EXPLORING REGIONAL INNOVATION CAPACITIES OF PR CHINA: TOWARD THE STUDY OF KNOWLEDGE DIVIDE

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EXPLORING REGIONAL INNOVATION CAPACITIES OF PR CHINA: TOWARD THE STUDY OF KNOWLEDGE DIVIDE

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For my parents

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LIST OF ABBREVIATIONS

CAS	Chinese Academy of Science
CCP	Chinese Communist Party
CNNIC	China Internet Network Information Center
CPI	Consumer Price Indices
EI	Engineering Information
EPSCoR	Experimental Program to Support Competitive Research
EU	European Union
FDI	Foreign Direct Investment
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
GRI	Government Research Institution
HDI	Human Development Index
HUST	Huazhong University of Science and Technology
ICT	Information and Communication Technology
IPR	Intellectual Property Right
ISTP	Index to Scientific and Technical Proceeding
LBIO	Literature-Based Innovation Output
LME	Large and Medium-Sized Enterprise
MIIT	Ministry of Industry and Information Technology of China
MOST	Ministry of Science and Technology of China
NAS	National Academy of Science
NBS	National Bureau of Statistics

NIC	National Innovative Capacity
NIS	National Innovation System
NSF	National Science Foundation
OECD	Organization for Economic Cooperation and Development
PIS	Post-Industrial Society
PRC	People's Republic of China
RIC	Regional Innovative Capacity
RIS	Regional Innovation System
R&D	Research and Development
SCI	Science Citation Index
SI	System of Innovation
SIPO	State Intellectual Property Office
SME	Small and Medium-Sized Enterprise
S&E	Science and Engineering
S&T	Science and Technology
SOE	State-Owned Enterprise
TFP	Total Factor Productivity
TRIP	Trade-Related Intellectual Property
UIC	University-Industry Collaboration
UK	United Kingdom
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States
USCBC	US-China Business Council
VIF	Variance Inflation Factors

WIPO World Intellectual Property Organization

SUMMARY

While the Chinese innovation system has achieved some promising developments at the aggregate level over the past few years, looking at the breakdown by regions unveils a different story behind the success. This study is a modest attempt to shed light on the issue of 'knowledge divide' in the Chinese context, as existing regional inequalities have appeared in conjunction with the production of knowledge and innovation in its transformation into an innovation-driven economy. In order to understand the major reasons for this new trend in regional divergence, the study explores the different levels of innovation activities among the provincial-level regions of China and analyzes underlying factors leading to the regional disparity in innovation performance.

Much of the analysis is concerned with an empirical and comparative exploration of the determinants of regional innovation capacity, employing a comprehensive and unified framework of a regional innovation system which can capture a dynamic process of building regional innovation capacity. Combining both quantitative (e.g., regression and factor analyses) and qualitative (e.g., comparative case analysis) methods, the research examines the relationship between regional innovative output (e.g., domestic patenting) and the explanatory variables associated with the regional innovative capacity as well as explore how innovation capacities are built in different regional contexts.

The quantitative empirical results show that the development of innovation infrastructure has been the most important factor that contributes to the enhancement of the capacities of the regional innovation systems. Accumulated knowledge stocks and

overall level of research and development (R&D) resources have the prominent and positive impacts on the level of the regional innovation productivity. Regional government policies also play a significant role in determining the innovation productivity but they have the distinctive effects on the different qualities of the innovation outputs. The public investments in human capital play a considerable role in technologically intensive innovation process, whereas the impact of government S&T supports is limited to the production of marginal innovation. This implies the inefficiency of public S&T support systems which lower the quality level of innovation outputs. However, the knowledge spillover effects of the foreign direct investment (FDI) inflow and international trade on the regional innovations are mostly insignificant and negative.

The results also suggest that the cluster innovation environment, measured by private S&T funding, is a critical determinant of advanced technological innovations. In fact, this is reflected in a rapid increase in the firms' share of institutional invention patent grants over the past decade. While industry becomes a major source of technologically intensive innovation, the knowledge spillovers from the science sector play a favorable role in generating marginal innovation. Given that the interactions or linkages between the private and science sectors have a limited effect on the regional innovation outputs, this indicates that the efficiency and quality of R&D productivity can be low in most regional innovation systems in China.

The detailed comparative case study of Hubei and Fujian complements the above empirical results, highlighting the importance of the government's policies and the interactions or links between private and science sectors. The contrasts between the two regional innovation systems reveal that the establishment of the strong knowledge base and learning culture for innovation, along with the effective government intervention is a determinant factor leading to differences in the innovation performance of the two regions. Specifically, it suggests that the effective government intervention policies, institutional incentive systems, science and technology (S&T) capabilities of industry, and research-oriented academic culture are crucial to induce the active learning trends which can contribute to the development of the regional innovation capacity.

CHAPTER 1

INTRODUCTION

1.1 Toward the Study of Knowledge Divide

It has been widely acknowledged that knowledge and technological innovation have become the key resources to sustain the development of economy as well as society. The last two centuries have witnessed the explosion of knowledge and information as a result of the rapid pace of scientific and technological breakthroughs. Without any doubt, this has brought about fundamental changes in all socio-economic life of people and nations across the world. When a new economic and technological paradigm based on information and communication technologies (ICTs) has been closely intertwined in the dynamic sectors of the global economy, knowledge has become the most crucial asset, surpassing the conventional factors of production—labor, land and capital (Powel and Snellman 2004; Pant 2009). Today, leading edge of economy in most of advanced countries has become driven by knowledge-based activities—generation, dissemination, and utilization of knowledge. More than half of the GDP in the major Organization for Economic Cooperation and Development (OECD) countries is knowledge-based, as its knowledge-intensive service sectors, such as education, communication and information, have been expanding faster (OECD 2009a). Also, this tendency is growing in some of developing countries.

As the tide of socio-economic change turns as a result of the explosive growth of knowledge and technological innovation, increasing attention has been paid to a new approach to the development issues among international development agencies as well as of some national governments. In 1999, the World Development Report indicated a need to approach the problems of development in a new way—from the perspective of knowledge. Knowledge is widely believed to be a crucial factor responsible for sustainable development—that is, economic well-being and quality of life. Given the context, the concepts of development and progress are discussed in terms of the capacity to generate, acquire, disseminate and utilize knowledge. With the emergence of 'knowledge society' or 'knowledge economy', the presence or absence of this capacity constitutes knowledge gaps between and within countries (Evers 2002; Sagasti 2004; Addy 2005). The gap reflects the unequal distribution of knowledge across the world, which may result in inequality of development. Thus, today's world is divided further not just by ideology or capital but by knowledge and technology (Drori and Jang 2003; Sachs 2003).

By linking the development with knowledge, the World Bank (1999) first voiced a concern about knowledge gaps as a challenge for international development. As the knowledge-based economy expands, the knowledge gap is likely to widen the disparities between rich and poor, imprisoning poor countries and poor people continuously in relative poverty (Persaud 2001; Parayil 2005; United Nations Educational, Scientific and Cultural Organization (UNESCO) 2005; Weingart 2006). This trend is reinforced by the North-South economic relations.[1] Since the commoditization and privatization of

[1] "The North-South divide is the gaps in socio-economic development in the countries belong to the northern and southern hemisphere. The northern countries are more modern, advanced and affluent than countries in the southern counterparts. The former has more advantages accruing from early industrialization, capitalism, colonization and democracy than the latter. In general, the wealthy developed countries in the North were categorized under the "First World" and the poorer developing countries in the South were categorized under the "Third World"" (Salam 1988: 19)

knowledge have been facilitated by few North countries, capital and other resources tend to flow to those countries with the stronger knowledge bases, adding to the inequality. For example, a few developed economies, such as G5 countries (e.g., the United States (U.S.), the United Kingdom (UK), Canada, Japan, and Germany), have played a major role in the world's production of knowledge. While they have broadened protection of intellectual property rights through patents, copyrights, etc., the vast majority of developing countries in the race towards a knowledge economy is either restricted to use essential knowledge or has to pay a high price for the access to it. As a result, nations or sub-national regions with a low level of knowledge are disadvantaged or marginalized further due to lack of competitiveness and lack of knowledge in the current knowledge-based economy. This, in turn, generates another layer to the process of socio-economic differentiation and reinforces already existent patterns of inequality.

Thus, development and the issue of inequality have become tied to knowledge and technological innovation and been widely discussed in public discourses, especially in the last decade. Nonetheless, the study of knowledge divide related to innovation competence-building is still a relatively new field of research where much remains to be done (Drori 2010). It is an opportune time for an in-depth investigation of the ramifications of the rapid growth of a knowledge-based or an innovation-driven economy. More broad and various approaches to knowledge gaps should be conducted and developed in more related research. In doing so, it needs to elucidate how knowledge divide is constructed and measured and what knowledge is actually underpinning current development as well as inequality. More research is needed on these and other unanswered questions about knowledge and inequality, which may contribute to development of the new study of inequality. In this regard, the present study explores the specific contexts of a developing country, particularly, China in which widening regional gaps in the development of knowledge has emerged as a challenge to overcome for its sustainable development.

1.2. Innovation as an Indicator of Knowledge

Since the meaning of knowledge is variously defined, it has been used as a much broader and multi-dimension concept and measured in many different ways. Knowledge generally refers to the things or facts of knowing or understanding gained through education, experience and research. However, it is broadly defined as every type of idea or mode of thought by social scientists, such as social and cultural products, ideologies, juristic and ethical beliefs, religion, philosophy, science, technology, etc. Considerable efforts have been made by social scientists to interpret the nature and function of knowledge.

The concept of knowledge has been understood within varying social milieus, underlining the social sources as well as consequences of knowledge. The sociology of knowledge especially focuses on the relationships between knowledge and existential (social) factors in the society and culture (Merton 1979). For example, Marx (2000) asserted that ideas (or knowledge) are shaped by the economic structure of society, as it often emerges and changes according the interests of the dominant class. In the same manner, other Marxist sociologists (Althusser 1972; Gramsci 2001) interpreted knowledge as means of maintaining and reinforcing the legitimacy and authority of the ruling class—that is, "ideological hegemony." Durkheim (2011) studied religious knowledge and belief systems, and addresses that all fundamental human knowledge is socially constituted as collective representations through time and space which constrain and organize human thoughts as bases for ethics and cognition. Foucault (1980) describes knowledge created through discourse as a form of power constructing mechanisms of social control.

Several earlier works in sociology of knowledge had pioneered the study of scientific knowledge or science. Scheler (1926: 55) set the fundamental principal of the sociology of knowledge that "the "forms" of the mental processes by means of which knowledge is acquired are always and necessarily co-determined sociologically, that is, by the social structure." In fact, he marks the distinction between knowledge '(as a cultural sphere such as religion, philosophy, science) and society (race and kinship, politics, economics) and they are interacted with each other. For him, "different types of knowledge as well as the techniques and motivation for extending knowledge are bound up with particular forms of groups" (Tonnies 2002: 28). This had influence on the sociology of science in which the contents of scientific knowledge is closely tied to the social institution of intellectual activity.

Sorokin's idealistic and emantionist theory (1937) set forth the formulations in the sociology of science. He proposes that every aspect of knowledge is derived from 'culture' (more specifically, 'cultural mentalities'—ideational, sensate, and idealistic culture), not just from the existential basis. He attempts to link scientific knowledge to the overall cultural mentalities in which knowledge appears and develops. In his account of scientific discovery and technological invention, he asserts that "any important new invention…or nay important new discovery in the natural sciences …is the result of a long process, with a multitude of small discoveries made step by step, [so that] the really new element in any important invention or discovery is comparatively a very modest one" (p.182). Thus, he traces the cumulative pattern of knowledge production within scientific communities and connects specific innovators to the scientific tradition and culture within which they operate (Coser 1977).

Mannheim's approach (1936) to the production of knowledge, which seeks to explain variation in knowledge within the historical and social conditions of the society, became not only the premises of the sociology of knowledge but also the root of the sociology of scientific knowledge. In his interpretation, knowledge is explained socially in that social position or social group determines our "perspective"—"the manner in which one views an object, what one perceive in it, and how one construes it in his thinking (p.244)."

Influenced by the above approaches from sociology of knowledge, some sociologists explore 'scientific knowledge' or 'science,' addressing the social and cultural aspects of the production of scientific knowledge (Merton 1979; Gieryn 1979; Cole and Cole 1981; Collins 1982 and 1983; Barber and Fox 1990; Bloor 1991; Kuhn 1996; Zuckerman 1996; Barnes et al. 1996; Barnes 2008). Unlike sociologists of knowledge, they claim that the contents and methodologies of science can also be explained by social factors such as the interests of different social groups (Bloor 1973; Merton 1979). From their perspective, "social and cultural factors are essential compositions in the construction of scientific knowledge" (Gieryn 1982: 282). In other words, the scientific belief or truth is not merely determined by the natural world, but the social process and structure of scientific activities.

Merton (1979) explains how the social institution of science involves the normative structure that guides and control scientists' actions to extend certified knowledge. Thus, scientists' actions and beliefs are constructed by social factors such as interests, conventions or processes of socialization. For example, the pattern of scientists' problem choice and scientific inquiry are predetermined or reflected by the reward system and opportunity structure of science which provides a stratified distribution of rewards and power among scientists (Zuckerman and Merton 1971; Gieryn 1979; Zuckerman 1979; Cole and Cole 1981). Since scientific knowledge is approximate and uncertain, scientists often tend to argue about, negotiate, and have doubts about the validity of the scientific outcomes, as experimental practices of science are situated in a social context (Collins 1975; Knorr-Cetina 1981; Pinch 1981). The content of scientific knowledge, therefore, is viewed as the social product of collective practice and goal-oriented action (Barnes 2008). This sociological account of the origin and nature of knowledge, in turn, can provide a better understanding of the knowledge production process in today's science where scientific and technological knowledge is largely developed in the social context through the complex networks of interactions.

While sociologists of science offer some insights into the production of knowledge, the theorists of the post-modern or post-industrial society and economy place more emphasis on the expansion in the social function of scientific knowledge as the agent of social change (Bohme and Stehr 1986). According to Bell (1973), every society lives with innovation and growth and the theoretical or codified knowledge is the source of invention and innovation, interrelated with science and technology (S&T). "[Theoretical] knowledge increasingly becomes the strategic resource, the axial principle, of a society.

And the university, research organizations, and intellectual institutions where knowledge is codified and enriched, become the axial structure of the emergent society." (p. 39). Similar to Bell, Lyotard (1984: 5) views knowledge as an "informational commodity indispensable to productive power" in the post-industrial society. The explosion of scientific knowledge as a commodity becomes a vehicle for changing society that is the condition of postmodern or post-industry society. Stehr, in his theory (2001) of 'knowledge societies,' defines knowledge as a capacity for action. He also views that scientific and technical knowledge is uniquely important in the transformation of modern societies into knowledge ones, "because it produces incremental capacities for social and economic action" (2001: 498). In the knowledge-based economy, thus, the capacity of creating knowledge is a key to the productive process that marks the structural changes of the economy and its dynamics.

In the context of the post-industrial or knowledge-based society and economy, much of discussion surrounding knowledge within social sciences has emphasized the importance of non-codified or tacit knowledge in the form of skills and competences—that is, know-how or scientific and technical knowledge (Popadiuk and Choo 2006). Collins's studies (1974; 2001) suggest the idea that scientists have 'tacit knowledge' consists of "tacit rule which may be impossible to formulate in principle" (1974: 167). He defines the tacit knowledge as "knowledge or abilities that can be passed between scientists by personal contact but cannot be, or have not been, set out or passed on in formulae, diagrams, or verbal descriptions and instructions for action" (2001: 72). His two cases specifically show how scientists face the difficulties in replicating scientific and technological experiments which was successfully executed by others. From his perspective, tacit knowledge can only be transmitted to other through personal contact or group learning when team perform the experiment together and constantly learn what the critical factors led to the success. Several empirical studies also found the importance of tacit knowledge in the development of science and technology (S&T) (Cambrosio and Keating 1988, Collins 1992; Mackenzie and Spinardi 1995; Pinch et al. 1996; Collins and Kusch 1998).

With the widespread of ICTs, information or codified knowledge is easily produced and disseminated in the form of document, numbers, formula, and manual. By contrast, non-codified knowledge remains tacit and mostly embodied in persons and organizations. Therefore, it is difficult to be shared and diffused until it is transferred with interactive learning between possessors (Johnson and Lundvall 2003). Today, much technological knowledge is not created codified but tacit in nature. As such, it represents disembodied know-how that is acquired via the socialization and collective learning procedures. In the context of the growing role of knowledge in the economy, it is increasingly recognized that tacit knowledge or 'know-how' is valued as the most important production resource (Rosenkopf and Almeida 2003).

Some scholars applying the concept of knowledge production and knowledge creation refer to technological knowledge and innovation as the outcome of knowledge production (OECD 2000; Lundvall 2006). In the knowledge economy age, knowledge is regarded as the main input as well as output in the production process. Knowledge production is a process of joint production in which innovation is one kind of output and learning know-how and tacit knowledge through interactions is taking place as the process. Under certain circumstances, technological innovation is often thought of as a key outcome of knowledge production, as it represents new knowledge or new combination of existing knowledge incorporated in products, processes, and services, generating economic value in markets (OECD 2005).

Table 1.1 Production Process in Knowledge Economy Age

	Input	Process	Output
Agricultural and Industrial Age	Raw Materials Capital Labor	Physical Labor works	Commodities Goods Machinery
Knowledge (Information) Age	Knowledge (e.g., Competences)	Learning	New Knowledge (e.g., Innovations and Competences)

Sources: OECD 2000; Lundvall 2006

Accordingly, it should be noted that the creation of knowledge can not be merely considered innovation unless it has been implemented or commercialized in some way. Innovation consists of the generation of new knowledge and "its implementation into a new marketable product or a new process with attendant cost reduction and increased productivity" (Urabe 1988: 3). Innovation involves the concept of novelty, commercialization, and implementation (Popadiuk and Choo 2006). In this respect, the primary components of successful innovation are often suggested to include newly acquired knowledge in the form of scientific or technological advancements, knowledge workforces, and environment that promotes innovation and entrepreneurship (National Academy of Science (NAS) 2005).

Given that the concepts of innovation and knowledge creation are tightly interrelated, innovation captures a complex but dynamic process of knowledge production. Recent innovation theory regards innovation and knowledge production as an interactive learning process in which a community of actors and institutions interact together by learning and sharing tacit skills and increasing their competence. Particularly, interactive learning as the most important production process is directed at developing new knowledge and in turn new products and processes (see Table 1.1). Accordingly, the dynamic social system of innovation, consist of increasingly complex collaborations between various stakeholders reflects the current mode of the production of scientific knowledge. Gibbons et al. (1994) mark the distinction between the traditional mode of knowledge production, termed "Mode1" and the rapidly growing new mode, termed "Model 2." While 'Mode 1' knowledge production is generally characterized as disciplinarily organized with the image of academic science, 'Mode 2' knowledge production is perceived as inter-disciplinarity and cross-organizational in open networks. The rapidly growing Mode 2 science is highly interactive and socially distributed, while scientific knowledge is produced in heterogeneous scientific institutional settings and disciplines (Hassels and Van Lente 2008).

The model of the Triple Helix networks is more institutionally defined as the network overlay of communication and expectations historically evolve and reshape the institutional arrangement among university, industry, and government agencies promoting the knowledge flows among them (Leydesdorff and Etzkowitz 1998 and Etzkowitz and Leydesdorff 2000). Triple Helix model is a complex system of innovation which "builds on the interfaces among both institutions and functions as different mechanisms of differentiation" (Leydesdorff 2005: 5). This hyper-network is generating overlapping institutional spheres where each sphere is increasingly able to take the role of the other and hybrid organizations emerge as knowledge infrastructure at the interfaces.

Especially, “universities are generating a variety of midwife institutions that link them to economic and social concerns” (Shinn 2002: 609). Along with its traditional functions of universities (e.g., teaching), universities also engage in entrepreneurial tasks by marketing knowledge and research as well as creating companies (Etzkowitz 2001; Ziman 2002; Bok 2003; Stein 2004)

Based on the systems of innovation approach, innovation is about social systems of creating and sharing knowledge based on an interactive and collective learning process within a web of personal and institutional connections which evolve over time. Innovation systems are constituted by various actors, institutions, policies and practices, and their interrelationship that form the basis for knowledge production and innovation (Nelson 1993; Lundvall 2010). The complex network of interconnected institutions fostering interactive learning constructs innovation systems within nations or regions.

Considerable attention has been paid not only to defining innovation in relationship to knowledge but also to exploring ways to compare innovation capacity of different nations or sub-national regions. In an economic system where innovation and learning is crucial for competitiveness, developing innovation capacities through knowledge creation and sharing is essential to obtain and sustain dynamic comparative advantage. Given that innovation is seen as one kind of knowledge output in the production process, innovation capacity can be defined as the ability to create new and commercially useful knowledge in effort to learn, absorb, and apply existing knowledge (Kim 1997). In this context, the present study regards innovation as an indicator measuring knowledge produced and presupposes that the disparity in the capacity to innovate leads to knowledge divides.

1.3. China's Successes and Challenges in the Knowledge Economy

Since the inception of the economic reforms and open door policy in the early 1980s, China has undergone very rapid economic growth and development. Over the past 20 years, the average annual growth rate of the gross domestic product (GDP) was around 10%, and the rise in the service sector's share in GDP made a structural shift in the Chinese economy. This has delivered higher incomes and impressive reductions in poverty levels of the country. The unprecedented economic growth has largely been driven by not only accumulation of physical and human capital but also technological progress. Recent studies have revealed that along with the GDP growth, the total factor productivity (TFP) increased, which contributed significantly to the economic growth rate in post-reform China (Li 1997; Tong 2001; Yan and Yudong 2003; Fan and Watanabe 2006).

In a last decade, the successful adoption and development of ICT in the country has transformed traditional mode of China's economy to a new knowledge-based one. China has made a shift in growth path, moving from that low-skill, labor and resource-intensive production to knowledge-intensive manufacturing and service. As a result, it has made a startling leap into the front ranks of high-tech producer as well as exporter. The share of high-tech exports in China's overall exports increased from 5% in the early 1990s to over 31.2% in 2006 (OECD 2007). In 2004, China became one of the major ICT hardware producers as well as leading exporters of ICT goods in the world, surpassing Japan, the European Union (EU), and the U.S.. The rapid growth of the ICT sector in the country has contributed to an increase of GDP three times faster over the past decade (Qiang 2007). Significant efforts made by the Chinese government to leapfrog development through targeted S&T megaprojects such as nanotechnology have resulted in remarkable high-tech growth (Appelbaum and Parker 2008).

Along with its remarkable economic progress, China's S&T capabilities have been developing. Since the mid 1980s, the Chinese government has initiated a new phase of S&T reform and policy, which reconstructed China's innovation system in the context of market-oriented economy. Various government's policy initiates have aimed at facilitating commercialization of scientific and technological research outcomes. Moreover, foreign direct investment (FDI) projects as well as imported technology goods have helped to improve China's access to advanced technology, know-how and skills over time.

The rapid evolvement of innovation performance and capacity has been reflected in the recent growth of both S&T input and output. From 1995 to 2006, China's research and development (R&D) spending increased at a stunning annual rate of almost 20%. At the same time, its R&D intensity (e.g., R&D/GDP ratio) more than doubled, which reached 1.42% in 2006 compared to only 0.6% in 1995. China has ranked second in the world after the U.S. in number of R&D personnel (OECD 2007). The increasing level of higher education and the enhanced quality of the labor force in S&T have boosted output growth.[2]

In recent years, there also has been a rapid increase of S&T output. In a global context, the number of Chinese science citation index (SCI) papers soared more than

[2] According to Freeman (2005), China has competitive a advantage in high tech by possessing many science and engineering (S&E) specialists that can possibly make a change in the "North-South" pattern of trade in which developed countries dominate high tech, while developing countries specialized in less skilled manufacturing or traditional industries.

seven fold from 1995 to 2007. In 2009, China ranked second in the world in terms of the number of SCI papers. Notable growth has been recorded in some promising scientific fields such as agricultural and life-sciences (Thomson Reuters 2009) and nanotechnology (Zhou and Leydesdorff 2006). During the same period, China's patenting activity has increased dramatically. Significant growth in the number of domestic patent applications filed has fuelled China's share of the world's patent filings (World Intellectual Property Organization (WIPO) 2008).

Despite the tremendous success, however, a number of critical issues have surfaced as challenges in order to sustain China's long-term development and social stability. One major challenge facing China is significant disparities in the development of S&T and economy among its regions. In fact, the astonishing economic growth is accompanied with a sharp increase in inequality during the post-reform period. Despite rapid economic growth in the past 20 years, "there has always been an 'East-West divide' in the level of development and standard of living" (Zhu 2006: 106). China's GDP is unevenly distributed, particularly between the wealthier eastern coastal provinces and the underdeveloped western parts of the country. Income inequality has been widening not only between eastern coastal and other inland regions but also between urban and rural areas (Zeng and Wang 2007).

The long-term trend of regional disparities, 'East-West divide' is also manifested in S&T and innovation capabilities. Eastern province and province-level municipalities are more innovative than the provinces in the central and western parts of China (OECD 2007). For example, R&D intensity is much higher in most eastern provinces than in western counterparts. As matter of fact, the regional level of innovativeness is strongly correlated with that of economic development in China (Wang and Zhang 2003).

While technological innovation and knowledge have become the driving forces for national and regional economic development, innovation capabilities to produce new knowledge have tended to concentrate into few highly innovative and developed regions, mostly consist of eastern coastal provinces (Sun 2003; Fan and Wan 2006). As a result, the increasing returns and competitiveness gains from the production of knowledge and technological innovation benefit only a few, whereas the majority are disadvantaged because of inability to access the knowledge economy. Given the situation, the knowledge divide between those regions that are able to innovate and those that are unable to innovate have been getting wider. Today, it becomes much larger than economic disparities regarding income and high education among the China's regions.

In sum, current regional patterns of innovation performance and activities raise concerns, posing a social equity issue in China. The widening knowledge gaps may reinforce an existent socio-economic inequality further in the Chinese knowledge-based society. The fast rising regional inequality is of increasing concern to the Chinese authorities which views it as a threat for the harmony of the whole society and sustainability of long-term growth. Recently, the Chinese government is well aware of these challenges and adopts the concept of the "harmonious society" in developing and implementing policies to achieve a more balanced pattern of development. Importantly, S&T and innovation are significantly related to this objective.

The Chinese government has implemented the national economic and social development plan with constant emphasis on 'indigenous innovation' and 'harmonious development,' which are key components of new development strategy. The domestic debates about whether the Chinese model of growth is sustainable have pointed to need for a shift in the growth trajectory towards innovation driven growth and learning based economic development (Gu and Lundvall 2006). In effect, the new path of growth and equity has been found at the core of the recent issues concerning China's development strategy. The crucial challenge behind the strategic plans is how to build the indigenous innovation system to work in such a way that it contributes to economic growth and balanced development. In other words, how can China promote indigenous innovation capacity along with harmonious development?

Given the context, the present study aims to explore the different levels of innovation capacity development among the most regions of China and to analyze factors leading to the disparity of regional innovative capacity. The findings of the study can contribute to an understanding of the fundamental cause of the knowledge divide between regional economies and also provide policy solutions to reduce the gaps and to facilitate balanced regional development. The analysis offered in this study, therefore, has significant social and policy implications for China, especially in terms of such current issues as indigenous innovation capacity-building and harmonious development.

Few empirical studies have addressed significant inequalities in regional innovation capacity in China. Most previous studies, however, have put simply R&D inputs or socioeconomic and institutional variables at the center of the analyses with a lack of theoretical constructs and limited data. In addition, few researchers have approached a complex and dynamic interactive learning process in the context of China's regional innovation systems using a qualitative approach.

Considering these limitations, therefore, the present study differs from the previous approach in three respects. First, unlike previous research, it explores disparities in regional innovation capacities in the angle of "knowledge divide" and interprets its contexts from the sociological and policy perspectives. Most studies in economics and sociology have tended to ignore the connection between technological innovation and its related inequality. It has been pointed out that all too often social scientists, policy-makers and the general public easily believe the myth about technology and its positive relationship to growth and development (Smith 1997; Burnett el al. 2009). Accordingly, the silence on this issue results in limited sociological studies of the social causes of the technology-based divides which is subsumed into the global inequality (Drori 2010). Second, the study builds on qualitative analysis of in-depth interviews as well as quantitative analysis with comprehensive statistical materials in order to examine and compare different degrees of regional innovation capacities in China. It also offers a set of concepts for investigating the relationship between regional innovative output (e.g., domestic patenting) and the variables associated with the regional innovative capacity and for exploring how innovation capacities are created in different regional contexts. Thus, it can provide a more comprehensive research model and analysis than most previous studies of Chinese regional innovation. Third, it considers variables ignored in previous researches and incorporates each component necessary for the research model.

1.4. Overview

The major themes are discussed in the following seven chapters. Following this introduction, the Chapter 2 introduces the theoretical backgrounds and underpinnings, and conceptual framework for the study of regional innovative capacity in China. Chapter 3 describes the research design, presenting the research model, hypotheses, and data sources. Chapter 4 examines the trends and patterns of regional disparities in S&T and innovation capabilities in China through 1998-2007. Chapter 5 summarizes the main findings of the regression analysis that explores the relationship between regional patenting activity and the variables associated with the regional innovation capacity. Chapter 6 provides a comparison of regional innovation systems of each Hubei and Fujian province by investigating the process of building up their regional innovative capacity. Chapter 7 concludes with a summary of the main findings, discussion on social and policy implications and limitations of the study, and suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

Chapter Two presents a broad conceptual and empirical framework for the understanding of the dynamic nature of regional innovation system as well as the determinant components of its capacity building in a Chinese context. Before reviewing innovation literature, a discussion of the notions of the 'new economy' and 'knowledge divide' from the learning economy perspective will be provided as a theoretical background. In a new economic context, where the touchstone of competitiveness is the ability to learn and innovate, the developmental gaps among China's regional economies would be understood in the light of a holistic and systemic approach to innovation capacity building.

2.1 The New Economy: A Learning Economy Perspective

2.1.1 The Learning Economy as Context

Many scholars argue that our contemporary world is entering a new economic era in which knowledge is a key resource of production as well as sustained economic growth. Various concepts such as 'post-industrial society' (Bell 1973), 'knowledge society' (Stehr 2002), 'informational economy' (Castells 2009), and 'learning economy' (Lundvall 2006) discuss aspects of the new economy. Despite different conceptual schemes, most concede that knowledge and technology are the essential element driving a new economy.

Bell (1973) illuminates the emergence of a ‘post-industrial society’ which is characterized by the exponential growth of knowledge. He asserts that there is a transition from industrial to post-industrial society (PIS), due to the advance of scientific and technical rationality into the economic, social, and political spheres. According to Bell, PIS is a knowledge society in a double sense: first, the sources of innovation are increasingly derivative from knowledge-demanding activity such as R&D; second, the weight of the society is increasingly in the knowledge field. He argues that theoretical knowledge as the source of innovation and of policy formulation for society is the strategic resource of PIS. Because of this, universities are central institutions in the society and the scientists and engineers become crucial groups as the expansion of R&D activities and knowledge industries require more scientific and technical personnel.

Similar to Bell, some scholars contend that knowledge is central to modern society as the foundation of its economy and of social action (Drucker 1992; Stehr 2002). From their perspective, contemporary society is a ‘knowledge society’ in which scientific and technological knowledge deeply penetrates all the aspects of life and institutions. Above all things, the emergence of the knowledge society is accompanied with a radical transformation in the structure of the economy. There is a transition from an economy based on material goods to one based on knowledge. The major ‘discontinuity’ of the closing decades of the twentieth century is associated with knowledge, which has become “the central capital, the cost center, and the crucial resource of the economy” (Drucker 1992: xxiv). The central capital as the source of economic growth and value-added activities increasingly relies more on intellectual capabilities and knowledge-based inputs than on physical inputs or natural resources. As the scientific and technical knowledge has become a productive force in the modern economy, the larger number of professions engages in working with knowledge, whereas the number of jobs that demand low cognitive skills such as manufacturing is rapidly declining.

Unlike other previous theorists, Castells (2009) characterizes the new economy in a distinctive way. From his view, innovations in the field of ICT bring a fundamental change in economic structure or the forces of production, the social structure and culture of society. The new society emerges as a result of the globalization of the new techno-economic paradigm based on the ICT. Given the context, his notion of 'informational economy' sheds light on the rise of a new globalized knowledge and network-based economy. For Castells, a new economy is specifically based on informationalism—that is, a new technological paradigm characterized by information generation, processing, and transmission that have become the fundamental sources of productivity and power. Informationalism becomes the new mode of development, in that the production process is always based on a certain level of the knowledge and the processing of information. According to Castells, information and knowledge are key resources of economic productivity. As the new economy is globally expanding, he also sees that highly intelligent and skilled workers are more in demand than non-skilled workers.

In sum, as many scholars agree, knowledge and information are now at the very core of economic welfare and development. The new global economy is characterized by the trends of 1) a growing number of highly intelligent and skilled workers engaged in the production, distribution and processing of knowledge; 2) an increasing share of codified knowledge and information in the value of many products and services; and 3) intensifying knowledge-demanding activities (Cassiolato et al. 2003). This signifies the new economy as knowledge-based or knowledge-intensive (Foray and Lundvall 1996; OECD 2004). In this context of the new economy, production and accumulation of knowledge become crucial to sustain economic growth, since the privatization, capitalization, and commoditization of knowledge have been reinforced.

However, such concepts of 'information society', 'knowledge society' and 'postindustrial society' emphasize the role of information referred to codified knowledge in the society as well as economy. The rapid development of ICT has made much information more easily produced and accessible to people. As information becomes more complex and abundant, it requires more skills in selecting, managing, and using information intelligently. Given the situation, it has been recognized that the significant parts of knowledge which take the form of practical and tacit knowledge, such as "know-how" or competences, grow in importance in all economic activities (Peters 2006). Those concepts accentuating the significance of information or codified knowledge may not be well-suited to capture and cope with new emphasis on tacit knowledge in the recent pattern of development.

Since the notions of 'knowledge-based economy' or 'information economy' imply that knowledge is already acquired and accessible to a society as a whole, it rarely discusses the process of knowledge production in terms of how to generate it. While knowledge is considered as the main production resource and outcome, the production process is often underestimated in the realm of theoretical accounts. If new knowledge is the most important product and the source of competitiveness of the economies, it would be essential to acquire the 'know-how' to get access to new knowledge and technologies. In the context of a new economy where the rapid pace of economic, social and technical changes accelerates both the creation and destruction of specialized knowledge, the process is being more important than the product—that is, the stock of specialized knowledge (Johnson and Lundvall 2003).

In this respect, some scholars propose the concept of 'learning economy', instead of 'knowledge economy', stressing the importance of learning 'know-how' and tacit knowledge as the most important production process to developed new knowledge (Field 2000; Lundvall 2006). In fact, a knowledge economy increasingly relies on new learning processes. Thus, a new global economy can be defined as a learning economy where the ability to learn—building new competencies and establishing new skills—is critical to economic success of individuals, firms, regions and national economies. Specifically, Lundvall and Johnson (1994: 26) mention that:

> We regard the contemporary first world, capitalist economies not only as knowledge-based economies but also as 'learning economies'. In a way all economies are learning economies, which results in the production and introduction of new knowledge. But in the modern learning economy, technical and organizational change has become increasingly endogenous. Learning processes have been institutionalized and feed-back loops for knowledge accumulation have been built in so that the economy as a whole, including both its production and consumption spheres, is 'learning by doing' and 'learning by using.'

The concept of 'learning economy' is based upon the hypothesis that an acceleration of knowledge creation is accompanied with the rapid pace of knowledge destruction. In a rapidly changing environment, individuals and organizations need to renew their competences and to establish new skills more often than before. Learning—building new competencies and skills—is an important activity which takes place in all parts of the economy and society as well. Thus, the key to success in a new economy is in the process of rapid learning and forgetting.

Importantly, it is pertinent to note the learning as a social process, because 'know-how' or competence can be gained in social interaction and to some extent in specialized educational environments. Given that the learning is embedded in a social context, social capital—social capability to collaborate and share knowledge and information with different kinds of people and institutions—is perceived as a crucial element of the learning economy. It facilitates coordination and cooperation between social actors for mutual benefit in the forms of networks, norms, and trust (Putnam 2000; Suh 2008). In this regard, social capital illuminates the increased importance of the 'know-who' type of knowledge in the learning economy, which accentuates social dimension of economic and technology processes. This kind of knowledge involves not only information about 'who know what' and 'who knows how to do what', but also the social ability to cooperate and communicate with various social actors (OECD 2000).

Gregersen and Johnson (1997) highlight the learning process for knowledge accumulation in the new economy. In the modern learning economies, the means of learning (e.g., schools, universities, training system, etc.) and the incentives to learn (e.g., intellectual property rights, supporting learning networks) have promoted interactive learning, and have led to the development of a learning culture or society. They argue that life-long formal education and re-training become the normal aspects of economic life in the learning society. Similarly, the concept of 'learning societies' can be explored with emphasis on the learning capabilities in gaining knowledge through education and research and to the opportunity to apply what has been learned in a creative way. This line of reasoning denotes learning societies as those ones where "a fair proportion of the population and of the social and economic organizations permanently perform knowledge-demanding activities where many social actors need to and are able to upgrade their skills systematically" (Arocena and Sutz 2003a: 308). In those societies, interactive learning spaces, in which a partnership among government, universities, and industry or other organization is often established to build learning capabilities for generating knowledge, are easily created. The learning societies tend to be easily taking place in the most developed economies today.

In short, the learning economy is based on the idea that learning and innovation is fundamentally a social and interactive process of generation, acquisition, diffusion, and sharing of specialized knowledge. In contrast to the concept of 'information economy' that accentuates the capacity to acquire and access technology and information, the 'learning economy' puts a great emphasis on the capacity to learn know-how and to innovate as being crucial to the productivity and competitiveness of economies (Borras 2002). Since tacit knowledge is considered as the key resource of production in the new economy, it has been suggested that such knowledge is only transferred with interactive learning, through social and localized processes among a variety of actors and institutions. Therefore, the learning process as the acquisition of competences and skills is the locus of learning economy that captures better the dynamics of our new economic age.

2.1.2 The North-South Knowledge Divide in the Learning Economy

The emergence of a new global economy driven by the explosion of knowledge and new technologies reproduces already extant geo-political patterns of inequality (Smith 1997; Rothboeck 2000; Chen and Wellman 2004; Warschauer 2004; Sagasti 2004; Guillen and Suarez 2005; Parayil 2005; Drori 2006; Arocena and Sutz 2010). While a few developed economies dominate the production of technological knowledge, the rest of the world is technologically backward or excluded, not being able to access and acquire that knowledge. The UNESCO World Science Declaration highlights this issue (UNESCO 1999: 2):

> Most of the benefits of science are unevenly distributed, as a result of structural asymmetries among countries, regions and social groups, and between the sexes. As scientific knowledge has become a crucial factor in the production of wealth, so its distribution has become more inequitable. What distinguishes the poor (be it people or countries) from the rich is not only that they have fewer assets, but also that they are largely excluded from the creation and benefits of scientific knowledge.

In a new global order of knowledge, there is the knowledge fracture—that is, the great divide between the rich and the poor with respect to the capacity to generate, acquire, diffuse and utilize knowledge (OECD 2004). Today, the disparities between S&T and innovation capabilities of developed and developing countries are more extreme than economic disparities. As a result, the cumulative inequality in S&T and innovation capabilities builds more barriers for marginalized countries and societies. Over the past decades, the knowledge divide has been increasingly deepening and enlarging across the world. This, in fact, has led to "'knowledge apartheid' which radically separates those societies that have an endogenous S&T base from those that do not" (Sagasti 2004: 57).

Several studies reveal the widening knowledge gaps between the North and the South (Serageldin 1998; Persaud 2001; Sachs 2003; Westholm et al. 2004). Most report that the production of the world's scientific and technological knowledge is geographically skewed. According to OECD (2008a), only three parts of the world, such as the EU, Japan and the U.S. have been the main producers of world scientific and technological knowledge. While they account for nearly all of the world patent production and scientific publications, the rest of the world are primarily using that knowledge without making any visible contributions to it. Such inequality between producers and consumers of knowledge is persistently prevalent in today's world (Parayil 2005).

Arunachalam (1999) uses the term of "knowledge imperialism" in which the existent S&T capacities between the North and the South are getting wider, because of higher levels of brain drain and dependence of less developed countries on advanced ones. He especially contends that there is a growing gap in the availability of scientists and engineers between the North and the South. In fact, developing countries lag far behind the advanced countries in terms of both quantity and quality of scientists and engineers. This consequently produces undesirable effects that made scientists in the South difficult to get accepted into the mainstream of Western science.

Salam demonstrates the widening gap in S&T between the North and the South, pointing out that in fact, "creation, mastery, and utilization of modern science and technology are basically what distinguish the South from the North" (Salam 1988: 19). The widening knowledge gaps are reflected in the differences in national expenditures on S&T between two regions. For example, the Northern countries invest S&T, on average, nine times more than the Southern counterparts. He suggests that three factors, namely, a lack of commitment to S&T in a society, inadequate institutional and legal framework, and a shortage of scientific entrepreneurs in the knowledge industry may explain why S&T lagged behind in the underdeveloped world.

According to Sagasti (2004), key factors determining a nation or society's position relative to the knowledge divide are its scientific and technological capabilities not only to access knowledge and information, but also to generate, diffuse, and utilize it. In his study, the uneven distribution of scientific publications and registered patents shows an extreme degree of inequality in S&T and innovation capabilities between the North and the South. Disparity in access to the ICT, such as telephone, computers, and Internet are also very large, which results in the widening knowledge divide between those two countries. He argues that developing endogenous scientific and technological capabilities as well as the ICT infrastructure are very crucial for developing countries to accelerate their technological and economic catch-up with advanced one.

While there is a great disparity in the level of S&T and innovation development between the North and the South, the important issues for the developing countries in the South are: 1) what the fundamental source of knowledge divide is and 2) how to build endogenous innovation capabilities to bridge the gap with advanced economies in the North. According to Arocena and Sutz (2003b), knowledge gap is a main consequence of 'learning divide', in the sense that weaknesses in the formal and informal learning processes often lead to the low level of innovative capability. They argue that the North-South division in the new economy is increasingly associated with different social capabilities to participate in knowledge-demanding activities, that is, "learning divide".

In other words, the divide between the northern and southern regions or countries is linked to learning, "which is bounded to having opportunities to learn, which are related with access to education and also with possibilities to apply knowledge creatively while interacting in problem solving activities" (Arocena and Sutz 2000: 1). Developed countries generally show high educational averages and are rich in interactive learning spaces where different social actors enhance their capabilities to learn and innovate. By contrast, developing countries have fewer interactive learning places with a lower share of highly educated population. They, thus, generate de-learning trends that a less proportion of population and of the social and economic institutions engage in knowledge-demanding activities.

Arocena and Senker's study (2003) illustrates significant learning gaps between the North and Latin American South. In contrast to developed countries in the North, most Latin American countries suffer from a shortage of human resources in S&T, because of a lack of access to advanced training and to formal education at tertiary levels. They suggest that the pervasive economic inequality and lack of access to adequate education and training in those countries contribute to increase the knowledge gap with the North. Compared to the developed economies which are solidly based on S&T, innovation, and advanced education, most Latin American countries are unable to use and produce knowledge as a fundamental tool for sustained development. As a result, they not only have less opportunity to access to new high-skilled jobs created by new technologies, but also been excluded from global technology generation.

Weingart (2006) attributes a growing knowledge inequality between the developed and developing countries to the gap in the ability to acquire, apply, and produce knowledge. He asserts that education and training and technological learning are the most crucial condition for the acquisition and use of knowledge. His study describes that the literacy rate, educational enrollment, public expenditure on education, public expenditure on R&D and scientists and engineers in R&D are the basis of participation in the production of knowledge. Thus, the uneven distribution of those capacities widens an existent North-South division further.

To sum up, in the context of the new economy, the knowledge divide may result from the learning or competence-building for innovation in that "people with different backgrounds and capabilities learn a technological application" (Pant 2009: 10). Permanent de-learning trend and accumulate de-learning process in the South may put more difficulties for less developed countries to participate in the production of new knowledge and innovation. As the building of competence yields increased economic returns, the uneven distribution of competence-building between and within countries, in turn, causes the inequality in ways that reinforce the processes of wealth and income concentration in the North (Cozzens and Kaplinsky 2009). Eventually, this leads to further marginalization of the Southern nations or regions in the new economy.

As an underlying cause of knowledge divide, the capacity of learning and innovation through sharing knowledge are now crucial to bridge the knowledge gap that exists between the North and the South. Knowledge divide is not just merely technology gaps as differences in access and use of new technologies, but "differences in capabilities and in learning, something even more difficult to bridge" (Arocena and Sutz 2000: 6). In the era of globalization, ICT and the Internet have been identified as a primary means of achieving socio-economic development by alleviating poverty, reducing inequalities, and ensure social inclusion throughout the world (Webb 2006; World Bank 2006; Papaioannou and Dimelis 2007; Tiwari 2008; Hanna 2010). As ICT becomes crucial in the development agenda, the issue of development gaps between the North and the South has been discussed in relation to the access to ICT, particularly regarding the "digital divide."[3] However, although ICTs have been conceived as development mechanisms, placing the emphasis on them reflects the simplistic view of technological determinism that may mislead the understanding of the fundamental causes of underdevelopment. Rather, the emergence of knowledge and skills as the core of the new economy implies that the development divides are deeply rooted in learning gaps related to the acquisition of knowledge and competence through education and research. In the sense that the increasing diffusion of ICT stimulates learning processes between social actors, "digital divide is an important but comparatively small component of the learning divide" (Arocena and Sutz 2003b: 310). Therefore, in order to narrow the knowledge divide, it requires not only universal access to information and technologies, but, most important, the capacity to learn, absorb and generate new knowledge and innovation.

