTUMPGpm	.878**	.900**	.752**	1	.518**	.357**	.711**	.308**	.605**	-.022	.075	.047	.297**
lgNHEIpb	.584**	.511**	.569**	.518**	1	.386**	.585**	.292**	.579**	-.098	.035	.221**	.087
lgNLMEpm	.394**	.343**	.228**	.357**	.386**	1	.359**	.024	.396**	-.206**	.280**	.262**	.257**
lgGDPpp	.753**	.810**	.834**	.711**	.585**	.359**	1	-.064	.314**	-.020	.261**	.147**	.168**
lgSTFpthGDP	.240**	.196**	.261**	.308**	.292**	.024	-.064	1	.719**	.253**	-.192**	-.206**	.294**
lgFTE_SEpm	.537**	.471**	.510**	.605**	.579**	.396**	.314**	.719**	1	.058	-.126*	-.164**	.305**
Emprate	-.082	.044	.117*	-.022	-.098	-.206**	-.020	.253**	.058	1	-.022	-.409**	.110
lgFDIpthGDP	.184**	.221**	.096	.075	.035	.280**	.261**	-.192**	-.126*	-.022	1	.412**	.040
lgEITpthGDP	.175**	.128*	-.044	.047	.221**	.262**	.147**	-.206**	-.164**	-.409**	.412**	1	.049
lgTCVpthGDP	.353**	.296**	.229**	.297**	.087	.257**	.168**	.294**	.305**	.110	.040	.049	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix III Summary of estimated results

	Overall	Stage one	Stage two	Group one	Group two	Group three

	A	G	IG	PG	A	G	IG	PG	A	G	IG	PG	A	G	IG	PG	A	G	IG	PG	A	G	IG	PG
lgNHEIpb	+			+		-	-	-				+				-	+				+			+
lgNLMEpm			-				-		+	-									-				-	
lgGDPpp	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
lgFSTpthGDP	+		+	+			+						+		+		+						+	
lgFTE_SEpm	+	+	+	+		+		+			+		-		-	-			+		+	+	+	
Emprate						-						+			-		-		-		+	+	+	
lgFDIpthGDP	-	-	-	-	-	-	-	-		+			-	-	-	-	-		-	-	-	-	-	-
lgEITpthGDP	+	+	-	+			-	+	+	+	+	+	+	+	+	+	+		+	+	+	+	-	+
lgVDTCpthGDP	+		+		+		+	-		+		+	+		+	+	-				+		+	
lgFST*lgFDI			+	+	-	-	+		+	+	+	+					-						+	
lgFST*lgEIT	+	+	+	+		-			+	+	+	+	+	+					+					+
lgFST*lgVDTC		-		-		-		-									+			+	-	-	-	-
lgFDI*lgVDTC		+		+	-		-		+													+	-	+

Note: Please refer to Table 4.1 for the meaning of the variables