2.2 System of Innovation Approach

[3] There is no single definition of 'digital divide', but it generally refers to the gap between those who can effectively access and use ICTs such as the Internet and mobile phones and those who can not. According to the OECD's definition (2001: 5), the digital divide is "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities." Subsequently, other scholars view the digital divide in a more complicated way. For example, not only the lack of materials (e.g., computer and Internet connection) and digital skills but also insufficient digital experience due to computer anxiety, indifference and unattractiveness of the new technology as well as inadequate usage opportunities can be the factors, causing the digital divide (Dijk 2005).

The system of innovation (SI) approach is a useful analytical tool for learning and innovation gaps between the 'core' and the 'periphery' or the 'North' and the 'South' (Cassiolato et al. 2003). By focusing on economic development, studies of innovation system raise the inequality issues regarding the uneven distribution of knowledge and innovation in nations, regions, and sectors (Chang and Chen 2004). The SI approach helps us to understand the knowledge and innovation distances between nations or sub-national regions as well as the way to reduce them, highlighting a broad set of institutions and their pattern of innovation activities and interactive learning.

The basic concept of the SI derives from the study of national innovation system (NIS) (Nelson 1993; Patel and Pavitt 1994; Edquist 1997). Freeman (1987: 1) firstly introduces the concept of the NIS in his study of Japanese economic performance, defining it as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies." Subsequently, many NIS researches illuminate the diversity in national approaches to innovation, focused on social interaction and learning processes between various innovation actors. They address that the pace and pattern of technological progress and accumulation vary across countries according to the nature of innovation system in the particular country. The contribution of the NIS studies is to deviate from the simplistic accounts of linear approach to technological progress and to provide a more complex and systemic approach that technological progress occurs through feedback loops within the system composed of networks of the institutions.

The SI approach has the basic underlying propositions, developed from the NIS framework. First, building sustainable system of innovation serves as the basis for development strategies not only in advanced economies but also in emerging economies that hope to foster technological and economic catching-up processes. Second, "innovation and technical progress are the result of a complex set of relationship among actors producing, distributing and applying various kinds of knowledge" (OECD 1997: 9). Innovation is embedded in social relationships, largely depending on how various actors function and interact with each other to create new knowledge. Based on this framework, innovation activities are explored and conceptualized at various levels, including global, national and sub-national (or regional and local), sectoral, and technological dimensions.

The SI approach has been widely used as a tool for enhancing national and regional competitiveness by activating a learning interaction among major innovation actors. On the other hand, it has faced the criticisms with regard to the absence of theoretical formalization and its applicability for developing and emerging economies. The SI approach is generally not regarded as a formal theory but an analytical tool and a guide for policy-making (Edquist 2005). Despite its vague concept and difficult measurement, however, it has been favored by many scholars due to a flexible and useful framework for analyzing innovation dynamics (Cassiolato et al. 2003) as well as for reconsidering the problems of development (Arocena and Sutz 2005).

Since the SI framework was constructed based on experiences of developed economies, there has been some skepticism about its applicability to developing countries. Viotti (2002) specifically criticizes that the concept of innovation system is not applicable to developing economies, because the process of technical change in those countries often occurs outside the realm of main innovative actors such as firms which are at the core of innovation system in most cases. However, innovation systems can also be developed in small countries without the presence of the leading firms which introduce innovation that are new to the world. Rather, those small countries can prosper because of a high level of the capacities to absorb and utilize new technologies in developing unique new innovations (Freeman and Lundvall 1988; Fagerberg et al. 2008).

Arocena and Sutz (2005: 1) propose the concept of innovation system as "a tool for studying the concrete aspects of innovation activities in underdeveloped countries, thus contributing to a revitalization of development thinking". They suggest that the SI approach can be taken from the perspective of underdevelopment as an "ex-ante" concept for the cases of developing countries. The innovation system framework provides not only an understanding of the roots and primary causes of the knowledge divide between the advanced and developing nations or regions, but also the policies and institutions capable of bridging the gaps. In this sense, the SI approach suggests the development strategy, especially to policy-makers in developing countries by identifying the missing linkages and interactions which do not occur for different reasons thereby reducing the innovation performance of economy.

2.2.1 The Concept of Regional Innovation System

The concept of regional innovation system (RIS) has been gaining a considerable attention as an analytical framework for the understanding of the localized processes of innovation and learning (Asheim and Gertler 2004). Today, the region has been recognized as the important locus of innovation, in that regional scale and resources stimulate the innovation capabilities and competitiveness of firm and regions (Cooke

2001; Asheim et al. 2007). According to Porter (2008), the enduring competitive advantage in a global economy is often extremely local, arising from a concentration of highly specialized skills and knowledge, institutions, related business and customers in a particular region. The increased focus on regions as the best geographical scale for an innovation-driven learning economy is premised on innovation as being a socially and territorially-embedded process.

In order to stress the importance of regional innovative activities, the RIS approach is evolved in the concept of the NIS. As analogous to the NIS, a RIS is understood as a complex of institutions in a specific region involved in the generation, diffusion, and utilization of knowledge (Chung 2002). The ideas of the RIS basically lies in the premises as follows: 1) innovation is locally embedded as created and sustained through a localized process and 2) it is a social process characterized by the interactive learning between local firms and other knowledge producing organizations, such as universities, R&D institutes, training organization and so on.

A growing literature on RIS confirms the fact that innovation is fundamentally an interactive and geographical process. According to scholars in the RIS tradition, geographical concentration and proximity facilitate the localized interactive learning and the emergence of the innovation system at regional level (Gertler et al. 2000). In the regional context, the common regional cultures, such as the set of rules, shared values, norms and trust, promote localized interactions and communications in exchanging information and knowledge. In this case, regional cluster, a group of firms in close geographical proximity, takes a crucial dimension of regional innovation systems (Doloreux and Parto 2004). Clusters have in common specialization, proximity and cooperation that easily foster knowledge spillovers and knowledge transfer between local institutions. Porter (1998a and 1998b) asserts that innovation clusters—geographic concentrations of interconnected firms and institutions in a particular field—lead to technological advances and competitive improvements, since clustered firms and knowledge institutions build the complementary relationships involved in innovating. Such concepts as 'learning region' (Morgan 1997), 'innovative milieu' (Crevoisier 2001), 'industrial cluster' (Porter 1998b) or 'industrial districts' (Enright 2001) have been introduced to understand the localized learning through interaction in innovation process and knowledge accumulation as a source of regional development.

Beside the importance of systemic relations in the course of learning and innovation, the RIS approach also emphasizes territorially-embedded factors leading to differences of regional innovation capacities. Regional innovation capacities may depend mainly on social-cultural and institutional context-specific conditions, but it can be also augmented by localized strengths such as specialized labor markets and resources, availability of human resources, established physical and knowledge infrastructure, private and public R&D capacities, and so on (Gregersen and Johnson 1997).

Most RIS literature highlights that innovative capacities are not evenly distributed geographically but also knowledge itself tends to localize spatially. Because of different economic, social, political, and geographical context of regions, the RISs have different levels of organizational and infrastructural capacity and competence in related to innovation (Christopherson and Clark 2007). For this reason, "RISs have evolved through different trajectories and developments" (Doloreux 2004: 483). Although many

RISs have common features, they also have distinctive characteristics in the different regions.

Several authors distinguish between different types of RIS (Cooke et al. 2000; Asheim and Isaksen 2002). According to Asheim (2007), there are three types of RISs: 1) territorially embedded RIS; 2) regionally networked innovation system; and 3) the regionalized NIS. The first type of RISs referred to territorially embedded RIS places emphasis on localized inter-firm learning process in close geographical proximity, such as industrial districts and regional clusters. Second type is the regionally networked innovation system where firms and knowledge producing organizations (e.g., R&D institutes and universities) are embedded in a specific region and characterized by localized interactive learning. As an extension of the first type of RISs, the second one stresses the networked relations, which is better planed and more systemic than the first type. The last type of RISs is the regionally NIS where innovation actively occurs in cooperation with exogenous actors outside the region through such cross inter-regional or international interaction.

Among three types of RISs, the regionally networked innovation system is the most ideal-type of RISs, since it facilitates localized interactive learning and innovation of knowledge. In the networked system, a local supporting institutional infrastructure (e.g., R&D institutes, universities, and vocational training organizations, etc.) participates in firms' innovation processes. Cooke (1998) also identifies this type of RIS, which consists of two sub-systems of actors who are systematically involved in innovation processes: the firms as regional productive structure and the regional institutional infrastructure, including public and private laboratories, and other local organizations.

The ‘networked RIS’ is created through the dynamic process of cross-organizational interaction that helps not only to enhance regional innovation capacity, but also to strengthen collective learning. From this standpoint, the sufficient social capital based on cooperation, trust, and network is essential to sustain the competitive advantage of regional economies (Chen 2009).

In short, the RIS approach has been known as a useful tool to explore regional innovation capabilities, identifying main factors leading to sustenance and emergence of the RIS. Especially, it focuses the social and institutional dynamics supporting regional innovation activity and the complex web of various types of interactions among different actors and factors inside the region. Additionally, it accounts for disparities in innovation capacities and competitiveness of regions, capturing the different structural elements of RISs and the different degree of interactions among them. According to Chung (2002), the concept of RIS is very effective not only for building an competent NIS, but also for preventing the problem of unfair regional concentration of technological and economic capabilities that block the sustainable development of national economy as a whole. The RIS research has a great deal to contribute to reduce inequalities between sub-national regions with the concepts of economic development (Cozzens (forthcoming)).

In the context of developing economies, however, RISs should be understood conceptually as ex-ante constructions of RISs (Perez et al. 2009). Unlike well-functioning RISs such as found in the developed countries, the counterpart of developing countries are relatively either immature or newly emerging. Most systems of innovation in developing countries rarely show a high degree of integration and interaction, thus failing to perform on the same level as developed and mature RISs. The vast majority of firms and other organizations lack the indigenous capabilities to engage in interactive learning and innovation (Chaminade and Vang 2008). In this regard, the RIS approach may provides the new ways to cope with innovation problems such as building an efficient innovation system in underdevelopment contexts, stressing the missing linkages, synergies or innovative circuits between the parts which form the system as a whole.

2.2.2 The China's System of Innovation in Transition

China's innovation system started with the Soviet model in 1950s, establishing specialized universities and a large network of government research institutions (GRIs) whose activities and interactions were controlled by a central government (Liu and White 2001a). At the very beginning, S&T resources were greatly employed to produce military technologies, such as atomic and hydrogen bombs, satellites, and ballistic missiles. In the period of the planned economy (1949-80), S&T system did not contribute to economic growth, because it was disconnected to industrial activities. Most of all, GRIs played a dominant role in performing R&D and assimilating the imported technologies and few large research universities, such as Beijing and Tsinghua, played a complementary role for the GRIs. The state-owned enterprises (SOEs), the form of enterprise in the country, had extremely weak capabilities to carry out R&D and innovation activities. The role of SOEs in the innovation system was limited as they functioned as manufacturing units with few, if any, formal R&D centers (Liu 2009). Given the situation, there was hardly any interaction and linkage between public sectors (e.g., GRIs and universities) and industries. This resulted in increasing foreign technology dependency of the Chinese enterprises that cost more money than their own R&D during the planning regime.

Overall, the planned innovation system as a whole was less than efficient. Public sector had any incentive and demand from the private sector for technological innovation, since SOEs heavily relied on GRIs' technologies and did not pursue their own S&T activities. Moreover, because most of enterprises are output-oriented, the quality of research outputs or inputs was rarely considered. This is due to the absence of market incentives, so there was no motivation for main S&T actors to produce, adopt or diffuse technology proactively and to initiate linkages with each other. Intellectual property rights (IPRs) was also hardly established so as to promote incentives for encouraging innovation activities.

In the rigid structure of planned economy, the centralized system for allocating research resources provided a limited scope and range of research activities. Huang et al. (2006) describe that government controlled all S&T funding allocation for the researches and restricted experiment and development carried out in enterprises. For example, R&D funding was often distributed by government on the basis of institution's personnel scale. In this regard, the central planned S&T system failed not only to efficiently use research resources—both human and physical—to foster innovation, but also to win the competition with the market economy system.

In 1985, China reformed the economy and old S&T system with implementing the "Open Door Policy". With a market-oriented economic reform, the Chinese government attempted to transform the rigid, inefficient and centralized S&T system toward a highly dynamic, interactive and efficient system as those in the advanced countries. According to Liu (2009), the main goals of the S&T reform were two-fold: 1) to initiate a competition-based funding system; and 2) to establish a new and flexible governance system of S&T institutions in order to commercially use R&D results in a more efficient way. Strengthening R&D and developing the country's S&T capacity, the government endeavored to decentralize fiscal and managerial control, redefined public and private ownership, and promoted new linkage between the public and private sectors. The S&T reform, including a series of S&T policy initiatives has largely influenced the structure, dynamics and performance of China's innovation system.

Several authors witness that China's innovation system is undergoing transition from the centrally planned system to a market-driven open system. Huang et al. (2006) argue that the reform since 1985 is a decisive factor in transforming China's innovation system. In order to enhance scientific productivity (e.g., scientific publication) and strengthen the private-public linkages, numerous S&T policies targeted on reforming on the R&D funding system, improving R&D management and fostering industry-academy relationships. One of notable changes in the reform period was that government alleviated direct funding and subsidy for GRIs and attempted to diversify the source of S&T funding for them (Gu and Lundvall 2006; Liu and Lundin 2009). The Chinese government's intentions behind this change were to strengthen incentives for innovation as well as to promote commercialization of researches findings. This imposed increased pressure on scientists to engage in more commercial activities, pursing relatively short-term research projects with more immediate and higher economic returns.

By the same token, the reform of reducing the subsidies for GRIs created many spin-off enterprises from existing R&D institutes and universities. In order to accelerate commercialization of research production, a spin-off policy in 1980s encouraged universities and GRIs to be more entrepreneurial in the high-tech industry. The government allowed GRIs and universities to set up their own spin-offs, so that they could sell their technology and research results. Spin-off companies provided GRIs and universities with alternative sources of funds, which could compensate for budget-cut from government. They also granted many opportunities to scientists from GRIs and universities to access new technology market. The spin-off enterprises, therefore, become the unique feature of the Chinese innovation system after the reform (Chen and Kenney 2007).

During the reform period, however, the Chinese government initiated a series of S&T policies to promote innovation. Large-scale national research programs for technological progress such as the 863 programs and Torch program of 1980s contributed to build a well-functioning infrastructure to serve as a platform for innovation activities and interactions between industry and science sectors. Chinese government especially made an effort to strengthen the industry-science linkages by not only encouraging spin-off firms but also building new high-tech zones in close proximity to universities and GRIs. Universities have appeared as the main collaborative objects for enterprises to carry out joint research activities, due to the majority of research resources and highly qualified human resources (Chang and Shih 2004; Xue 2006). In this context, university-based science parks were established as an important incubator for university-owned spin-offs. Most of high-tech firms and incubators have been developed in the high-tech zones and university-based science park during the reform period. Although some point out that rapid expansion of the technology zones does not represent the general notion of high-technology (e.g., Cao 2004), it has played an important role in not only developing the high-tech industry but strengthening linkages between industry-science sectors.

In the transitional context, economic and enterprise reform has had a clear impact on the structure and dynamics of the innovation system under central planning. Particularly, the institutions have undergone a dramatic change during the reform due to "the decentralization of decision making over both resource allocation within economy and operational decision within institutions" (Liu and White 2001a: 1099). The government's strategies to increase the R&D activity and human resource in S&T and to foster the private-public linkage, and emergence of end-users also evolved the China's innovation system. As a result of reforms, the innovation system has become much more efficient and effective than that under the central planning system. Conversely, it also exposes several problems that weaken its performance. For instance, inadequate incentives affecting firms' innovative behavior, incomplete legal environments and large regional discrepancies in terms of innovative activities are important weaknesses of China's innovation system in transition.

Gu and Lundvall (2006) explore the transformation of the China's innovation system in the context of market-oriented economic reform. According to them, a two-pronged policy was especially designed to develop the S&T system during the reform period: 1) establishment of technology markets and 2) excellence-based allocation mechanisms of public R&D funds. The new specialized market was constructed by the central government to facilitate technology transaction between producers and users of technology. In order to activate technology market, public R&D institutes are given greater degree of autonomy, such as hiring personnel, selling research outputs, engaging in joint projects and acceptance of contractual fee, to respond to the demand from technology market. The transformation of the innovation system after reform was constructive in rebuilding the innovation system. However, a weak absorptive capacity and a lack of social capital and technological infrastructure in the innovation process remain the problem to move toward more sophisticated innovation system.

The reform of China's S&T system, therefore, has brought positive changes in the rigid, segmented, and inefficient plan-oriented S&T system. The S&T reforms of the past two decades have substantially upgraded and improved China's S&T capabilities especially in a few fields, such as ICT, bio-and nanotechnology. However, despite some success, China's innovation capacity is still quite low (Jakobson 2007; Liu and Lundin 2009). The part of the reasons is that the economic growth of China has been highly dependent on foreign technology and investment. There is little doubt that FDI has played a significant role in China's economic take-off. In the early stage of China's opening up, the majority of FDI originated from Hong Kong and Taiwan. Since the early 1990s, however, a growing portion of FDI inflow has come from other sources. The top investors of FDI have been Hong Kong, Taiwan, Japan, Singapore, the U.S., South Korea, UK, Germany and Canada[4] (US-China Business Council (USCBC) 2010). A

[4] Hong Kong is now a largely self-governing "special autonomous region" of the People's Republic of China (PRC) and continues to be China's greatest source of foreign capital. In reality, however, Hong Kong-source FDI in China is mostly investment by domestic Chinese located in Hong Kong to receive incentives available only to foreign investors (Graham and Wada 2002). It is unknown how much of investment money was channeled through Hong Kong by foreigners. Thus, it is more like a "round-trip" investment in ways that domestic funds funneled out of China that return disguised as FDI. According to USCBC (2010), the U.S. and Japan are next big investors followed by Hong Kong, contributing 9% of the FDI in China between 1990 and 2004. During the same period, the East-Asian countries (e.g., Singapore, South Korea, and Taiwan)

rising share of FDI inflow from Europe, North America, and Japan has triggered the investment of multinational corporations on a large scale.

The role of FDI becomes even more important as foreign firms have served as a major channel of advanced technology in China. They account for a higher proportion of domestic invention patents granted and applications as well as high-tech exports. In contrast to the general expectation that the technologies and know-how from foreign firms have greatly contributed to the local economy, however, many studies reveal that the degree of technological transfer is very limited in that foreign companies have neither established relationship with local firms nor performed little technological innovation in China (Lemonine and Unal-Kesenci 2004; Kong 2005; Wang 2006).

Another drawback is a relatively weak innovation capability of the domestic firms in China. Innovation capabilities of the Chinese firms are mostly based on incremental innovation with little radical innovation. Most of Chinese firms are largely concentrated on product development and design through copying and imitation with little emphasis on hard-core research (Jakobson 2007). Although R&D spending by Chinese enterprises has risen sharply over the past decade, their R&D capabilities are still weak, especially in terms of R&D output and its quality. In effect, GRIs and universities have played more favorable role in innovation activities in China (Lu and Etzkowitz 2008). In pursuing quick and short-term paying offs, Chinese firms mainly depend on imported technology and equipment rather than domestic sources. This reflects the fact that firms have a lack of interest in engaging in an interactive learning with domestic research institutions for their R&D efforts. The separation of innovation and economy and organization rigidity

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contributed between 5 and 7 percent, whereas the European counterparts (e.g., UK, Germany, and France) contributed only between 1 and 2 percent.

between industry and science sectors, thus, remain deep-rooted problems of China's innovation system (Cao et al. 2009). From this standpoint, Chinese innovation system is still in transition to the enterprise-centered system.

China's lack of S&T talent has been recently addressed as a critical challenge to sustain domestic economic growth and advance the level of domestic innovation capabilities. Simon and Cao's study (2009) argues that a serious 'brain drain' of Chinese best talent to foreign countries and foreign-invested enterprises in China has led to the substantial shortage of local S&T talent. In the U.S., for example, the vast majority of the foreign S&E doctorate recipients have their origins in China (Pearson 2008). Many of Chinese students prefer to stay in the U.S. upon receipt of their doctorates, especially for their employment or postdoctoral research and training (Nation Science Foundation (NSF) 2010). This trend has restricted domestic access to higher-quality human resources, which turn into China's innovation bottlenecks. Although China's current S&T talent pool is outstanding in terms of its quantity, the quality issue keeps raising with regard to the domestic S&T graduates.

To sum up, while China has made tremendous progress in rebuilding its S&T capabilities during post-reform period, the country has faced several challenges for moving toward more competitive and indigenous innovation system. The overall challenges now include a low level of innovative capabilities of the private sector, inadequate IPR protection, a shortage of skilled workers in S&T, a regional discrepancy in innovative activities, and a weak linkage between innovative actors.

Under the circumstances, in early 2006, Chinese government has implemented the 'Medium-and Long-term Plans for S&T Development 2006-2020' as a long term S&T

policy framework. The main objectives of the new plan are to make China an innovation-driven country by enhancing indigenous innovation capability, leapfrogging in key scientific and technological fields, and utilizing S&T as an engine of future economic growth (Cao et al. 2006). The 15-year S&T plans mainly focus on strengthening China's independent and indigenous innovation in order to reduce its reliance on foreign technology and, at the same time, to increase both absorptive and innovation capabilities of domestic firms with the establishment of a strong IPR regime. Thus, the concept of 'indigenous innovation' introduced in the current S&T policy represents the Chinese government's efforts to overcome the challenges in building their own innovation capabilities.

2.2.3 The Features of the Regional Innovation System of China

As China's S&T system has been transformed after the reform, RISs also have distinctive features in transition. First, during the past decade, there has been rapid increase in R&D and innovation activity in most of China's regions. For example, in terms of the patent activity, the number of invention patent granted to institutions increased more than 10 times from 1998 and 2007 (National Bureau of Statistics (NBS) 2008). Both financial and human resources devoted to R&D activities have been largely increased across the country: for example, total R&D expenditure (e.g., the R&D/GDP ratio) and total number of R&D personnel more than doubled during the same period.

Second, many institutions engaged in innovation activities among the regions during the transition period. In general, the primary innovation actor groups in the Chinese innovation system are firms, universities and GRIs, since they are all major

R&D performers. As discussed earlier, firms have not played a major role in innovative activities in most Chinese regions, since universities and GRIs have been dominant innovators as well as R&D performers (Guan and Liu 2005; Li 2009). During the last decade, however, firms have emerged as the largest R&D performer in the country (OECD 2009b). Although the innovation capacity and efficiency of the private sector is still insufficient, compared to the developed economies, a large increase in R&D expenditure with the industry's self-funding may imply that firms may become the locus of China's innovation. Since 2000, a number of invention patents granted to firms have been increasingly expanding, even surpassing that of universities and research institutes. In this respect, it can be argued that Chinese firms have gradually improved their innovation capabilities over time.

The most prominent feature of China's regional innovation system is increasing variations in regional innovation capacity (Liu and White 2001b; Li 2009). Innovation activity, highly correlated with economic development, has been very uneven across regions. While China's innovation system has gradually evolved since the reform of 1980s, the disparity of innovative capacities and resources between regions becomes widening. Many scholars reveal that the post-reform has widened the technology and economy gap between the coastal and interior regions of China (Yang 1990; Lyons 1991; Tsui 1993; Fan 1995; Jian et al. 1996; Long 1999; Tian 1999; Lee 2000; Fujita and Hu 2001; Lu and Wang 2002; Shan 2002; Zhang and Zhang 2003; Lu and Song 2004; Liu and Li 2006; Chen and Zheng 2008; Kanbur and Zhang 2009).

According to Song et al (2000: 254), "regional disparities are caused not only by historical and geographical factors but also by regional development policies of the government." Historically, East China has been more developed than inland regions with a better infrastructure and resources. It also has benefited from the geographical location, having a relatively easy accessibility to both domestic and international markets. In contrast, inferior ecological conditions, labor shortages, infrastructure, and remote geographical location of the inland regions become the major bottlenecks for economic development (Chen and Fleisher 1996; Hare and West 1999; Bao et al. 2002; Demurger et al. 2004).

Focused on the fast pace of economic growth, the new development strategy of the post-reform have heavily favored the coastal regions. Due to the readily accessible geographic location, the central government has further encouraged the economic development and fostered technological innovation in coastal provinces and open zones through foreign investment and international trade, resource allocation, taxation, fiscal transfer, and public investment (Fan 1997; Wei and Fan 2000; Lu and Song 2004; Kanbur and Zhang 2009). At the same time, decentralization of central control and significant roles of the state during the post-reform period are also proposed as the driving forces underlying China's regional inequality (Lin 1999; Wei 2000; Hao and Wei 2010). In addition, industrialization and economic agglomerations in coastal regions are identified as another source of increasing the region gaps (Yao and Zhang 2001; Huang et al. 2003; Okamoto 2005).

Accordingly, productive resources, such as S&T, domestic bank loans, and foreign investment, have become more concentrated in only a few regions in post-reform China. As a result, the provinces and municipalities on the East coastal region are more innovative than the central and western part of China. While the east coastal regions has benefited most from the economic reforms, the central and western regions have lagged far behind in growth of both innovative inputs (e.g., R&D personnel, R&D spending, infrastructures, and so on) and outputs (e.g., scientific publication and patents). The imbalance of S&T infrastructure and innovation capacity across different geographic locations and regions are a critical challenge for China today in becoming innovation-driven economy.

2.3 The Determinants of Regional Innovation Capacity

2.3.1 The Conceptual Framework of Regional Innovative Capacity

The system of innovation literature has shown that different innovation systems have different capabilities to innovate. While there has been much attention paid to identify sources of these differences, Furman et al. (2002) develop a conceptual framework of the national innovative capacity (NIC) by integrating three perspectives regarding the sources of innovation: 1) the ideas-driven growth theory (Romer 1990; Jones 1995 and 2002); 2) the theory of industrial competitive advantage (Porter 1998a and 2008); and 3) the innovation system approach (Nelson 1993; Edquist 2005; Lundvall 2010). According to them, the capacity to innovate is defined as an economy's ability or potential, at a given point in time, to sustain innovation by producing and commercializing a flow of innovative technology. In other words, "the capacity to innovate is not concerned with any single aspect of innovation performance, but with the sources of its sustainability" (Hu and Mathews 2005: 1328). Within this scheme, innovation capacity depends basically on an interrelated set of investments, labor forces, policy choices, resource commitments, and behaviors of government and the private sector that determine the extent and success of innovation effort over the long term.

Furman et al. (2002) employ the NIC framework to empirically investigate the factors of cross-country differences in the production of innovative output—patenting rates. In effect, their framework has guided researchers to identify the factors determining the innovative capacity at both national and sub-national levels. Although it is originally formulated based on the case of the 17 OECD countries, a few studies also demonstrate that it works in the context of emerging economies such as China, as well (Furman and Hayes 2004; Hu and Mathews 2008).

The Furman et al.'s framework of innovation capacity was primarily built for application at the national level, while several authors propose that it can also be applicable to evaluate innovative capacity at the regional level (Guan and Liu 2005; Hu and Mathews 2005; Li 2009). Given that innovation systems have a regional dimension, the innovation capacity as well as intensity varies across sub-national regions like states or provinces (Gertler and Wolfe 1998; Capron and Cincera 1999; Evangelista et al. 2001). In this sense, Li (2006: 172) addresses that "it would be reasonable to argue that the concept of NIC can be extended to regional innovation system."

Accordingly, a conceptual framework of the determinants of regional innovative capacity (RIC) can be formulated based on three main sets of ideas. First, ideas-driven growth theory or the notion of a knowledge production function assumes that the knowledge sector in the economy generates and promotes the new flow of knowledge that contributes to economic growth (Jones 1995). In general, the innovation studies have accentuated endogenous growth dynamics, focused on the indigenous capacity-building. The role of technological progress in economic growth has been appreciated since the Solow's seminal work (1956) but it was only in the late 1980s that technological change was recognized as endogenous. The Romer (1990) articulates and develops the model of endogenous growth by introducing the R&D-based growth model, in which economic growth results directly from physical and human capital investment in R&D sector, generating new knowledge. The knowledge production function is centered on R&D-based growth models, describing the evolution of knowledge creation as the primary determinant of a long-run economic growth. The underlying assumption is that the creation of new knowledge is a function of the cumulative stock of knowledge (e.g., previously generated ideas) as well as the size the available pool of scientists and engineers who can contribute to the production of new knowledge and products. Therefore, the rate of new knowledge production depends on the overall level of human and capital resources devoted to R&D activities and the existing stock of knowledge. Such innovative inputs—R&D scientists and engineers, the stock of knowledge available to R&D researchers, and the R&D investments—would determine the RIC in generating new technology and knowledge, which in turn provide sources for regional development.

Furman et al. (2002) expand the conception of the knowledge production function by adding other factors that impact innovative activity—public investments and policies on innovation. As a part of the innovation infrastructure, the policy choices and investments of regional government, including patent and copyright laws, the extent of R&D tax credits, investment in higher education and S&T, the rate of taxation of capital gains, and openness of the economy to international competition, have a cross-cutting impact on innovation across the regional economies.

According to Porter's notion (1998a; 1998b; 2008) of industrial competitive advantage, the particular innovation environment in the regional industrial clusters, where firms invest and compete on the basis of innovation, has an impact on innovation efficiency and R&D productivity. In effect, he stresses the role of enterprises in introducing and commercializing innovations. Innovation and the commercialization of new technologies often occur in cluster—geographic concentrations of interconnected companies, specialized suppliers, service providers, and associated institutions in a particular field that are present in a region. The presence of a cluster offers potential advantages to firms in perceiving both the need and the opportunity for innovation. Reinforcing the advantages of clusters for innovation depends on the competitive milieu that is inherent within a concentrated group of firms in the same field. In other words, the competitiveness of a region is based on the competitiveness of the industries, which is improved if an industry is embedded in regional clusters.

A variety of cluster-specific circumstances, investments, and policies, therefore, develop and commercialize innovation that determines the competitiveness of a region. For Porter, innovation and commercialization of new knowledge take place unevenly in clusters, so the disparity in the RIC reflects different regional environment for innovation. Especially, he emphasizes four key elements of the particular environment for innovation in his diamond framework, which affect the rate of innovation in a cluster as well as its overall competitiveness: 1) the presence of high-quality and specialized input (e.g., workforce, education, knowledge, capital, physical infrastructure, etc); 2) a local context that encourages investment and intense local rivalry; 3) pressure and insight gleaned from sophisticated local demand (e.g., a core group of demanding local customers); and 4) the presence of a cluster of related and supporting industries (e.g., a critical mass of capable local suppliers). Hence, RIC depends upon the extent to which regional industrial clusters support and compete on the basis of technological innovation.

Finally, the SI approach describes the institutions and the patterns of its activity that contribute to innovative activity. The key idea of innovation system approach is the interaction of disparate institutions, such as firms, public research institutes, and universities, and government policies in a systematic way to build the innovative capacity. According to RIS literature, social cooperation between various institutions is an essential element to produce technological innovation in the region. The RIC, therefore, is not only determined by inputs on innovation, but to a great extent by interaction among various social actors involved in innovation process.

Drawing upon three theoretical perspectives, the conceptual framework of the RIC can be formulated, incorporating a wide set of the social, economic, political, and institutional influences of region in explaining cross-regional differences in the intensity of innovation. The framework mainly organizes the determinants of RIC into tree elements: 1) resource commitments and policies that support innovation referred to as the common innovation infrastructure; 2) the particular innovation environment for innovation; and 3) the strength of the linkages between innovation actors.

2.3.2 Empirical Studies of China's Regional Innovative Capacity

Few studies have examined cross-regional differences in innovative capacities in China. Most of studies employed patent data as a proxy measure for China's regional innovation capability. Using this method, Sun (2000) finds that patents in China are unevenly distributed and highly clustered in certain provinces during 1985-95. In examining the distribution of patents by province in 1995, his factor analyses show that innovations in China are highly correlated with the level of regional development in that a variety of aspects of technical infrastructure significantly influence a region's patenting production. In his findings, R&D, openness (e.g., export and import, presence of foreign enterprise) and urbanization play the vital roles in regional innovation. Technology market and producer services are also found as important factors in facilitating innovation. Illuminating the different level of regional innovation capability, Sun's study reveals that innovation capabilities do cluster in China, since the establishment of a patent system in 1985 whereas the degree of concentration is gradually declining

Another Sun's study (2003) indicates that industrial innovation is mostly concentrated on China's eastern-coastal regions, which is consistent with some findings of the previous studies. However, analyzing data of patent granted to industry, new product sales and industry's R&D spending, he shows that the patterns of industrial innovation, to some extent, differ from his early findings. Contrary to his previous study, the regional concentration of industrial innovation has been rather increasing from 1991 to 1999. In addition, his study demonstrates that Chinese enterprises have experienced a dramatic change in their modes of innovative behavior, especially regarding their R&D spending. In the analysis, he identifies the provinces into two groups and applies the logistic regression to the model. Though the regression model does not work well, he found that almost two-thirds of China's provinces spend more on imported technologies by firms, whereas the rest spend more on in-house R&D. Thus, he concludes that the

Chinese innovation system is fragmented, since enterprises do not connect well with the domestic technology markets.

Similar to this line of research, Fan and Wan (2006) also argue that the Chinese patent concentration has tended to increase since 1995. Between 1995 and 2004, they found that eastern China dominated certified patents and the gap between the eastern regions and others had expanded. They conduct the regression and decomposition analysis to investigate the inequality in regional innovation capability, using the per capita number of patents at the provincial level during the period. In their findings, GDP, location, urbanization, human capital, and openness are significant factors leading to the disparity in innovation capabilities between regions. Furthermore, unbalanced development in high-tech parks across the country is found to play an increasing role in causing innovation disparity in China.

Li (2009) empirically investigates the disparity in innovation performance between China's provinces from 1998 to 2005. In estimating econometric models, he used explanatory variables associated with R&D inputs and dynamic links between innovation actors that increase the efficiency of innovation system. His findings show that government financial support for S&T activities and industrial structure are significant determinants of efficient innovation performance at the regional level. The regions with developed high-tech industries are found to be efficient in invention patenting. However, the interaction between major innovation actors and the linkages between technology users and producers are conducive to more utility model production than invention production. He suggests that firms have more different innovation productivities between regions than universities and research institutes. This may imply that firms-dominant regional innovation system further widens the gap of overall innovation efficiency between regions that underlies the growing gap in regional innovation performance in China.

Guan and Liu (2005) focus on the inequality of innovative capacities among the regions in China during 1990 and 1998. They examine the relationship between patenting and the variables associated with the institutional R&D efforts at the provincial level. The results of the ridge regression analyses show that the R&D personnel inputs in universities and research institutes and the industry's self-R&D funding contribute most substantially to the regional innovative capacity. The R&D cooperation between industry and university has less effect on regional innovative capacity, though their efficiency is better than that of cooperation between enterprises and research institutes. The findings highlight that it is important to foster the sound and competitive innovation milieu to encourage enterprises' investment in R&D activities to enhance regional innovative capacities in China.

Liu and White (2001b) explore variation in innovative activity and performance at the provincial level. Examining regional patent activities from the period 1992-95, their regression analysis presents that regional disparities in R&D inputs are closely associated to difference in its patenting activity. In their findings, scientific and technical personnel have a greater impact on the patent activity than other factors. R&D personnel especially in firms are crucial to develop the R&D capabilities. Moreover, it shows that the R&D funding of local research institute has a much impact than either university or firm expenditures. In other words, public research institutes played the central role in regional innovation activities during the mid 1990s, while the industries made progress. Based on the findings, the authors propose that the ability to exploit the inventions represented by patents is important for regional development in China. They suggest that regional governments may pay attention to mechanism that facilitates the effective exploitation of patents and other outputs of innovative activity as a knowledge-based development strategy.

Yunwei et al. (2009) analyze the application activities of Chinese patents in the eight economic regions of the PRC during the period 1999-2004. The results of their data analysis show that the number of Chinese patent applications increased rapidly for six years. At the same time, the number of patent applications was unbalanced in the eight economic regions. The North Coast and East Coast contributed most of the Chinese patent application, accounting for more than 50% of the patents applications filed. The annual growth rates of the two regions were also higher than any other regions, implying that the advantage of two regions may prevail continually and exist for a long time. Their findings also imply that regions with higher R&D spending tend to have higher patent applications. Therefore, in order to reduce the gaps in technological innovation capability between regions, the regions with low patent input may invest more in R&D.

In sum, these studies not only have confirmed the uneven development of regional innovation capacities in China as measured by patent counts but also illuminated several factors leading to the innovative gaps at the provincial level. However, most of them are limited to employ explanatory variables regarding to either R&D efforts or socio-economic and institutional factors, and examine the impact of those variables separately. In addition, most studies did not regroup the patent statistics by institutions (e.g., institutions or individuals) to get a precise measurement of the source of the innovative outputs. This, in turn, exposes the serious measurement issues. In recognition of this limit, the present study not only includes more explanatory variables ignored in the previous research models but also introduce the fixed effect regression method for count data, employing patent statistics—that is, patent grants to domestic institutions. The next chapter elaborates more details about research model and method and data applied in the analysis.

CHAPTER 3

RESEARCH DESIGN

The research in this study is undertaken to extend the understanding of 'knowledge divide' by exploring differences among China's regions in the production of innovations. It involves the testing and refining of some key concepts and working hypotheses about relationships between innovative outputs and the variables associated with the regional innovation capacity. This chapter introduces the sources of data and the analytical methods to be employed in the research. Prior to elaborating on the data and methodology, the research framework and hypotheses of the study will be presented.

3.1 The Analytical Framework of Regional Innovation Capacity

The increasing privatization and commercialization of "new-to-the-world" technologies or knowledge have attracted considerable research interest on innovation. As such, the literature on innovation has assisted significantly in promoting our understanding of the dynamic underpinnings of innovation and technological change. The intriguing question about what drives differences in innovation capacity or intensity has led to various theoretical explanations which revolve around the roles of international trade (Salomon and Shaver 2005; MacGarvie 2006; Pla-Barber and Alegre 2007), R&D capital or investment (Griliches 1979; Hall and Mairesse 1995; Tang and Koveos 2008), government policy (Amsden and Chu 2003; Mowery and Sampat 2004), industry conditions (Porter 1998a; Mowery and Nelson 1999; Appold 2004), FDI (Liu and Wang 2003; Sinani and Meyer 2004), and institutional linkages (Etzkowitz 2008).

Although these literatures have contributed significantly to advance theory taking account of the underlying factors determining the innovation capacity, few studies have attempted to incorporate them in a unified framework. This limits our perception of how variations in innovation capacity occur. In order to explore various innovation determinants, it may require a multidimensional conceptual framework combining theoretical constructs from the existing literature. Investigating the integrated effects on innovation capacity more comprehensively, a unified research framework allows us to better understand the relative significance and role of each effect (Wang and Kafouros 2009).

In the search for an analytical scheme that would advance the assessment of the determinants of innovation capacity, this study adopts an integrated approach and proposes and tests a research framework that combines a number of different explanations for innovation capacity. Particularly, it complements and extends Furman et al.'s framework (2002) to apply it to China's regional innovation systems. Furman et al. demonstrates the importance of an integrated framework of a national innovation system, tracing a dynamic process of innovation capacity-building within country. They highlight the role of government policy, industry condition, indigenous R&D effort, and infrastructure in explaining the differences in the level of innovation productivity.

However, since their study focused on developed countries, its framework may need to be adjusted for the application in the context of emerging countries like China. Most innovations in emerging economies where the primary strategic goal is to catch-up differ from those pursued by the advanced countries. Innovations in the case of emerging countries often mean "new-to-the-market" or "new-to-the-country" rather than "new-to-the-world." Under this circumstance, it has been acknowledged that emerging countries have the distinctive process of innovation capacity-building as divergent from the patterns for the advanced countries.

Hu and Mathews's study (2005) found that unlike most developed countries, public R&D expenditure plays an indispensable role in facilitating innovation activities in the East Asian latecomer countries by guiding and allocating the limited resources into the strategic industries. Additionally, it is widely believed that international technology spillover through FDI and trade has been an important driver of innovation in emerging economies (Liu and Buck 2007). In the context of those economies, it is particularly important to examine whether the international channel and sources of technological spillovers enhance indigenous domestic firms' innovation capabilities. However, these effects which are considered significant on the innovation experiences of emerging countries are actually omitted in the previous studies.

The present study, therefore, modifies the Furman et al.'s framework of NIC with some variables which they ignored, including the role of the regional government and foreign investment and trade (e.g., import and export) to extend its application to the regional innovation systems in an emerging economy context. In order to understand the various drivers of regional innovative productivity, the research framework of the study integrates conceptual developments from three main literatures: 1) the theories of endogenous growth, 2) industrial competitive advantage, and 3) the innovation system. Given that the development of innovation capabilities does not arise from any single factor, this framework provides a useful tool in assessing a broader set of influences driving regional innovative outputs. In doing so, it can clarify the properties and determinants of regional innovation system.

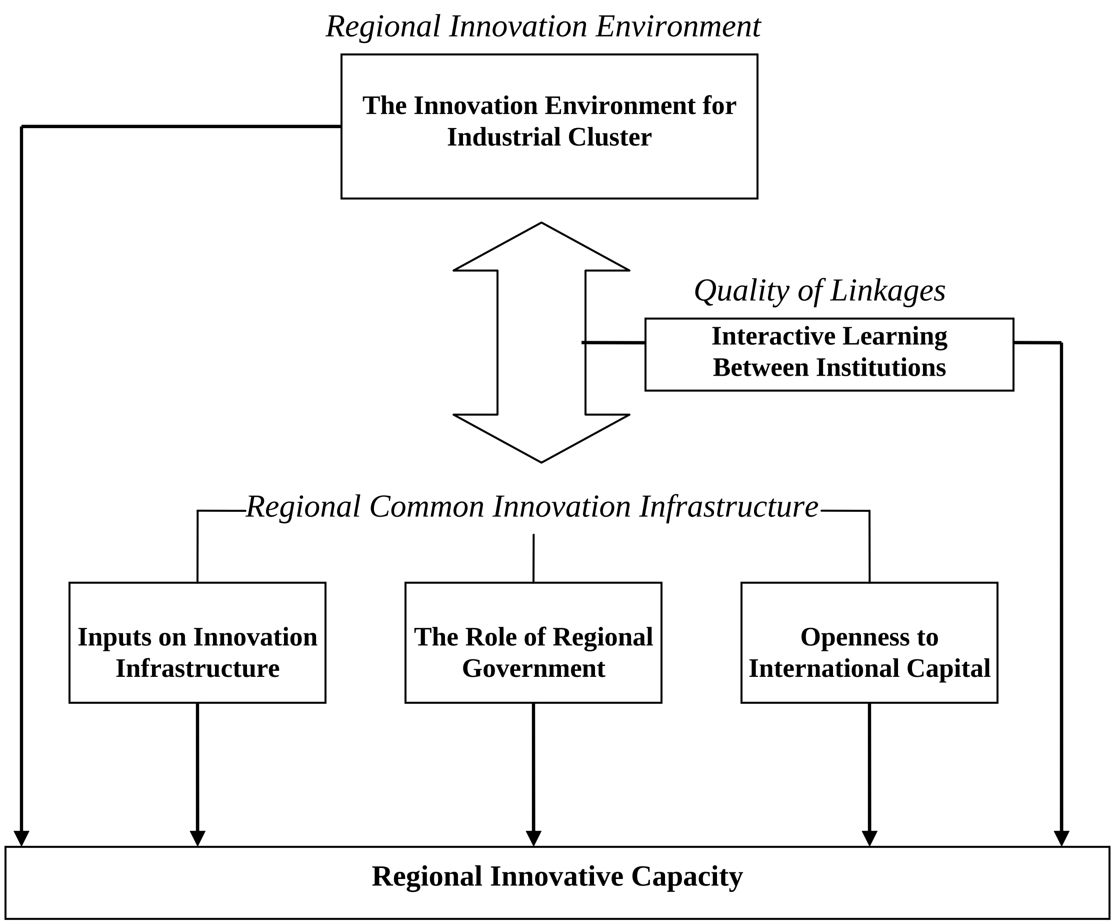

Figure 3.1 The Analytic Framework of Regional Innovative Capacity

Figure 3.1 shows an analytic framework for the determinants of RIC in China and highlights the focus of the present study. RIC in this study is understood as a regional economy's potential to produce a flow of commercially relevant innovations. This indicates the capacity of regional innovation systems in terms of knowledge production, distribution and absorption. The framework suggests that regional innovation capacity is determined by three main factors: 1) the common innovation infrastructure, 2) the innovation environment for industrial clusters and 3) the quality of linkages between two components—interactions between government, universities, and firms involved in the innovation process. The overall innovative capacity of regional economy results from the interplay among all three elements.

The regional common innovation infrastructure in Figure 3.1 incorporates innovation inputs within a region, the role of regional government, and openness of region to foreign trade and investment. The framework builds on endogenous growth models, placing an emphasis on the overall scale of innovation inputs (e.g., human and financial capital investment in innovation), while also including more nuanced factors (e.g., public policy choices and FDI and international trade), which can be important drivers of innovation output. The common innovation infrastructure denotes an economy's aggregate level of S&T sophistication and labor forces to produce new knowledge and product, government's policies that support R&D activities and higher education, and international technology spillover sources through FDI and trade. The presence of a strong innovation infrastructure, in turn, determines the realized level of regional innovativeness.

While the common innovation infrastructure provides the resources for innovation, the microeconomic environment in which the firms in a region's industrial clusters compete and invest on the basis of technological innovation develops and commercializes innovations throughout the regions. This perspective is particularly derived from the theories of industrial competitive advantage, stressing the important role of the private sector in advancing the level of innovation activity within a region (Porter 1998a).

Viewed from this angle, the investments, policies, behaviors of the private sector have a significant impact on the nature and extent of region-specific innovation outputs.

The analytical framework also addresses the dynamic interactions between cluster innovation environment and the common innovation infrastructure and regional institutions—ranging from universities to public institutions—that shape the rate of innovation. As presented in Figure 3.1, the common innovation infrastructure and cluster innovation environment are interrelated with each other. As the strength of the common innovation infrastructure tends to increase innovative outputs in particular clusters, a strong cluster innovation environment also contributes to the strengths of the common innovation infrastructure. For example, while local environmental regulations and policies supporting the firm's innovation activities may encourage investments on the basis of innovations in specific clusters, the capability of the cluster to introduce and commercialize innovation also depends on the overall availability of physical and human resources in S&T and macroeconomic policies which provide incentives to foster innovation activities.

The quality of the linkages between two areas affects the extent to which a given common innovation infrastructure produces a flow of innovative outputs in the industrial clusters. The innovation system literature serves as a basis for describing the linkage between these key components of regional innovation system, emphasizing the array of government policy, institutions, and relationships as important contributors to innovation outputs (Nelson 1993). The linkage mechanisms characterized by various types of institutions and their strong relationships, such as region's university-industry interaction, dynamic university research systems, and the greater availability of financial capital for new ventures, facilitate the development and commercialization of new technologies in the economy. Without these mechanisms, upstream scientific and technical activity may spillover to other countries or regions, before it is exploited by the local industries.

In short, RIC can not be simply understood by a single innovation determinant because it is a product of interactions among social, political and economic processes. The RIC framework which this study employs, therefore, integrates a broader set of social, political, and economic influences in explaining cross-regional differences in the intensity of innovation. Building on the approaches and results of previous theoretical and empirical studies, *this research framework makes a contribution to the understanding of the underlying factors that determine innovation capacity of China's regions by providing a more comprehensive and unified analytical framework than most previous works*.

3.2 Research Questions and Hypotheses

The main purpose of the present study is to identify the key factors contributing to disparities in innovation capacities among the Chinese regions by shedding light on the issue of regional inequality in the production of knowledge. The following comprise the four main research questions of the study: 1) what factors can account for great variations in innovation capacity between regions?; 2) what are the essential factors to construct and enhance the regional innovation systems?; 3) how could the gaps in the development of regional innovative capacities be reduced?; and 4) how can China promote indigenous innovation capabilities with the harmonious development? These research questions guide the present study of regional innovation systems in China and help to understand the sources of differences between regional economies in China's knowledge-based economy.

A regional innovation system is an adequate approach to compare and analyze innovation activities across the regions, since it captures the local nature of innovation. The regional innovation systems are far from the same, which imply that innovation capacity varies between regions. In order to explore the determinants of innovation disparity at the regional level, the present study adopts the basic premises of the RIS approach as follows: 1) innovation capacities are not equally distributed and new knowledge tends to localize spatially; 2) in a regional innovation system, the main innovation actors are firms, universities, and public institutes; and 3) the production of innovation depends on not only innovative inputs but also the interactive learning between those actors involved in innovation process.

In such a theoretical rationale, the development of innovation capabilities depends on the complex interactions of each structure of the innovation system, including human and financial resources, public policies, and institutions. In this regard, the research framework of the study integrates those elements that determine how well the regions employ the resources for innovation and develop their innovation capacities. By this framework, the following factors are, among others, expected as critical in determining the realized level of innovation potential.

A common innovation infrastructure is one of the most important determinants of regional innovative capabilities. A region with a strong common innovation infrastructure tends to have greater innovative capabilities (Furman et al. 2002). The regional innovation infrastructure comprises innovative inputs, policy choices, and foreign investment and trade. The specific hypotheses for these elements of the common innovation infrastructure are as follows:

Hypothesis 1: Regional innovation outputs measured by patent outputs are positively related to the aggregate level of innovation inputs within a region.

In a regional innovation system, resources commitments—as measured by R&D manpower and expenditure—and historical stock of knowledge are considered as direct inputs to the innovation process. The rate of new ideas production depends, in part, on the level of capital and labor resources devoted to R&D (Romer 1990). The greater scale of human capital and financial resources potentially available for innovative activity, the stronger the regional capacity to absorb and generate new knowledge and product. The outputs of innovation process also vary in relation to previous investment into the knowledge stock. The accumulated stock of technology and knowledge can benefit innovative actors by providing better technological opportunities in a region and then eventually become sources of technological progress and economic growth as well.

Hypothesis 2: The role of regional government in supporting innovation activity will be positively correlated to the innovation outputs of a region.

In emerging countries like China, state intervention and public sectors play an indispensible role in creating, maintaining and developing the innovation system (Hu and Mathews 2005). The support from the government is important, because it creates an innovation environment where high-tech firms may flourish and interact with other knowledge institutions. State involvement facilitates the success of the catch-up strategy in those countries by guiding and allocating the limited research resources into the strategic high-tech industries.

In China, however, since provincial governments have been gradually becoming relatively independent after the economic reform, the role of regional government becomes significant in building RISs (Guan and Liu 2005; Li 2009). Not only major municipalities such as Beijing and Shanghai, but also provinces attempt to promote innovation activities by setting up collaborative university science centers and establishing the partnerships with foreign investors.

Accordingly, S&T policies and innovation plans at the regional levels significantly impact the region-wide innovation potential. As a crucial determinant of regional innovative capacity, the role of regional government includes assigning public resources to innovation actors and formulating favorable policies that create the macroeconomic environment for innovation. In short, aggregate policy choices regarding public expenditures for higher education and S&T (e.g., R&D funding and tax credits) are expected to affect all innovation-oriented sectors in a region

Hypothesis 3: The openness of regional economy to foreign capital and international trade has a significant impact on innovation outputs.

Since the establishment of the open door policy, China has received a large part of FDI flows, playing a critical role in the fast growth of its exports. Inward FDI and international trade (e.g., imports and exports) have been seen as a main channel for international technology spillovers. Local indigenous firms can learn about know-how and designs of new technology and products through interactions with foreign firms. Particularly in China, multinational enterprises have been important agents of foreign technology transfer, enabling local firms to improve its innovation capability.

A few empirical studies have found positive effects of FDI on regional innovation in China. Using a provincial-level panel dataset, Fu (2008) found that FDI has contributed significantly to the overall regional innovation capacity measured by patent grants. In the coastal region, where most of China's R&D resources and activities are concentrated, FDI has been a great contributor to regional innovation performance as well as fast regional economic growth. By contrast, FDI is low and knowledge spillovers are limited in the inland region with the lack of absorptive capacity. Cheung and Lin (2004) show the evidence of positive spillover effects of FDI on the number of China's domestic patent applications at the provincial level, but the spillover effect of FDI is the strongest only for minor innovation such as design patents.

In the context of developing countries, participation in global markets is important to explore new global technologies and scientific knowledge, stimulating domestic innovation activities. Exporting firms can have a better chance to obtain diverse knowledge and information about competing products and customer preferences through foreign buyers, thus facilitating innovation. Imported technologies and goods can help boost domestic innovations by enabling local firms to access new technology and imitate foreign technological products (e.g., reverse engineering). Employing a panel of sub-sector level data, Liu and Buck (2007) found that there is a direct, positive link between the level of importing and exporting activities and innovation performances of Chinese high-tech firms. Their findings indicate that learning-by-exporting and importing with indigenous R&D efforts determine the innovation performance of Chinese high-tech sectors. Imports, especially, are important sources of domestic innovation, allowing local firms to adopt new technologies, absorb foreign knowledge, and interact with international clients.

Hypothesis 4: Regions with a stronger innovation environment in the industrial cluster tend to have greater innovation capabilities.

Apart from the common innovation infrastructure, the present study also attempts to demonstrate that the industrial environment for innovation in a given region is one of the most important determinants of regional innovation capacity. The intensity of industry's R&D activities indicates the vitality of the environment for innovation on the basis of innovation-based competition across industrial clusters. For example, as the competition of the industries in a region becomes intensified, investments in R&D activity are also increased by firms. Thus, the R&D investments at the industry level will be positively associated with regional innovative outputs, since the competitive milieu for innovation—as measured by private R&D investments—influences the potential for innovation output in a region.

In China, it has often been pointed out that the efficiency and the innovation capacity of private sector are weak and still not sufficient, compared to developed countries. However, in recent years, the industry has appeared as the largest R&D

performer in China. The private R&D expenditure has been increasing at an average annual growth rate of 20% since the early 1990s, with self-funding as the main financial source for R&D activities (OECD 2009b). The firms' indigenous R&D efforts, rather than foreign technologies, have a significant effect on industrial innovation in China. This suggests that Chinese industries may shift over time from an imitation strategy to practices that emphasize their own R&D efforts and S&T capabilities.

Exploring China's patent activity from 1991-2005, Hu and Mathews (2008) provide evidence supporting the significant role of the private sector in building China's innovation capacity. The analysis demonstrates that R&D expenditure in the private sector along with university R&D activity is the most influential drivers of China's innovation during the past 15 years. Chinese firms' R&D investment substantially contributes to their regional innovation capacity, measured by number of patent application at the provincial level. Thus, the innovation activity in the private sector can be expected to have a significant impact on regional innovation outputs in China.

Hypothesis 5: The regional innovation capacity is determined by the interaction between firms, universities, and research institutes involved in the innovation process.

This hypothesis builds on the assumption that regions with a higher degree of collaboration between those actors would produce more innovation outputs. In the regional innovation systems, interactive learning between innovation actors has a critical effect on innovation process and performance. This collaboration manner has been increasingly found in China, since the reform of S&T system in 1985. Motohashi (2008) evidences increasing science and industry linkage activities in China during 1985-2005, especially in the form of joint patent application by universities and firms. His findings show that such collaboration between industry and university take places mostly in the fields of chemical, medical and drug, and the role of university increases as an advanced technology provider to domestic firms through the collaboration relationship. Based on a survey of 950 industrial enterprises in Beijing, Guan et al. (2005) found that the collaboration between industry and universities/research institute has a significant, positive impact on industrial innovation.

3.3 Data and Methodology

3.3.1 Data and Measures

The primary data source for this research consists of a series of official statistical publications, statistical reports and database, scholarly publications and semi-structured, in-depth interviews. They cover both qualitative data and various statistical data sets, containing cross-regional and cross-sectional ones. For the quantitative analyses, the provincial-level panel dataset are compiled from official statistics published in various series of statistical yearbooks and reports from 1998 to 2008, including *China Statistical Yearbook*, *China Science and Technology Statistics Data Book*, *China Statistical Yearbook on Science and Technology*, and *Annual Report of Patent Statistics*.

China Science and Technology Statistics Data Book is an annual on-line publication provided by the Ministry of Science and Technology of China (MOST). The book contains China's basic S&T statistics, such as R&D expenditure, government S&T appropriation, human resource in S&T, output indicators, and high-tech. *China*

Statistical Yearbook has been published annually since 1981 by the Chinese National Bureau of Statistics, covering various datasets with regard to China's social and economic development. *China Statistical Yearbook on Science and Technology* is an annual publication which has been jointly published by the National Bureau of Statistics and the MOST since 1990. It presents basic statistical information on the development of China's S&T activities and innovation performances. Since Chinese statistical yearbook series provide the most comprehensive and authoritative data in terms of China's social, economic, and S&T developments, numerous scholars have used those data to perform their research that are published in professional journals.

Although Chinese official statistics have been widely used for social science research published in peer-reviewed journals, many scholars and general observers have had mixed views on its reliability. While some have raised doubts that the Chinese official data may be falsified for either political purposes or technical difficulties with the data collection (e.g., Rawski 2001; Holz 2003), others argue that the statistics are generally reliable and useful. Discussing the validity of Chinese official data, Chow (2006) points out that it is difficult to falsify the data because of the legal responsibility of Chinese officials to provide accurate statistics, of their being used for national policy decisions and planning that is open to public scrutiny. Given that very few supplementary Chinese data are available, the present study utilizes the usefulness and reliability of official data published from the Chinese NBS.

China's domestic patent statistics have been systematically collected by the State Intellectual Property Office (SIPO) of the PRC for over the past 20 years and published annually. SIPO's annual reports of patent statistics provide a rich and reliable dataset, covering information on Chinese domestic patent applications and grants for invention patents, utility models and designs. The patent statistics published in this report, particularly for granted invention and utility patents awarded to domestic institutions between 1998 and 2007 are employed for the quantitative analysis of this study.

For the case study, the data collection procedure consists of gathering policy documents, public journals and reports, and in-depth interviews. Two cases (Hubei and Fujian provinces) that share the similar characteristics on innovation environments but possess a different level of innovation capacity are chosen from the cluster analysis. The comparative cases analysis would explain why two regions have moved along different innovation trajectories. In order to compare two specific cases, interview data are collected through semi-structured telephone and email interviews with faculties of higher academic institutions in two provinces in China, as well as with the industrial managers who interact with university researchers. Total number of interviewees is six: three interviewees (e.g., university faculty-industrial manager) are selected from each region. In the interviews, both university faculties and industrial managers are asked to examine the ways that they initiate, manage, and develop the process of interactive learning for innovation between universities and industry. Interview analysis provides an in-depth understanding of the mechanisms which promotes knowledge transfer and production through the interactions between two regional innovation actors in the distinct regional contexts.

3.3.1.1 Measuring the Innovation Output

As technological innovation plays an important role in economic growth, many scholars have attempted to measure technological change using diverse indicators. In the absence of a complete and direct measurement of technological innovation, a few indicators of innovation output have been proposed and used, such as R&D data, patent data, new product sales, literature-based innovation output (LBIO), and the number of patent citations. Although these indicators fall into similar pitfalls and present measurement issues, patent data have long been widely used as a well-grounded measure of innovation outputs, because of its availability and reliability.

R&D data (e.g., R&D expenditures and R&D personnel), have been used to estimate technological changes at the firm, sectoral, sub-national, and national levels. As an input into the innovation process, R&D data do not necessarily indicate the amount or quality of innovation outputs, but it assesses technological innovation in both private and public sectors by gauging the rates of return to R&D investments. However, R&D data suffer from a shortcoming of measurement, since it focuses solely on the financial and human resources devoted to innovation productivity. Given that it is mostly considered as innovative inputs rather than outputs, R&D data are not an appropriate dependent variable in the present study.

Compared to R&D, new product sales and LBIO provide more direct measurements of innovation. The amount of new product sales is a good indicator of market acceptance of a new innovative product, representing the extent of the success of innovation (Atuahene-Gima and Li 2004). The disadvantage of new product sales is that it is unlikely to totally capture all innovation outputs. New product sales measure not only excludes potentially important process innovation, but also is inconsistency across industries and fields. Moreover, new product sales are closely associated with the local market prices.

Another measurement, LBIO is generated by sampling the 'new product announcement' sections of technical and trade journal. The strengths of LBIO is that it includes not only process and marketing innovations which have been generally ignored in the measurement of innovation output, but also commercialized inventions. However, LBIO has also some limitations, in that it exposes serious problems in the process of selecting relevant journals. A lack of adequate journal selection during the data collection process may cause the inconsistency of the LBIO data. Even though literature-based innovations can be objectively counted, its importance and value are only subjectively judged (Albert 1995). In addition, LBIO measures are very time consuming and expensive to collect, so that it can be available for only selected years and countries (Ace et al. 2002).

On the other hand, patent data have been widely employed as useful indicators of innovation productivity and other innovative activity. They "measure the outcome of invention process that is closer to commercial application than other possible indicators, such as academic publications and R&D data" (Liu and White 2001b: 114). In contrast to new product sales and LBIO, patents, as computerized and publicly available data, are easy to access. Another advantage of patent data is flexibility. Patent records provide "detailed information on the innovation itself, the technological area to which it belongs, the inventors and the organization to which the inventors assign the patent property right" (Jaffe and Trajtenberg 2002: 3).

This allows researchers to more easily construct and customize datasets that relate to their specific and various research questions. Since patent data show the temporal, geographical, sectoral distribution of invention and innovation, it enables us to analyze technological changes at both macro (e.g., national and regional) and micro (e.g., firm an individual) levels in a given time period. A further advantage to patent data is that unlike other indicators, they include invention or innovation outputs of the public sector, because universities, GRIs, and other non-profit organizations are also patent filers as well as recipients.

However, using patent data also poses some drawbacks. Most of all, patents are not complete measurement of invention because “not all inventions are patented, and the inventions that are patented differ greatly in quality” (Griliches 1990: 1669). Because the quality of the patented inventions differs greatly in terms of their technical and economic value, patent counts do not provide an accurate estimation of technology strength or economic payback. Therefore, the data can neither represent all important technological innovations nor indicate the importance of different innovation. Another drawback of patent data is that the patentability of an invention largely depends on the industry and the propensity to patent an invention also varies across industries, regions, and institutions. One way to reduce this inconsistency is to disaggregate patent counts by particular sectors or regions.

As an alternative indicator, patent citation indicators have been proposed to overcome the measurement issues arising from using patent data. Patent citation is to count the total number of citations that each patent has received from subsequent patents and use the number to compute weighted patent counts. Thus, the number of patent citation can be a measure of technological significance by quantifying the importance or value of patents, of the technology innovation of industries, regions, and countries, and of knowledge flow among institutions, regions and countries. By contrast to patent counts which generate purely quantitative measure, patent citations measure both the quality and quantity of patents. Unfortunately, since patent citation information is not available in the Chinese domestic patents, this measurement can not be taken into consideration in the present study.

In short, there is no perfect indicator in measuring the precise extent of innovation output. Comparatively, new product sales, LBIO, and the number of patent citations are good alternative indicators of innovation output beside patent data, but they are usually not available and not easily accessible. Despite some downsides, patent data have been accepted as a reliable measure of innovation activity. Due to its availability for a long time period, they are frequently employed in various empirical studies and policy reports to measure innovation capabilities and technological changes and as the dependent variable to identify the determinant factors behind technological innovation. Several studies also confirm the usefulness and reliability of using patent data as a measure of innovation activity (Ace et al. 2002; Jaffe and Trajtenberg 2002; Hagedoorn and Cloodt 2003).

As far as total availability of alternative indicators is concerned in the context of China, patents are the best indicators, among others, to compare regional innovative output. Thus, in order to measure and compare the innovation capacity between China's regions, this study chose to use the number of domestic patents as dependent variables. It is worth mentioning that China's domestic patent data are very comparable between the regions, since each region is subject to the same national patenting legal system, including processing fees and procedures. This, in turn, provides consistent measure of economically and technologically significant innovation (Li 2009).

Considering the quality of patents, this study uses patent grants as a proxy measure for the level of commercially valuable innovative output. In comparison with patent applications, patent grants are more qualified in terms of novelty and utility of inventions, since they have passed the additional scrutiny of patent examiners. Patent grants also have relatively less measurement errors as an indicator of technological innovation, in that they are more related to the commercialized new products or processes than patent applications.

In China, patent system came to exist at the beginning of Open Door Policy in the late 1970s. In 1985, China enacted first patent law, which has been enforced since then. Enforcement of the Chinese patent law has been greatly enhanced since the mid 1990s, mainly due to both increasing domestic interests and the international pressure from its major trading partners, such as the U.S. and some European countries (Lin 2001). Today, the legal framework of Chinese patent system, except for a few specific details, is not so much different from the international patent systems, in that China's patent law has been in line with international standards. China has acceded to all the international patent treaties and its IPR laws conform to the requirements of the WTO's Agreement Trade-Related Intellectual Properties (TRIPs).

With regard to the Chinese domestic patent data, there are two important characteristics. First, the Chinese patent office, the SIPO examines and certifies three types of patents: inventions, utility models and designs. Of the three types of patents, invention patents represent the most important and technologically sophisticated inventions like a significant technological improvement in products or processes. Utility model patents are less technologically innovative than invention patents, such as the form, construction, or fitting of the product. Design patents account for only trivial modifications and aesthetic design improvements. As three categories of patents show the different degree of patent quality, this study considers invention and utility model patents granted as innovation outputs. Each type of patent grants would be analyzed separately.

Second, among Chinese domestic patents, a large number of patents are granted to individual applicants. Non-institutional patents represent the regional innovation capacity contributed by individual residents living in a specific region. Given that most data on R&D efforts are generally calculated at the institutional level, this can raise measurement issues with the overall combined patent counts. The Chinese domestic patent data used in most prior studies on the regional innovation (e.g., Sun 2000; Liu and White 2001b; Cheung and Lin 2004; Guan and Liu 2005; Fan and Wan 2006; Yunwei et al. 2009) are highly aggregate patent counts which do not classify patents by the various institutions and non-institutions. Because of this data constraint, previous researches were unable to precisely measure China's regional innovation activities.

To reduce such measurement errors, therefore, the present study focuses only on the number of invention and utility design patents granted to domestic institutions, including universities, firms, public institutions, and other types of organizations.[5]

[5] The Chinese domestic patent data include patents issued to both foreign invested enterprises (wholly foreign owned and joint venture) located in China and Chinese firms. In reality, it is difficult to differentiate between domestic firms completely owned by

Considering the time lag between the measures of innovation capacity and the innovation output, this study set it as 3 years for invention patents and a year for utility design patents.

3.3.1.2 Measuring Regional Innovation Capacity

In the present study, RIC is understood as the ability of a region to produce a stream of commercially relevant innovations. Innovation capacity "is not the realized level of innovation output per se but reflects more fundamental determinants of innovation process" (Furman et al. 2002: 900). In order to analyze determinants of the process operating in the regional innovation systems, the study measures common innovation infrastructure, the innovation environment for industrial cluster, and the linkages between two elements. The variables measuring three region-specific factors that determine the flow of innovation reflect directly or indirectly the different process of innovation—that is, pre-production (e.g., research, design, and development), production (e.g., efficient manufacturing), and diffusion process (e.g., the spreading of consumption of an innovation).

Table 3.1 provides the definitions and sources of variables used in the empirical analysis.

Chinese investors and domestic firms funded or owned by foreign investors and multinational corporations, if both of them filed patents to SIPO using Chinese addresses. Therefore, total number of Chinese domestic firm patents are all issued to firms located inside China rather than firms wholly owned by Chinese people. In addition, foreign invested companies file legal protections for its intellectual property in advance before they establish a subsidiary or a joint venture in China. In this case, the patent application and the patent grants are classified as 'foreign', rather than domestic (Chueng and Lin 2004).

Table 3.1 Variables, Definitions, and Sources

Variable	Full Name	Definition	Source
Dependent Variable: Innovative Output			
$Patg_{i,t+3}$	Invention patent grants	The number of non-individual invention patents granted in region j in year (t+3)	A
$Patu_{i,t+1}$	Utility model patent grants	The number of non-individual utility model patents granted in region j in year (t+1)	A
Independent Variables			
Common Innovation Infrastructure			
$GDP_{i,t}$	GDP PER CAPITA	GDP per capita at regional level adjusted by the real growth rate to 1998 level	B
$FTE_{i,t}$	S&T personnel	Full-time equivalent of S&T Personnel	C
$GEST_{i,t}$	Aggregate S&T expenditure	Gross domestic expenditure on S&T (100Million 1998 Yuan)	C
$HIGHED_{i,t}$	Population with high education attainment	The population attaining above college degree divided by total population aged 15 and over (%)	B
$OADR_{i,t}$	Old Age Dependency Ratio	The ratio of the elderly population aged 65 and over to the working-age population aged 15-64 (%)	B
$ED_{i,t}$	Public education expenditure	Percentage of public expenditure on education (%)	B
$PUBST_{i,t}$	Public S&T support	Percentage of regional government S&T appropriation in total regional government expenditure (%)	D
$OPENNESS_{i,t}$	Openness to international trade	Exports plus imports, in constant prices, divided by GDP (%)	B
$FDI_{i,t}$	FDI	Total Amount of inflow FDI (100Million 1998 $)	B
Regional Cluster Innovation Environment			
$PRIVATE_{i,t}$	Private funding for S&T	Self-raised S&T funds by industry divided by total S&T funds (%)	C
Quality of Linkages			
$UNIVIN_{i,t}$	University R&D performance	R&D expenditures performed by universities and research institute divided by total S&T expenditures (%)	C
$LINK_{i,t}$	University-industry linkage	Share of university and research institute S&T funds raised from firms (%)	C

Sources: A. Annual Report of Patent Statistics 1998-2007
B. China Statistical Yearbook 1998-2008
C. China Statistical Yearbook on Science and Technology 1998-2008
D. China Science and Technology Statistics Data Book 1999-2008

The common innovation infrastructure comprises a region's cumulative knowledge stock, the overall level of financial and human capital devoted to R&D, regional government's policies, and resource commitments supporting innovation activities. The variables on innovation infrastructure indicate the overall level of S&T infrastructure and region-wide resources as well as macroeconomic environment to facilitate R&D activity and diffusion of innovations such as new products and process. $GDP\ PER\ CAPITA_{i,t}$ measures the knowledge stock, capturing the potential ability of a region to convert its knowledge stock into a realized level of economic development. In terms of knowledge stock, two alternative indicators, such as GDP per capita and cumulative patent stocks, are generally employed in prior works (Furman et al. 2002; Furman and Hayes 2004; Hu and Matews 2005). However, since Chinese domestic patents have risen sharply in recent years, patent stocks can be dominated by the number of patents granted in recent years and also it is highly correlated with other independent variables. Patent stocks (from the start of the sample period until the year of observation) as a lagged dependent variable pose some issues in the panel data models by producing biased and inconsistent estimates (Kelly 2002). Although it provides a more direct measure of knowledge stock, this study uses only regional *GDP PER CAPITA* as a proxy for accumulated knowledge due to the above reasons. Regional GDP PER CAPITA can not only measure the overall state of a region's economical and technological development but also highlight a region's ability to translate its accumulated knowledge into a realized state of economic development. In this study, the variable can be interpreted in these two ways.

Each region's number of full-time equivalent (FTE) scientists and engineers ($FTE_{i,t}$) and gross expenditure on S&T ($GEST_{i,t}$) is the measures of E, indicating the extent of

R&D effort in a region. Additionally, population with high education attainment (*HIGHEDU* $_{i,t}$) and old age dependency ratio (*OADR* $_{i,t}$) are included to measure the overall scale of human resources potentially available for regional innovative activity.

As the part of the common innovation infrastructure, some policy choices emphasizing the role of regional government are also considered as influencing a region's innovation environment, including the regional government S&T appropriation (*PUBST* $_{i,t}$) shown as a percentage of total expenditure and the percentage of public spending on education (*ED* $_{i,t}$).

Moreover, the possible international technology or knowledge spillover channel is measured by the region's openness to foreign trade (*OPENNESS* $_{i,t}$) and investment (and *FDI* $_{i,t}$). Considering inward FDI and international trade as an indispensable variable for the Chinese case, they are added into the measure of innovation infrastructure.

The cluster innovation environment is difficult to measure because of its vague concepts and a lack of data. Nonetheless, private R&D funding is often used as an alternative indicator which measures the vitality of innovation environment in industrial clusters (e.g., Furman et al. 2004; Hu and Mathews 2005). The intensity of private R&D investments in a region indicates the extent of innovation-based competition among firms, which affects regional innovation activities. Thus, percentage of S&T funded by private industry (*PRIVATE*$_{i,t}$) is employed as a measure of competitive milieu. The variable of regional innovation environment implies the level of regional capacities to conduct R&D and manufacture innovations.

To gauge the strength of the linkage between industrial cluster and the common innovation infrastructure, this study employs the percentage of total R&D expenditures spent by universities and research institutes ($UNIVIN_{i,t}$) and share of university and research institute S&T funds raised from firms ($LINK_{i,t}$). The S&T performance of university and research institutions measures the importance of the public research system in producing new knowledge and innovation output and transferring them to the industrial firms. The variable of $UNIVIN_{i,t}$ captures the unique role of universities and research institutes in the innovation process. The S&T investment of industries in universities and research institutes can measure the interaction between firms, universities, and research institutes. The variable of $LINK_{i,t}$, thus, indicates the value of the knowledge flow from the science sectors (e.g., universities and research institutes) to industry and also their degree of cooperation. These two variables represent the mechanism for knowledge transfer, which stimulates R&D productivity.

In order to prevent the problem of the unobserved heterogeneity in the analytical models, three control variables are additionally included. The most models contains a dummy variable of the east-coastal region to distinguish whether the province is located on the east-coast, because most of the east coastal regions are wealthier and more technologically and economically developed than any other parts of China (*East Regions*). Therefore, the effect of the region location is controlled by coding a province as 1 if it is located on the east-coast.[6]

Second dummy variable is utilized in the models to control the regional scale (*Metro. Regions*). Regional studies have made a conceptual distinction between the territorial and functional region (Friedmann and Weaver 1979). In general, a territorial

[6] In general, the east-coastal regions indicate 12 provinces and municipal cities, including Beijing, Shanghai Tianjin, Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong. Guangxi, Guangdong and Hainan.

region refers to administrative and political regions within a country, such as federated states or provinces. In those regions, the territorially-based regulations and governance which reflect the territorial interests control social relationships, resources redistributions, and economic activities. By contrast, a functional region typically refers to the city-region or metropolitan area, such as a municipality. A functional region is an urban economy characterized by the developed labor market, basic public facilities (e.g., transportation, communication, welfare and education services), supply of the private services, and considerable local market potentiality. In China, however, among 31 administrative provincial-level regions, there are four direct-controlled municipalities with equal status to the province: Beijing, Tianjin, Shanghai and Chongqing. Given that those city regions conceptually differ from the territorial region such as provinces, the regional scale is controlled in the models by coding a province as 1 if it is a city-centered metropolitan economy.

Lastly, most models include a time trend to control for factors other than region-specific characteristics (*Year*). The valuable of a time trend accounts for the evolving differences across years in the overall level of innovation output during the study period 1998-2007. In general, dummy variables for each year are used in order to control for the variation arising from changes in the annual rate of patent grants. However, it should be noted that inclusion of the year dummy variables as the year fixed effects results in serious problems with multicollinearity in the panel data models of this study. Thus, year dummy variables can not be employed but a time trend variable is alternatively used as year-specific fixed effects. In econometric analysis, a time trend variable is often included in a regression specification as a useful proxy for a variable that reflects changes in the dependent variable through time. It can serve as a catch-all for all omitted variables that have a time component but can not be directly observable (Wooldridge 2009).

3.3.2 Analytical Strategy and Methods

The scientific method generally encompasses two kinds of processes: 1) inductive process in which investigations move inductively from observation to theory formulation and hypotheses and 2) deductive process of moving from theories and pre-specified hypotheses to logical implications of them. Inductive method allows the investigators to determine the theoretically relevant similarities and differences through examining empirical cases. By contrast, deductive method uses initial theoretical notions to examine casually relevant similarities and differences. Accordingly, it is inevitable to combine both methods to investigate scientific inquiries.

In such research tradition, mixed method research has been increasingly employed by social scientists, bringing the paradigm wars between quantitative and qualitative researchers ended. It is generally referred to as the type of research employing mixed quantitative and qualitative approaches, techniques, or data (Creswell 2003; Tashakkori and Teddlie 2003). According to Tashakkori and Creswell (2007: 4), “mixed methods research is defined as research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or a program of inquiry.”

Conducting mixed methods research, however, has both pros and cons. First of all, a mixture or combination of qualitative and quantitative research approaches can have complementary strengths and also provide a more comprehensive view of the problems or phenomena being studied (Creswell 2003). If different approaches have the same results for the same phenomenon, the research findings would show more convincing and validating evidences. The mixed methods research can also offer multiple ways of viewing research problems by complementing more than one set of different results, expanding a set of results, and finding something that would have been missed or ignored if only single approach and data is employed. Thus, it can have stronger and more accurate evidence for a conclusion through convergence and corroboration of findings (Johnson and Onwuegbuzie 2004). In addition, mixed methods is well-suitable for interdisciplinary study, allowing researchers to use multiple philosophical perspectives and approach that guide their research (Creswell and Plano Clark 2006)

Despite the strong methodological strengths, the mixed method research is relatively difficult to pursue, since it is very time consuming to collect extensive data and resources as well as requires qualitative, quantitative, and mixed methods expertise and skills. Another weakness is a difficulty to integrate discrepancies between different types of data and analytical results. However, researcher can have better and more valid analytical results than using single methods, when the use of mixed approach is feasible (Tashakkori and Teddlie 2003).

Therefore, the basic analytical strategy of the present study is to utilize a mixed methodological approach with quantitative analyses and qualitative investigations. The fixed-effects negative binomial regression analysis, cluster analysis, and factor analysis are the methods of quantitative analyses and the comparative case study with the interview analysis is qualitative research method.

3.3.2.1 Quantitative Analysis

For the quantitative analysis, this study estimates a series of negative binomial fixed effect regression models, using the data from 1998 to 2007. The dependent variable in the analysis, patent counts is a count variable taking only non-negative integer values. A linear regression does not fit the nature of the count variables because the predicted value of a linear regression could be negative, which is restricted to the non-negative nature of patent counts. Because of the discrete nature of patent counts, which normally contains many zero and small values with a skewed distribution, an ordinary least squares regression that assumes a normal distribution of disturbances would not be appropriates. A log-log function where the natural log of patent counts is regressed on a vector of explanatory variables has been used as an alternative to model the count data. Yet this model also exposes the problems as restricted to nonnegative integer domain and the presence of zero values.

For this reason, the preset study assumes that non-linear regression models, such as Poisson models and negative binomial regression models, provide a better fit for the patents data. However, Poisson models may lead to biased results due to the overdispersion phenomenon displayed by patent counts because the variance of the patent counts often far exceeds the mean. If the conditional variance greater than conditional mean (e.g., overdispersion) or smaller than the conditional mean (e.g., underdispersion), Poisson models would produce biased results. In this case, the negative binomial model can still produce unbiased results under the condition of overdispersion and fit better for the data than the more restrictive Poisson model (Hausman et al. 1984; Greene 2000; Zhang and Rogers 2009; Hagedoorn and Wang 2010).

In the context of count panel datasets, discrete count distribution-based fixed effect models are the most appropriate since they not only fit the features of the count data but also control for unobserved factors at the regional level that influence its innovative output. Therefore, this study uses the negative binomial fixed effect model as the most appropriate regression model for this study because this model solves the issue of the presence of zeroes and small values, fits the nature of patent data, allows for overdispersion, and controls for the unobserved regional specific effects.

Before conducting the regression analysis, the diagnostic method is taken so as to ensure statistical accuracy and robustness in the models. In order to check for the existence of multicollinearity among variables, the zero-order correlation of the independent variables with the patent variable and with each other is estimated. The variance inflation factors (VIF) is computed to assess the severity of multicollinearity. If the VIF value does not exceed the cut-off point of 10, it implies that multicollinearity does not pose a problem for the estimation models.

Along with the regression analyses, the study uses the factor analysis to extract the main factors that determine the regional innovative capacity. This shows the underlying common factors that explain the main variance of the capacity of the regional innovation system. In addition, the cluster analysis is conducted to measure the regional innovative capacity, using the principal components scores from the factor analysis from 1998 to 2007. With the K-Means cluster analysis, the study classifies and clusters the concerned regions according to their innovative capacity. As a result, China's 31 provinces and province-level municipalities can be classified into the three homogeneous groups: regions with high, middle and low innovative capacity. Based on the results of the cluster analysis, the most innovative and the least innovative regions are selected for the comparative case study. The results of cluster analysis show the group type and the Euclid distance from the group centre for each region. Therefore, the most innovative region is selected from the group of regions with high innovative capacity, whereas the least one is selected from the group of regions with low innovative capacity.

3.3.2.2. Comparative Case Analysis

The quantitative analysis allows the research models with greater precision and specificity. In addition to the use of quantitative approach geared for broad generalization, employing qualitative analysis can reduce the possibility of imprecise overgeneralization about the structural relationships. Qualitative approach provides the detailed description and analysis of the quality of actual cases, such as event, interactions, people cultures, and human experience in a thoroughly understood context (Marvasti 2004; Denzin and Lincoln 2011). The comparative method often increases the strengths of measurement approach by providing in depth the particular details and contexts of the case and tracing concrete causes and consequences.

The case study design is the qualitative comparative research method to distinguish and define characteristics of single case or multiple ones and give conceptual reflections about contrasting findings. A key strength of the comparative case study method includes multiple sources and techniques in the data collecting process. The researchers determine in advance what empirical evidence to gather and what analytical techniques to use with the data to investigate the research questions. In general, the collected data are mostly qualitative, but it can also be quantitative. The case study design, thus, can employ a mixture of qualitative and quantitative methods. In the present study, descriptive statistics with qualitative data are used to investigate the cases to bridge between the qualitative and quantitative methods (Byrne and Ragin 2009)

The advantage of the qualitative case study is its applicability to real-life, contemporary, human situations and interactions. The case study method is a useful tool employed in understanding and describing human experiences and its meaning for those involved. Since human behaviors and social interactions are difficult to quantify, in-depth qualitative investigation is unavoidable. For this reason, this study analyzes the processes of interactive learning for innovation between two social actors—university and industry—based on the empirical evidences from the interviews.

Therefore, in order to understand and interpret the nature and causes of regional innovation process, the present study conducts a case study to compare two regions which are selected by statistical references. The comparative case study can identify the distinctiveness of the case, which trace the specific patterns and causes of S&T development of the regions. The analysis encompasses both macro and micro levels: 1) a regional comparison of the structure and functions of the innovation systems and 2) a regional comparison of social networking and interaction between innovation actors within the systems. Similarity and differences between two regions can be examined to decipher important causal mechanisms in testing some specific theoretical propositions. The exploration of casual conditions through the comparative study, therefore, can contribute to answer the reasons for the disparity in the regional innovation capacity in China.

3.3.2.2.1 Case Selection Method

In order to select two provinces for the comparative analysis, a K-Mean cluster analysis was undertaken using the principal component scores of the RIC variables from the factor analysis, employing the 2007 data. Cluster analysis is a statistical technique used to classify cases into groups that are relatively homogenous among themselves and heterogeneous between each other based on the set of variables. Among 31 provinces, nine provinces are grouped as the high innovation capacity region, eight provinces are grouped as the middle innovation capacity region, and fourteen provinces are grouped as the low innovation capacity region. Each region for the case study was selected from the groups with the high innovation capacity and low innovation capacity.

This study selected Hubei province from the group with the high innovation capacity and Fujian province from the group with the low innovation capacity.[7] Two cases are chosen with the following reasons. First, Hubei is only one inland region belong to the high innovation capacity group, as most inland provinces are in either middle or low innovation capacity group. In contrast, Fujian as one of the developed coastal regions is included in the low innovation capacity group. Despite its higher GDP per capita than Hubei, Fujian is among provinces with the low innovation capacity, unlike most coastal provinces. The results are in contrast to the general assumption that coastal provinces tend to have higher innovation capabilities and perform better at innovation activities compared to inland regions. It is important to understand how two

[7] It should be noted that the results of cluster analysis can be different depending on what variables and what period of data are used. For example, employing different indicators, the 2008 report of Research Group on Development and Strategy of S&T of China shows that innovation capacities between two provinces, Hubei and Fujian, are not much different, so they may be in the same group. In this study, however, they are placed in two opposite groups based on the independent variables.

provinces with the different level of socio-economic development are placed in the two different ends of the innovation capacity spectrum.

It also found that both provinces have the similar level of R&D resource commitments but they have a different level of innovation productivity. S&T personnel capita of Hubei and Fujian are 3.15 and 3.04, respectively. The R&D intensity is a little higher in Hubei than in Fujian. While Fujian has better economic infrastructure such as FDI and international trade and relatively well-established private sector, Hubei has stronger human resource base and higher education systems with well-supporting government incentive systems. Thus, two provinces may have both similarity and differences in building their RICs over time.

However, despite the similar level of R&D resource commitment, Hubei shows better R&D performance than Fujian. For example, non-individual invention patent per capita is mostly higher in Hubei than in Fujian but it is opposite in the case of the non-individual utility patent capita. In addition, Hubei has higher scientific productivity than Fujian; the scientific publications in international journals (e.g., SCI, Engineering Information (EI), and Index to Scientific and Technical Proceeding (ISTP)) are over three times larger in Hubei than in Fujian. In 2007, the value of contract deals in domestic technical market in Hubei and Fujian is 522,146 and 145,579 respectively, indicating that Hubei has a stronger diffusion mechanism to promote technology transfer between knowledge users and producer.

Therefore, the comparison between innovation systems in inland and coastal regions can provide a better understanding of similarities and differences between these distinct regional contexts. But the results should be interpreted cautiously because two regions may have the same innovation capabilities, or one of two regions may have stronger ones. Comparing internal dynamics of the RIS in different regions of China, this qualitative case study consequently takes into account the diversity of regional variations in building innovation systems.

3.3.2.2.2 Interview Methods and Procedures

For the comparative case analysis, qualitative data are collected through the semi-structured in-depth interviews with four university faculty and two industry engineer/manager. All respondents were recruited through email contacts and snowball sampling.[8] In-depth interviewing is a useful qualitative research technique when conducting intensive individual interviews with a small number of respondents to explore their feelings and perspective on a certain subject, idea, program, or situation (Boyce and Neale 2006). This allows researchers to gain rich background and the hidden perception about the subject. According to Johnson (2002: 106):

> In-depth interviewing begins with commonsense perceptions, explanations, and understandings of some lived cultural experience...and aims to explore the contextual boundaries of that experience or perception, to uncover what is usually hidden from ordinary view or reflection or to penetrate to more reflective understandings about the nature of that experience.

Another benefit of in-depth interviewing is that it can provide a muti-perspective by capturing the complexity of respondents' attitudes and feelings through the interview

[8] Snowball sampling is "a popular technique for finding research subjects. One subject gives the researcher the name of another subject, who in turn provides the name of a third, and so on" (Vogt 1999: 303). In this research, four university faculty were recruited first by the researcher's email contacts and industry engineer and manager were subsequently introduced by academic respondents.

process. In the semi-structure format of in-depth interviewing, interviewer and interviewee can freely express their own points of view about the subject by not completely limiting them to a fixed set of answers. This enables the researcher to obtain some new ideas that has not been predetermined by them and to explore complex and unrevealed issues (Warren and Karner 2005; Berg 2009; Denzin and Lincoln 2011).

The semi-structured in-depth interview generally involves many open-ended questions, though they also contain predetermined or closed questions (Ayres 2008). While interviewers use a formalized and limited set of questions, they can bring up new questions during the course of the interviews. Compared to the unstructured and structured formats of interview, the researcher can have relatively more control over the topics and process of the interview and also have open responses from the interviewees.

In the present study, the interviews were conducted in order to understand and expand the knowledge of the patterns and process of the interactive learning for innovation between university and industry in the Chinese regional contexts. In-fact, in-depth interviews are a useful research tool to “expand researcher’s knowledge of areas about which little is known” (Schensul et al. 1999: 122). In this respect, it is a suitable qualitative method to this research, allowing access to detailed background as well as social, cultural, regional, and historical contexts in which the interactions between innovation actors can be created and facilitated.

Although the format of interviews were mostly open-ended, the interview was also structured in that nine questions for six basic indicators were prepared in advance and the special topics of interests were chosen by author prior to conducting interviews. Using the closed question has some advantages over the open-ended one: 1) saving time for the interviewer and the respondent; 2) providing the chronological order to help the interviewees answer more easily; and 3) enabling a quick statistical summary of the interview results (Gorden 1998: 38).

Table 3.2. Interview Questions for Six Indicators

Indicators	Questions
Motives of the Collaboration	• What are the benefits for you to collaborate with industry/or university?
Regional Communication Channel or platform for Collaboration	• What kinds of local communication channels (e.g., forum, government, local meeting, etc.) help you find the collaboration with industry/or university? • How you initiate the collaboration with industry/or university?
Patterns of the Collaboration	• What forms of the collaboration do you usually have? (e.g., Joint research project, consulting, training, technology licensing.) • Is the industry-university collaboration prevalent in your province?
Process of the Collaboration	• How do you interact with the university/or industry during the collaboration? (e.g., regular meetings, joint working team, progress report, email, deliverables, etc.) • Have you experienced any challenge in the collaboration process with the university/or industry?
Results of the Collaboration	• What are the general results of the collaboration? (e.g., co-patent, co-publication, new product and services, etc.)
Assessment of the Collaboration	• Do you think that the university-industry collaboration promote the development of innovation in your province?

Table 3.2 shows the six indicators that guided the course of the interview questions. The interview guide can help not only researchers collect data systematically with flexibility but also respondents understand the interview contents. The interview was pursued with the interview protocol and follow-up questions formulated based on the six indicators or special topics. The follow-up questions or probes are open-ended to

obtain detailed information regarding interviewees' experiences of the collaboration with either industry or university, including their attitudes, action, thoughts, or feeling. For example, the following probes were in this study: "what did you do when you faced any conflict and challenge in the collaboration process with the partner?" "How could you manage risks and overcome the difficulty during the collaboration process?" Why do you think that these government policies have an important impact on the development of the collaboration? How do you feel about the government's preferential policies implemented in your province?

All interviews were conducted over a period of three month and the average length of each interview was one hour and thirty minutes. All conversations during the course of the interview were tape-recorded with the interviewees' consent, and later all transcribed.[9] In most case, the communication with the interviewees was in Chinese, but the interviews were also carried out in English occasionally, since some interviewees were able to speak English. Thus, all participants could use either English, Chinese, or both. When interviewees wanted to speak Chinese during the interview, the interview was arranged with a Chinese interpreter.[10] Before the interview, the interpreter was well-informed of all necessary interview procedures and interview questions.

Online research methods have been widely used in all fields of social science and become more established as a legitimate means of data collection and analysis for the

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[9] According to Gorden (1998: 176), tape-recording method has some advantages: "1) avoid the danger of omitting relevant points of the interview; 2) preserve all of the audible non-verbal cues; 3) free the interviewer from the distracting note-taking task, and 4) store not only the responses but also the interviewer's questions and probes complete with the audible nonverbal cues." This assists researchers in interpreting and analyzing the meaning and judging the validity of the answers. A total transcript is very useful for researchers to understand the whole interview processes and responses.
[10] It should be noted that the primary investigator in this research is an English speaker.

social science research over the last decade (Mann and Stewart 2000; Hine 2005 and 2008; Dillman 2007; O'Connor et al. 2008; Tran 2009). The forms of such methods include online survey (e.g., Web and email), online asynchronous interviews (e.g., email), and online synchronous Interview (e.g., instant message and video and telephone conferencing through online communication software such as MSN messenger and Skype). Especially, online interviewing is considered as a useful qualitative research method, extending access to groups and individuals who are geographically dispersed or difficult to reach, with great travel cost and time savings (O'Connor et al. 2008).

In general, the characteristics of online interviews are asynchronous or synchronous, public or semi-private (Mann and Stewart 2002). Email is most often employed as the asynchronous and semi-private interview (Mann and Stewart 2002; Kivits 2005; Meho 2005; James and Busher 2006). It is conducted in non-real time with text messages being written and read at different time and places. There are several advantages to using an email interview. First, the use of email in research can reduce the cost of time allowing researchers to interview more than one participant at a time. It is also useful for researchers to save the time of transcribing in that data from email interviews can be created in electronic format requiring little editing and formatting before the analysis (Meho 2006). In addition, interviewee can answer the questions with considerable time at their own convenience. Responses, therefore, are more likely to "produce a 'socially desirable' answer, rather than a more spontaneous response which can be generated through synchronous interviews or more traditional face to face interviews" (O'Connor et al. 2008: 273).

While email interviewing has enabled interviewees to have independent and flexible time and place to answer the interview questions, this also poses the risks that interviewees may take a longer time to finish their answers. For example, interviewees may lose their interests in the research and forget to reply the questions (Kivits 2005). Another disadvantage of the email interview is the lack of social cues available in face-to-face interview, such as facial expression, tone of voice, and body language (Kazmer and Xie 2008). Especially, the lack of social cues may result in some cultural and language barriers, while carrying out the interviews in a foreign language (Elron and Vigoda 2003). However, email interviewing is a very useful method when the interviewer is not fluent in a foreign language for face-to-face interview, since online translating is widely available and very helpful for conducting these interviews.

Online synchronous interviews have been facilitated through online communication software such as instant messenger. Access to the software would be arranged by interviewer and download and installed by the participants. Synchronous interviews of this type can be real-time and semi-private communication as same as traditional onsite interviews. It can be conducted through instant messaging and video and audio conferencing. The important advantage of the synchronous interview is the ad hoc conversational nature of the exchanges and interactions which can generate more spontaneous and honest answers (O'Connor et al. 2008). In addition, using and developing probes during the interviews can be easier than asynchronous interviews such as email, since the interviewer can know how respondents express themselves in either writing or speaking (Kazmer and Xie 2008). Like asynchronous interviews, interviews can be automatically recorded as the text or audio format, so that researchers can create transcripts easily.

A downside of the synchronous online interviews is the lacks of social cues available in face-to-face conversation (Tran 2009). However, limited social cues such as voice and intonation can be still available. In addition, online synchronous interviews require more complicated computer and network settings than a basic email interview (O'Connor et al. 2008). Technology problem also can occur during the course of the interview, accompanying by the disconnection, loss of data, etc.

In the present study, online in-depth interviews through email and Skype are employed as the qualitative research methods. Email interviews were initially conducted and followed by the Skype-telephone-interview and another set of email interviews for subsequent questions. Skype is one kind of online communication software, "available for free download, that provides its users with a range of communication options for research, including connecting with other Skype users, phoning landlines or mobile phones, as well as providing messaging and file transfer capabilities" (Saumure and Given 2010:1). Thus, it provides researchers with the opportunity to conduct inexpensive and geographically flexible interview. Wide geographical access with least costs would be a key benefit of Skype in that people from all over the world can be interviewed, if they have either telephone or computer.

Online interview through Skype was carried out, making computer-to-telephone calls. Researcher employed the functions of the audio-recording of conversation and telephone conferencing provided by the Skype. Online interviews using Skype were an ideal research tool for this research to interview geographically disparate research participants.[11] Through the telephone conferencing using Skype, interpreter, respondents, and interviewer could have synchronous communication of time and asynchronous communication of place.

Email interviews were designed and conducted before and after the Skype interviews.[12] Online, asynchronous, in-depth interviewing can also be feasible via email which is different from the web-based survey (Murray and Sixsmith 1998; Curasi 2001; James and Busher 2006; Kazmer and Xie 2008). Unlike email surveys, email interviewing is generally semi-structured "involving multiple email exchanges between the interviewer and interviewee over an extended period of time" (Meho 2006: 1284). However, direct probing is only allowed in follow-up email, which can take place anytime at the stages of data collection and analysis.

Therefore, prior to the Skype interview, email interviews were pursued using both closed and open-ended questions for the interview indicators. Based on the respondents' answers, more intensive in-depth interview with the open-ended questions was carried out through telephone conferencing. Subsequently, additional probes or new questions emerged after the Skype interviews were asked by interviewer via email in order to clarify participants' responses as well as elicit addition information and depth.

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[11] In the present study, the primary researcher was living in the U.S. and the interviewees resided in different Chinese cities and provinces.

[12] In this study, four interviewees had both email and Skype interviews and two interviewees had only email interview and follow-up question and answer (Q&A) email.

CHAPTER 4

THE REGIONAL INNOVATION ACTIVITIES IN CHINA: TRENDS AND DISTRIBUTIONS

Chapter Four aims to explore the trends and distributions of regional innovation activities in China from 1998 to 2007. While the development of the innovation system appears promising at the aggregate level in the country, a breakdown by regions reveals that there is a substantial disparity in the levels of regional innovation activity. In order to systematically compare and examine science, technology and innovation capabilities between regions, the present study selects China's 30 administrative provincial-level regions with different geographical, cultural, and socioeconomic features as the unit of analysis. Through the regional comparison of innovation activities, the characteristics as well as current status of the regional innovation systems in China will be presented.

4.1 The Unit of Analysis

Within the RIS approach, the scale of the regional innovation is variously applied to territories and jurisdictions which possess distinctive supra-regional or sub-national administrative, cultural, political, or economic homogeneity (Cooke 2001; Asheim and Isaken 2002; Cumbers et al. 2003; Doloreux 2004; Leydesdorff and Fritsch 2006; Todtling and Traipple 2007; Asheim 2007). For instance, the RISs can occur within metropolitan areas (e.g., diverse cities), major sub-national administrative units (e.g., provinces, states, departments, or counties), and small-scale industrial districts. The diverse scales of the RIS are characterized by specific local institutional structures and cultural traditions that promote and regulate innovation activities within a region.

As most aggregate levels, administrative regions have been employed to capture distinct and coherent patterns of regional innovation activities at a sub-national scale (Wonjnicka et al. 2002; Doloreux 2004; Niosi 2005; Arvanitis and Jastrabsky 2006). The administrative areas, such as provinces, municipal cities, or autonomous regions, "could represent a more homogeneous and appropriate unit of observation for representing the context-specific nature of innovation activities" (Evangelista et al. 2001: 735). In the context of China, administrative regions are considered as the suitable scale to examine the regional innovation systems based on the following considerations.

First, since China had been under a centrally planned economic regime, the policy implementation, project planning and execution, and the assessment of social, economic, or technological development were carried out on the basis of the administrative regions for a long time. In some cases, the RIS have evolved over time within the vigorous economic development zones in China (e.g., Bo-Hai rim, the Yangtze River Delta, and the Pearl River Delta) which is either an area across provinces or an area across administration within a province. However, as most regional S&T policies and programmes have been designed, implemented, and assessed within administrative areas, China's regional innovation systems tend to be restricted by the administrative partition of areas, such as provinces and municipal cities.

Second, administrative areas, such as provinces and municipal cities, are administratively and economically independent geographical regions in China, while they are all subject to the same legal and political systems that are controlled and operationalized by the central government. Since the economic reform, 'bureaucratic decentralization' has increases the autonomy of provincial-level governments in initiating and implementing its own economic and social development policies (Liu and White 2001a; Guan and Liu 2005; Gu and Lundvall 2006). While there are still central policies that have affected all parts of China, each region can set its own governance rules. Accordingly, the S&T policies and innovation plans formulated at the regional level, to some extent, reflect distinct regional features.

In addition, the relative autonomy given to provincial-level governments under the economic reforms has resulted in the emergence of regional protectionism which restricts China's regional innovation systems by the administrative partition of areas. The reform of fiscal decentralization provides a strong incentive for the regional authorities to maximize their tax revenues and protect local industries from interregional competition by imposing obstacles to the inward trade of goods and services from other regions or countries (Bai et al. 2004). In a similar manner, the protectionism perspective has also been adopted by regional policy makers in launching and implementing their own S&T policies.[13] The trend of regional protectionism, in turn, has ended up enforcing a degree of "inward orientation" among most China's provincial-level regions.

Lastly, each administrative region can be distinguished by its own unique historical, cultural, and geographic features. People residing within the region share the dialect, customs and local cultures which connote distinctive regional characteristics. Thus, it can be argued that local tacit knowledge and social capital are locally embedded and affect evolutionary process of innovation within a region (Li 2009). In addition,

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[13] In China, regional protectionism has been considered as one of the major problems in building a fully developed and integrated NIS. It not only impedes an effective knowledge or technology transfer through cross-region collaboration but also results in inefficient allocation and use of the innovation resources among regions, creating problems such as repetitive establishment of S&T programs, scattered allocation and waste of resources (Chen and Wang 2003; Hui 2007)

since labor mobility had been restricted between administrative regions due to the strict regulation on registered permanent residence (*hukou* system),[14] social capital tended to be accumulated and developed within, rather than between the regions. Although this regulation has been lightened in recent years, local knowledge and social networks developed in the past are still closely tied to the region and can be accessed within a particular region.

Based on the above considerations, the present study adopts administrative areas as the unit of analysis, selecting 30 provincial-level regions of China.[15] Given the high degree of internal cohesions at the provincial-level, it would be reasonable to regard regions as relatively independent innovation systems. Thus, each region that constitutes the part of China's national innovation system is scrutinized to understand the sources of differences in innovation capacities. The innovative activities of the administrative unit could reveal some characteristics and dynamics of China's innovation system.

4.2 The Trends and Distributions of Regional Innovation Activities in China

4.2.1. Rapid Growth of Innovation Activities

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[14] A *hukou*, a system of residency permits, was enforced by the laws of the PRC beginning in 1958 to control population movement as well as mass urbanization. "The Communist government pursued an extremely strict household registration system that successfully prevented rural residents from entering the cities" (Lu 1999: 360). Because the *hukou* system has imposed limits on ordinary Chinese citizens changing their permanent place of residence, people could hardly work or live outside their registered permanent residence. However, this strict regulation has gradually moderated since the economic reform.

[15] In this study, administrative areas refer to provinces, municipal cities, and autonomous regions. Hong Kong, Macao, Taiwan, and Tibet are excluded in the analysis, because they differ in their social, economic, and political conditions from most of other regions. In the reminder of the dissertation, the terms "region" indicates the administrative units and it would not make distinctions between provinces, municipalities, and autonomous regions.

The regional innovation systems constitute the important parts of the national innovation system and function as the springboards for developing indigenous technological innovation. In China, the regional dimension of innovation has been crucial for growth through the market-oriented reform in S&T and economic system as well as the reforms of bureaucratic and fiscal decentralization. Along with a notable growth of China's overall regional economy, regional innovation activities have made considerable progress. Especially, the fast growing high-tech industrial parks and small and medium-sized enterprises (SMEs), technology markets, and regional S&T investments have shaped the new S&T landscape as a platform for building regional innovation systems and developing regional innovation capacities.

High-tech parks have been an important technology and innovation hubs for the country, boosting regional innovation capacities and stimulating regional economic development as well. Since the reforms of the early 1980s, S&T parks, university science parks, and technology business incubators were launched under the Torch Programme as new S&T infrastructures to promote industry-science relationships and many spin-offs from GRIs. National high-tech industrial development zones known as S&T parks have been rigorously established by provincial governments for the development of high-tech industrial clusters. Most of them built in close proximity to universities and public research institutes in order to strengthen the linkage between universities/research institutes and private sectors. The efforts of regional government on building up the S&T infrastructure and supporting institutions for the high-tech industrial zones served as incubation bases for new high tech enterprises.

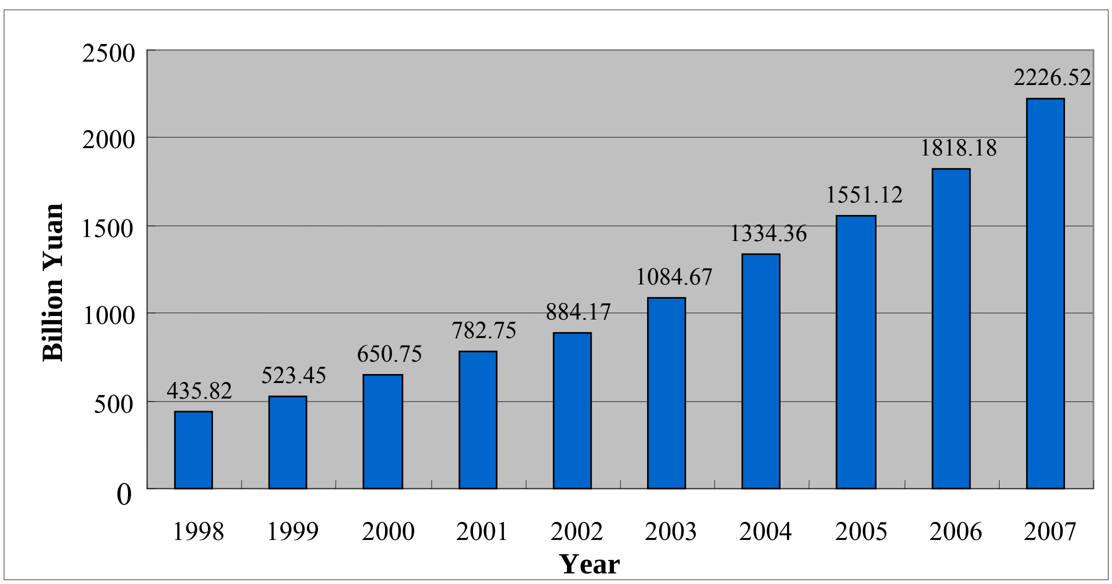
One of the most successful cases is Zhongguancun Science Park, which is home to the prestigious universities, such as Tsinghua University and Peking University, and many research institutes of the Chinese Academy of Science (CAS). They have been the incubator of Chinese domestic spin-offs in the IT industry, including Lenova, Stone Group, Beida, and so on. This paves the way to promote the collaborative interaction between industry and universities/research institutes and industrial innovation found to be positively related to the linkage between them (Guan et al. 2005). However, it is also observed that not all S&T parks and spin-offs have been successful. For example, the lack of institutional support and venture capital, unclear ownership and the dominant role of government become the factors that obstruct the development of the western notion of S&T parks (Cao 2004).

Table 4.1 Development of S&T Parks and Enterprises Incubators 2000-2007

	2000	2001	2002	2003	2004	2005	2006	2007
Number of Enterprises in S&T Parks	20,796	24,293	28,338	32,857	38,565	41,990	45,828	48,472
Gross Output Value of High-Tech Firms (RMB 100Million)	7,942	10,117	12,937	17,257	22,639	28,958	35,899	44,377
Number of S&T Enterprises Incubators	164	324	378	431	464	534	548	614

Source: MOST (2001b-2008b)
Note: Total number of S&T enterprises incubators includes all kinds of incubators, including enterprise start-up centers and enterprise start-up parks of students studying abroad.

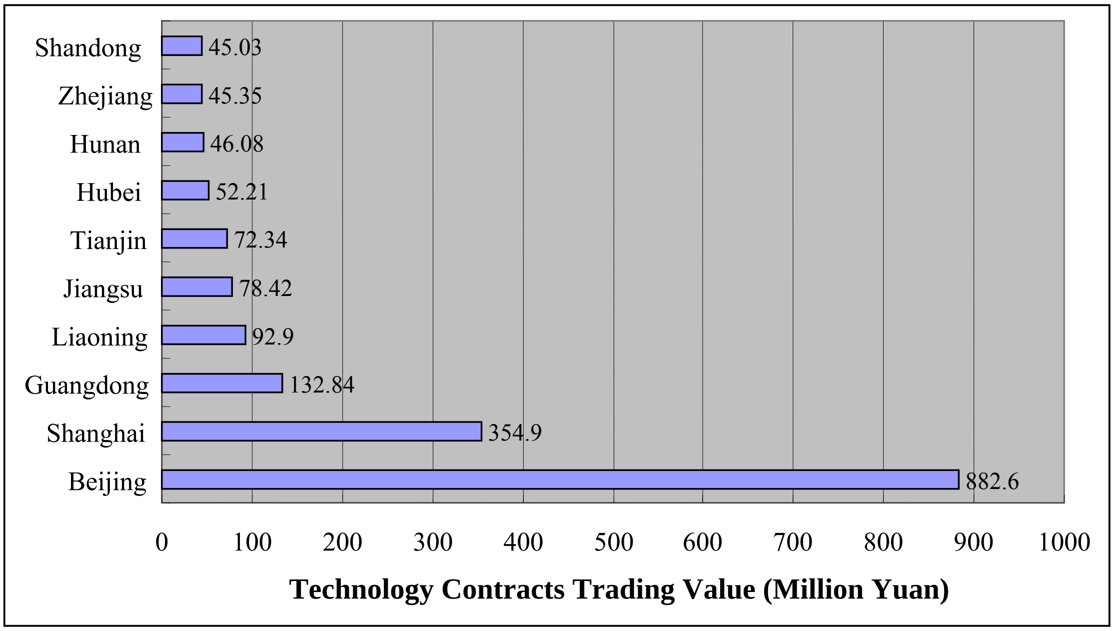
According to the statistics of the MOST, in 2007 there were 54 national S&T parks in China and the number of high-tech enterprises in the S&T parks has been growing rapidly, as shown in Table 4.1. The number of S&T enterprises incubators in China reached 614 in 2007, which increased fourfold since 2000. S&T parks have become an engine of regional economic growth, providing high-paying jobs and renovating old manufacturing industries. In 2007, high-tech parks hired 6,502,370 employees and industrial added values of nearly 20 high-tech parks accounted for more than 37% of the total industrial added values in their own regions. From 2000 to 2007, gross output value of high-tech industries increased from 7,942 million (one billion US dollars) Yuan to 44,377 million Yuan (six billion in US dollars). The leading regions in the high-tech industry are the provinces of Bo-Hai rim (e.g., Beijing, Shangdong, and Tianjin), Yangtze River Delta (e.g., Shanghai, Jiangsu, and Zhejiang), and Pearl River Delta (e.g., Guangdong). These provinces located on the east-coast have been recognized as the main drivers of China's economic growth. In 2007 they produced 66 percent of total national high-tech outputs.



Source: NBS (2008b)

Figure 4.1 Value of Technology Contracts in China 1998-2007

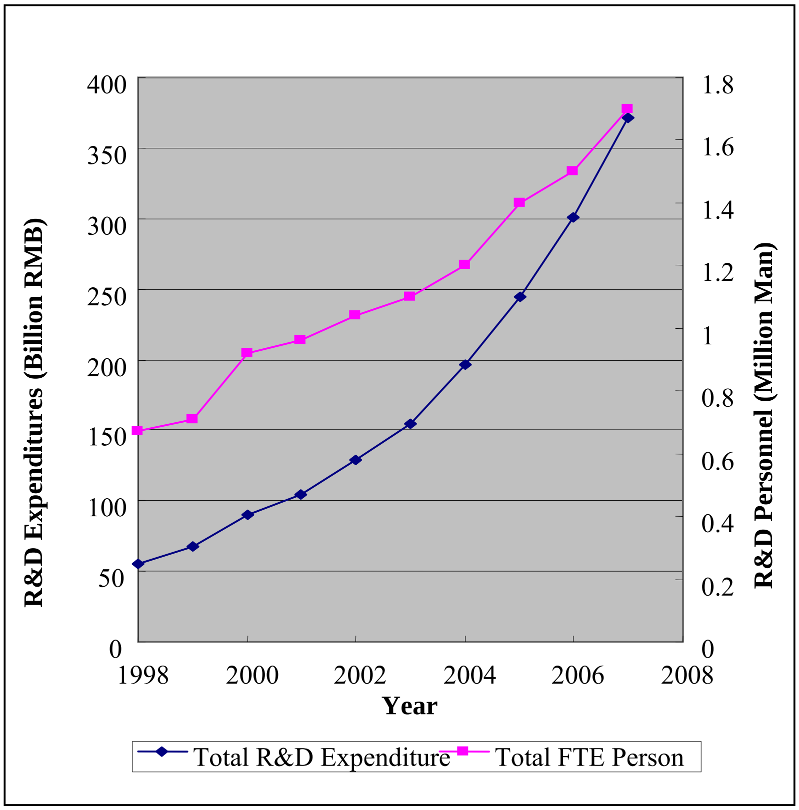
Driven by increasing technology demands, the markets for technology has been developing rapidly and becoming more activated. Since the reform of China's S&T system in the early 1980's, the technology market has been considered as a diffusion mechanism to promote the technology transfer between organizations or between technology producer and users. The size of the technology market grows more than 5 times from 1998 to 2007. The large and fast-growing domestic market can not only stimulate Chinese domestic firms to engage in developing new technologies to meet domestic demand, but also give them an access to advanced foreign technology and products. According to the statistics of the MOST, 220,868 technology contracts were signed in 2007 and its trading value reached 2,226.5 billion Yuan, increased by 18.33%, compared with 2006 (see Figure 4.1). Contract values have increased sharply over the last decade, reflecting that S&T transfer has been reinforced across the country. The fast growing domestic technology market, therefore, has resulted in productivity growth at the regional levels in China (Men and Motohashi 2005).



Source: NBS (2008b)

Figure 4.2 Top Ten Provinces of Technology Contracts Value 2007

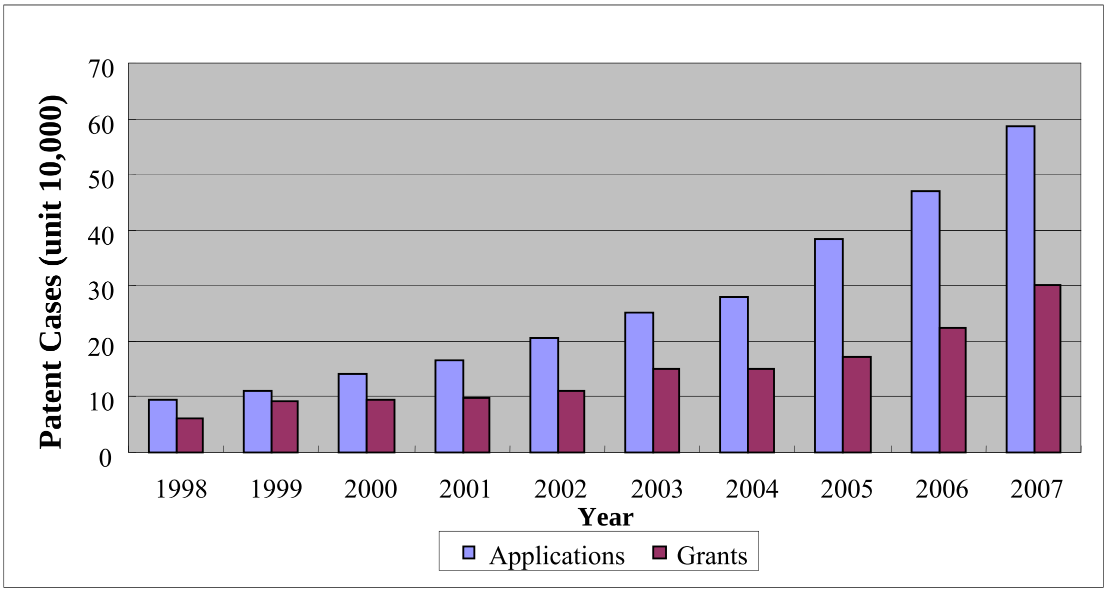
In 2007, top provinces on the technology contracts trading value are Beijing, Shanghai, Guangdong, Liaoning, Jiangsu, Tianjin, Hubei, Hunan, Zhejiang, and Shandong, as shown in Figure 4.2. Beijing has long been the major operation locus for the active technology market, which not only catalyzes the technology market in the country, but also shapes the competitive edge for the regional economy and S&T development. Except for two provinces, such as Hebei and Hunan, most top provinces lie on the east-coast, which have relatively well-established markets as the national platforms for S&T transfer and development.



Source: MOST (2008a)

Figure 4.3 The Trend of R&D Activities from 1998 to 2007

In addition, there was an overall increase in R&D and innovation activities in most parts of China. China's R&D spending has increased from 55.1 billion Yuan a year in 1998 to about 371 billion Yuan in 2007 (see Figure 4.3). The R&D spending as a share of GDP has more than doubled in a decade and reached 1.6% in 2008 compared to only 0.7% in 1998. Beyond the increased expenditure of R&D, the total number of FTE R&D personnel also has increased by double. In 2007, the country had 1.7 million people devoted to R&D—the number of its R&D scientists and engineers with a higher educational requirement reached 1.42 million people. China has ranked second after the United States in the number of R&D personnel (OECD 2007). However, despite the development in the human and financial capitals devoted to R&D activities, the question is raised in terms of the efficiency of China's R&D system. The output of scientific and technical publications and patents is not in proportion with the increase in the R&D inputs, and the output per unit of R&D input in China lags significantly behind the advanced economies (Zeng and Wang 2007).



Source: NBS (2008b)

Figure 4.4 Patent Applications and Grants from 1998 to 2007

Table 4.2 The Growth of Patent Applications and Grants by Regions

	Eastern Region			Central Region			Western Region		
	1998	2003	2007	1998	2003	2007	1998	2003	2007
Patent Grant	38,076	104,869	221,160	9,601	17,514	33,933	7,317	14,297	28,611
Growth Rate	-	175%	480%	-	82%	253%	-	95%	291%
Patent Application	57,997	171,874	441,154	17,485	34,042	68,969	12,109	25,376	50,941
Growth Rate	-	196%	660%	-	94%	294%	-	109%	320%

Source: NBS (2008b)
Note: Growth rate is calculated for 1998-2003 and 1998-2007

Aside from R&D inputs, its outputs have remarkably risen over the last decade especially in terms of patent registration. The patenting activity in terms of patent applications and grants has increased significantly across China's regions in 1998-2007. As shown in Figure 4.4, the number of patent applications rose from 96,000 in 1998 to 586,000 in 2007, while that of patent grants grew 5 times higher during the same period. According to Table 4.2, there has been the large growth of patenting activity in all parts of China—eastern, central, and western region.[16] The number of domestic patent applications in East China increased by seven times from 57,997 in 1998 to 441,154 in 2007.

In fact, domestic inventors in the east coastal region had produced the highest proportion of total patent applications and grants in the country. During 1998-2007, the eastern region accounted for over two thirds of the total patent applications and grants. Especially, they had the largest increase in patent production, achieving 480 percent growth rate of patent grant (see Table 4.2). While the number of patent application rose steeply, the eastern region increased its share of total domestic patents from 69% in 1998 to 79% in 2007. The six east coastal provinces and municipalities, consisting of Beijing, Shanghai, Jiangsu, Zhejiang, Guangdong, and Shandong, represent as major producers,

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[16] In general, the 31 province-level regions of China under direct guidance of the central government are geographically categorized into three zones: the eastern, the central and the western zones. In terms of the levels of economic development, the eastern region is the most advanced, followed by the central region and finally by the underdeveloped western region. The eastern region includes 12 provinces and municipal cities: Beijing, Shanghai, Tianjin, Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangxi, Guangdong, and Hainan. The central region consists of the nine provinces: Shanxi, Neimenggu, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan. The 10 provinces and autonomous regions of the western zone include Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. Figure A.1 in the Appendix A shows the map of the regional division of China with further information.

making up of more than half of the total patent grants. In contrast, both central and western regions together explain only 20%.

Although the central and western provinces underwent nearly four-fold increases in the number of domestic patent applications and grants, its share dropped over time. For example, the central region accounted for about 12.4% of the total patent grants in 2007 which decreased from 18.4% in 1998, while its share of domestic patent applications also dropped from 20% to 12.3% at the same time. The shares of both patent application and grants from the western provinces were less than 14% in the same years. This is because the eastern region experienced much greater rises in patent activities than other two regions during the same period. The growth rate of patent activities in the eastern region was three times higher than that in other regions from 1998 to 2007, as shown in Table 4.2. This exhibits not only the rapid growth of regional patenting in China, but also the high degree of geographical agglomeration in innovation activities in few developed regions. In other words, China has achieved rapid but highly unequal growth in innovation activities.

4.2.2. The Characteristics and Capacities of the Regional Innovation Systems

The most noteworthy feature of Chinese regional innovation systems is an increasing variation in the level of science, technology, and innovation capabilities. There exist significant inequalities in the development of S&T and economy among regions in China. During the past two decades of the reform, the capacity to generate and utilize scientific and technological knowledge has been unevenly distributed and highly concentrated in a few developed regions. This has created a ‘knowledge divide’ particularly between the east coastal regions in which knowledge is tightly intertwined with economic production as well as consumption, and the other parts of China in which traditional knowledge, techniques and products play a major role.

While knowledge advancement has stimulated aggregate regional economic growth, the increasing returns and competitiveness gains from the production of knowledge and technological innovation benefit only a few developed regions in China. Those regions could have successfully managed to build science, technology, and innovation capacities in the post-reform China, whereas others have not even had enough human resources, institutional, financial and physical infrastructures to support the capacity-building. As a result, widening regional knowledge disparities can reinforce the long-term trend of China's regional inequality, such as the 'East-West divide,' by increasing the gap in the level of development and the standard of living between the regions.

Table 4.3 Economic Disparity and Knowledge Divide in China (2007)

	(A) East-Coastal Regions	(B) Central Regions	(C) Western Regions	Ratio (A)/(B)	Ratio (A)/(C)
Per Capita GDP (Yuan)	401,614	151,587	127,975	2.65	3.14
Per Capita Annual Income of Urban Households (Yuan)	193,579	103,644	109,219	1.87	1.8
Population with High Educational Attainment (person)	38,122	22,976	12081	1.66	3.16
R&D intensity (gross domestic expenditure on R&D as % of GDP)	1.59	0.82	0.84	1.94	1.89
Scientific Papers taken by Foreign Referencing System (piece)	112,993	37,350	21,405	3.02	5.28
Patents Granted (piece)	221,160	33,933	28,611	6.52	7.73
Gross Industrial Output from High-Tech Industries (10,000 Yuan)	1,807,463,214	483,018,530	313,659,349	3.74	5.76

Sources: NBS (2008a and 2008b).

Table 4.3 provides a snapshot of the striking disparities between east-coastal, central and western regions of China in their capacities to generate scientific knowledge, to develop new technologies, and to produce high-tech goods and services. Evidently, a huge gap of science, technology, innovation capacity exists between eastern regions and other two parts of China. In 2007, R&D intensity is nearly twice higher in most eastern provinces than in central and western counterparts. The disparity in gross domestic expenditure on R&D (GERD)/GDP ratio between highest eastern province (Beijing) and lowest western province (Xinjiang) was even more than 10 times.

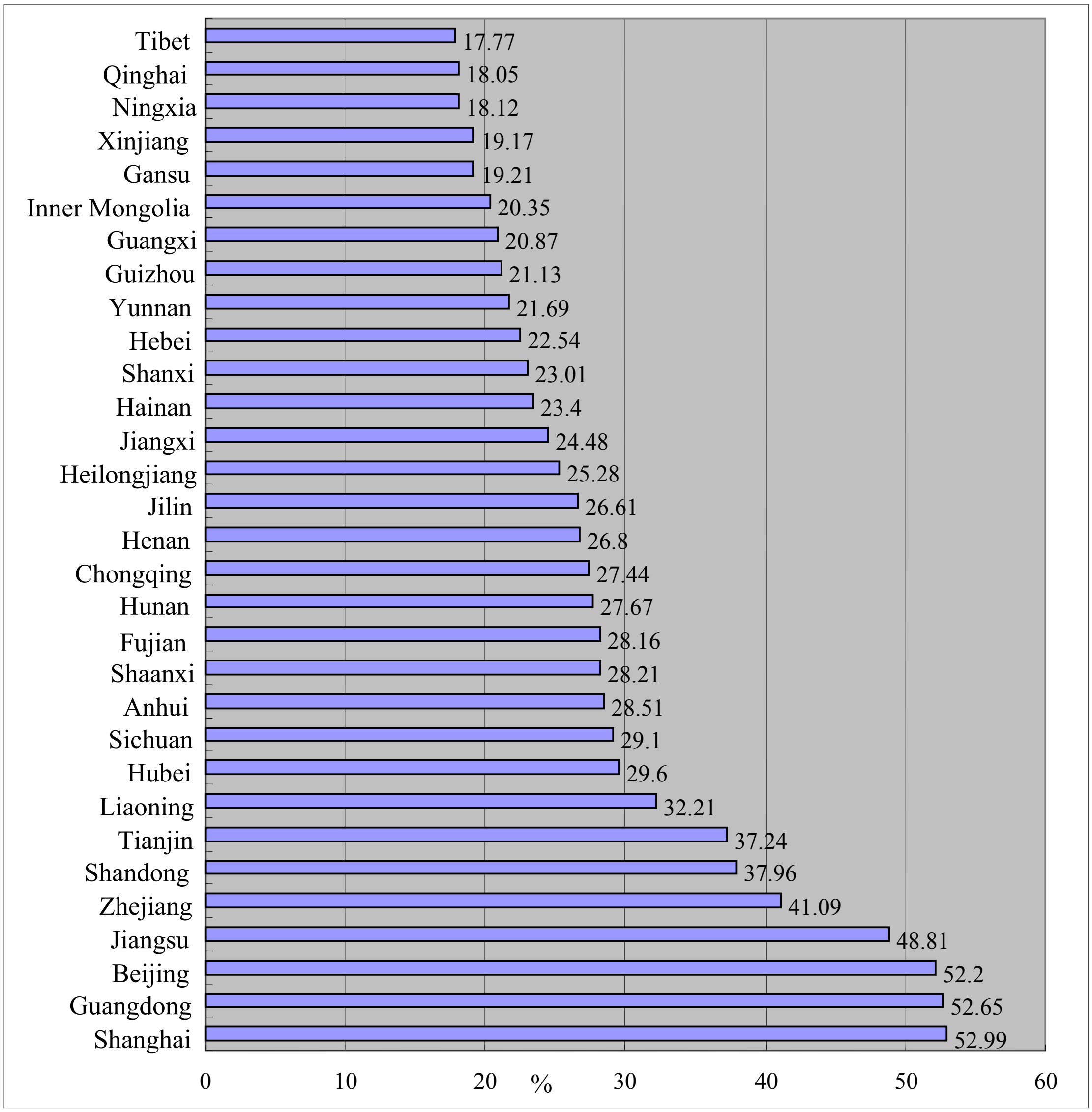
From Table 4.3, it can be noted that the regional pattern of such a disparity runs parallel to that of economic inequality, in the way that the regions with the advanced levels of income and economic development exhibit stronger science, technology, and innovation capacities. The eastern regions have been a geographically strategic location of economic development in the post-reform China because of a traditionally well-developed infrastructure and economic base as well as a readily accessible geographic location. Some scholars suggest that eastern China historically had been more developed than interior areas due both to differences in region-specific production resources, and over a century of foreign colonial influence before 1949 (Lu and Wang 2002). As contrasted to the east-coastal regions, the inland ones have inferior ecological conditions and also more remote that has obstructed economic development and limited their accessibility to both domestic and international markets. Also, the lack of hometown connections of overseas Chinese becomes a critical disadvantage in attracting the FDI in the inland areas (Song et al. 2000).[17] As a result, productive resources, such as S&T, domestic bank loans, international trade, and foreign investment, have mainly concentrated in those regions, and central and western region's economic development becomes relatively backward.

The coastal regions in East China have played a leading role in the rapid growth of the China's GDP since the economic reform—the GDP per capita in 2007 was 401,604 Yuan, nearly three times higher than that of both central and western regions (see Table 4.3). Also, the income level of east coastal region almost doubled that of other two regions. Regional innovativeness, however, seems to be highly correlated to the level of

[17] For historical and geographic reasons, most overseas Chinese have origins in the coastal areas that have made a contribution in bring a massive inflow of capital and new technologies from overseas, especially Hong Kong and Taiwan. This makes the economy in the eastern coastal region develop faster, leading to larger economic disparities between the coastal and inland regions.

regional economic development. In sum, while the east coastal region has benefited most from economic reforms in constructing its innovation systems, the other parts of China have lagged far behind in growth of innovation activities (Liu and White 2001a).

Regional differences in the development of science, technology and innovation capabilities appear much larger than economic disparity. In 2007, the distribution of the innovation outputs, such as scientific publications and patent grants, shows a high degree of concentration of capabilities to generate knowledge and technology in more developed regions. According to Table 4.3, the ratios of scientific publications in international journals (e.g., SCI, EI, and ISTP) in the east coastal regions to that of the central and western regions were 3.02 and 5.28 respectively. The ratios between patent grants were 6.52 and 7.73, while those of gross industrial outputs of high-tech industries were 3.74 and 5.76 respectively.



Source: Research Group on Development and Strategy of S&T of China (2008)
Note: Based on five keys indicators—knowledge creation, knowledge acquisition, enterprise innovation, innovation environment, and innovation performance—overall regional innovation capacity was assessed nationwide in 2008.

Figure 4.5 Overall Index of Chinese Regional Innovation Capacity in 2008

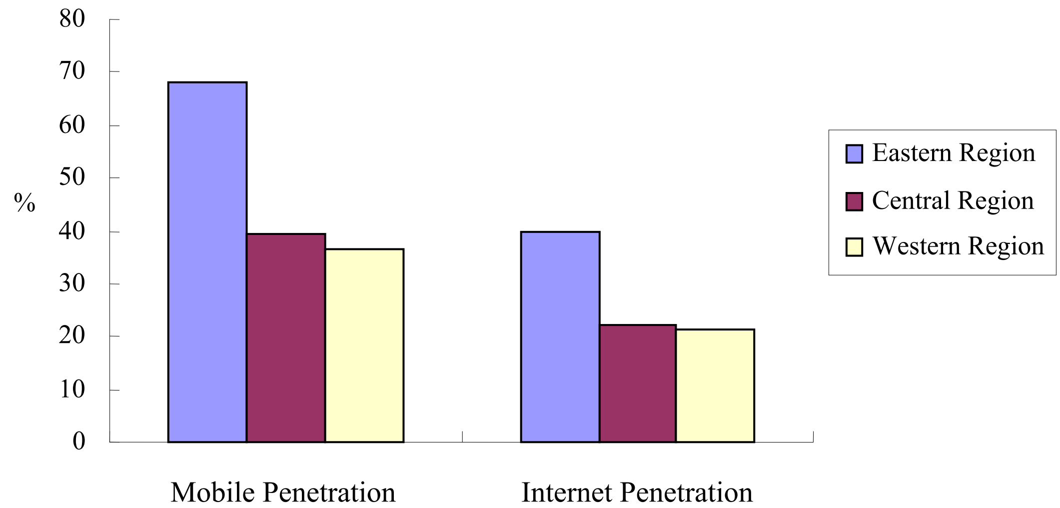
On the whole, the capacity of China's regional innovation systems exhibits a ladder-like structure from the east to the west, as shown in Figure 4.5. The innovation capacities of coastal regions in East China are more developed than that of the central region; the central region is in turn has a higher capacity than the western inland area.

Among top eight provinces and municipalities with the highest innovation capacity were all located on the eastern coasts in 2008, including Shanghai, Guangdong, Beijing, Jiangsu, Zhejiang, Shandong, Tianjin, and Liaoning. The list of those eight provinces with the highest innovation capacity did not change significantly over the years, because of the establishment of a more flexible innovation system and well-functioning market economy, making enterprises the main center of technological innovation in the region. Beijing and Shanghai take a leading position in knowledge production and innovation environment, while Guangdong province shows the strength in innovation performance and enterprise innovation (Research Group on Development and Strategy of S&T of China 2008). Guangdong, Zhejiang, Shandong and Jiangsu, have the high degree of market-driven industrial clusters which serve as the foundation or building block of the regional innovation system. Those provinces are the main destinations of heavy FDI in China and have local support, new material and knowledge infrastructure. Noticeably, enterprise innovation has been vigorously activated in those regions.

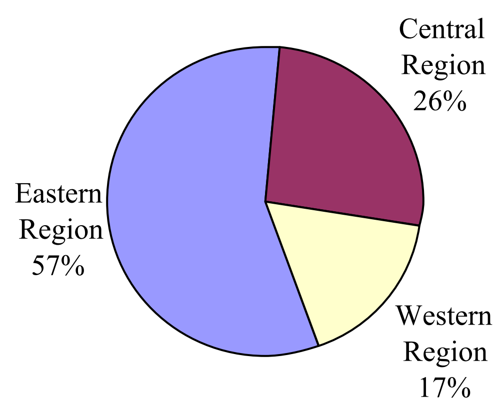
Most provinces in the central region rank in the middle, whereas the western inland areas rank bottom in the overall level of innovation capacity. Although the western provinces of Sichuan and Shaanxi show dynamic R&D activities with several high ranking universities and government research institutions, other western areas are mostly limited to the peripheral regions with an absence of innovation activities. The list of the five western provinces—Tibet, Qinghai, Gansu, Ningxia, and Xinjiang—with the lowest innovation capacity was almost stable over the years. They are mostly remote inland regions of China which have almost none of FDI and weak local R&D capabilities. The gap of regional innovation capacity between the eastern and western regions is quite large in many aspects of innovation.

Access to knowledge and information, beside the capacity to produce and utilize it, has become essential in the process of building science, technology, and innovation capabilities. Disparities in access to ICTs, such as Internet, telephone, mobile phone, and personal computer, cause a new form of socio-economic inequality between the technology haves and the technology have-nots. A number of studies have confirmed the existence of significant digital gaps in terms of the ICT penetration and usage between eastern and western regions or between urban and rural areas in China for over a decade (Meng and Li 2002; Wensheng 2002; Harwit 2004; Sun and Wang 2005; Jing 2006; Wei-xian and Tao-feng 2006; Zhu 2006; Harwit 2008; Song 2008; Wei-xian 2008; Miller et al. 2009). In fact, digital divide reflects a significant feature of the social structure of Chinese society—structured socio-economic inequality not only between regions and between urban and rural areas, but also between social segments with different socio-economic status (e.g., income and education) (Cartier et al. 2005; Chen et al. 2009; Guo and Chen 2011).

Between 2000 and 2009, the number of Internet users increased from 22 million to 384 million in China, while that of mobile phone users increased from 84 million to 786 million (China Internet Network Information Center (CNNIC) 2010; Ministry of Industry and Information Technology of the People's Republic of China (MIIT) 2010). Despite the rapid development of information infrastructure with the high rates of growth in the number of ICTs users, a 'digital divide' exists between the regions and the gap seems to widen over the years. The accessibility to ICTs is also found to be positively correlated to the level of regional economy development. The east provinces with higher GDP per capita tend to have a better access to Internet or mobile phone and higher usage of it.



a. Mobile Phone and Internet Penetration by Region, 2009



b. Percent of Total Internet Users by Region, 2009

Sources: CNNIC (2010) and MIIT (2010).

Figure 4.6 ICTs Penetration Rates and Users by Region

In 2009, the mobile penetration rate was nearly 70 percent in the eastern region while Internet penetration was 40 percent, as shown in Figure 4.6a. However, mobile penetration was just 39.3 percent in central regions and 36.7 percent in western regions, and Internet penetration was around 20 percents in both. The rapid growth of mobile phone users has played a significant role in China's internet development, in that the number of mobile Internet users reached 233 million, accounted for 60.8% of the total number of Internet users (CNNIC 2010). The eastern region has the highest mobile phone users per capita, marking 7.4 per 1,000 persons higher than 4.9 of both central and western regions. With the gradual spread of the 3G mobile phone service in China, it appears that the number of 3G mobile phone users per capita is three times higher in the eastern region. The Figure 4.6b also indicates the digital gap between regions in terms of Internet use, illustrating that almost 60 percent of Chinese Internet users live in the east coastal regions. The number of Internet users per 1,000 persons in eastern and western regions was 4.1 and 2.3, respectively.

All these suggest that there are the large regional disparities in the development of innovation capabilities as well as the ICT infrastructure in China. The difference worsens an already-existent regional economic inequality between East and West China, bringing about social, economic, and political repercussions. More developed eastern region reaps the benefit of increasing returns to scale from the advancement of scientific knowledge and technological innovation by creating more income, jobs, and economic opportunities. The underdeveloped regions, however, lack the capacity to create, absorb, adapt and utilize knowledge, and the capacity to upgrade traditional knowledge and techniques. Those regions that are poorly equipped with the infrastructure to adopt ICTs and to create knowledge are further disadvantaged because of their inabilities to access the global knowledge economy as well as to compete in the market.

The uneven regional development results in a significant gap in the quality of life, since China faces growing human development disparities between regions. The recent human development index (HDI) for the eastern region is much higher than for the western region; for example, the highest ranking, for Shanghai, was over 40 percent higher than the lowest ranking, in Tibet and Guizhou.[18] The level of human development in Beijing, Shanghai, and other eastern regions was on par with Portugal and other countries with a high HDI, while the low level of the western region was similar to that of some African countries, such as Namibia (United Nations Development Programme (UNDP) 2010). The widening regional inequality, in turn, becomes a threat to social stability as well as sustainability of long-term growth in China (Fan et al. 2011).

This poses a major obstacle to the building of indigenous innovation capabilities, and also highlights the importance of achieving a balanced development in the China's knowledge economy. In this respect, it is important for S&T policy-makers of the regional governments as well as of the central government to find the ways to bridge the knowledge gaps among regional economies and to facilitate harmonious development. This is surely a critical challenge facing China today in its becoming an innovation-oriented nation.

4.2.3. Regional Disparities in the Distribution of Innovation Activities

[18] According to the UNDP (2010), the HDI measures basic dimensions of human life, such as the life expectancy at birth, the adult literacy rate, combined school enrolment ratio at primary, secondary, tertiary level, and GDP per capita.

4.2.3.1 Regional Patenting Activities

During the sample period 1998-2007, the number of domestic patent registration increased sharply, and a surge of domestic patenting reflects growing innovation capabilities of Chinese inventors. The trend of increasing number of registered patents can be attributed to a sharp increase in patent applications as well as a shortened period of patent examination for a patent application to be approved—from around 5 years in 2000 to around 3 or 4 years in 2005, a time lag between patent application and patent grant (Motohashi 2008).

Table 4.4 Distribution of Patent Types within Regions (%)

	Eastern Region			Central Region			Western Region		
	1998	2007	1998-2007	1998	2007	1998-2007	1998	2007	1998-2007
Invention	2.51	9.45	+6.94	3.55	12.1	+8.55	3.99	11.1	+7.11
Utility	47.24	45.33	-1.91	72.98	64.72	-8.26	63.59	51.37	-12.22
Design	50.24	45.22	-5.02	23.48	23.18	-0.3	32.42	37.52	+5.1

Source: NBS (2008b)

In terms of the patent types, there were increases in the proportions of both invention and external design patents, accompanied by a declining proportion in utility model patent between 1998 and 2007. Table 4.4 shows the proportions of different type of patent grants within the eastern, central, and western regions in China. Three types of patent grants, such as invention, utility model, and external design, expose different degree of innovation intensity with regard to economic value, technological significance, and requirement for R&D input. The pattern of regional patenting by different types illustrates the difference in the quality of patenting across regions. Although all three regions experienced increased shares of invention patents between 1998 and 2007, their shares were still low (around 10%), compared to the other two types of patents which belong to less innovative categories. The majority of domestic patent grants are utility model and design: especially, utility model has the largest share of domestic granted patents in China, accounting for nearly half of total patents.

However, there are several explanations for this patenting trend in China. First, utility model and external design patents are relatively easier to obtain and cost less than invention patent. In China, utility model patent application usually takes a 1 year to be approved, which is less than about 3-4 years time lag for invention patent application. Second, due to the fast changing market dynamics, many of Chinese small firms prefer conducting a short-term R&D projects in order to avoid higher R&D costs and to pursue quick pay-offs in a short period (Cao et al. 2009). As a result, a few Chinese enterprises are more likely to file applications for utility model and external design patents rather than for invention patent in order to enable their new products to penetrate the market more quickly and to obtain legal protection at the same time.

It is noteworthy that the east coastal region has the lowest share of invention patent among the three regions, but the largest shares in design patent. For example, Guangdong province, occupying the first rank in terms of total domestic patent, had less than 7% of invention grants but 55% of design grants in 2007. To some extent, this can be explained by huge FDI inflow into the coastal region, which is easier to import foreign product and equipment as the means of access to the foreign technology and know-how (Cheung and Lin 2004). By 2007, Guangdong province was not only the largest recipient of FDI but also one of the top regions that spend most on foreign technology acquisition in China. Since a successful invention often requires higher R&D investment and longer period of time, many Chinese firms tend to spend less money on R&D and depend more on foreign technology imports.

Table 4.5 Spatial Distribution of Domestic Patent Granted, 1998 and 2007

	1998				2007				R	
	All	Invention (%)	Utility (%)	Design (%)	All	Invention (%)	Utility (%)	Design (%)	1998	2007
East	**38,929**	**978**	**18,392**	**19,559**	**223,067**	**21,086**	**101,479**	**100,502**	**1.72**	**1.81**
Beijing	3800	8.13	66.37	25.50	14954	32.26	49.24	18.50	6.84	4.19
Tianjin	1042	4.13	67.75	28.12	5584	20.85	54.85	24.30	2.44	2.29
Hebei	2090	2.68	67.08	30.24	5358	8.62	66.63	24.75	0.71	0.35
Liaoning	3162	4.14	73.97	21.88	9615	12.69	73.17	14.14	1.71	1.02
Shanghai	2334	4.16	52.23	43.62	24481	13.31	39.70	46.99	3.57	6.03
Jiangsu	3787	2.24	60.44	37.31	31770	6.99	40.74	52.27	1.18	1.91
Zhejiang	4470	1.05	44.00	54.94	42069	5.26	38.29	56.45	2.25	3.81
Fujian	2318	0.86	29.72	69.41	7761	4.33	42.82	52.85	1.58	0.99
Shandong	4127	2.20	66.13	31.67	22821	6.29	67.29	26.42	1.05	1.12
Guangdong	10707	0.72	18.60	80.68	56451	6.58	38.33	55.09	3.36	2.74
Guangxi	853	2.23	57.44	40.33	1907	9.86	63.92	26.22	0.41	0.18
Hainan	239	1.26	20.08	78.66	296	17.23	48.31	34.46	0.71	0.16
Central	**10,124**	**359**	**7,388**	**2,377**	**35,246**	**4,226**	**22,749**	**8,271**	**0.52**	**0.40**
Shanxi	644	6.37	68.01	25.62	1992	15.41	63.50	21.08	0.46	0.27
Neimenggu	523	2.29	71.70	26.00	1313	9.14	45.49	45.05	0.50	0.25
Jilin	1051	4.09	69.08	26.83	2855	15.90	68.06	16.04	0.89	0.48
Heilongjiang	1517	3.56	78.58	17.86	4303	15.52	71.55	12.92	0.90	0.52
Anhui	933	2.14	67.63	30.23	3413	9.29	58.69	32.02	0.34	0.26
Jiangxi	765	2.61	59.61	37.78	2069	8.51	63.61	27.89	0.41	0.22
Henan	1803	1.77	76.98	21.24	6998	8.05	64.55	27.41	0.43	0.34
Hubei	1265	5.30	72.81	21.90	6616	13.39	66.51	20.10	0.48	0.53
Hunan	1623	4.31	77.70	17.99	5687	12.92	60.45	26.62	0.56	0.41
West	**5,941**	**237**	**3,778**	**1,926**	**25,391**	**2,869**	**12,691**	**9,831**	**0.47**	**0.40**
Chongqing	612	2.45	59.31	38.24	4994	7.09	50.06	42.85	0.45	0.81
Sichuan	1971	3.40	58.14	38.46	9935	8.30	40.49	51.20	0.52	0.56
Guizhou	418	3.35	60.77	35.89	1727	13.49	64.85	21.66	0.26	0.21
Yunnan	832	5.41	57.33	37.26	2139	17.20	47.55	35.25	0.45	0.22
Shaanxi	1129	5.05	71.74	23.21	3451	21.88	58.94	19.18	0.70	0.42
Gansu	349	5.16	75.93	18.91	1025	17.56	64.00	18.44	0.31	0.18
Qinghai	62	1.61	75.81	22.58	222	12.61	37.84	49.55	0.28	0.18
Ningxia	96	4.17	81.25	14.58	296	10.81	67.57	21.62	0.40	0.22
Xinjiang	462	3.03	72.94	24.03	1534	5.87	67.47	26.66	0.59	0.34
Tibet	10	20.00	10.00	70.00	68	5.88	32.35	61.76	0.09	0.11
National Total	54,994	1,574	29,558	23,862	283,704	28,181	136,919	118,604	1.00	1.00

Sources: NBS (2008b)

Notes: A. The number of domestic patent grants combined individual and non-individual patents granted.

B. R denotes regional patent per capita, relative to the national average. A region with R>1 indicates as performed better in patent production than the national average, and vice versa.

Table 4.5 specifically exhibits the numbers of three types of patent grants in 31 provinces in year 1998 and year 2007, indicating that there has been a large discrepancy in the distribution of domestic patent granted between regions in China. The East China, especially Beijing, Shanghai, Zhejiang, Shandong, and Guangdong dominated granted patents. Those most innovative five provinces made up of 46% of the total patent grants in 1998 and its share increased to 60% in 2007. With regard to invention patent grants, a geographical agglomeration shows a similar pattern. In 2007 the 10 provinces on the east coast, including Guangdong, Zhejiang, Jiangsu, Shanghai, Shandong, Beijing, Liaoning, Fujian, Tianjin, and Hebei accounted for about 75% of the total invention grants with only 25% coming from the rest of the region. Its share of invention patent grants actually increased from 60% in 1998.

In Table 4.5, the R score of east coastal region was increased from 1.72 in 1998 to 1.81 in 2007, whereas that of west and central China was lessened. This suggests that the inequality of innovation capacities between the eastern region and others had expanded during the period. Some provinces and municipal cities, such as Shanghai, Jiangsu, and Zhejiang experienced a substantial increase in R values, while Beijing, Liaoning, Fujian, and Guangdong had a significant drop over time. In 2007, all eastern provinces except for Hebei, Guangxi, and Hainan, performed better in patent registration than the national average, since its R value is greater than one. All provinces in central and west China had R values less than one in both 1998 and 2007, which means that most of those regions maintained the lowest innovation performances in the country during the period. Only Hubei, Chongqing, Sichuan, and Tibet underwent slight increases in R value among central and western provinces. In short, the huge disparities between innovation capabilities of east coastal and other inland regions had not narrowed but rather grew over time. The high degree of concentration in the geographic distribution in East China, in turn, has not changed much during 1998-2007.

Table 4.6 Three Regional Clusters with the Accumulated Number of Invention Patent Grants (1998-2007)

	Provinces (The sum of invention patent granted, 1998-2007)					
First Tier	Beijing	17,231	Jiangsu	5,492	Tianjin	3,305
	Shanghai	10,390	Zhejiang	3,714	Shandong	3,220
	Guangdong	9,119	Liaoning	3,401	Hubei	3,075
Second Tier	Sichuan	2,326	Heilongjiang	1,237	Henan	814
	Shaanxi	2,028	Yunnan	1,115	Chongqing	695
	Jilin	1,530	Hunan	814		
Third Tier	Shanxi	1,132	Gansu	596	Neimenggu	216
	Hebei	846	Guizhou	521	Ningxia	107
	Anhui	828	Guangxi	397	Hainan	102
	Hainan	814	Xinjiang	355	Qinghai	95
	Fujian	803	Jiangxi	308		

Sources: SIPO (1998-2007) and author's calculation
Notes: A. Tibet, Hong Kong, Macao, and Taiwan are excluded from the cluster analysis;
B. Total accumulated number of institutional invention patent grants during the period of 1998-2007[19]

In Table 4.6, 30 provinces and province-level municipalities are classified into the three clusters based on their innovation capacity, ranked from the region with high

[19] In contrast to most developed countries, in China, there are a large number of patents granted to individual or non-institutional assignees. In addition to individual assignees, four types of institutional assignees are mainly classified as follows: firms, university, research institute, and others (e.g., hospital or other types of domestic institutions). In the present study, only institutional patents are employed in the analysis due to the data availability.

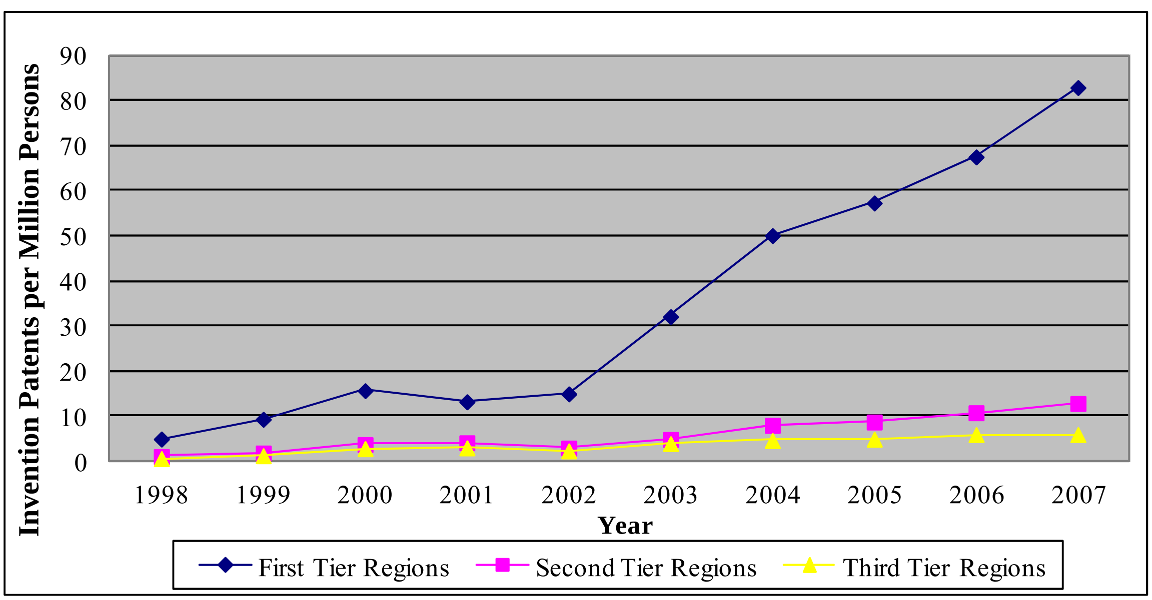
innovation capacity to those with the low one.[20] The first tier, consisting of the three most vigorous economic zones: Bo-Hai rim (e.g., Beijing, Shandong, Liaoning, Tianjin), Yangtze River Delta (e.g., Shanghai, Jiangsu, Zhejiang), and the Pearl River Delta (e.g., Guangdong) in China, represents the high-levels of innovation capacity during 1998-2007. Those provinces in the East Coast are recognized as the main drivers of China's economic growth as well as leading innovators (Research Group on Development and Strategy of S&T of China 2008). The first tier group of provinces benefits from strong government policies support, heavy FDI inflows, concentration of prestigious research universities and public research institutes, well-developed technological market and industrial clusters, and effective RIS in generating, acquiring, and utilizing knowledge (Cheung and Lin 2004; Lai et al. 2005; Zhang and Rogers 2009). Hubei province, as only one central region in this group, has the strong bases of university science parks and higher education system in China, though it has relatively fewer FDI and weaker industrial capabilities that other first tier region.

Second tier region with middle innovation capacity includes the eight provinces from the central and western China. Most of those provinces have old industrial bases and R&D centers developed under the planned economy with a number of high-ranking universities and research institutions. However, compared to the first tier provinces, its regional innovation system is somewhat fragmented and inefficient that is less supportive of innovation activities. For example, Shaanxi and Sichuan have inherited military R&D centers which were built for strategic regions during the Cold War and a large amount of

[20] To more deeply understand differences in the current level of innovation capacity across regions, author undertakes a K-Mean cluster analysis by using the principal component scores from the factor analysis, employing the 2007 data.

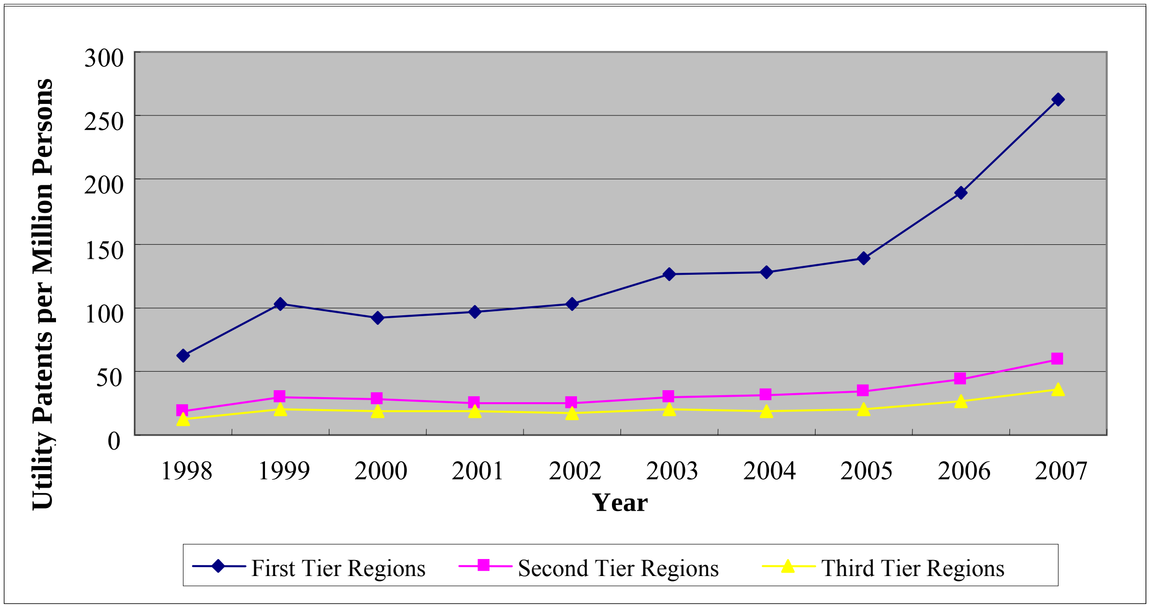
R&D are performed by university and research institutes. After the economic reform, the conversion of military R&D facilities into industrial R&D ones becomes the difficult challenges for these provinces due to the lack of interactions between industry and science sector (OECD 2007).

The third tier group, mostly consisting of underdeveloped inland regions such as Ningxia, Qinghai, and Xinjiang, has relatively low levels of innovation capacity in China. Some coastal provinces with weak local research capabilities are also included in the group. Especially, Fujian and Hainan are large recipients of FDI but perform little R&D activities to get direct benefits from FDI. Fujian ranks in top five provinces in terms of total inflow FDI, but its R&D expenditure and patent productivity lag far behind other coastal regions.



Source: NBS (2008b)

Figure 4.7 Invention Patents per Million Persons, Grouped by Regional Clusters



Source: NBS (2008b)

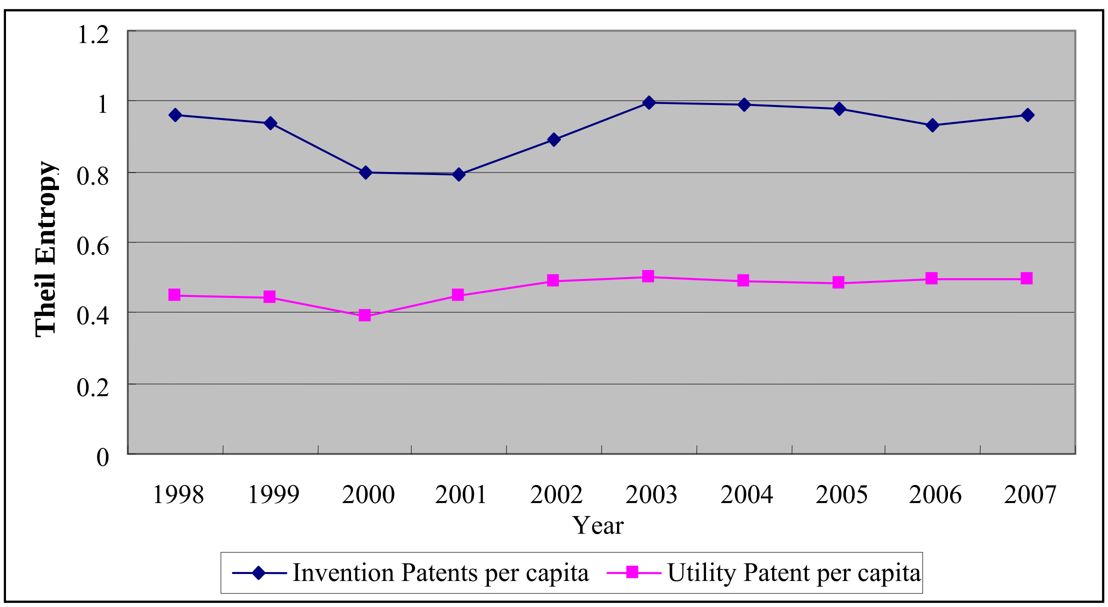
Figure 4.8 Utility Patents per Million Persons, Grouped by Regional Clusters

Figure 4.7 and 4.8 report differences in the intensity of innovation regarding to the production of invention and utility patents per capita by regional clusters. There is a noticeable widening gap between the first tier and other two groups over time. From 1998 to 2007, first tier group of provinces average invention patenting rates increase from less than 10 patents per million persons to approximately 83 patents per million persons. Invention patenting rates of the first tier group surged rapidly starting in 2002, making a significant gap with the second and the third tier groups, as shown in Figure 4.7. Average per capita invention patenting rates for both the second and the third tier groups maintained less than 15 patents per million persons throughout the same period.

The dramatic upsurge in invention patenting can be partly attributed to the second revision of the Chinese patent law in 2000, in that domestic invention patent grants have grown at an annual rate of 20% since then (Zhang 2010). The second amendment to the

Chinese patent laws established full TRIPs compliance in patent regulations that strengthens the IPR protections in line with international norms, and simplified patent application examination procedures. This results in a rapid increase, especially in domestic invention patenting, along with a highly unequal distribution of those patenting activities across the regions of China.

A per capita utility patenting of three regional groups also exhibited the similar patterns of the invention patenting. First tier group average utility patenting rates ranges from a minimum of 63 patents per million persons to a maximum of over 263, while that of other two groups were kept below 60 patents per million persons over the period.



Source: Author's calculation, original data from the NBS (2008b)

Figure 4.9 Inequality of Regional Innovation Capacities, Measured by Invention and Utility Model Patents per Capita

In Figure 4.9, the inequality of regional innovation capabilities is measured in terms of the invention and utility model patents per capita, by using Theil entropy index.[21] For invention patents, the total inequality dropped in 2000 but increased again in 2002 and stabilized for next 4 years. The inequality indicator for utility model patents also slightly decreased in 2000 but went up right after the year and entered a smooth period. Similarly, the total regional inequality for both invention and utility patents experienced decline in 2000 but showed the increased trend of innovation inequality around the country after 2001. Utility model patents seem to be distributed more equally than invention ones during 1998-2007.

<u>4.2.3.2 Regional Science and Technology Activities</u>

From 1998 to 2007, the R&D activities had increased in almost all regions of China. The overall levels of human capital and regional investment in R&D reflect the extent of innovation efforts in the regional economy. Thirty Chinese regions employ an average of nearly 112,000 FTE S&T workers and invest nearly 10 billion Yuan annually on S&T over the period.

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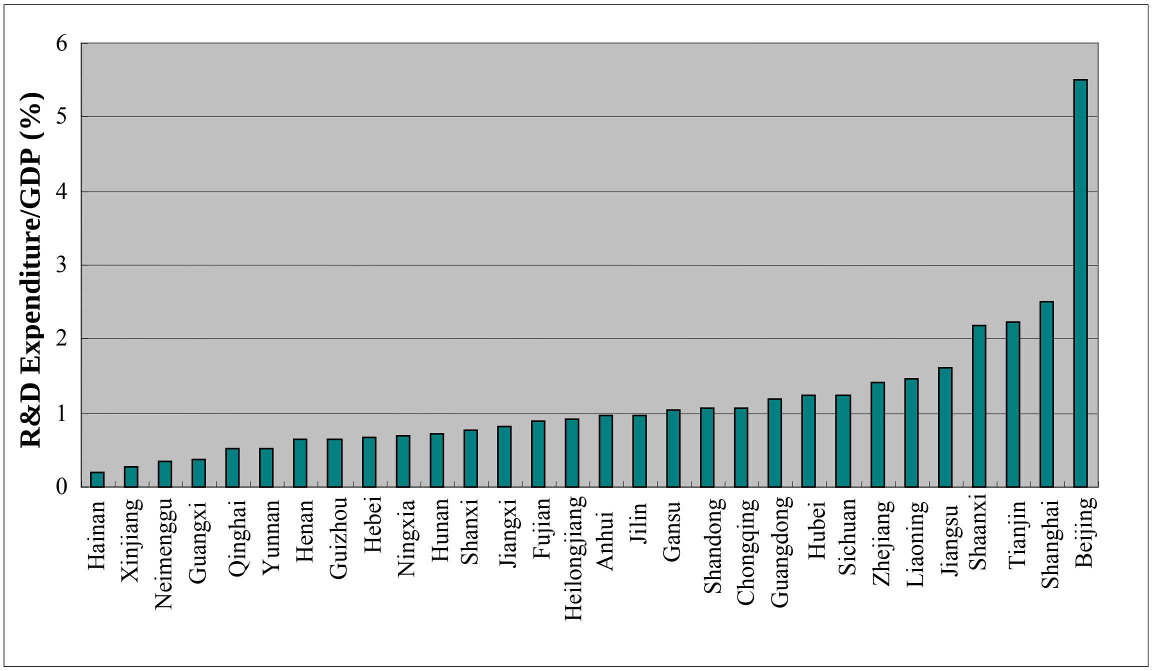
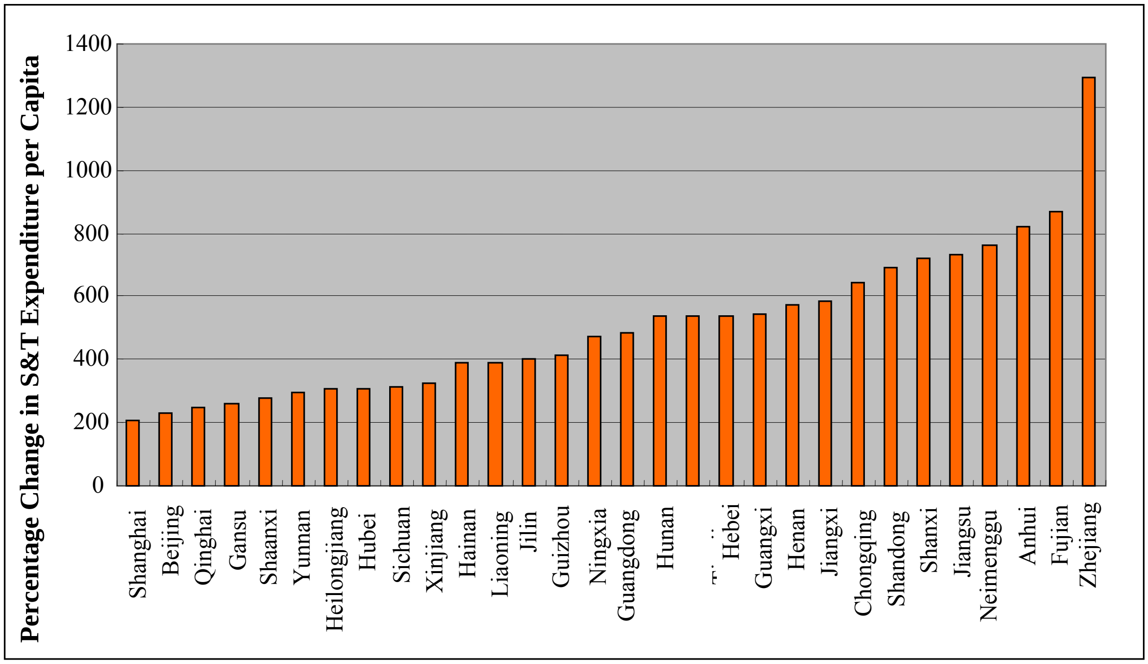
[21] The Theil index can be defined as $T = \frac{1}{N}\sum_{i=1}^{N}\frac{y_i}{\bar{y}}\log(\frac{y_i}{\bar{y}})$, where N denotes the number of regions and y is the total number of patents per capita ($\bar{y}$ is the mean of y). Employing the patents per capita for each three cluster from 1998 to 2007, the author could gain the total inequality indexes of regional innovation capacities, consisting of the inequality within each three clusters and the inequality between those clusters. During the sample period, the inequality among the three clusters contributes to the development of the total inequality of regional innovation capacities. By contrast, the internal inequality of each regional cluster is relatively small and decreases over time.



Source: MOST (2008a)

Figure 4.10 Regional R&D Intensity at Provincial Level in 2007

The group of regions with high innovative capacity like Beijing, Shanghai, and Tianjin generates significant R&D intensities as its R&D/GDP ratio is above 2.0%, which is much higher than the national average of 1.2% in 2007, as shown in Figure 4. 10. Especially, Beijing is well known as a solid national R&D base with a strong application-oriented basic research infrastructure due to the highest density of prestigious universities and research institute in the country. A number of universities and research institutes, the headquarters of many large enterprises and R&D centers located in Beijing perform large amount of national R&D activities. The R&D/GDP ratio of the regions with lower level of innovative capacity, such as Xinjiang, Qinghai and Guangxi, are way too below the national average.



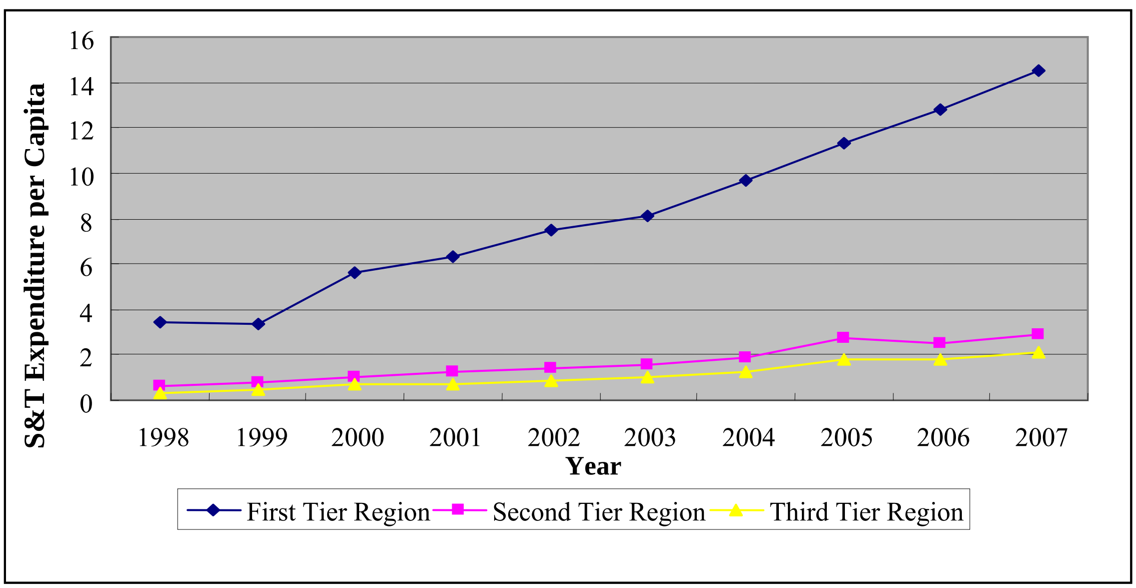
Source: NBS (2008b)
Note: In Year 1998 Yuan

Figure 4.11 Growth Rate in S&T Expenditure per Capita, 1998-2007

Figure 4.11 depicts the growth of S&T expenditures per capita over the sample period.[22] Zhejiang had the highest growth in S&T expenditure per capita, while Beijing and Shanghai actually experienced the smallest increases in S&T expenditure per capita. During the period, the sharp rise of the industries' S&T expenditure contributed to the highest growth in S&T expenditures in Zhejiang; the private sector achieved 456 percent growth rate in its R&D expenditure. On the other hand, Beijing and Shanghai, where university and public research institutes are major R&D performers, had a significant fall in the S&T expenditure of the research institutes which results in the smallest change in their R&D expenditures over time. This indicates that Beijing and Shanghai were greatly

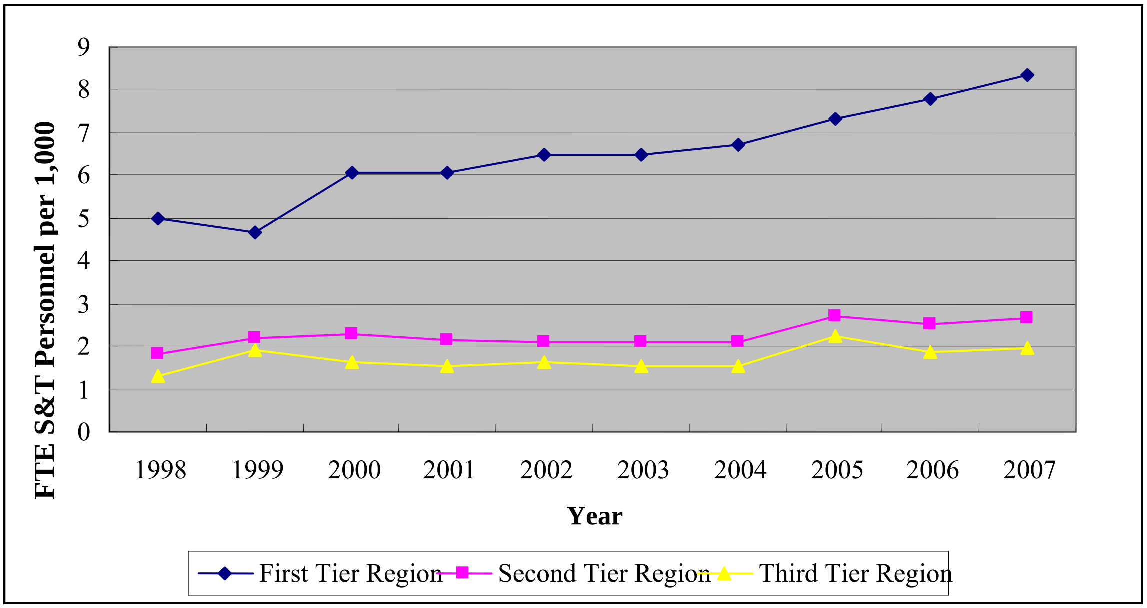
[22] S&T expenditures refer to the actual expenditure on S&T activities, including expenditure on R&D and application of R&D results, expenditure on capital construction for scientific research, and related S&T service fees.

influenced by the reform of the early 2000s that led to a large cut in the government subsidies to the public research institutes. Except for Zhejiang, most of the regions with the lowest level of R&D investment in 2007 are among those with the greatest relative increase in S&T investment over the period. For example, although Fujian spends less than the median amount of R&D expenditure in 2007, its level of S&T investment represents a remarkable increase of 870% relative to its expenditures in 1998. Likewise, Neimenggu, whose R&D spending as a share of GDP is among the lowest in the sample, had increased its S&T investment by 760% between 1998 and 2007, which ranks fourth, followed by Zhejiang, Fujian, and Anhui (see Figure 4.11).



Source: NBS (2008b)
Note: In Year 1998 Yuan.

Figure 4.12 S&T Expenditure per Capita by Regional Clusters, 1998-2007



Source: NBS (2008b)
Note: In Year 1998 Yuan.

Figure 4.13 FTE S&T Personnel per Thousand Persons
by Regional Clusters, 1998-2007

Figure 4.12 and 4.13 plot the levels of S&T expenditure per capita and FTE S&T personnel per capita by three regional clusters over time. This actually demonstrates regional divergence in the level of resources devoted to S&T activities. Particularly, S&T expenditure per capita has significantly increased among the first tier region and its growth has been greater than that of other two regional clusters over the sample period. Since 1999, S&T expenditure has risen sharply in the first tier region, while the second and the third tier regions have maintained the same levels. Likewise, FTE S&T personnel capita also displays a similar pattern of regional divergence in S&T expenditure per capita.[23] Within the whole sample period, the FTE S&T personnel were

[23] S&T personnel refer to 1) personnel directly engaged in S&T activities, such as researchers, engineers, technician in R&D institutions, universities, and research institutes, laboratories, technology development centers, and industrial workshops; 2)

dispersed from 3,600 to 448,946 among regions. There was an increasing trend in the level of S&T workforces in the first tier group, whereas the second and the third tier regions remained the same level during the sample period. This shows that the development of human resources on S&T tends to be geographically concentrated.

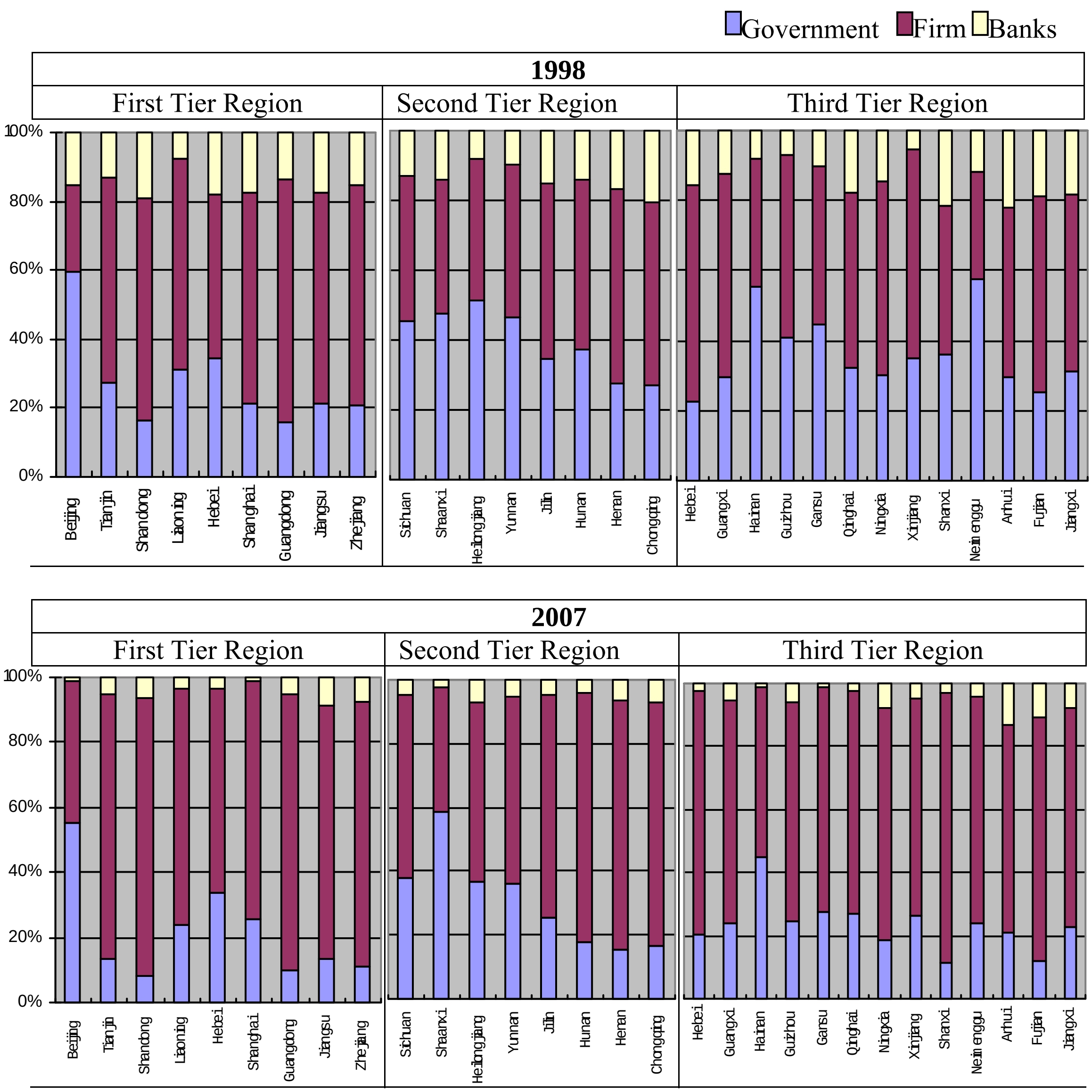


Figure 4.14 Share of S&T Funds from Three Sources, 1998 and 2007

personnel engaged in the management of S&T activities and in providing direct service to S&T activities, including senior management people responsible for S&T activities in R&D institutions and others.

However, in most of Chinese regions, major proportions of region-wide S&T funds are raised from firms and government, while bank loans only account for a very small proportion of S&T funds. As demonstrated in Figure 4.14, there was an increasing trend in private S&T investment between 1998 and 2007, reflecting the vitality of the innovation environment in regional industrial clusters. In 1998, the share of S&T funds contributed by industry ranged from 19.09 % (Beijing) to 61.82% (Guangdong) with a mean value of 44.4%. Beijing is home to more prestigious universities and research institutes than any other regions, which has strength of public R&D systems (See Table A.1 in the Appendix A). Beijing concentrates the lion's share of basic research in universities and public research institutes, so that it may not have a relatively strong industrial base that often commercializes the research results (OECD 2007). In contrast, Guangdong is one of the manufacturing powerhouses in the country with the development of the new electronics and electricity sectors. While Guangdong lacks of strong science sector, most R&D center are set up within firms, which provide higher private investment in R&D than other regions. By the end of 2007, the mean value of private sources of S&T funds had increased to a level of 66.7%, with its range between 37% (Beijing) and 84% (Shanxi).

Compared by the regional clusters, the third tier region with low innovation capacity had the largest growth in the share of private S&T investment, increased it by about 60% over the period. The averages of growth rates for the second and the third tier regions were 47%, and 54%, respectively. This reflects not only the increasing role played by the private sector in regional innovation activity but also the enhancement in innovation capabilities of Chinese firms across the regions.

Government's financial support for S&T activities can create the innovation environment in a region by guiding and allocating the limited S&T resources.[24] S&T activity funded by the regional government affects the process of innovation as well as the quantity and quality of innovation outputs. In almost all Chinese regions, the S&T funds raised from the government were decreased during the sample period. Only Beijing, Sichuan, and Shaanxi, the major R&D centers of China in which university and research institute are main R&D performers, had the increases in the proportion of S&T funds raised from regional government. As the private sources increased a substantially higher fraction of regional S&T funding in most of regions, the proportion of public S&T funding declined accordingly.

Among the Chinese regions, average 2% of the budgetary fund for S&T was spent in the total government expenditure in 2007. The share of regional government appropriation for S&T in its total expenditure denotes the importance of S&T activity in the regional government's budget allocation process and its higher value indicates the strength of the government's financial support for regional innovation. During the period, the share of government appropriation for S&T ranged from 0.68% to 5.5% among the regions. The first tier region, especially east coastal areas tends to have more government's financial supports for S&T activities as the percentage of regional government S&T appropriation in its total expenditure is above the national average for all sample years. Namely, Beijing, Shanghai, Zhejiang, Guangdong, and Tianjin represent the top five regions that have stronger government financial supports for S&T.

[24] S&T activities refers to organized activities which are closely related with the creation, development, dissemination, application of the scientific and technical knowledge, including R&D activities, application of R&D results, and related S&T services.

In China, however, the R&D activities are mainly performed by firms, universities, and research institutes, involving directly in the process of knowledge production. Since the S&T reforms in the mid 1980s, the role of the science sector, including research institutes and universities, has evolved dramatically in the Chinese innovation systems. The university and research institutes in R&D performance are often recognized as not only an important mechanism of technology transfer from the science sector to industry but also a reservoir of potential S&T workforces. In this respect, the high level of R&D activity in the science sector implies the strength of the linkage between the science and industry sector.

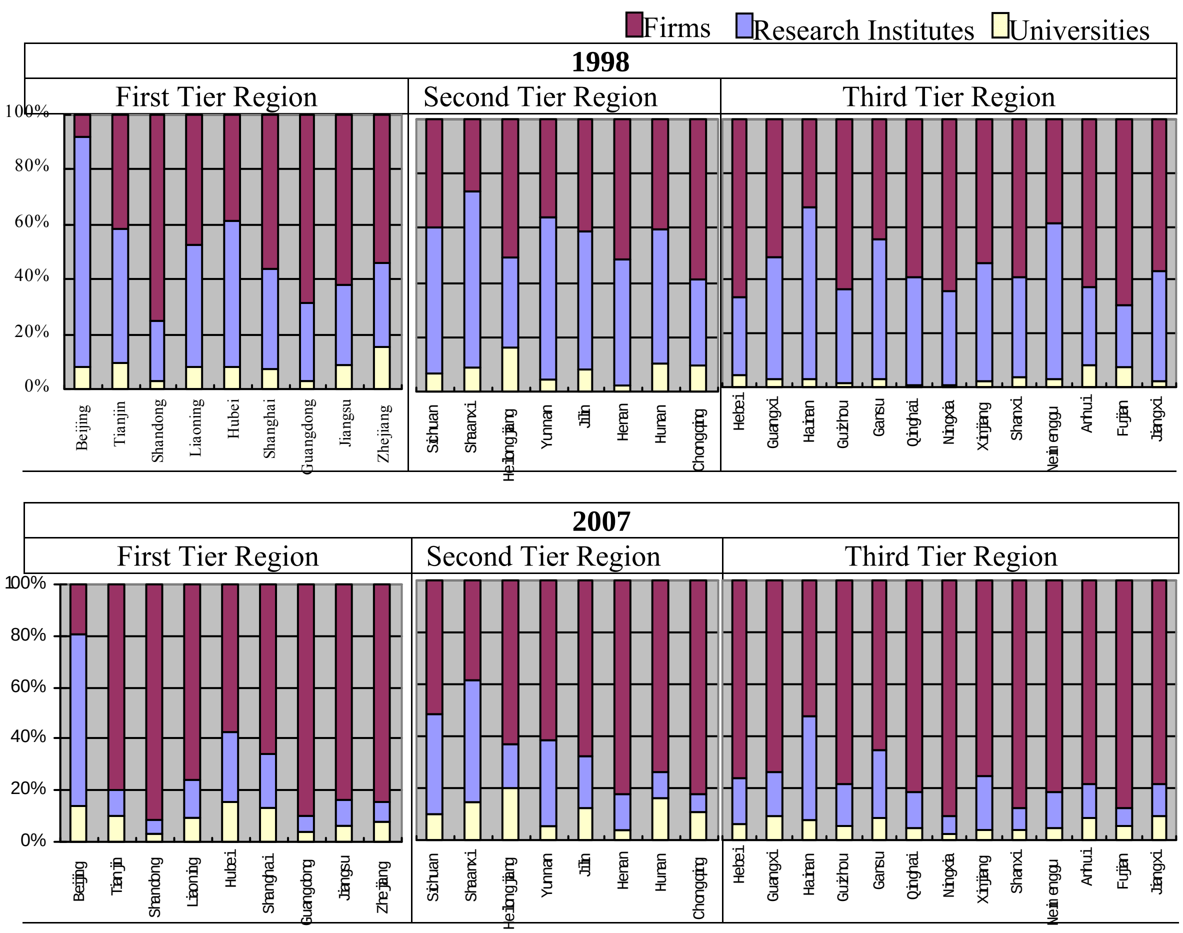


Figure 4.15 Share of S&T Activities by Sector of Performance, 1998 and 2007

In 1998, about 60% of total R&D was undertaken by research institutes and universities, while the government funded nearly half of regional R&D activities. The share of R&D expenditure by universities and research institutes ranged from 17% (Ningxia) to 92% (Beijing). In case of Beijing, nearly 60% of total S&T funds were supported by the government and the largest share of the R&D expenditure was spent by the universities and research institutes in the country. This is because universities and research institutes located in Beijing have played a considerable role as a S&T human capital provider as well as core academic research center for the entire county. During the transition period, however, the share of S&T activities contributed by firms continued to increase in most regions (see Figure 4.15). In 2007, the share of R&D expenditure by universities and research institutes had fallen drastically between 6.43% (Guangdong) to 66.11% (Shaanxi). This reflects that the industry has become an important actor in most regional innovation systems.

As firm's S&T activities have largely increased and enhanced over time, a linkage between the science and private sector evolved by various Chinese government policies. Universities and research institutes have provided the seeds for a number of spin-offs, and some of them have grown to be large companies. A few Chinese leading universities actually own and operate firms in high-tech development areas, high-tech parks, and university science parks. For example, spin-offs from universities in the Zhongguancun Science Park have become well-known high-tech firms in China, such as the Founder Group and Beida Group of Beijing University and the Tongfang group of Tsinghua University. From 2001 to 2010, more than 80 national university science parks were established in China. Given the context, universities can develop close relationships with the private sectors through joint R&D projects, professional consulting, and training, etc. This consequently facilitates the interactions between firms, universities, and research institutes, which improve the innovation performance of the regions by increasing the efficiency of the regional innovation systems. Despite some successful cases, however, it is also suggested that there are potential negative consequences, since “some Chinese universities might go bankrupt of the universities because of the losses their affiliated firms were suffering” (Chen and Kenny 2007: 1062).

The S&T funds of universities and research institutes received from firms can represent the degree of a linkage, capturing the knowledge flow from universities/research institutes to industries. The strength of the linkage varies between regions during the sample period. The share of S&T funds raised by universities/research institutes from firms ranged from 0.2% (Hainan) to 39% (Heilongjiang), with a mean value of 13.35%. Interaction between innovation actors is stronger in the first tier region and weaker in the third regions. In the group of the first tier region, the proportion of S&T funds of universities/research institutes received from firms had been at the average level of 19.37% over the period. Among those regions, Zhejiang has the highest proportion of S&T investment of industries in universities and research institutes, at the level of 30% since 1998. However, in the group of the third tier region, this proportion had been around 8.25%.

4.2.4. Regional Disparities in the Distribution of Innovation Infrastructure

Previous studies identify significant inequalities in the geographic distribution of physical, human, infrastructure, and foreign investment in China (Cheung and Lin 2004;

Liu and Li 2006; Fleisher et al. 2010). In general, the east coastal provinces have strengths in education, research, and innovation infrastructure, since they have a large amount of FDI, well-developed industrial clusters, strong government investments, and concentration of key universities, public research institutes, and qualified workforces.

Table 4.7 Innovation Infrastructure Indicators of 30 Chinese Provinces: Average Value between 1998 and 2007

	Provinces	GDP Per Capita (Billion 1998 Yuan)	Population with High Education (%)	Old Age Dependency Ratio (%)	Public Education Expenditure (%)	Openness to International Trade (%)	FDI (Billion 1998 Yuan)
1st Tier	Beijing	31,364	24.55	13.17	15.94	151.13	24.02
	Tianjin	26,301	13.27	13.26	16.32	95.95	22.69
	Shandong	14,331	4.70	12.29	20.04	28.15	55.24
	Liaoning	14,886	8.07	11.82	14.29	35.64	34.89
	Hubei	9,338	5.78	11.55	17	8.39	15.03
	Shanghai	41,892	17.72	18.05	12.99	130.68	45.59
	Guangdong	18348	5.61	10.91	18.23	154.04	96.83
	Jiangsu	17,704	5.65	14.16	19.3	68.44	100.85
	Zhejiang	20,110	6.13	13.81	21.25	50.02	44.58
	First Tier	**21,586**	**10.16**	**13.22**	**17.26**	**80.27**	**48.86**
2nd Tier	Sichuan	6,715	3.77	13.13	16.65	7.55	6.18
	Shaanxi	7,215	6.20	10.99	17.51	10.17	4.74
	Heilongjiang	11,801	5.38	8.63	16.82	10.69	8.04
	Yunnan	6,131	2.81	10.24	16.78	9.6	1.47
	Jilin	10,098	6.69	9.31	16.34	14.17	4.06
	Hunan	7,623	4.64	12.43	16.84	6.43	12.34
	Henan	8,229	3.86	10.95	19.57	4.9	9.05
	Chongqing	8,014	3.76	14.06	15.82	9.74	3.86
	Second Tier	**8,228**	**4.64**	**11.22**	**17.04**	**9.16**	**6.22**
3rd Tier	Anhui	6,779	3.84	12.69	17.12	11.32	6.88
	Fujian	15,043	4.62	11.58	20.17	53.84	31.88
	Jiangxi	6,660	4.64	10.98	19.2	7.7	13.46
	Guangxi	6,513	3.80	12.44	19.21	9.45	4.21
	Hainan	8,829	5.82	11.22	16.45	25.83	5.62
	Guizhou	3,734	3.76	10.79	20.9	5.81	0.56
	Gansu	5,153	4.06	9.22	18.36	8.28	0.44
	Qinghai	7,238	6.11	8.14	12.35	6.13	1.34
	Ningxia	7,251	7.17	7.61	19.56	13.24	0.41
	Xinjiang	9,973	9.63	8.25	17.95	18.2	0.41
	Hebei	10,988	4.66	10.53	18.81	10.57	11.74
	Shanxi	8,013	5.63	9.82	17.26	10.26	3.63
	Neimenggu	10,350	6.16	9.31	14.19	10.52	5.65
	Third Tier	**8,194**	**5.38**	**10.20**	**17.81**	**14.70**	**6.63**

Source: Dataset constructed by author using data from the NBS (1998a and 2008a)

Table 4.7 presents an overview of the average main innovation infrastructure indicators of 30 Chinese provinces from 1998 to 2007. These indicators reflect the extent of a region's ability to realize the economic value of its knowledge stock, regional government policies, and openness to international trade and foreign investment that encourage innovation. The first tier group of provinces that mostly consists of the eastern economically developed regions has a higher GDP per capita and a larger educated population attaining above college degree than other two groups. Three municipal cities, Beijing, Shanghai, and Tianjin, have the largest scales of human resources as well as knowledge stocks potentially available for innovation activities in the country. Educational and research advantages tend to be concentrated in those cities with more access to financial and human resources.

The geographic distribution pattern of FDI and international trade shows that there is a large discrepancy between three groups of regions. Within the whole sample period, nearly 80% of both international trade and FDI were concentrated in the first tier region. For example, five provinces in the group—Guangdong, Jiangsu, Shandong, Shanghai, and Zhejiang—received 60% of total FDI. The geographic distribution pattern of international trade openness was also the same as that of FDI. In fact, these patterns of uneven distribution had been consistent over the sample period. The primary reason would be due to the fact that most eastern coastal regions of the first tier group were favored by post-reform development strategy of the central government, because of its readily accessible geographic location with a relatively well-developed infrastructure (Huang et al. 2003). As a result, productive resources, such as S&T, domestic financial loans, and foreign investment, have become more concentrated in only a few coastal regions (Liu and Li 2006).

In terms of old age dependency ratio, there is not much difference of its average value between three groups of regions. During the sample period, the dependency ratio of the elderly population aged 65 and over to working population ranged from 6% (Ningxia) to 22% (Shanghai) and its mean value had been at a level of 11.38%. For the share of public expenditure on education, average 16% of the public expenditure on education was spent by the regional government, with the range between 9.69% (Qinghai) and 21.25% (Zhejiang) over the sample period. There is not much difference in the average share of public expenditure on education between the three groups of regions.

CHAPTER 5

THE DETERMINANTS OF REGIONAL INNOVATION CAPACITY IN CHINA

This chapter presents the empirical results of factor analysis and several regression models evaluating the determinants of regional innovation capacity among the 30 provinces of China. First, the primary results of a factor analysis show main factors that determine the regional innovation capacity in the evolvement process of the regional innovation systems from 1998 to 2007. Second, a series of negative binomial, fixed-effect regression models explore the relationship between regional patenting activity and the independent variables associated with the regional innovation capacity over the period.

5.1 The Factor Analysis

Table 5.1 Descriptive Statistics of Variables

Variable		Full Name	N	Mean	Std. Dev.
Innovation output					
	Patg	Invention Patent Grants	300	254.87	537.5
	Patu	Utility-Model Patent	300	741.18	1196.33
The Common Innovation Infrastructure					
A1	GDP	GDP PER CAPITA	300	12226.39	9636.2
A2	FTE	S&T Personnel	300	113011.8	90594.85
A3	GEST	S&T Expenditure	300	108.55	137.29
A4	HIGHED	High-Educated Population	300	6.63	5.32
A5	OADR	Old Age Dependency Ratio	300	11.38	2.51
A6	ED	Public Education Expenditure	300	15.54	2.34
A7	PUBST	Public S&T Support	300	1.78	0.87
A8	OPENNESS	Openness to International Trade	300	32.98	44.53
A9	FDI	Foreign Direct Investment	300	20.6	31.39
Regional Cluster Innovation Environment					
B1	PRIVATE	Private Funding for S&T	300	57.04	14.23
Quality of Linkage					

Table 5.1 (continued)

C1	UNIVIN	University R&D Performance	300	34.97	17.67
C2	LINK	University-Industry Linkage	300	13.39	8.17

In order to seek the reasons underlying the disparity in regional innovation capacity, the method of factor analysis is used to extract the main factors from the determinants of the innovation capacity of regional innovation systems, using data for 10 years (from 1998 to 2007). Factor scores are computed for each provincial unit. The regional patterns of evolution of innovation systems are identified by comparing factor scores. Table 5.1 reports the means and standard deviations of each variable, and Table A.2 in the Appendix A includes the correlation matrix between the variables.

Table 5.2 Eigenvalues and Cumulative Contribution

Component	Eigenvalues	% of variance	Cumulative (%)
1	5.583	46.529	46.529
2	2.005	16.707	63.236
3	1.173	9.773	73.009
4	0.967	8.055	81.064
5	0.741	6.175	87.239
6	0.595	4.958	92.197
7	0.334	2.785	94.981
8	0.203	1.688	96.67
9	0.162	1.352	98.021
10	0.106	0.88	98.901
11	0.09	0.752	99.653
12	0.042	0.347	100.000

The 12 eigenvalues and their cumulative contribution are shown in Table 5.2. The cumulative contribution of the first three factors is 73.009%, indicating that the first three factors are able to explain 73% of the total variation of the capacity of the regional innovation system. Therefore, three key factors will be used in exploring the determinants of innovation capacity in the evolution process of the regional innovation system. In order to extract the main factors, principal component analysis is employed as the extraction method and the Varimax is selected as the rotation method. Three main factors are further adjusted by a Varimax rotation to reduce the number of variables with high loading scores and to make the interpretation of the factors more easily.

Table 5.3 Factor Loading and Factor Coefficients

	Factor Loading			Factor Coefficients		
Variable	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
A1	0.916	0.144	0.050	0.213	0.045	-0.133
A2	0.695	0.059	0.534	0.087	-0.085	0.257
A3	0.839	0.119	0.332	0.152	-0.018	0.082
A4	0.810	-0.156	-0.263	0.245	-0.069	-0.282
A5	0.536	-0.060	0.492	0.058	-0.141	0.274
A6	-0.226	0.150	0.703	-0.169	-0.032	0.501
A7	0.757	0.124	0.219	0.149	0.008	0.014
A8	0.912	0.086	0.011	0.220	0.019	-0.149
A9	0.632	0.397	0.447	0.074	0.130	0.144
B1	0.149	0.871	0.228	-0.026	0.461	-0.021
C1	-0.004	-0.960	0.004	0.029	-0.559	0.177
C2	0.297	0.091	0.605	-0.023	-0.066	0.362

The factor loading patterns after the rotation as well as factor coefficients are presented in Table 5.3. The variables with a high loading score (usually over 0.5) are selected to denote the factor. The loading scores of each factor provide a quantitative insight into the pattern and changes of regional innovation capacity in the sample period. The variables that have high loading scores on the first factor include almost all variables listed in the category of the common innovation infrastructure (A1 through A9, excluding A6) in Table 5.1. The loading scores of these variables are all positive, indicating that they make a positive contribution to the factor 1. Therefore, a province with better innovation infrastructure will have a larger score on factor 1.

Factor 2 can be interpreted as an indicator of regional innovation environment, as variable that have high loading scores on the second factor are related to the private innovation resources, such as the firms' self-raised R&D funding. These variables include both B1 (0.871) and C1 (-0.96), but only B1 makes a positive contribution to the factor 2. Thus, a province with a better environment for innovation in regional industrial clusters will have a larger score on factor 2. However, the variables that have high loading scores on the third factor includes A6 (0.703) and C2 (0.605). Factor 3 can be described as the quality of a linkage for innovation. Hence, a province with a higher level of linkage between industry and university for innovation will have a larger score on factor 3.

Table 5.4 Factor Scores by Region in 1998 and 2007

	1998			2007		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
National Average	-0.363	-0.831	0.203	0.429	0.418	0.430
Std. Dev.	0.602	0.948	0.920	1.373	0.958	1.087
First Tier	**0.241**	**-0.862**	**0.780**	**2.100**	**0.668**	**0.815**
Beijing	1.632	-3.243	-0.269	4.600	-1.705	-0.892
Tianjin	0.146	-0.840	0.825	1.978	1.023	-0.707
Shandong	-0.528	0.355	1.012	0.829	1.666	1.976
Liaoning	0.160	-0.609	-0.132	1.075	0.642	0.602
Hubei	-0.445	-1.752	0.549	0.155	-0.439	0.834
Shanghai	1.094	-1.308	0.894	4.105	0.333	-1.078
Guangdong	0.841	0.959	-0.190	2.308	2.022	1.439
Jiangsu	-0.282	-0.588	2.674	2.287	1.216	2.844
Zhejiang	-0.446	-0.736	1.656	1.560	1.256	2.314
Second Tier	**-0.490**	**-1.472**	**0.452**	**-0.177**	**-0.217**	**0.696**
Sichuan	-0.366	-2.177	0.954	-0.022	-1.070	1.462
Shaanxi	-0.465	-2.212	1.279	0.074	-1.891	0.861
Heilongjiang	-0.285	-0.865	-0.356	-0.068	-0.147	0.378
Yunnan	-0.654	-1.950	0.109	-0.521	-0.756	0.001
Jilin	-0.130	-1.322	0.102	-0.081	0.123	-0.075
Hunan	-0.540	-1.480	0.278	-0.152	0.470	1.081
Henan	-0.778	-1.219	1.043	-0.407	1.004	0.988
Chongqing	-0.699	-0.550	0.210	-0.236	0.536	0.874
Third Tier	**-0.702**	**-0.415**	**-0.350**	**-0.354**	**0.635**	**-0.001**
Hebei	-0.720	0.150	0.403	-0.339	0.679	0.783
Guangxi	-0.861	-1.036	0.724	-0.639	0.317	0.780
Hainan	-0.423	-1.697	-0.909	-0.242	-0.969	-0.414
Guizhou	-0.969	0.300	-0.510	-1.040	0.605	0.945
Gansu	-0.821	-1.026	-0.071	-0.741	0.187	0.478
Qinghai	-0.709	0.075	-1.464	-0.237	0.875	-2.075
Ningxia	-0.608	0.795	-1.944	-0.544	1.443	-0.595
Xinjiang	-0.695	-0.229	-0.671	-0.175	0.509	-0.844
Shanxi	-0.765	-0.453	0.000	-0.172	1.376	-0.197
Neimenggu	-0.553	-1.284	-0.774	-0.056	1.163	-1.139
Anhui	-0.791	-0.707	0.411	-0.204	0.103	0.789
Fujian	-0.326	0.277	0.354	0.237	1.304	0.827
Jiangxi	-0.891	-0.557	-0.102	-0.451	0.667	0.653

Table 5.4 shows both national trend and regional pattern of factor scores in 1998 and 2007. The national average scores on factor 1 increased from -0.363 in 1998 to 0.429 in 2007, suggesting that the level of innovation resources and infrastructure has expanded in the country as a whole. However, regional gaps also widened at the same time, as the standard deviation was increased by double between 1998 and 2007. While the average score of the first tier region increased nearly nine times (from 0.241 to 2.1), that of the second and third tier groups of regions relatively had a marginal increase. This demonstrates that more innovation resources and better government supports were allocated to develop regional innovation systems in the first tier region. By contrast, other two groups of regions had very limited access to innovation resources and had been in a relatively disadvantaged position in receiving government's supports that affect innovation incentives and R&D productivities throughout the regional economy.

As shown in Table 5.4, the two centrally administrated municipalities—Beijing and Shanghai—had the highest scores on factor 1 in both 1998 and 2007. In 1998, most provinces in the country had a negative score on factor 1. The first tier region had a higher average score than both the second and third tier regions. In addition to Beijing and Shanghai, three more eastern coastal provinces in the first tier scored positively. By contrast, all provinces in the other two groups scored negatively. This picture actually had not changed much in 2007. The score gap between the first tier and second/third tier regions was further increased. All provinces in the first tier had the largest increase in its score and they were all positive. However, the scores of the second and third tier regions remained negative and they experienced relatively a small increase in its score. This spatial pattern evidences that innovation resources and infrastructure are developed in an imbalanced way among the regions. Government's supports were also concentrated on the important national political and economy centres, such as Beijing and Shanghai.

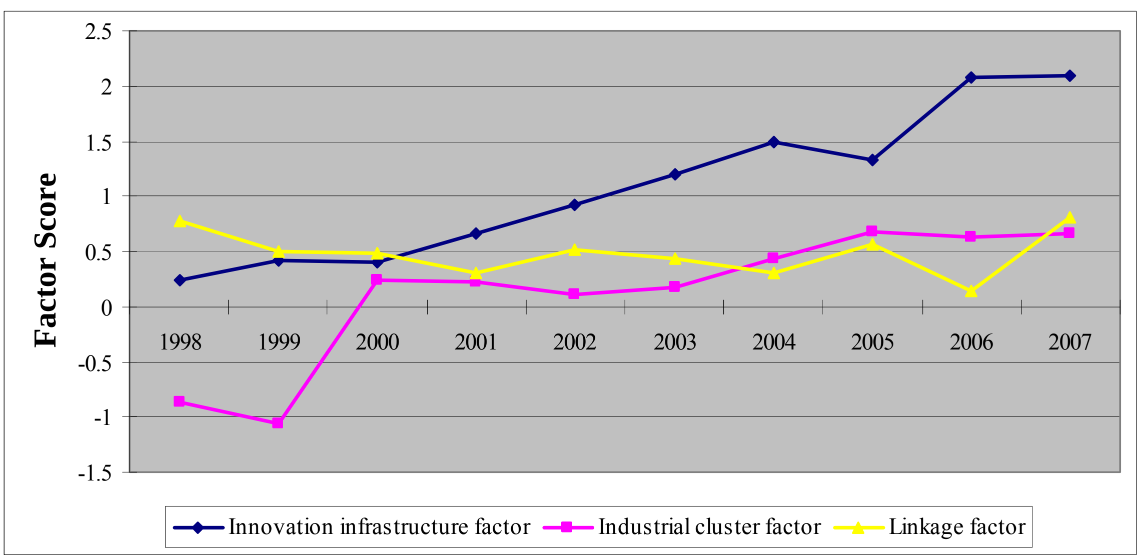
The environment for innovation in industrial clusters at the national level improved between 1998 and 2007, as indicated by changes in the national average scores on factor 2 from negative to positive (see Table 5.4). While the majority of provinces had negative scores in 1998, the number of provinces with positive scores drastically increased from 6 in 1998 to 22 in 2007. The inter-provincial gaps on factor 2 maintained almost the same level during the period as the standard deviation slightly increased. In 1998, only a few provinces with a higher degree of industrial clusters scored positively—specifically, Pearl River Delta in Guangdong province (electronically household appliances industry), Jinan in Shandong province (textile and machinery manufacturing industry), Mindong in Fujian province (electrical appliances and footwear industry), and Tangshan in Hebei province (steel industry). The third tier region had a higher average score on factor 2 than both the first and the second tier regions; there were five out of the thirteen provinces in the group with positive scores. Followed by the third tier, the first tier came second and the second tier had the lowest average score. The provinces with the lowest scores on factor 2 in the country were Beijing, Sichuan, Shaanxi, and Yunnan.

However, the situation was somewhat changed in 2007. The first tier region overtook the third tier region and ranked first in terms of regional innovation environment. Private innovation resources increased nationwide but there was a notable rise of private resources in innovation activities in both the first and the third tier regions. Most of the first tier regions scored positively, excluding Beijing and Hubei. In the third tier region, only one province (Hainan) scored negatively. The second tier region still had the lowest scores and the half of the provinces in the group scored negatively.

These results seem to suggest the following regional patterns in terms of private resources in regional innovation activities. First, some of provinces, in which the major source of region-wide S&T funds comes from government, tended to have the lowest scores on factor 2 over the sample period. For example, Beijing, Sichuan, and Shaanxi are the national R&D centers of China where over half of its S&T funds have been raised from government. Those provinces have a strengthened position for university and research institutes in its regional innovation systems. Second, private source of innovation activities had become important in the regional innovation systems of the third tier group, especially among the poor western provinces.

In accordance with the first second factors, the score patterns on factor 3, which represents the strength of linkages between innovation actors, also have an increasing tendency of the factor scores over the sample period. The national average score increased from 0.203 in 1998 to 0.403 in 2007, implying that the interactions between innovation actors had been facilitated in the country. As evidenced by an increase in the standard deviation, the inter-provincial gaps on the strength of linkage also widened. The increasing trend can be partially explained by the effects of S&T reforms since the mid-1990s. The restructuring of S&T systems motivated many universities and research institutes as the efficient resource of innovation. When the government reduced the cost of supporting the universities and research institutes, many spin-offs and affiliated firms were generated from universities and research institutes in order to make profits that they can use to fund their operations (Chen and Kenney 2007). As a result, the interactions between industry and science sector considerably increased over time.

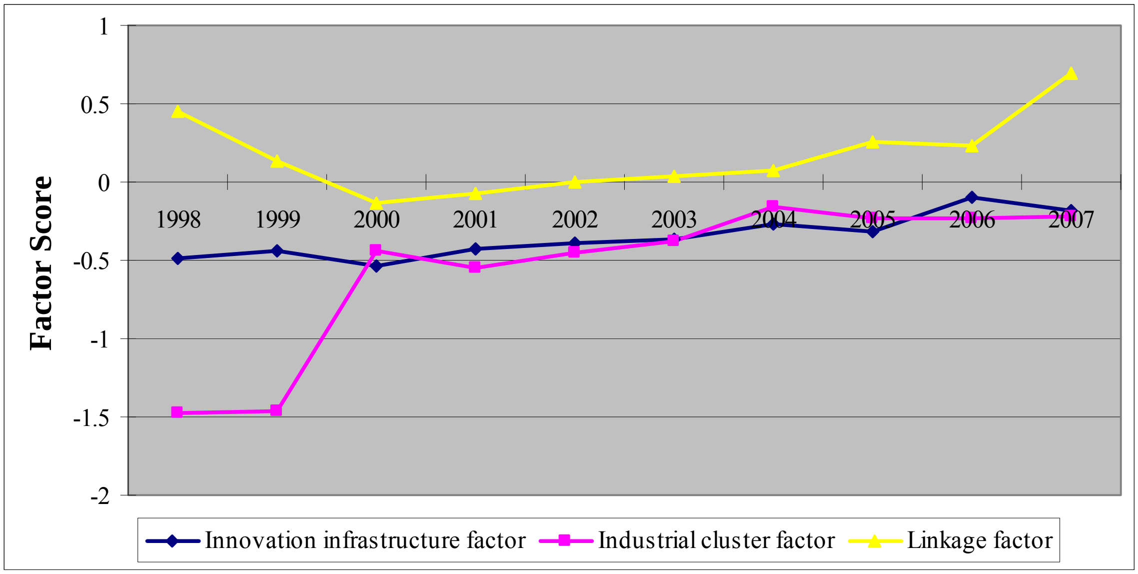
During the sample period, the first tier region maintained its leading position with increased positive scores on factor 3. Followed by the first tier region, the second tier region ranked the second place and the third tier region had the lowest average score. Comparably, the linkage between industry and science sector was more developed and strengthened in the first tier region. The two provinces in the first tier group, such as Zhejiang and Jiangsu, had the highest scores on factor 3 in both 1998 and 2007. They have the large number of universities and R&D institutes, which are able to collaborate with the industry. By contrast, most provinces of the third tier scored negatively. The two provinces with the lowest scores in the country were Qinghai and Neimenggu. Those provinces have relatively the small numbers of universities and research institutes than those of the first tier provinces.



Source: Author's calculation

Figure 5.1 The Scores of the Three Factors for the First Tier, 1998-2007

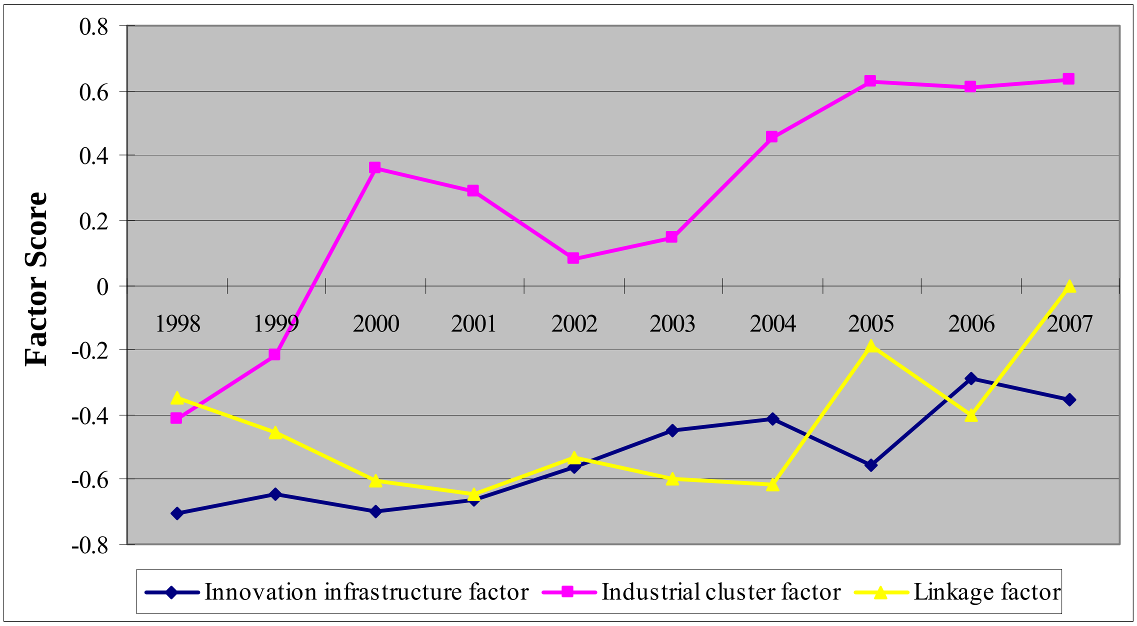
The scores of the three factors—f1) innovation infrastructure factor; f2) industrial cluster factor; and f3) linkage factor—are computed for each three regional cluster from 1998 to 2007. Specifically, Figure 5.1 shows the scores of the three factors for the first tier region. During the sample period, the innovation infrastructure had made the most significant contribution to the enhancement of the regional innovation capacity in the first tier region. As the factor scores of the innovation infrastructure factor were larger than those of the industrial cluster and linkage factors in all sample years, it had a major impact on building the innovation capacity in the evolution process of the regional innovation systems. The scores of industry cluster factor rose sharply in 1999 and had an increasing trend afterward, but they were all lower than those of the innovation infrastructure factor. However, this finding is not surprising, because many coastal regions in the first tier have the strength of innovation infrastructure by receiving large amounts of FDI as well as massive government's supports. From 1998 to 2007, the first tier provinces with larger average factor scores of the innovation infrastructure factor than those of the other two factors include four provinces, namely, Beijing, Tianjin, Liaoning, and Shanghai. For Shandong and Guangdong where industry S&T funding is a major source of S&T activities, the factor scores of the industry cluster factor exceed those of the other two factors. Jiangsu and Zhejiang have higher factor scores of the linkage factor over the period.



Source: Author’s calculation

Figure 5.2 The Scores of the Three Factors for the Second Tier, 1998-2007

The scores of the three factors for the second tier region from 1998 to 2007 are shown in Figure 5.2. In contrast to the first tier, the second tier group has larger factor scores of the linkage factor than those of the innovation infrastructure and industrial cluster factors. In 2000, the linkage factor scores tended to decrease, but turned into the opposite right after the year. In the same year, industrial cluster factor scores rose steeply but kept remaining the negative scores. Among the second tier regions, the provinces for which the factor scores of the linkage factor are larger than those of other factors include six provinces, namely, Sichuan, Shaanxi, Yunnan, Hunan, Henan, and Chongqing. Only for two provinces, Heilongjiang and Jilin have higher factor scores of industrial cluster factor.



Source: Author's calculation

Figure 5.3 The Scores of the Three Factors for the Third Tier, 1998-2007

As shown in Figure 5.3, the scores for the industrial cluster factor increased faster in the third tier region and then exceeded the scores for the innovation infrastructure factor as well as the linkage factors during the sample period. In contrast to the first tier, the factor scores of the innovation infrastructure factor for the third tier region were lower than those of the other factors and stayed almost the same level for 9 years. It can be reasonable to postulate that private R&D funding is the only substantial sources of R&D in the third tier regions due to a lack of the innovation infrastructure. Among the third tier regions, the provinces for which the factor scores of the industrial cluster factor are larger than those of the other two factors include 8 regions—Guizhou, Qinghai, Ningxia, Xinjiang, Shanxi, Neimenggu, Fujian, and Jiangxi. Four other provinces, such as Hebei, Guangxi, Gansu, and Anhui, have larger factor scores of the linkage factors exceed those of the innovation infrastructure and industrial cluster factors. Only for one province, Hainan has the highest factor scores of the innovation infrastructure factor in the group.

To sum up, from Figure 5.1-5.3, for the first tier region with a high innovation capacity, the scores for the innovation infrastructure factor are higher than those of both the industrial cluster and linkage factors. The industry cluster factor has the lowest scores among the three factors in the first tier group. Comparably, the opposite is true for the third tier region with a low innovation capacity, as the industrial cluster factor has the highest scores among the three factors and the innovation infrastructure factor has the lowest scores in the group. For the second tier region with middle innovation capacity, the scores for the linkage factor are higher than those of the innovation infrastructure and industrial cluster factors. Followed by the linkage factors, the innovation infrastructure factor has the second highest scores in the group.

These findings suggest that the innovation infrastructure contributes more to enhancement of the regional innovation capacity than do the industrial cluster and the linkage between innovation actors. In 2000, all three groups of regions experienced a sharp rise in its scores of the industrial cluster factor simultaneously. This can demonstrate that all regions of China may recognize the importance of private innovation resources to regional innovation capacity and then make an effort to improve the industrial cluster environment for innovation. However, only the third tier region with a low innovation capacity continued an increasing trend in its scores of the industrial cluster factor, while the other two groups maintained a same level after the sharp rise in 2000. This implies that compared to the innovation infrastructure, the increase of private innovation resources seems relatively less efficient in enhancing the regional innovation capacity over time. Once the private resources for innovation rose steeply at the certain level, an increasing pattern of both the industrial cluster and linkage factor scores similarly went together. This may suggest that the rise of the private innovation resources influences the evolvement of the linkages between the industry and science sector.

5.2 The Regression Analysis

5.2.1. Empirical Approach: Modeling Regional Innovation Capacity

Based on the research framework (see Figure 3.1) and indicators (see Table 3.1) described in Chapter 3, a series of the count panel data models for two types of patents are estimated. In the context of panel dataset, the negative binomial fixed effect models are the most appropriate regression model for using patent data, because the model fits the discrete nature of the patent counts (e.g., the preponderance of zero and small values of patents with a skewed distribution), solves the problem of overdispersion, and controls for unobserved regional specific effects (Baltagi 2008; Zang and Rogers 2009).[25]

In the analysis of this study, the negative binomial model specifies the probability that a region received y_{it}—i.e. the expected number of patents received by a region *i* in period *t* is determined by a Poisson distribution with parameter λ_{it}, which is an exponential function of the regressor x_{it}. The regressor x_{it} is a vector of explanatory variables, including GDP per capita, S&T personnel, population with high education, old age dependency ratio, public education expenditure, public S&T supports, openness, FDI, private S&T funding, university R&D expenditure, and science-industry linkage.

[25] The use of negative binomial regression model is further supported by the result from the goodness-of-fit test which rejected the Poisson distribution assumption.

The specification of Poisson panel regression is given by

$$\text{Prob}\,(Y_{it} = y_{it} / x_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y_{it}}}{y_{it}!}, \; y_{it} = 0, 1, 2, \ldots; i = 1, \ldots, N; t = 1, \ldots, T \qquad (1)$$

The most common specification for the negative binomial model is,

$$\lambda_{it} = \exp(x_{it}\beta + \varepsilon) \qquad (2)$$

Where β indexes the vector of coefficients associated with x_{it}, and ε_i denotes the unobservable individual specific effect. The expected number of patents received by a region per year drew from the two equations:

$$E\,(y_{it}/x_{it}) = \text{Var}\,(y_{it}/x_{it}) = \lambda_{it} = \exp(x_{it}\beta + \varepsilon) \qquad (3)$$

Where $E\,(y_{it}/x_{it})$ is the conditional mean of patent counts given x_{it}, and $\text{Var}\,(y_{it}/x_{it})$ is the conditional variance of patent counts given x_{it}—that is, the number of patent grants by a specific region is independent of one another and average patents per year shows the characteristics of the given province, which depends on the vector of the regressor x_{it}. However, the negative binomial model rejects the assumption of the Poisson model that the conditional mean is equal to the conditional variance, known as *equidispersion*. In order to model the *overdispersion*, the negative binomial model uses the different specification of parameter λ_{it} as shown in equation (2) by inserting ε_i into the Poisson specification of parameter $\lambda_{it} = \exp(x_{it}\beta)$. Based on the equation (2), the negative binomial distribution has conditional mean λ_{it} and variance $\lambda_{it} + \theta^{-1} \lambda_{it}^{2}$, where θ is the parameter of the gamma distribution. The negative binomial model can be estimated using the maximum likelihood techniques, shown in equation (4):

$$L\,(\beta, \lambda_{it}) = \sum_{i=1}^{N} \sum_{t=1}^{N} [-\lambda_{it} + y_{it}(x_{it}\beta + \varepsilon_i) - \ln y_{it}!] \qquad (4)$$

Therefore, in the regression model of this study, the equation is written as

$$y_{it} = \exp[\beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln R\&D\ INPUT_{it} + \beta_3 HIGHED_{it} + \beta_4 OADR_{it} + \beta_5 ED_{it} + \beta_6 PUBST_{it} + \beta_7 OPENNESS_{it} + \beta_8 \ln FDI_{it} + \beta_9 PRIVATE_{it} + \beta_{10} UNIVIN_{it} + \beta_{11} LINK_{it} + \beta_{12} CON_{it} + R_i + T_i] \quad (5)$$

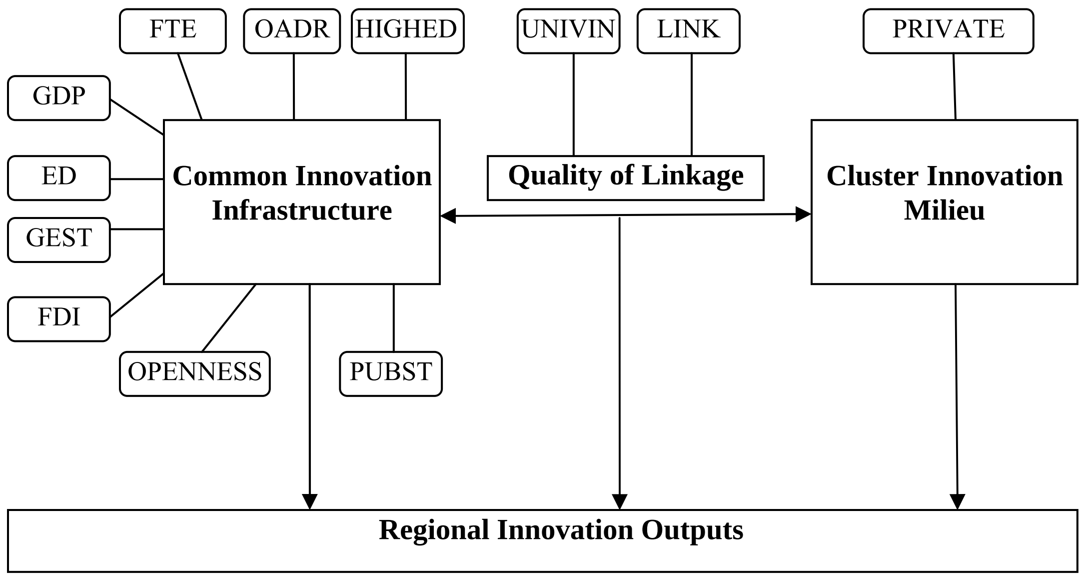


Figure 5.4. The Research Framework of Regional Innovation Systems

The dependent variable y_{it} in the models is the total number of patents in each region i for a given year t. The independent variables included in the models are: GDP_{it} indexes GDP per capita of region i in year t; two measures of R&D inputs—1) FTE_{it} indexes the full-time equivalent of S&T personnel in region i and year t, and 2) $GEST_{it}$ indexes gross domestic expenditure on S&T in region i and year t; $HIGHEDU_{it}$ indexes the population with high educational attainment of region i in year t; $OADR_{it}$ indexes the elderly population dependency of region i in year t; ED_{it} indexes the public expenditure on education in region i and year t; $PUBST_{it}$ indexes the public S&T appropriation in region i and year t; $OPENNESS_{it}$ indexes a region i's openness to international trade in year t; FDI_{it} indexes the total amount of FDI to region i in year t; $PRIVATE_{it}$ indexes the self-raised S&T funds by firms in region i and year t; $UNIVIN_{it}$ indexes the total R&D performed by the universities and research institutes in region i and year t; $LINK_{it}$ indexes the S&T funds of universities and research institutes raised from industry in region i and year t; CON_{it} are control variables regarding to whether a region i is a eastern region in year t and whether a region i is a metropolitan region in year t; R_i are unobserved regional specific factors that do not change over time; and T_i is a unobserved time specific factor that do not change across regions.

All independent variables employed in the analysis either enter in a natural logarithm form or are expressed as ratio in order to minimize heteroskedasticity and also to allow easier elasticity interpretation for their coefficients. When the variables contain monetary values, they are deflated by consumer price indices (CPI) to the 1998 value. In addition, prior to the analysis, a diagnostic test based on VIF is taken to check the severity of multicollinearity among independent variables. The average of VIF value is less than 3.4, with the maximum VIF value of 4.58, which are well below the cut-off point of 10 (Cohen et al. 2003), implying that multicollinearity does not pose a big problem among explanatory variables for the estimation models in this analysis.

5.2.2. Main Results of Regression Models

In the following, the estimated results from several regressions using fixed effects negative binomial models specified for two different measures of innovation output are presented. First, the models taking the number of invention patent grants as a measure of innovation output are estimated and then present its primary results regarding the relationship between innovation output ($Patg_{i,t+3}$) and the drivers of regional innovation capacity. Beside inventions patents, utility model patents which contain the second most sophisticated technological novelties are another measure of innovation output ($Patu_{i,t+1}$) in this analysis. Thus, the estimated results of the regression models for utility model patents would follow up. Lastly, the models for each three regional cluster are estimated in order to examine the impact of their regional innovation systems on the two different patenting activities.

5.2.2.1. Determinants of Invention Patent Counts

The first set of models analyzed the panel data for 30 provinces from 1998 to 2007 to investigate the effects of the variables of the regional innovation capacity described in Figure 5.4 on invention patenting rates.

Table 5.5 Regression Results of Negative Binomial Models with Invention Patents

	Dependent Variable: Institutional Invention Patents by Province i year t+3 ($Patg_{i,t+3}$)			
	MODEL 1	MODEL 2	MODEL 3	MODEL 4
The Common Innovation Infrastructure				
L GDP PER CAPITA	2. 315***	1.291***	0.461*	0.208
	(0.189)	(0.248)	(0.251)	(0.191)
L FTE	0.633***	0.634***		
	(0.130)	(0.136)		
L GEST			1.159***	0.920***
			(0.114)	(0.118)
HIGHEDU	0.029**	0.039***	0.031**	0.035***
	(0.013)	(0.012)	(0.011)	(0.011)
OADR	-0.028	0.015	0.004	0.028
	(0.026)	(0.024)	(0.022)	(0.023)
ED	0.059**	0.065***	0.040**	0.061***
	(0.025)	(0.022)	(0.018)	(0.020)
PUBST	-0.134	-0.123	-0.122*	-0.158**
	(0.085)	(0.079)	(0.067)	(0.068)
OPENNESS	0.002	0.002	0.001	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
L FDI	-0.071	-0.046	-0.051	-0.033
	(0.056)	(0.055)	(0.051)	(0.054)
Cluster Innovation Environment				
PRIVATE S&T		0.024***		0.013***
		(0.005)		(0.005)
Quality of Linkages				
UNIVIN		-0.009***		-0.008***
		(0.003)		(0.003)
LINK		-0.011*		-0.008
		(0.006)		(0.005)
Controls				
Year	0.009***	0.008***	0.007***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
Metro. Regions	-2.067***	-0.972**	-1.589***	-0.825**
	(0.386)	(0.430)	(0.372)	(0.400)
East Regions	-1.218***	-0.950***	-0.513	-0.765**
	(0.348)	(0.328)	(0.326)	(0.322)
Constant	-26.446	-18.651	-6.955	-4.524
	(1.865)	(2.205)	(1.952)	(1.607)
Log Likelihood	-905.405	-880.857	-880.629	-869.112
Observations	209	209	209	209

Notes: The natural logarithm of a variable X is denoted as L X . Standard errors are in parentheses. Two tailed-tests significant at: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5.5 provides the results for the regression models 1-4, predicting invention patenting. Model 1 and 2 incorporate each component of regional innovation capacity: the common innovation infrastructure, the cluster innovation environment, and the quality of linkages, using total FTE S&T personnel (FTE) as a measure of R&D inputs. Model 1 includes all variables of common innovation infrastructure and three control variables for both year and region-specific effects. The results for the Model 1 show that GDP PER CAPITA and FTE have a significant and positive impact on the level of invention patenting. Interpreting the coefficient as elasticities, for every 1% increase in GDP PER CAPITA, the number of invention patents increases by 2.3%. Similarly, the coefficient on FTE implies that a 10% increase in FTE results in 6.3% more patents. This result is consistent with endogenous growth theory, suggesting that a region's existing level of technological sophistication and the level of R&D inputs have played an important role in determining innovation output.

Along with FTE, the population with higher educational attainment (HIGHEDU) and old dependency ratio (OADR) are alternative indicators of the regional scale of human resources potentially available for innovation activities. While HIGHEDU is positively and significantly associated with the number of invention patents, OADR has a negative impact on the level of invention patenting and its coefficient is statistically insignificant. The coefficient on HIGHEDU can be interpreted as follows: for every 1% point increases in the percentage of the working age population with high educational attainment, the number of invention patents increases by 3%. This implies that regions with a larger population with high educational attainment have been able to achieve significantly higher invention patenting productivity.

The importance of the role of the regional government is captured by two regional policies, such as public education expenditure (ED) and government's S&T appropriation (PUBST), reflecting the strength of the government's resource commitments. In Model

1, ED has an important impact on innovation output, as demonstrated by a statistically significant positive coefficient. For every 1% increase in the public expenditure on education, the number of invention patents increases by 6%. A high level of public education investment can create a pool of highly skilled personnel, which enable firms and other institutions within a region to engage more in S&T activities. By contrast, PUBST has an insignificant effect as well as a negative relationship with the level of invention patenting. This indicates that the impact from government S&T supports is not significant in the case of invention patenting. To some extent, this implies the inefficiency of government S&T support in increasing the level of innovation outputs.

As shown in Model 1, the effect of international technology spillover channels, such as FDI and international trade (OPENESS), seems to be trivial and the estimated coefficients of both variables are statistically insignificant. In fact, openness to international trade does not affect invention patenting, since its coefficient is almost as same as zero. The coefficient on OPENNESS is at least an order of magnitude smaller than that on FDI. A negative coefficient of FDI suggests that FDI inflows have a negative influence on the level of invention patenting.

Model 2 includes the remainder of the measures of the cluster innovation environment and the quality of linkages along with the year and region-specific fixed effects. These additions retain the significance and make no big changes in direction and size of the coefficients of the measures included in Model 1. Only the coefficient of GDP PER CAPITA appreciably decreases from 2.315 to 1.291 but remains highly significant at the level of 0.01.

In accordance with the industry cluster perspective that innovation-based competition of the industries increases the R&D resources as well as R&D productivity, the PRIVATE S&T FUNDING enters positively and significantly in Model 2. A 1% point increase in the fraction of self-raised S&T funds by firms is associated with a 2.4% increase in invention patents. This implies that higher levels of private S&T funding are associated with higher levels of S&T productivity.

The measures of the quality of linkages—both UNIVIN and LINK—have statistically significant negative coefficients with small magnitude. An increase in the share of R&D performed by the science sector, including universities and research institutes, negatively affects the invention patenting productivity. This implies that R&D performance by the science sector does not help to raise the level of R&D efficiency. In addition, the sign of LINK coefficient indicates that financial support from firms to S&T activities in universities and research institutes is negatively associated with invention patenting, but its impact is very small. Similarly to UNIVIN, the interaction between firms, universities, and research institutes does not increase the level of innovation productivity regarding to invention patents.

Model 3 and 4 present the estimated results of the regressions that employ the gross expenditures on S&T (GEST) as the measure of R&D inputs. Although it is generally includes both human and capital resources in the estimation of knowledge production function (Romer 1990), each two variable has to be used in separate models, since they are highly correlated with each other.[26] Thus, Model 3 and 4 repeat the analysis utilizing GEST as the capital resources devoted to R&D activities. Model 3

[26] Within the sample period, the correlation coefficient between FTE and GEST is 0.910 (see Table A.2 in the Appendix A.)

shows that there are changes in the magnitude of some variables and the significance of others, but the overall results are similar to those shown in Model 1. Compared to Model 1, the most notable difference is that the impact of knowledge stock, GDP PER CAPITA, decreases largely in Model 3. Also, PUBST becomes negative and significant.

Model 4 adds measures of the cluster environment for innovation and the quality of linkages to Model 3. These additions have an impact on the coefficients of some variables in the prior model, but most results remain significant with the expected sign. However, the magnitude of the coefficient on GDP PER CAPITA becomes insignificant and its impact is also reduced from 0.461 in Model 3 to 0.208 in Model 4. The effect of PUBST increases and becomes significant at the level of 5%. As compared to Model 2, PRIVATE S&T FUNDING and university R&D expenditure (UNIVIN) stay the same in terms of significance and sign of the coefficients, whereas LINK becomes insignificant with a small decrease in the coefficient.

In all models 1 though 4, the effects of control variables are found to be consistent. With regard to the year fixed effects, the time trend (year) are both positive and statistically significant, indicating that some unobserved factors that change over time are causing a upward trend in invention patenting over the sample period. The estimated coefficients of both Metropolitan Regions and East Regions are significant but, contrary to expectations, in a negative direction. The negative signs of those variables can be due to multicollinearity with other variables or the small number of observations.[27]

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[27] The 12 eastern coastal provinces and four municipal cities (e.g., Beijing, Tianjin, Shanghai and Chongqing) generally have the high levels of socioeconomic development in China. Thus, those regions can be highly correlated with some infrastructure variables, including GDP, openness to international trade, public S&T expenditure, and population with higher educational attainment. The possible sign of multicollinearity is the

Therefore, the overall findings from the Model 1-4 can be summarized as follows: 1) the level of R&D inputs and knowledge stocks/the level of regional technological and economic development is a critical factor determining the level of innovation outputs; 2) the population with higher educational attainment as the scale of human resources has a significant influence on the level of innovation outputs; 3) the government policy, particularly public education investment, is positively associated with the level of realized innovation, while government S&T supports may lower the level of innovation efficiency; 4) the cluster environments for innovation plays an important role in determining the innovation productivity; 5) linkages between innovation actors are neither effect nor efficient in producing innovation outputs.

5.2.2.2. Determinants of Utility Model Patent Counts

Beside invention patents, the most technologically sophisticated innovation output, utility model patents represent marginal innovation which contains the less technological content and commercial value than the invention ones. Taking the number of utility model patent grants as another measure of innovation output, the regression models are estimated.

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relatively large standard errors for two dummy variables, EAST REGIONS and METRO. REGIONS. However, the small sample size can also be the reason for the large stand errors (Fox 2005).

Table 5.6 Regression Results of Negative Binomial Models with Utility Model Patents

	Dependent Variable: Institutional Utility Model Patents by Province i year t+1 ($Patu_{i,t+1}$)			
	MODEL 5	MODEL 6	MODEL 7	MODEL 8
The Common Innovation Infrastructure				
L GDP PER CAPITA	1.385***	1.557***	1.355***	1.367***
	(0.100)	(0.110)	(0.157)	(0.146)
L FTE	0.153*	0.200**		
	(0.084)	(0.079)		
L GEST			0.073	0.227***
			(0.076)	(0.081)
HIGHEDU	0.004	0.003	0.004	0.002
	(0.005)	(0.005)	(0.005)	(0.004)
OADR	0.027	0.016	0.022	0.016
	(0.018)	(0.017)	(0.018)	(0.017)
ED	-0.021	-0.022	-0.013	-0.018
	(0.018)	(0.017)	(0.017)	(0.016)
PUBST	0.227***	0.217***	0.229***	0.228***
	(0.037)	(0.036)	(0.037)	(0.036)
OPENNESS	-0.002	-0.001	-0.001	-0.001
	(0.002)	(0.001)	(0.002)	(0.001)
L FDI	-0.054	-0.062	-0.051	-0.056
	(0.039)	(0.038)	(0.039)	(0.039)
Cluster Innovation Environment				
PRIVATE S&T		-0.005		-0.007**
		(0.003)		(0.003)
Quality of Linkages				
UNIVIN		0.006**		0.007***
		(0.003)		(0.003)
LINK		0.003		0.004
		(0.003)		(0.004)
Controls				
Year	0.002	0.002	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Metro. Regions	-1.477***	-1.951***	-1.416***	-1.753***
	(0.345)	(0.374)	(0.369)	(0.377)
East Regions	-0.471*	-0.236	-0.459	-.0.303
	(0.282)	(0.297)	(0.284)	(0.295)
Constant	-11.714	-13.654	-10.042	-10.457
	(0.943)	(1.028)	(1.213)	(1.126)
Log Likelihood	-1374.759	-1365.538	-1375.993	-1364.808
Observations	270	269	270	269

Notes: The natural logarithm of a variable X is denoted as L X. Standard errors are in parentheses. Two tailed-tests significant at: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5.6 reports the estimated results of Model 5-8 using the utility model patent counts as another measure of innovation output. The first thing to note is that the estimated coefficients of GDP PER CAPITA are highly significant at the level of 0.01 in all four models. However, changes in GDP PER CAPITA have a much larger influence on utility model patenting than those in R&D inputs—FTE S&T personnel and S&T expenditure. For example, interpreting the coefficients as elasticities, Model 6 implies that for every 1% increase in GDP PER CAPITA, the number of utility model patents increases by 1.6%, while for every 1% increase in FTE S&T personnel, the number of utility model patents increases by only 0.2%. The same pattern is also observed in the case of invention patenting. Thus, the existing accumulated prior knowledge over the sample period plays key roles in determining two different innovation outputs. This finding is somewhat reversed to previous study (Li 2009) that utility model patenting is more likely driven by human resources devoted to R&D than by accumulated prior knowledge.

Model 7 and 8 show that the impact of GDP PER CAPITA remains positively significant, when replacing FTE with GEST as a measure of R&D inputs in the specifications. Similarly to Model 5 and 6, GDP PER CAPITA has a much impact on utility model patenting than the level of R&D inputs. However, this is the opposite case of invention patenting. Model 3 and 4 in Table 5.5 show that GEST is likely more an important driver of the process of invention production than GDP PER CAPITA. Therefore, financial resources devoted to R&D are more valuable in producing high-quality invention patents than marginal innovation leading to technological improvement and modification such as utility model patents.

As in the case of invention patents, the R&D resource commitments, including human and capital resources, are crucial determinants of the level of utility model patenting. However, the impact of R&D inputs is more significant and larger in invention patenting than utility model patenting. Alternative measures of potential human capital for R&D activities, such as HIGHEDU and OADR, are not significantly associated with the level of utility model patenting, as shown in Table 5.6. By and large, the findings indicate that the production process of the most technologically sophisticated innovation outputs in related to invention patents is more resource intensive.

Government policies affect the two types of the innovation outputs distinctively. While public education investment has a significant influence on the level of invention patenting, the impact from government S&T support is highly significant in the case of utility model patenting. Model 8 suggests that a 1% increase in the share of government appropriation on S&T results in 22.8% more utility model patents. This is contrasting what has been reported in Model 4 in the case of invention patenting: the government S&T support is negatively associated with the level of invention patenting. Although the government puts a higher priority on supporting for the most important S&T activities, the results indicate that its effect can be limited to the generation of less technologically sophisticated innovation outputs. This demonstrates that the efficiency of the government S&T funding is lower in performing technologically intensive innovation activities.

The knowledge spillover effects of the FDI inflow and international trade appear to be insignificant in all patenting activities. Contrary to expectations, the coefficients of FDI are all negative in Table 5.5 and 5.6, suggesting that FDI is not favorable to both invention and utility model patenting. The negative impact of FDI on the domestic innovation is suggested by the crowding-out hypothesis that foreign-invested enterprises with superior technological assets and manage skills monopolize the competition market, crowd out the domestic firms in the industry, and then decrease the market share of domestic firms (Chen 2007). In addition, the insignificant results of overall FDI could be due to the fact that a majority of inward FDI contains the least technology or knowledge components since it has been concentrated in more labor intensive sectors, such as light industrial and textile goods. The large amount of low quality FDI in China came from Hong Kong weakens the significant impact of relatively small amount of high quality FDI from Western countries (Zang and Rogers 2009). In the same manner, the importance of openness to international trade appears to be insignificant in two types of patenting activities. Although not statistically significant, the coefficients of OPENNESS are positive in the case of invention patenting, suggesting that accessing diverse foreign knowledge and advanced technology have a positive influence on the innovation outputs involving a higher level of technological novelty.

The contrast effect of PRIVATE S&T FUNDING between Table 5.5 and 5.6 highlights the distinction between the two types of innovation outputs. As shown in Table 5.6, the coefficient of PRIVATE S&T FUNDING on utility patenting is negative and its magnitude is small, contrary to the result in the case of invention patenting. Model 8, controlling for gross S&T expenditure, presents that the impact of PRIVATE S&T FUNDING on utility model patenting is significant. Although Chinese firms hold a dominant share of utility model patents granted, the result does not support their positive role in generating utility model patents. Rather, it demonstrates that private firms are major sources of technologically intensive innovation in related to invention patents.

In Model 6 and 8 from Table 5.6, the coefficients of the linkage variables—UNIVIN and LINK—are all positive but only UNIVIN has a significant impact on utility model patenting. Comparing the estimated coefficients of UNIVIN and LINK for the two types of patents suggest that the effect of both linkages variables is more important for innovation in the utility model than in inventions. The sign of UNIVIN indicates a positive impact from universities and research institutes in terms of utility model patenting. However, this is opposite to the case of invention patenting. Along with the firms, universities and research institutes are major recipients of invention patents granted, but the result shows that innovation activities performed by the science sector are not efficient in the process of invention production. As contrasted to invention patenting, the estimated coefficient of LINK is positive, suggesting that financial supports from firms to S&T activities in universities and research institutes plays a favorable role in the generation of utility model patents. However, the impact of LINK is not significant.

From the comparison of the estimated results for the two types of innovation outputs, it is evident that the influence of factors regarding to the innovation environment and the quality of linkage on innovation depends on the types of patents. As the private S&T investment and activities largely increased across regions (see Figure 4.14 and 4.15 in Chapter 4), firms became an important source of invention patenting, while the effects of knowledge or technology spillovers from universities and research institutes are stronger in generating utility model patenting. Contrary to the expectations, the interaction between private and science sectors (LINK) are neither effective nor efficient in performing the two types of patenting activities. These empirical results highlight the importance of the cluster innovation environment to major innovation (e.g., invention patent) and manifest the positive role of knowledge spillovers from science sector on marginal innovation (e.g., utility model patent). This is in contrast to the findings of the recent study conducted by Li (2009) that university and research institutes play a more favorable role in invention patenting at the Chinese regional level. However, his results also indicate that regions with developed high-tech industrial clusters are more inclined to produce innovation patents. Guan and Liu's study (2005) also found that the industry's R&D funding is most efficient in enhancing innovation activities in related to invention patents.

Table 5.7 The Share of Institutional Patent Grants by Three Sectors

	Invention Patent (%)			Utility Patent (%)		
	University	Research Institute	Firms	University	Research Institute	Firms
1998	25.5	35.3	19.1	7.1	15.0	74.2
1999	25.2	32.2	27.4	5.8	12.7	78.9
2000	23.1	32.2	36.0	5.6	9.9	82.6
2001	22.1	30.6	41.7	5.7	8.9	83.3
2002	22.2	28.8	46.5	5.3	6.9	85.8
2003	25.1	24.3	49.1	6.6	6.2	85.3
2004	28.6	19.8	50.3	7.3	5.9	85.1
2005	30.2	16.4	52.2	8.2	5.5	84.7
2006	33.7	13.9	51.3	8.2	5.9	84.4
2007	33.5	13.0	52.5	8.7	4.9	84.9

Source: SIPO (1998-2007)

The significant influence of private S&T investment on innovation is reflected in a rapid increase in the firms' share of institutional invention patent grants, as shown in Table 5.7. In 1998, Chinese firms had 182 invention patents, the lowest number of institutional patents behind universities and research institutes. By 2007, Chinese firms owned 12,851 invention patents, surpassing that of universities and research institutes.

This large increase implies that Chinese firms had substantially improved its innovation capabilities. At the same time, the share of institutional invention patent grants for universities and research institutes fell gradually from 60.8% in 1998 to 46.5% in 2007. With a decrease in its share of invention patent grants, S&T activities undertaken by universities and research institutes were not effective on the production of invention patents, but utility models. While the firms' own S&T efforts become a major source of invention patenting, possible knowledge spillovers from universities and research institutes have contributed more to the generation of utility model patents.

To sum up, the overall findings from the Model 5-8 can be summarized as follows: 1) the accumulated knowledge capacity/the level of regional economic and technological development, and the level of S&T inputs are critical factors in determining the level of utility model patenting; 2) government S&T supports significantly impact on the generation of utility model patents; and 3) the linkage between public and private sectors, represented by S&T performance of universities and research institutes, has a significant and positive influence on utility model patenting.

Table 5.8 Exploring Robustness

	Dependent Variable: Model 9&10: Institutional Invention Patents by Province i year t+1; Model 11&12: Institutional Utility Model Patents by Province i year t+1			
	MODEL 9	MODEL 10	MODEL 11	MODEL 12
The Common Innovation Infrastructure				
L GDP CAPITA	-0.021	1.295***	0.795***	1.557***
	(0.083)	(0.247)	(0.292)	(0.110)
L FTE	0.695***	0.654***	0.202*	0.196**
	(0.141)	(0.146)	(0.119)	(0.089)
HIGHEDU	0.011	0.040***	0.005	0.003
	(0.013)	(0.013)	(0.005)	(0.005)
OADR	0.0001	0.014	0.017	0.016
	(0.028)	(0.024)	(0.021)	(0.017)
ED	0.013	0.064***	-0.050***	-0.022
	(0.025)	(0.022)	(0.016)	(0.017)
PUBST	0.030	-0.119	0.231***	0.217***
	(0.073)	(0.079)	(0.036)	(0.036)
OPENNESS	0.003	0.002	-0.004**	-0.001
	(0.003)	(0.002)	(0.002)	(0.002)
L FDI	-0.010	-0.047	-0.028	-0.062
	(0.045)	(0.055)	(0.043)	(0.038)
Cluster Innovation Environment				
PRIVATE S&T	0.011***	0.024***	-0.009***	-0.005
	(0.004)	(0.005)	(0.003)	(0.003)
Quality of Linkages				
UNIVIN	-0.006***	-0.009***	0.005*	0.006**
	(0.002)	(0.003)	(0.003)	(0.003)
LINK	-0.002	-0.011*	0.001	0.003
	(0.005)	(0.006)	(0.003)	(0.003)
Controls				
Year	0.212***	0.008***	0.113***	0.002
	(0.029)	(0.002)	(0.030)	(0.002)
Province fixed effects	Included		Included	
Pre-sample fixed effects		0.002		0.0001
		(0.005)		(0.001)
Metro. Regions		-0.915**		-1.957***
		(0.452)		(0.378)
East Regions		-0.909		-0.256
		(0.344)***		(0.344)
Constant	-38.226	-18.834	-8.454	-13.624
	(4.300)	(2.234)	(2.985)	(1.059)
Log Likelihood	-823.897	-880.785	-1334.569	-1365.532

Notes: The natural logarithm of a variable X is denoted as L X. Standard errors are in parentheses. Two tailed-tests significant at: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

In order to explore the robustness of the primary results from Table 5.5 and 5.6, additional regression models with a number of modifications are estimated, as shown in

Table 5.8. Model 9 and 10 for invention patents reproduce the primary results of Model 2, altering some of measures included in the model. To establish more precise role of cross-sectional variation in the results, Model 9 substitutes two control variables—METRO.REGIONS and EAST REGIONS—for province fixed effects. Given that these two dummy variables may result in some problem with multicollinearity with other variables, they are constructed by a combination of province fixed effects. Key measures of S&T resource commitments in terms of the human capital, innovation environment, and the quality of linkage remains significant. However, many of the measures of the common innovation infrastructure become insignificant. The estimates of these variables are sensitive to province-specific fixed effects, suggesting that cross-sectional variation drives significance. It is interesting to note that the coefficients of most variables are largely reduced after adding province fixed effects. Noticeably, the magnitude of the coefficient on GDP PER CAPITA substantially changes, suggesting that the level of invention patenting is sensitive to changes in GDP PER CAPITA within a given province.

Model 10 adds the pre-sample fixed effects (e.g., the average number of invention patents granted in the period from 1985 to 1997) to Model 2 in order to control for the region-specific unobserved heterogeneity that is not fixed throughout time. The permanent capability of a given region to produce and commercialize new knowledge or technology can be reflected in the pre-sample history of innovation output.[28] Thus, pre-knowledge capabilities are expected to have a positive effect on the level of innovation

[28] Blundell et al. (2002) introduce the method of conditioning on the pre-sample patent stock to control for the unobserved heterogeneity in firm innovation. The present study applies it to the Chinese regions by including the pre-sample average patent count to proxy for the unobserved heterogeneity in regional innovation.

outputs (Blundell et al. 2002; Hagedoorn and Wang 2010). As presented in Model 10, the results from the previous model are robust in that all variables stay the same in terms of significance, sign and magnitude of its coefficients. The year variable as a time trend variable is consistently positive and significant. The pre-sample patent variable is positive but statistically insignificant, indicating that it may not be important to control for the unobserved differences in the innovation capabilities with which regions entered the sample of this study.

In the similar manner, Model 11 and 12 for utility model patents explore the robustness of the results presented in Model 6. Model 11 demonstrates robustness to the inclusion of province fixed effects. Most of results from the previous model stay the same as the coefficients of GDP PER CAPITA, FTE, PUBST, and UNIVIN remain significant and of the expected sign in accounting for utility model patents. However, some of nuanced measures of the common innovation infrastructure and innovation Environment, such as ED, OPENNESS, and PRIVATE S&T FUNDING become significant, suggesting that the level of utility model patenting is sensitive to changes in these variables within a given province. In addition, the coefficient of the year variable increases and also becomes significant. This indicates that unobserved factors that change over time substantially increase the level of utility model patenting.

Model 12 incorporates the pre-sample fixed effects into the previous model. The addition of the pre-sample fixed effects has almost no effect on the coefficients of all variables, as they stay the same as those in Model 6. The pre-sample patent variable is positive but statistically insignificant. The magnitude of its coefficient is close to zero, indicating that it does not really affect utility model patenting.

5.2.2.3. Determinants of Patenting Activities across Regions

In order to examine the impact of the regional innovation system on two types of patenting activities, regression models are estimated for each of the three regional clusters using fixed effects negative binomial methods. The ability of a given region to patent their inventions depends on the quality of the regional innovation systems, including the level of innovation infrastructure, cluster environment for innovation, and the quality of the linkages between innovation actors.

Table 5.9 Determinants of Invention Patenting by Regions

	Dependent Variable: Institutional Invention Patents by Province i year t+3 ($Patu_{i,t+3}$)		
	MODEL 13 First-Tier Region	MODEL 14 Second-Tier Region	MODEL 15 Third-Tier Region
The Common Innovation Infrastructure			
L GDP CAPITA	0.981***	2.612***	0.520
	(0.341)	(0.708)	(0.318)
L FTE	0.945***	1.086***	0.402
	(0.309)	(0.381)	(0.255)
HIGHEDU	0.025*	0.006	0.077***
	(0.014)	(0.037)	(0.023)
OADR	0.032	0.037	0.024
	(0.026)	(0.051)	(0.060)
ED	0.045	0.125*	0.121***
	(0.037)	(0.065)	(0.044)
PUBST	-0.217**	-0.067	-0.072
	(0.098)	(0.144)	(0.170)
OPENNESS	0.003	-0.027	0.015*
	(0.002)	(0.027)	(0.008)
L FDI	-0.045	0.209	-0.127*
	(0.098)	(0.137)	(0.074)
Cluster Innovation Environment			
PRIVATE S&T	0.051***	0.014	0.020***
	(0.008)	(0.009)	(0.007)
Quality of Linkages			
LINK	-0.028***	-0.020***	0.006
	(0.009)	(0.008)	(0.013)
Constant	-21.381	-34.642	-9.942
	(2.555)	(5.350)	(3.325)
Log Likelihood	-329.481	-221.390	-296.577
Observations	63	56	90

Notes: A. All control variables were taken off from the regression in order to get significant results because of the fewer observations after splitting data by three categories of

Table 5.9 (continued)

regions. The variable of UNIVIN is also excluded to avoid the strong collinearity with other variables.

B. The natural logarithm of a variable X is denoted as L X . Standard errors are in parentheses. Two tailed-tests significant at: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5.9 presents the estimated results of Model 13-15 for invention patenting. The estimated results show that the impacts of GDP PER CAPITA and FTE S&T personnel on the level of invention patenting are both positive and significant in the first and second tier region. However, GDP PER CAPITA is significantly higher in the second tier: its coefficient implies that, ceteris paribus, an additional 1% of GDP PER CAPITA increases invention patents by 2.6%. For the third tier region, HIGHEDU, more nuanced measure of the labor resources for S&T activities, has a greater effect on the number of invention patents.

With regard to the government policies, public investment on human capital is effective in performing technologically intensive innovation activities in the second and third tier regions. By contrast, the importance of government financial supports on S&T appears to be significant only for the first tier region, but it is negatively associated with the level of invention patenting. Although the provinces in the first tier are generally larger recipients of government policy supports, it is not effective incentive supports for high-quality invention outputs.

The effect of FDI is negative in the first and third tier regions, and it is only significant in the third tier ($p<0.1$). The negative sign of FDI could be explained by the so-called crowing-out effect that FDI crowds out domestic firms in the original competitive market, because the over-reliance on foreign technologies removes the firms' indigenous efforts on R&D. OPENNESS is significantly positive only for the third-tier region ($p<0.1$). Although not significant, the effect of openness to international trades is also positive for the first tier region. Most provinces in the first tier are major destinations for FDI inflow and international trades in China, the beneficial spillover effects on the production of major innovation are not significantly high. This finding confirms that both crowding out effect as well as the spillover effect may co-exist across the regions.

The innovation environment in the first and third tier regions has a significant and positive influence on the level of invention patenting. The results in Table 5.9 show that the invention patenting productivity from the private S&T investment is significantly higher in the first-tier region. For every 1% increase in S&T investment by firms, the number of invention patents increases by 5.1% in the first tier, 1.4% in the second tier, and 2% in the third tier. This finding indicates that private firms are important sources of invention patenting in the first and third tier region, reflecting the fact that the private S&T investment is the sole source of S&T activities in most western provinces in the third tier, while the coastal regions in the first tier have enhanced the innovation environment by developing industrial clusters and innovation infrastructure.

In addition, possible knowledge spillovers from universities and research institutes to firms are significant in the first and second tier regions, but its impact on invention patenting is negative. For the third tier region, however, the impact is positive as expected but not significant. This finding suggests a low patenting productivity resulting from the increasing interactions between innovation actors, such as firms, universities, and research institutes. In other words, the dynamic linkage between those regional actors is weak and ineffective in all three regions, lowering the efficiency of its regional innovation systems.

Based on the overall results in Table 5.9, the level of S&T input, accumulated knowledge capacity, and innovation environment play an important role in determining high-quality S&T productivity. While Chinese regional innovation systems have made substantial S&T resource commitments as a direct input to the process of knowledge production, knowledge flows in the systems is quite weak, resulting in the low S&T efficiency. This points to the absence of strong linkage mechanisms which encourage the commercialization of new knowledge generated from the upstream sector in particular industrial clusters. As a result, despite the rapid increase of R&D inputs into the innovation process, the increased innovation outputs are not in proportion with the increase in inputs as well as the quality and relevancy of the outputs are low (Zeng and Wang 2007).

Table 5.10 Determinants of Utility Model Patenting by Regions

	Dependent Variable: Institutional Utility Model Patents by Province i year t+1 ($Patu_{i,t+1}$)		
	MODEL 16 First-Tier Region	MODEL 17 Second-Tier Region	MODEL 18 Third-Tier Region
The Common Innovation Infrastructure			
L GDP CAPITA	1.206***	1.385***	1.149***
	(0.181)	(0.194)	(0.298)
L FTE	-0.025	0.557**	0.333**
	(0.214)	(0.266)	(0.154)
HIGHEDU	0.005	0.025**	0.015
	(0.006)	(0.012)	(0.014)
OADR	-0.030	0.071***	0.066
	(0.025)	(0.021)	(0.043)
ED	-0.020	-0.025	-0.036
	(0.035)	(0.028)	(0.035)
PUBST	0.199***	0.251***	0.101
	(0.043)	(0.083)	(0.122)
OPENNESS	0.0004	0.020	0.012**
	(0.002)	(0.013)	(0.006)
L FDI	0.124	-0.042	-0.055
	(0.087)	(0.076)	(0.062)
Cluster Innovation Environment			
PRIVATE S&T	0.0003	-0.008**	-0.013**
	(0.006)	(0.004)	(0.006)
Quality of Linkages			
LINK	0.002	-0.0005	0.009
	(0.007)	(0.005)	(0.006)
Constant	-8.902	-15.379	-11.044
	(1.651)	(2.792)	(2.628)
Log Likelihood	-510.270	-348.384	-494.989
Observations	81	72	117

Notes: A. All control variables were taken off from the regression in order to get significant results because of the fewer observations after splitting data by three categories of regions. The variable of UNIVIN is also excluded to avoid the strong collinearity with other variables.

B. The natural logarithm of a variable X is denoted as L X. Standard errors are in parentheses. Two tailed-tests significant at: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

As shown in Table 5.10, the effects of GDP PER CAPITA on the number of utility model patents are significant and positive in all three regions. This result is consistent with what is revealed in Table 5.6. As in the case of invention patenting, the effects of GDP PER CAPITA is larger in the second tier region (1.385). With regard to resource commitment, FTE S&T personnel is significantly positive for both the second and third tier regions. For the second and third tier, accumulated prior knowledge stocks and devoted resources are important factors in generating utility model patents. However, in the first tier, the process of utility model patents production is more likely to be driven by prior knowledge than devoted resources. This actually supports the previous results that invention patenting is more resource intensive than utility model patenting. In this respect, it can be postulated that the third tire region is not able to mobilize S&T resources in engaging in technologically intensive innovation activities. The effects of HIGHEDU and OADR appear to be positive and significant only for the second tier. The positive sign in OADR is in opposition to expectations that the region with the higher old age dependency ratio generates the higher number of patents.

As contrasted to the case of invention patenting, government financial supports on S&T are important sources of utility model patenting in the first and second tier regions. This finding suggests that government S&T supports are effective incentives to the generation of utility model patenting for those two regions, whereas its effect on invention patenting is insignificant. For the third tier region, there may be no substantial S&T supports from the government or government supports are neither effective nor efficient in performing S&T activities. As a matter of fact, it is evident that the first and second tier regions receive more effective and better S&T supports from the government than the third tier region.

Similarly to the results in Table 5.9, the impact of FDI is not significant in all three regions. Although insignificant, the effect of FDI is positive in the first tier, suggesting a favorable role of international spillover channels in the production of utility model patents. For the third tier region, OPENNESS is also positive and significant ($p<0.1$) in the generation of utility model patenting and its impact is slightly higher than that on invention patenting.

The results in Table 5.10 show that PRIVATE S&T FUNDING is significantly negative for the second and third tier regions, whereas its impact is insignificant for the first tier region. Compared to the results in Table 5.9, PRIVATE S&T FUNDING seems more an important source of major innovation in related to invention patents, while public S&T supports are more valuable sources of minor innovation, such as utility model patents. In case of utility model patents, PRIVATE S&T FUNDING neither affects the process of utility model production nor helps to increase the level of S&T productivity. Additionally, as in the case of invention patenting, the effect of linkages between innovation actors on utility patenting is not significant in all three regions.

CHAPTER 6

THE COMPARATIVE STUDY OF REGIONAL INNOVATION SYSTEMS IN CHINA: THE CASES OF HUBEI AND FUJIAN

Chapter Six provides the comparative case analysis of the regional innovation activities in two distinct regions—Fujian Province and Hubei Province of China. Investigating and comparing internal dynamics of two different regional innovation systems will allow us to better understand similarities and differences in innovation system building between the distinctive regional contexts and characteristics. In order to highlight the specific factors leading to the regional variations in innovation capacities, the study explores the structure and function of the innovation systems as well as the nature of the interaction between regional actors involved in the innovation process. Special attention will be given to the knowledge linkage between universities and firms that constitutes the main modes of interaction often determining the performance of the innovation systems.

6.1 Backgrounds of the Study Regions

The regions of Fujian and Hubei are chosen as the cases for the comparative analysis based on the following reasons. First, two regions sharply differ in their geographical location and characteristics. Fujian Province is located on the Southeast coast of China, one of the economic engines in the country, especially designated by the central government as the strategic areas of national development plans. Because of the geographic accessible location, the province has historically benefited from the large flow of foreign investment and trade as well as the development of export-oriented economy.

Specialized industrial clusters and bases are well established and developed within the major cities such as Xiamen and Fuzhou.

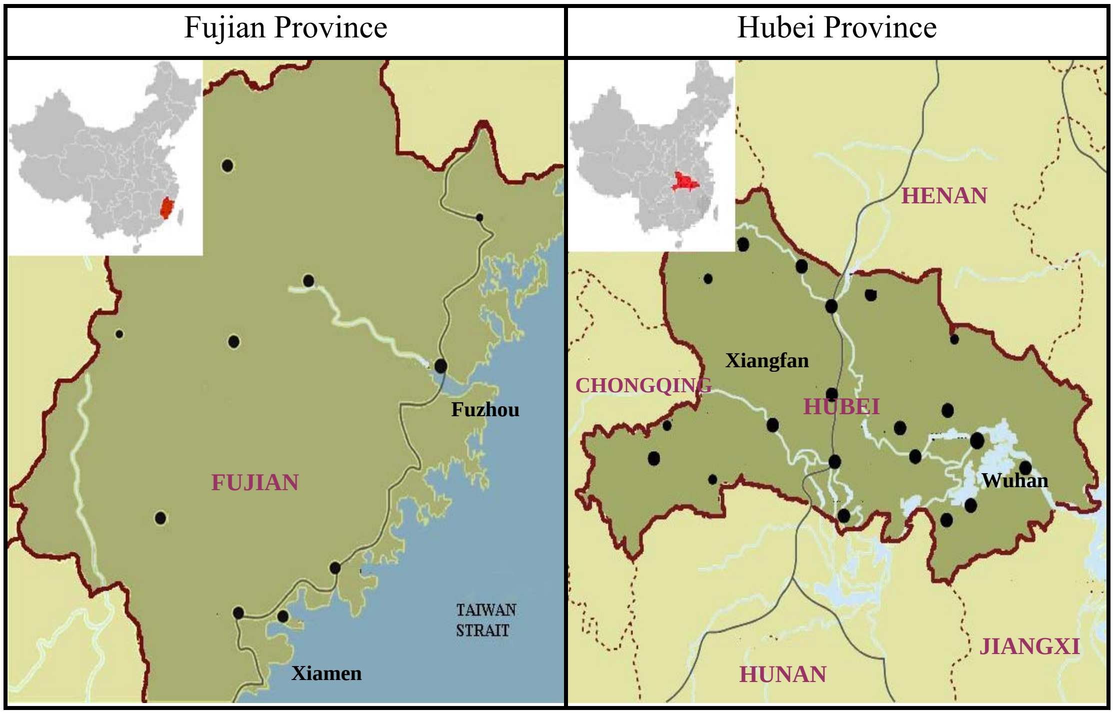

Figure 6.1 The Two Research Regions

Hubei Province is located in Central China, one of the key industrial bases with a large-scale manufacturing capability in the country (see Figure 6.1). Although the province has a relatively weak infrastructure and inadequate supports from the central government compared to the eastern coastal regions, it is endowed with the high-quality knowledge institutions providing human resources as well as supporting technology transfer. High-tech and economic infrastructure and resources are mostly developed and clustered in its capital city of Wuhan.

Second, despite their different preconditions for innovation, two regions have a similarity in terms of the innovation environment and resource commitments over time.

Both regions are mainly specialized in medium-and low-tech manufacturing sectors, including wood, textile, building materials, steel and iron, and face the challenge to transform its economy into more knowledge-driven one by increasing higher value added production. They have experienced a gradual increase in the added value of high-tech industry as well as their contribution to GDP over the past decade. The two regions also have a similar level of the R&D resource commitments and technological efforts.

Third, Hubei and Fujian have moved along different innovation trajectories during the research period. In the cluster analysis, Hubei appears as only one inland region in the first tier with the upper level of innovation capacities, whereas Fujian Province belongs to the third tier with the low level of innovation capacities (see Table 4.6 in Chapter 4). This is, to some extent, contrary to the expectation that the coastal developed regions with higher GDP per capita exhibit stronger innovation capacity than the inland counterparts. The selected cases which share both the similar and different characteristics can explain why two regions are in the two different ends of the innovation capacity spectrum over the period.

Table 6.1 Regional Indicators in Fujian and Hubei, 2007

	Fujian	Hubei
Land Areas (km^2)	121,400	185,900
Population (10,000 persons)	3,581	6,070
Urban (%)	48.70	44.30
Rural (%)	51.30	55.70
Total Population with Higher Educational Attainment (%)	7.35	10.40
Old Age Dependency Ratios (%)	13.94	13.28
GDP Per Capita (Yuan)	25,908	16,206
Primary (%)	14.9	10.8
Secondary (%)	43	49.20
Service (%)	42.1	40.00
Number of Employees (10,000 persons)	1999	2763

Table 6.1 describes some regional indicators from each of the two regions. The population of Hubei Province is 60 million which almost doubled that of Fujian Province. In Hubei, about 10% of the total population aged 15 and over has a higher educational attainment which is larger than Fujian. However, the aging population for two regions is almost the same at the level of 13%. Both provinces also have a similar urban-rural structure; urban population accounts for 48.7% and 44.3% in Fujian and Hubei respectively. During the past decade, they have faced increasing urbanization, since their industries and main economic activities have moved from the rural to urban areas along with an increasing share of the service sector in the regional economies.

The GDP size of Fujian Province is almost twice larger than Hubei. The GDP per capita of Fujian Province was 25,908 Yuan, an increase of 63% compared to 1998 and ranked the eighth among 30 province-level regions. For Hubei Province, its GDP per capita reached 16,206 Yuan, for the 16th place. It increased by 66% from 1998 to 2007. The secondary sector is the largest one for both provinces, accounting for 43% in Fujian and 49% in Hubei. As mentioned earlier, this is due to the fact that two regions are more specialized in the medium-and low-tech manufacturing sectors. Major industries in Fujian include traditionally dominant industries such as textile, clothing, metallurgy, and building materials as well as leading industries of electronics, petrochemicals, and engineering machinery. Hubei, however, has the strengths of industries, such as iron and steel, textile, auto manufacturing, machinery, electric power, and chemical industry.

The employed population of Hubei Province is larger and also its share of service employment is slightly higher than Fujian. On the contrary, a greater high-tech employment is offered in Fujian than in Hubei. For example, in the end of 2007, the number of employees in the high-tech industry is three times higher in Hubei. Fujian specializes in the high-tech sector, especially, electronic information, advanced manufacture, new materials, and bio-medicine and medical equipments.

Two provinces, however, have distinctive historical backgrounds in China. Hubei was historically one of the cradles of Chinese civilization as well as the earliest centers of industrialization. Hubei's central geographical location creates the unique cultural atmosphere integrating diverse regional cultures in northern and southern China. The capital city of Hubei, Wuhan (also known as *Hankou*) was developed as a commercially significant place from the Ming (1368-1644) to Qing (1644-1911). By the end of the 19th century, Wuhan's opening as a trading port brought the large FDI inflows from the western countries (e.g., the U.K. the U.S., Russia, France, Germany, Netherlands, etc.) and Japan to Hubei.[29] This contributed to development of the modern industrial sector as well as capital market which financed import and export trade. The building of the railways and several treaty ports in the early years of the 20th century also accelerated the pace of industrialization in the region. At the same time, the foundation of first modern iron and steel plant in Hanyang municipal-city helped Hubei to be the leading site of heavy industry in the country (Boland-Crewe and Lea 2002).

The relatively high-level of modern industrial and commercial development with the environment of international trade in the region, in turn, paved the way for the China's bourgeois revolution in the early twentieth century, leading the success of the revolutionary movement against the Qing Dynasty and dynastic rule in the country.

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[29] Although Hubei was integrated into the world economy about 20 years later than the coastal provinces such as Shanghai, Zhejiang, Guangdong and Fujian, it was far way ahead than other inland provinces. After opening to the outside world, "Wuhan earned the reputation of being 'China's Pittsburgh' or 'China's Manchester' (Yun 1999: 156)."

During the Civil War (1927-1949), Hubei became even more famous as the one of important places in the history of the Chinese Communist Party (CCP) where communist groups had emerged and formed before the CCP was founded.[30] During the pre-reform period from 1949 to 1979, Hubei was favored by the central government through the planned economic system and heavy industrialization strategy (Yun 1999). Hubei was one of the key provinces which benefited from the central government's development strategy by receiving a large share of centrally allocated investment before 1980. A long history of trade and transport was strengthened in the pre-reform period by building a great bridge in Wuhan. Hubei produced a large portion of the national agricultural source as well. Consequently, Hubei was developed as one of the major industrial and agricultural bases and economically was the wealthiest and most power province in central China.

Since the economic reform, however, Hubei came to lag behind not only the east-coastal regions but also the other central regions in economic development due to the decrease of central government's investments and the absence of the preferential policies. During the reform period, total investment from the central government begun to decline as the focus of the national development strategy shifted to the coastal areas. This made a negative impact on the Hubei's overall economy, which used to highly rely on the central government's investment. In order to restore its historical position by catching up with the coastal provinces, the Hubei provincial government has made constant efforts in implementing a series of the provincial development strategies.

[30] Among the 13 representatives of the first National Congress of the CCP, five were from Hubei, including Lin Biao and Li Xiannian who was the key figures of the CCP. In addition, among 254 marshals, generals of the PRC, 49 came from Hubei (Yun 1999)

Fujian, also referred as "Min," was integrated into the Chinese territory when the Qin dynasty ended in the third century BC. Particularly, Fujian has a long history of the maritime trade as well as the emigration and overseas settlement in China as one of the earliest provinces to open for foreign trade in the national history. Since the third century, Fuzhou (also known as Yecheng, the capital city of Fujian) and Quanzhou had been developed as the most important coastal seaports for the trade and transportation between China and South Asia. Quanzhou was one of the busiest and the most active port in the world during the Song (960-1276) and Yuan dynasties (1271-1368). Chinese domestic products such as handcrafts, silk, sugar, paper and gold were exported and those from South Asian countries—mainly Arab and India—were also imported through Quanzhou seaport (China Statistics Press 2008b). The flourishing maritime trading of the Fujian coast had attracted large numbers of South Asian settlers at the same time. This, in fact, had some impacts on the ethnic composition of the Fujian population. Fujian is a multi-ethnic area where there are total 54 ethnic groups besides the Han majority.[31]

Meanwhile, Xiamen (also known as Amoy) was established as an active seaport in the 14th century and became the refuge for Ming dynasty fled the Manchu Qing invaders in the 17th century. Xiamen was especially a favorite place for foreign trading base to the Dutch and other Europeans during the 17th century. When the port was closed to foreign trade in the 18th century, it was forced to re-open by the western countries through the First Opium War and the 1842 Treaty of Nanjing. At that time, most of domestic tea in

[31] The 53 minority ethnic groups only take account of 1.7% of the total Fujian population. Among the ethnic minority groups, the She and Gaoshan minorities have the largest population in the province. Fujian is also the birthplace of the Hui minority.

China was shipped to the West via Xiamen. Xiamen and Fuzhou were among the Treaty Ports opened to foreign tradesmen during the 19th century.

In addition to sea-faring and commercial tradition, Fujian historically depended on emigration to "relieve population pressure and to provide a flow of remittances and investment funds for kinfolk back home" (Lyons 1997: 2). The severe restrictions on maritime commerce during the Ming dynasty in the 15th century resulted in the massive emigration created a Diaspora; many especially went to Taiwan (Boland-Crewe and Lea 2002). Due to the historical reason, about 10 million overseas Chinese are Fujian descendants; among them, over one million residents in Hong Kong and Macao and about 80% of Taiwanese are Fujian descendants (China Statistics Press 2008b). Following the fall of the Ming dynasty, Taiwan was officially incorporated into Fujian province by the Qing dynasty. However, Taiwan was specially managed by the Qing government to reduce piracy and vagrancy in the areas, restricting immigration and controlling aboriginal land rights. Nonetheless, illegal immigrants from Fujian continued to enter Taiwan in order to rent aboriginal lands. For this reason, the majority of the Taiwan's population today is descent from these Fujian immigrants. During the Chinese civil war, Taiwan was separated from Fujian province and became the jurisdiction of the Taiwan-based 'Republic of China.'

Geographical isolation owing to its steep mountains and rugged terrain kept the province economically and technologically backward. Through most of the Maoist era, Fujian's GDP ranked almost bottom among 30 provinces. The inland bias of central government's investment in transport and industry and potential conflicts with Taiwan contributed to Fujian's relatively underdeveloped economy and level of development.

For example, the Chinese government strictly restrained interregional and foreign trade, stressing self-sufficiency at the regional level. Fujian suffered directly from these policies, since core cities traditionally relied on food imports, nonagricultural specialties, and remittances from overseas Fujianeses (Lyones 1997).

However, the economic reform in the late 1970s marked a crucial turning point for Fujian. The shift in the government's development strategy from inland to coastal provinces became the opportunity for Fujian to boost its economic development. In 1979, Xiamen was among the China's first four "special economic zones" established by the central government and Fuzhou was one of original "open coastal cities." As domestic and international trade through coastal ports was reactivated, Fujian could attract increasing amounts of Taiwanese and foreign investment. Especially, "Taiwan meant more to the related people of Fujian as a source of major investment" (Boland-Crewe and Lea 2002: 85)

In recent years, Hubei and Fujian race to catch up with the economically most advanced provinces on the east coast, including Shanghai, Beijing, Tianjin, Jiangsu, Zhejiang, etc. Hubei has achieved the highest economy growth rate since the economic reform, with its average annual GDP growth of 13.7% during the last five years (Hubei Provincial Government 2010). In 2009, Hubei's GDP per capita ranked 3rd among the central provinces after Neimenggu and Jilin (NBS 2010a).

In 2006, Hubei has benefited from the national development plan targeting at the central China. The Chinese government implemented new regional development initiatives, 'the Rise of Central China' for the resurgence of the central region in China.[32] Hubei was one of the six central provinces designated by the central regional development plan. Six central provinces in the Rise of Central Plan have received the investment from the central government in implementing their own economic development and industrialization plans (Lai 2007). With the central government support, Hubei has been deemed as "the new boost to the economy" in central China, achieving rapid economic growth rate.

Hubei has also made a particular effort to mark the shift of its economic structure from traditional to knowledge-based industries. The current provincial government's five-years development plan reflects this attempt, focusing on the development of high-tech industries, such as optoelectronics, new energy vehicles, new materials, energy saving, environmental protection, and biomedicine, which took account of more than 30% of total industry outputs in 2009. With the fast-growing knowledge sector, Hubei has restored its historically superior position by overtaking the neighboring provinces in central China, such as Anhui, Henan, and Jiangxi. However, although the geographic and historical advantage enjoyed by Hubei seems to revive gradually, its development level still falls behind the coastal regions.

Since the economic reform, Fujian has become one of the dynamic market-oriented economic regimes in China, leading the country's economic boom (Hook 1996). At the present, Fujian is one of the wealthier provinces in China, as it is the top ten

[32] According to Lai (2007), the Chinese government formulated five policies in the central China development programme: 1) provide support for agriculture production; 2) assist in the development of agglomerate of major municipal cities; 3) support central China to upgrade its old key industrial bases; 4) grant the region more autonomy in opening up to the outside world; and 5) encourage the region to develop education and human resources.

provinces with more than 1 trillion Yuan GDP (NBS 2010a). Although the Fujian's GDP ranks almost at the bottom among coastal provinces, it has experienced a rapid economic growth rate with its average annual GDP growth of 14% since the early 2000s. The size of its GDP increased three-fold during the last decade (China Statistic Press 2010).

The Fujian's rapid economic development in recent years can be attributed to the large scale of inflow of foreign capital, especially from Hong Kong, Macao, Taiwan, and Singapore. Increasing inflows of FDI has been channeled into infrastructure, agriculture, S&T projects, and high-tech sector. Above all, the flourishing business relationship with Taiwan has contributed significantly to economic modernization in the province through promoting export-led growth and generating local employment (Hook 1996; Wannan 2011). The relatively cheap and abundant land and labor has attracted many Taiwan investors and led to the rapid expansion of Taiwan's investment in Fujian over time.

In 2009, the Chinese government has approved the program to establish the Taiwan Strait West Coast Economic Zone, which aims to support the efforts of the Fujian's government in strengthening infrastructure and fostering economic integration between Fujian and Taiwan (Tung 2006; Wannan 2011). The Western Taiwan Strait Economic Zone covers 9 cities in Fujian, including Fuzhou and Xiamen and 11 cities in other neighboring provinces such as Zhejiang, Jiangxi, and Guangdong. Through the establishment of the Economic Zone, Fujian and other coastal provinces are expected to accelerate the infrastructure construction to receive large amount of investment from Taiwan. In the near future, Fujian will continue to take advantages of the longstanding cultural and historical ties with Taiwan to facilitate bilateral exchange and cooperation.

With its particular advantages, Fujian will play an important role in boosting the national economy as well as transferring foreign capital and technology to the inland regions.

6.2 Regional Innovation Systems: Institutional Features and Functions

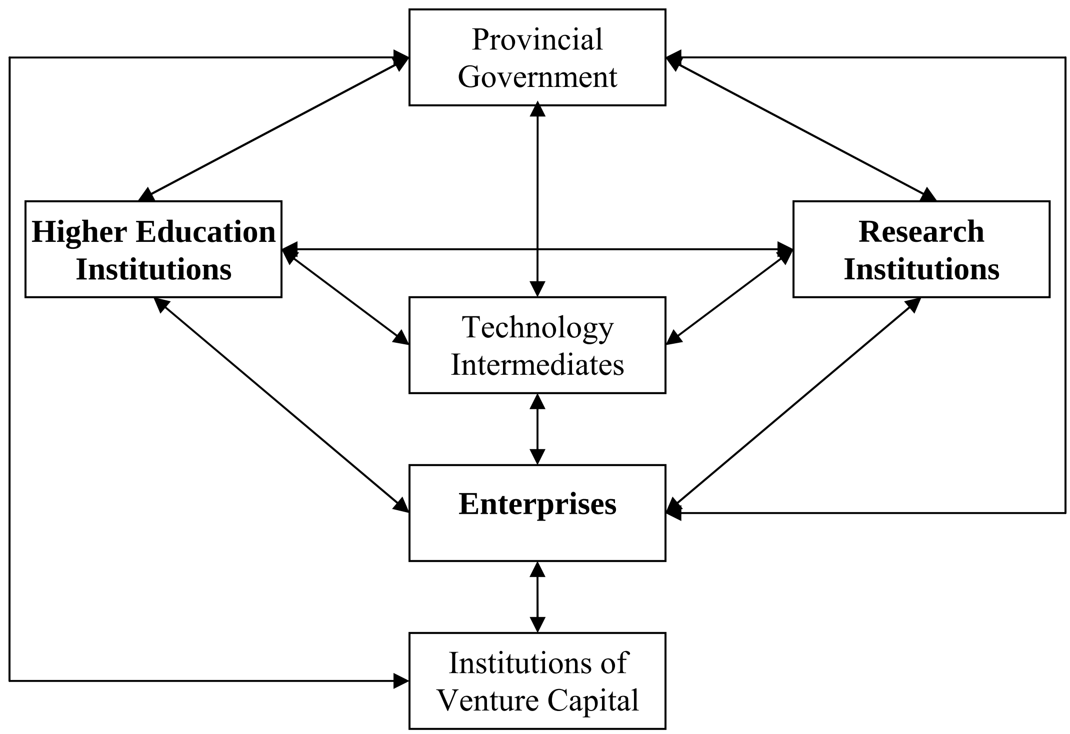


Figure 6.2 Main Institutions and Interaction Flows in the Regional Innovation System

The differences among regional innovation systems reflect the activities of regional innovation actors and the strength of their relationships. As shown in Figure 6.2, the three core actors in the regional innovation systems are enterprises, research institutions, and higher education institutions, since they are main R&D performers among China's regions. Research institutes and universities are the key knowledge institutions which play an important role as not only the main base of regional knowledge activities such as technology creation and transfer, but also the important pillars of industry-science relationships.

Table 6.2 Knowledge Institutes in Hubei and Fujian, 2008

	Hubei	Fujian
Number of Public R&D Institutions	161	103
Number of Higher Education Institutions	86	72
211 Program	Wuhan University Huazhong University of S&T China University of Geosciences Wuhan University of Technology Huazhong Agricultural University Huazhong Normal University Zhongnan University of Economics and Law	Xiamen University Fuzhou University
958 Program	Wuhan University Huazhong University of S&T	Xiamen University

Sources: NBS (2008a); Simon and Cao (2009)

According to Table 6.2, Hubei has more knowledge institutes, such as higher education institutions and public R&D institutions, than Fujian. In 2008, 161 research institutes of regional government are located in Hubei while there are 103 institutions in Fujian. Although the number of public research institutes has been downsized in both provinces due to a series of reforms since 1999, they still play an important role in supporting basic and applied research as well as experimental development in the fields of natural science and technology.

Hubei has 86 higher education institutions, including university, polytechnics, and advanced vocational school, which is higher than 72 institutions in Fujian. The number of R&D institutions of higher education in Hubei is double that in Fujian. As shown in Table 6.2, Hubei also has more key national leading universities than Fujian. In China, key institutions of higher education at national or provincial levels are determined by the government through the government programs, such as the 211 Program and the 985 Program.[33] Under the direct administration of the Ministry of Education, the central and regional governments, and government ministries, key universities selected in the 211 program and the 985 program have benefited from various prestigious national funding projects and received continuous government's supports. As a result, "not only have they been resources-rich, they also have been able to leverage their status to recruit outstanding faculty and excellent students from across the entire nation" (Simon and Cao 2009: 122). Hubei has seven key universities identified by the 211 program and two universities designed by both the 211 and the 985 program. By contrast, Fujian has two universities selected by the 211 program and one of them was recognized as a key institution by two programs.

In 2007, both Hubei and Fujian have a similar proportion of large and medium-sized enterprises (LMEs) engaging in S&T activities, accounting for around 20% of total number of LMEs.[34] The number of private research institutes founded by enterprises in Hubei and Fujian was 278 and 389, respectively. More S&T projects were accomplished by those industrial research institutes in Hubei than in Fujian. In terms of high-tech industrial cluster environment, each province has two major cities which are important

[33] In 1993, the 211 program designated 100 universities as key academic institutions in order to upgrade the infrastructure of China's leading universities. Subsequently, the 39 institutions were selected as elite universities by the 985 program and sponsored by the government. The goal of these government projects is to promote the development of Chinese universities as world class distinguished academic institutions.

[34] In China, LMEs can be state-owned, joint ventures, or collectively and privately owned. The Chinese government puts much importance in LMEs for national economic development as well as innovation. They are not only the main economic actors but also the major S&T performers in many Chinese regions.

bases for the high-tech industrial sector. For Hubei, the majority of high-tech industries are concentrated mainly in Wuhan and Xiangfan where the high-tech industrial development zones at the national-level are established, such as the Wuhan East Lake Technology Development Zone and Xianfan High-Tech Industrial Development Zone. Nearly half of Hubei's high-tech enterprises are located in those two national high-tech industrial development zones (Hubei Provincial Department of S&T 2007). At the provincial level, 11 high-tech zones are founded along the Yangtze River, and almost 90% of the Hubei's high-tech enterprises are located in the high-tech industrial development zones.

Fujian also has two high-tech industrial development zones at the national-level in Xiamen and Fuzhou (Xiamen Torch High-Tech Development Zone and Fuzhou High-Tech Industrial Development Zone) that create a local optimization of the high-tech industrial cluster environment. Similar to Hubei, the majority of Fujian's high-tech enterprises are clustered mainly in those two cities, accounting for 40.9% and 28.1% respectively. In addition, there are four high-tech development zones at the provincial-level established in other cities, including Quanzhou, Zhangzhou, Putian, and Sanming.

Table 6.3 High-Tech Industry Development in Hubei and Fujian, 2007

	Hubei	Fujian
Number of High-Tech Enterprises (unit)	2,759	2,384
Number of S&E Employees (person)	13,980	14,866
Value of High-Tech Industrial Output (Billion Yuan)	262	371
High-Tech Industrial Value Added (Billion Yuan)	86	94
Export Delivery Value for High-Tech Products (Billion Yuan)	20.5	49.1
High-Tech Industry's Contribution to GDP (%)	10%	12%

Sources: Hubei Provincial Department of S&T (2009); Fujian Provincial Department of S&T (2008)

In comparison, Fujian has larger outputs of high-tech industries than Hubei, as denoted in Table 6.3. In 2007, Hubei had total 2,759 high-tech enterprises, while there were 2,384 high-tech enterprises registered in Fujian. The major high-tech industries established in the Hubei's high-tech industrial development zones are optoelectronics, biomedicine, new materials, advanced manufacturing, software, new energy and environment protection. In Fujian, the main high-tech industrial sector includes computer and office equipment, electronic and communications equipment, pharmaceuticals, medical equipment and instrumentation, and aerospace. Fujian realized more high-tech industrial output value than that of Hubei in recent years (see Table 6.3). Fujian's total output value from high-tech industries reached 371 billion Yuan in 2007 increased from 77 billion Yuan in 2000. In Hubei, it increased from 86 billion Yuan to 262 billion between 2000 and 2007, at an annual growth rate of 26%. The export delivery value for high-tech products in Fujian was also more than twice that for Hubei. The proportion of high-tech product exports in the total exports accounted for 30.8% in Fujian and 40% in Hubei. Similarly, for both provinces, the high-tech sector contributed about 10% to its GDP.

Table 6.4 Foreign Investment and Trade in Hubei and Fujian, 2007

	Hubei	Fujian
Number of Foreign-Funded Enterprises (unit)	3,964	18,655
Foreign Direct Investment (US $100 million)	27.7	40.6
Total Import and Export (US $100 million)	148.6	665.7
Total Import	66.8	195.8
High-Tech Product Import	10.7	57.09
Total Export	81.3	469.8
High-Tech Product Export	14.1	100.5

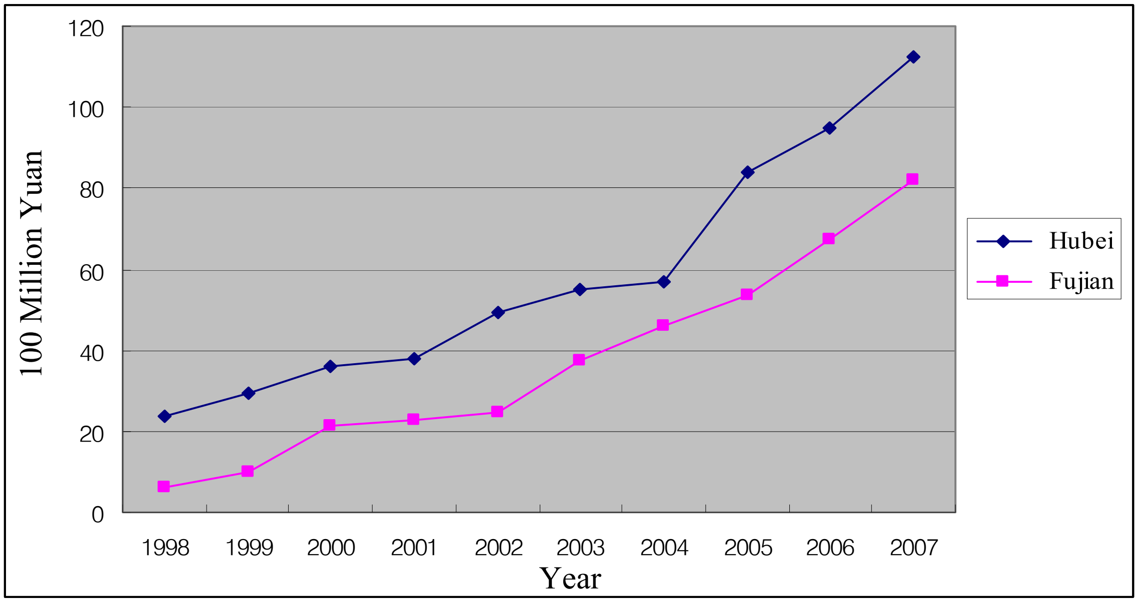
Sources: China Statistics Press (2008a and 2008b)

However, it should be noted that foreign-funded firms have played a dominant role in the development of high-tech sector in Fujian as contrasted to Hubei. Because of the readily accessible geographic location, Fujian has benefited from large amounts of foreign direct investment as well as strong foreign trade growth. In 2007, Fujian received 4.1 billion US dollars of FDI, while Hubei received 2.8 billion US dollars (see Table 6.4). During the same period, the number of foreign-funded enterprises in Fujian was almost 5 times larger than those in Hubei. Particularly in Fujian, foreign-funded enterprises take nearly 80% of total high-tech industrial output value. Among the foreign investors, Hong Kong, Macao, and Taiwan are major investors of the Fujian's high-tech industry, in that their invested enterprises account for 40 percent of the total high-tech industrial output value, while the share of domestic enterprises is only 21 percent. In contrast to Fujian, the share of foreign-funded enterprises in the Hubei's high-tech sector is below 5%. Foreign capital, therefore, makes up a very small proportion of S&T investments for domestic enterprises in Hubei (Hubei Provincial Department of S&T 2005).

In terms of the openness to international trade, Fujian is also far ahead of Hubei. Fujian has been top ten exporters as well as importer among 31 Chinese provinces; in 2007, Fujian's export and import ranked he sixth and eighth respectively, whereas Hubei ranked the sixteenth and the twelfth. Table 6.4 also illustrates that Fujian's exports and imports of high-tech capital goods far surpassed those of Hubei. A dominant role of foreign-funded enterprises in the Fujian's high-tech sector can account for the large amount of the high-tech product exports, whereas relatively small inflows of FDI and weak foreign trade lead Hubei to be less export-oriented.

Assuming that FDI and high-tech goods imports can be an important channel to obtain technology and knowledge from foreign sources, they would play a major role in Fujian for the acquisition of advanced technology and a minor role in Hubel. A heavy reliance on FDI and technology importation results in 'crowding out' of domestic firms in the market and preventing technology transfer and knowledge spillovers in the region. The increasing share of foreign-funded enterprises in the high-tech sector becomes a prominent issue in Fujian for developing the capabilities of domestic high-tech enterprises.

6.2.1 R&D Resource Commitment and Performance

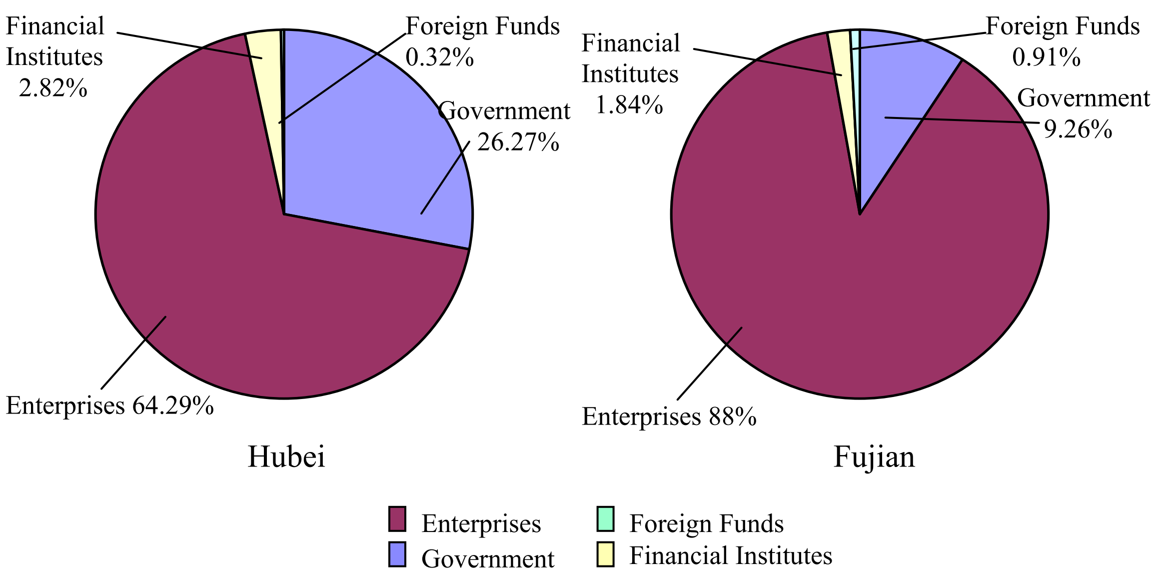


Source: MOST (2008a)

Figure 6.3 Gross Domestic Expenditure on R&D in Hubei and Fujian, 1998-2007

The pattern of R&D resource commitment as well as the nature of main actors' R&D activities reflects the one component of the regional innovation systems. Figure 6.3

presents that R&D expenditure in both provinces rose at a rapid pace between 1998 and 2007. This indicates that both provinces made a significant effort to engage in R&D activities. The share of Fujian's GDP devoted to R&D increased from 0.2% in 1998 to 0.90% in 2007, demonstrating that R&D intensity has largely increased over time. At the same time, Hubei expanded its R&D expenditure, spending 0.71% of GDP in 1998 and 1.18% in 2007. It was slightly higher than Fujian in all sample period. In recent years, Hubei and Fujian rank the 9th and the 15th respectively among China's 31 provinces in terms of the R&D intensity (MOST 2010).

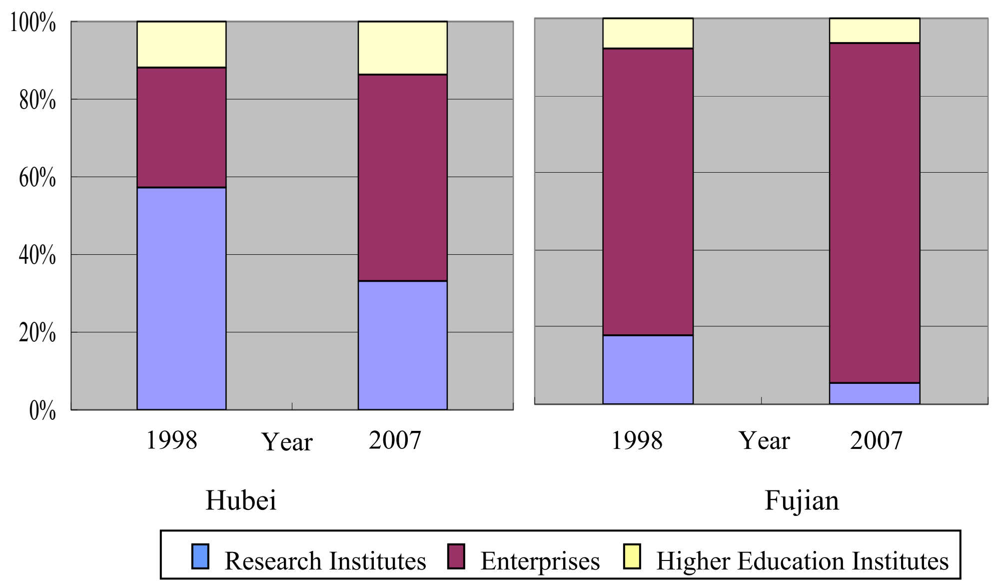


Source: NBS (2008b)

Figure 6.4. R&D Expenditure by Source of Funds in Hubei and Fujian, 2007

R&D expenditure in both provinces is mainly financed by four sources, that is, the government, enterprises, financial institutes, and foreign capital. The enterprises and government are two major sources of R&D funding in its innovation systems. As Figure

6.4 indicates, the enterprises are a major source of R&D activities in Hubei and Fujian, accounting for 64% and 88% of total R&D expenditure respectively. Since a series of reforms in 1999, the government's R&D funding has been reduced in most of Chinese regions, while private R&D investment has increased gradually. In both Hubei and Fujian, there was a 20% increase in the share of private R&D funding of the total R&D expenditure between 2000 and 2007. The government is the second largest source of R&D funding, particularly providing financial supports for R&D activities in universities and research institutes. Hubei government is responsible for a larger part of the total R&D expenditure than Fujian, whereas the enterprises play a dominant role in R&D investment in Fujian. Meanwhile, bank loans and foreign funds for R&D activities have accounted for a small part of the total R&D expenditure in both provinces.



Source: NBS (2008b)

Figure 6.5 R&D Expenditure by Sector of Performance, 1998 and 2007

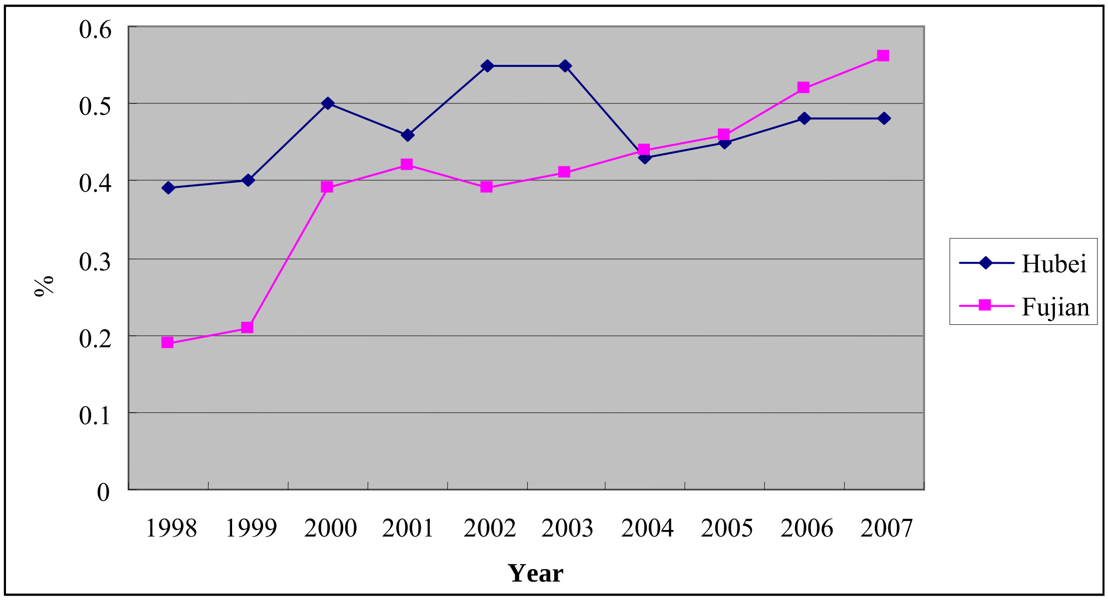
The major performers of R&D in China are research institutes, enterprises, and universities. In Fujian, enterprises are the most important actor in the innovations systems, not only in R&D financing, but also in R&D performance. LMEs have spent a major proportion of the total expenditure on R&D, accounting for 74% in 1998 and 63% in 2007. There is a tendency that the R&D expenditure of the small sized enterprises has been increasing, while that of the LMEs has been dropping over time. In 2007, the small sized enterprises consumed a 17% of total R&D spending in Fujian.

As shown in Figure 6.5, universities and research institutes are the smallest R&D spenders in Fujian, sharing less than 10% of total R&D expenditure. Their share of total R&D spending fell precipitously from 26% in 1998 to 9% in 2007. Especially, the R&D expenditure of research institutes was reduced significantly from 18% to 4%. This can be the result of a major reform of Chinese innovation systems that have forced research institutes to be industrialized in order to promote an enterprise-led innovation system (Huang et al. 2005; OECD 2007). For example, in 2000, Fujian provincial government made an effort to accelerate the industrial transformation of research institutes, providing employees benefits and tax incentives to research institutes. Fujian's universities also have met difficulties to play a role as the knowledge institutions for innovation due to a lack of the public supports to basic and applied research, insufficient R&D funds, and limited R&D activities (Fujian Provincial Department of S&T 2005).

By contrast, research institutes and enterprises play a major role in R&D implementation in Hubei. For example, in 2007, the R&D expenditure of research institutes was 29%, while that of enterprises was 46%. Since the reform of 1999, the former has been decreasing, while the latter increasing. In 1998, research institutes were the primary performers of R&D in Hubei, consuming almost 60% of the total R&D spending (see Figure 6.5). However, Hubei provincial government has begun reforming the provincial scientific research units to establish “open, mobile, competitive and cooperative scientific research institutions” (General Office of Hubei Province Government 2000). It has implemented a series of reform policies, including cutting government subsidies to research institutes, through the restructuring plans, supporting employment benefits, recruiting the S&T talents from overseas, and actively supporting them for business registration. During the reform, research institutes with an applied R&D focus were turned into spin-off companies and some units merged into the universities. Although almost a half of its R&D expenditure was reduced in recent years, they remain the second key R&D performer in Hubei.

Universities, the other R&D performer, spent around 12% of total R&D spending in both 1998 and 2007. As mentioned before, Hubei has relatively many well-known universities, such as Wuhan University. Universities are the primary performers of basic and applied research and most of S&T activities are supported by the Hubei provincial government. In order to foster technology transfer, Hubei’s universities are urged to set up their spin-offs and offer various technology services to the enterprises, such as technical training, consulting, and contracting. Hubei provincial government has established the corporate income tax exemption policy for the first and second year of technology contracts with universities to promote interactions between industry and universities. Furthermore, university science parks are set up in the high-tech industrial development zones for technology transfer, business incubation, and entrepreneurship services.[35] As a result, universities have played an important role in the development of the high-tech industry in Hubei by not only providing education and knowledge resources but also creating many high-tech spin-offs.

6.2.2 Promotion of Science and Technology Workforce Development



Sources: Hubei Provincial Department of S&T (2009); Fujian Provincial Department of S&T (2008)

Figure 6.6 S&T Personnel Intensity in Fujian and Hubei, 1998-2007

From 1998 to 2007, both Fujian and Hubei enlarged their S&T workforce—S&T and R&D personnel and scientists and engineers involved in S&T and R&D activities. Fujian's S&T personnel rose sharply from 30,256 in 1998 to 112,758 in 2007, while that

[35] Wuhan University, Huazhong University of S&T, and Huazhong Agricultural University have established their own science parks in the Wuhan East Lake High-Tech Industrial Development Zone and the Wuhan Donghu New Technology Industrial Development Zone. Their key development fields are optical-electronic information, optical-mechanical-electronic integration, biology technology, new medicine, hi-tech agriculture, new materials, and environment protection.

of Hubei had a relatively small increase in its S&T personnel from 131,007 to 173,490. As indicated in Figure 6.6, Fujian achieved a sharp increase in S&T personnel intensity (e.g., ratio of S&T personnel divided by the total number of employees) which exceeds that of Hubei in recent years.

However, with a strong base of knowledge institutions, Hubei has a relatively large pool of human resources in general. In 2007, total undergraduate student enrollment in higher educational institutions in Hubei and Fujian was 1.2 million and 0.51 million, respectively (NBS 2008a). In terms of the total undergraduate enrollment, Hubei ranked the third among 31 provinces, whereas Fujian ranked the 16th. Those specializing in S&E reached 598,758 in Hubei, accounting for about 52% of the total enrollment of undergraduates. By comparison, in Fujian, there were 202,555 undergraduate students enrolled in S&E majors, representing 40%. The postgraduate enrollment in Hubei also has been stronger than in Fujian; in 2007, 75,352 students were enrolled in the postgraduate programs in Hubei, which was almost triple those of Fujian.[36]

Table 6.5 S&T Workforces in Hubei and Fujian, 2007

	Hubei	Fujian
Total R&D Personnel (person)	67,403	47,642
Research Institutes (%)	18.1	4.6%
Enterprises (%)	45.4	51.2%
Higher Education Institutes (%)	18.8	10.1
Scientists and Engineers Involved in R&D Activities (person)	58,208	37,443
Total S&T Personnel (person)	173,490	112,758
Research Institutes (%)	11.9	4.8

[36] In 2007, the number of postgraduate degrees awarded in Hubei was more than four times higher than those in Fujian. Specifically, Hubei awarded 3,099 doctorates and 22,001 master's degrees, while Fujian graduated 5,143 students with master's degrees and awarded 582 doctorates (China Statistics Press 2008a and 2008b). *Data on the number of postgraduates and undergraduates by the field of study are not available for Hubei Province.*

Table 6.5 (continued)

Enterprises (%)	42.4	47.5
Higher Education Institutes (%)	16.1	9.3
Scientists and Engineers Involved in S&T Activities (person)	125,143	75,787

Source: MOST (2008a)

In recent years, the number of S&T personnel and scientists and engineers in S&T activities in Hubei were larger than that of Fujian (see Table 6.5). Hubei had 125,143 scientists and engineers in S&T activities who either have received a bachelor's degree and up in S&T fields or have possessed a professional rank, whereas there were 75,787 scientists and engineers in Fujian. However, in both provinces, almost half of S&T personnel mainly concentrate in the private sector. The ratio of distribution of S&T personnel in research institutes and universities was higher in Hubei than in Fujian, accounting for 28% and 14% respectively.

Hubei has a relatively strong base for S&T workforce among 31 provinces; in 2009, Hubei ranked the 8th in terms of R&D personnel (MOST 2010). In 2001, Hubei provincial government set the long-term S&T human resources development plan of 'the New Century Talents Project' for two periods of time (2001-2005 and 2006-2010). In order to strengthen regional S&T workforce, 5,000 qualified young researchers and engineers were selected for training, offered government special funds and incentives (General Office of Hubei Provincial Government 2002). At the same time, Hubei provincial government has implemented the overseas S&T talent policies in order to encourage the qualified overseas S&T talents to engage in academic researches and government-funded projects in Hubei. Returned overseas students and scholars are not only offered provincial research funding and special funds in conducting their own research in a particular field, but also appointed at universities, research institutes, or state-owned enterprises in Hubei with a high-level of salary.

In contrast, Fujian has faced a shortage of the human workforces for a long time due to the historical reason.[37] There has been less public investment in S&T higher education with a relatively small number of colleges and universities in the province. This leads to the weak scientific research capacities of higher education institutions as well as the lack of S&T personnel (Fujian Provincial Department of S&T 2004). In 2001, Fujian provincial government implemented the "science and education zone" strategy in Xiamen with an emphasis on "production, learning, and research." Several policies were designated to create a social environment for the cultivation and use of S&T personnel. For example, top-notch young talents in S&T fields were selected for the professional and technical training, 51 teaching and research bases were established in the science education zones, and public financial and personnel supports were provided to improve the quality of primary and secondary education (Fujian Provincial Department of S&T 2002). Fujian provincial government also has established special funds for qualified scientists and engineers. Either returned overseas personnel or young talents from outside Fujian are provided with the research funding to attract and retain young S&T talents. In addition, there was an effort to attract foreign S&T researchers, especially from Taiwan by implementing the 'Fujian-Taiwan S&T exchange program.'

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[37] Because of the close geographic proximity with Taiwan, Fujian has been considered the battlefield frontline in a potential war between mainland China and Taiwan. For this reason, Fujian had less investment and support from the central government as well as its infrastructure and resources were developed more slowly than other East-Coastal regions before 1978. However, since the economic reform in the early 1980s, Fujian has not only received significant foreign investment but also particularly formed a good economic connection with Taiwan.

As compared with Hubei, however, there were relatively fewer specific government programs and policies implemented in Fujian in terms of S&T education and personnel during 1998-2007. While Hubei developed a few policy programs in terms of S&T talent development and education in the early years, Fujian implemented the less number of policies and had a small investment for S&T education and research in the institutions of higher education. In recent years, Fujian government initiated the ambitious program of the 'long-term talent development in Fujian Province (2010-2020)' in order to develop a pool of high-quality S&T human resources.[38]

6.2.3 Regional Innovation Policies Formulation

In general, the Chinese central government has formulated national S&T development plans as the fundamental policy tools to allocate and mobilize resources as well as to organize and develop R&D activities at national level. The national S&T plans set the broad orientation and outline the main direction for S&T development during a particular period of time. In recent years, the 11th five-year plan (2006-2010) and medium-to long-term S&T development (2006-2020), the most influential blueprints for the China's social and economic development, were proposed by the state council. Each national S&T plan stresses the strength of indigenous innovation capacity for the national sustainable development by enhancing the role of enterprises in the innovation systems, intensifying IPR protection, and promoting institutional reform.

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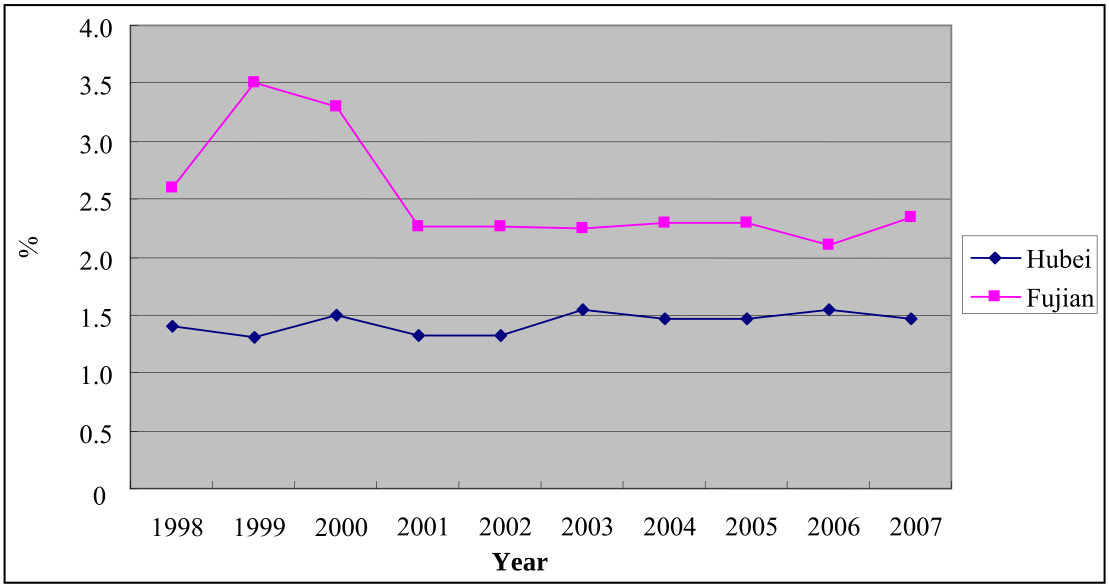
[38] The 'Fujian long-term talent development program' implements a wide range of policies, including training outstanding young scientists and engineers, attracting Taiwanese talents to promote industrial connection between Fujian and Taiwan, guiding highly skilled personnel to work for enterprises in S&T parks, providing entrepreneurial skills training and guidance service to S&E students, increasing the talent development funding for research projects and training (Fujian Provincial Department of S&T 2011).

Within the overall national policy framework, however, the provincial and lower-level governments can develop their own S&T and innovation strategies based on the local needs and adopt policies in the regional context (OECD 2008b). As the institutions of innovation policy formulation at the regional level, the provincial-level governments play an important role in effectively promoting, managing, and coordinating overall regional innovation activities. The General Office of Provincial Government and the Department of S&T are mainly responsible for planning, policy, projects and general S&T development plans, in conjunction with the other departments of the provincial government under certain circumstances. While the former sets the macro goals and directions of innovation policies, the latter takes the lead in designing, preparing, and implementing the specific policies in the provincial context. Several offices of the Department of S&T are directly involved in the S&T policy making process, including the policy and regulation office, the high-tech and industrialization office, the development office, the S&T achievements and technology market office, etc. The innovation policy formulation at the provincial level; therefore, results from the collective work of these offices and the final approval is given by the General Office of Provincial Government.



Source: MOST (1998a-2008a).

Figure 6.7 Hubei and Fujian Provincial Government S&T Appropriations, 1998-2007

Likewise, Hubei and Fujian have developed their own social and economic as well as S&T development plans in line with the general policy framework at the national level. In China, financial resources spent by the provincial-level governments come either directly from their budget or from the central government in the framework of national S&T programs (OECD 2008b). Figure 6.7 shows that Fujian provincial government spent more on S&T budget than Hubei during1998-2007. Since 2001, there was almost no change in the share of each provincial government appropriation in its total S&T expenditure. However, Hubei received more funding from the central government than Fujian in implementing two national programs, such as Torch Program and Spark Program.[39] In 2007, 3,800 million Yuan were arranged to Hubei for 336 Torch

[39] Torch Program is launched in 1988 as the national S&T program of high-tech industries. This program aims at organizing and performing projects of developing high-tech products, establishing high-tech industrial development zones across the country,

and Spark projects, whereas Fujian received 1,981 million Yuan funded for 201 projects (NBS 2008b).

From 1998 to 2007, the S&T development strategies of both provincial governments reflect the broad strategic objectives and orientations set at the national level: the 9th (1996-2000), the 10th (2001-2005), and 11th (2006-2010) national five-year plans. In 1995, the national strategy of the ”Revitalizing China through Science and Education” was initially implemented as the new development strategies for the 21st century of China. The main idea of this strategy is to put science and education in the core of economic and social development, translating S&T advances into primary productive forces. By 2010, its goals were targeted at consolidating and improving the new S&T system that has been basically set up and integrating S&T with the economy.

Hubei and Fujian set the S&T strategic plans based on this national development strategy with the four main targets of 1) reforming its S&T systems in the market-oriented economy context; 2) promoting development of key high-tech industries and industrialization; 3) strengthening basic research; and 4) developing high-tech and agricultural R&D for socio-economic development. However, each province also put different goals and different emphases in formulating their own S&T development planning and policies at the same time.

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and building management systems and operation mechanisms for high-tech industrial development. The projects of the Torch Program are carried out in new high-tech fields, including new material, biotechnology, ICTs, energy-saving technology, etc. Spark Program, however, is launched in 1986 to revitalize rural economy through S&T development and to popularize S&T in rural areas.

Table 6.6 Main Objectives and Implementation of S&T and Innovation Policies in Hubei and Fujian, 1998-2007

	Term	Hubei	Fujian
Main Objectives	1998 | 2003	● Developing agricultural S&T ● Promoting High-Tech industries and industrialization ● Reforming the S&T Systems ● Strengthening S&T human resources ● Creating S&T policy environment ● Increasing investment in basic research at knowledge institutions ● Mobilizing S&T for rural and social development	● Developing agricultural S&T ● Promoting High-Tech industries and industrialization ● Reforming the S&T systems ● Strengthening basic and soft science research ● Creating S&T policy environment ● Mobilizing S&T for rural and social development ● Fostering regional Informatization
	2004 | 2007	● Developing leading key High-Tech and pillar industries ● Enhancing agricultural S&T ● Increasing the contribution rate of S&T progress to economic growth more than 50% ● Increasing the value added of high-tech industries more than 10% of GDP ● Promoting knowledge institutions as innovation platforms ● Increasing S&T outcomes (patents)	● Focusing certain S&T for social Development (e.g., agriculture) ● Cultivating S&T human resources ● Increasing the proportion of R&D expenditure in GDP above national average ● Promoting integration of S&T resources ● Developing nine key S&T high-tech and pillar industries ● Increasing S&T outcomes (patents)
Main Implementations	1998 | 2003	● Restructuring research institutes ● Creating S&T intermediaries ● Establishing the government's SME innovation funds and high-tech projects ● Implementing tax incentives policies for high-tech industry ● Implementing the 'new century talents project' and overseas S&T talents recruiting policies ● Setting up provincial S&T award programs ● Promoting agricultural R&D projects	● Restructuring research institutes ● Expanding technological cooperation with foreign countries ● Establishing high-tech industrial development zones ● Launching provincial SME innovation funds ● Providing funding for agricultural S&T and industrialization projects ● Supporting funding for soft science and basic research projects ● Implementing "Digital Fujian" projects ● Building S&T intermediaries
	2004 | 2007	● Strengthening IPR protection laws ● Constructing university parks ● Implementing procurement policies ● Building provincial key labs ● Increasing provincial SME fund ● Expanding high-tech enterprise tax and incentive policies ● Improving public intermediary service systems ● Implementing high-level S&T personnel training project and "one village one student" program ● Launching "Food Production Technology Project" and "Spark Enriching People" program	● Implementing the "bring S&T talent projects" ● Enforcing IPR protection ● Implementing major projects focusing on 10 S&T fields. ● Continuing to build the productivity pro-motion center and business incubators ● Further implementing the "S&T management reform" ● Strengthening S&T cooperation and ● exchange with Taiwan ● Implementing soft science research programs and advisory services ● Providing "three rural" services to foster county-level S&T works

Table 6.6 (continued)

Source: compiled by author

In the first phase (1998-2003), the overall S&T plans of both Hubei and Fujian echoed most of the key themes of the national S&T plan, as described in Table 6.6. In Hubei, developing high tech industry and infrastructure and realizing industrialization was the most integral part of the S&T plan during the period. The three major projects, including the high-tech industrialization projects, enterprise technology projects, and agricultural technology projects, were specially implemented to cultivate new economic growth and transform and upgrade traditional industries. Electronic information, biotechnology and new medicine, and new materials were designated as priority areas of focus of high-tech industry in Hubei. In addition, the construction of the provincial high-tech zones, such as Xiangfan High-Tech Zone, was vigorously promoted along with the S&T intermediary service institutions. The agricultural high-tech industrial park was also constructed in Wuhan at the same time in order to promote the industrialization of agriculture and the rapid development of rural economy.

Similarly, Fujian provincial government fully implemented the "High-Tech Development and Realizing Industrialization" policy for building high-tech industrial belt in Southeast Fujian. The high-tech and industrial development action plan had the strategic areas of focus, including electronic information, mechanical and electrical integration, new materials, and biotechnology. There was an effort to integrate existing electronic and information industry base, high-tech industry development zone, the software industry base, technology business incubators, universities science parks and other sources. Agricultural S&T Park was also constructed in Zhangzhou City to strengthen the agriculture technology innovation and accelerate the process of agricultural modernization. Fujian Province especially strived to foster the agricultural cooperation with Taiwan to increase R&D investment as well as to develop agriculture S&T projects in the park.

The S&T policy environment in both provinces, however, was not yet well-established in the first phase. Given the situation, two provincial governments similarly followed the basic lines of the national S&T plan, creating a conducive policy environment for S&T development. By implementing the "Law of the PRC on Promoting the Transformation of Scientific and Technological Achievement" in 2001, Hubei provincial government attempted to strengthen technological innovation policies and law enforcement. The main policy measures were implemented in terms of 1) broadening financial channels for the high-tech industry through the establishment of venture capital fund and SME fund; 2) developing S&T talents policies; and 3) reforming public research institutions by transforming the universities and research institutes into high-tech enterprises.

Fujian provincial government launched the "Regulations of Fujian Province to promote S&T achievements" for the S&T law enforcement. The provincial S&T department made a particular effort to improve the policy environment by investing a number of soft science research projects. Once the S&T department set the major strategic issues in S&T, selected experts and scholars undertook the relevant projects contributing to the provincial government's strategy. Significant research results were employed in the provincial government's S&T policy-making process. The focuses of main policies implemented were 1) increasing the financial supports for the development of high-tech enterprises; 2) transforming research institutions into high-tech enterprises; and 3) strengthening technological cooperation and exchanges with Hong Kong and Taiwan.

While the provincial innovation strategy in the first phase mainly focused on building the innovation infrastructure as the strategic basis of S&T development, the second phase (2004-2007) lays more emphasis on enhancing independent innovation capability which can increase both quality and quantity of provincial S&T outputs and then make a positive contribution to regional economy. In the second phase, the five-year national plans and medium-to long-term S&T development plan became the general frameworks of the S&T development plans in two provinces. In Hubei, the five strategic priorities for its S&T development plans were: 1) promoting firm-led innovation; 2) developing manufacturing industry with the pillar industries; 3) improving agricultural science; 4) advancing the energy resource and environment protection technologies; and 5) enlarging scientific and technological achievement.

During the same period, Fujian vigorously planned for the construction of the Taiwan Straits Economic Zone Construction in several cities of Fujian for building infrastructure and fostering regional economic integration between Fujian and neighboring provinces and between Fujian and foreign economies. Part of this strategic plan aims to strengthen S&T cooperation and exchange further between Fujian and Taiwan. The provincial S&T policy attention has been greatly paid to build the support system for the West Coast Economic Zone for accelerating high-tech industrial clusters, promoting the development of urban and rural integration, and maximizing the advantages of integration of the southeast coastal areas. In addition to this, the main S&T

policies focus on 1) enhancing the competitiveness of the enterprises; 2) developing technology platforms; 3) advancing ten strategic S&T for social and economic development; and 4) improving S&T project management.

Compared to the first phase, both Fujian and Hubei paid more attention to the improvement of the regulatory and institutional framework for the design and implementation of S&T policies in the second phase. For example, the institutional dimension, such as IPR protection, began to receive some attention in the innovation policy-making system. Hubei was more concerned about establishing government procurement and incentive mechanisms by allocating government special funds for R&D projects, human resource development and SMEs, implementing preferential tax policies, and promoting the S&T awards for the distinctive S&T achievement. By contrast, Fujian made much effort to strengthen the international S&T cooperation and exchange as well as to improve its management system for provincial S&T projects.

The overall innovation policies of two provinces cover a wide range of aspects in building regional innovation systems. However, the policy making system in Hubei and Fujian is still not full-fledged and some important components of innovation policies has been neglected in their policy making process. For instance, the linkage between main innovation actors has not been mentioned as the major policy issue in both provinces. While most innovation policies mostly focus on building high-tech infrastructure and enlarging S&T inputs, these policy practices lack of the systematic approach in making and implementing, such as the dynamic interactions between the components within the innovation system.

6.2.4 Science and Technology Intermediates

The S&T intermediary service institution is an important component of the regional innovation systems which serves as the platform to link the key actors as well as to provide innovation infrastructure for those actors. During the economic reform, Chinese government employed S&T intermediary institutions, such as technology business incubators and productivity promotion centers, in transferring the functions of public research institutes to the enterprises. Those institutions build bridges between SMEs, provincial government agencies, research institutes, higher educational institutions, and other financial institutions. Generally, they run in the high-tech development zones and foster the expansion of SMEs by providing technical information, technical consulting, personnel training, and technology intermediary service. Since the early 2000s, the S&T intermediary system has progressed rapidly as the basis for the construction of an innovation environment at the regional level.

Table 6.7 S&T intermediaries in Hubei and Fujian, 2007

		Hubei	Fujian
Technology Business Incubator	Number of Incubators	52	22
	Hatching Areas (m^2)	567,000	795,700
	Number of Incubated Enterprises	1187	1098
Productivity Promotion Center	Number of Productivity promotion Centers	27	80
	Total Service Avenues (Billion Yuan)	1.6	3.2

Sources: Hubei Provincial Department of S&T (2007); Fujian Provincial Department of S&T (2008)

In 2002, the Hubei province government and its S&T Department vigorously promoted the building of technology business incubators and set Wuhan as the first technology incubator pilot city. The number of technology business incubators grew from 38 in 2002 to 52 in 2007. In 2005, “Productivity Promotion Center Management Measures” derived from the “SME Promotion Law of China” were implemented in order to strengthen the high-tech zones and industrial clusters. Hubei established 27 productivity promotion centers in 2007; four of which were recognized as a national productivity centers.

Fujian also has accelerated the development of S&T intermediary institutions and attempted to fully establish S&T intermediary market mechanism. In 2002, the provincial government set up 22 high-tech business incubators and this number was unchanged until 2007; however, the total number of incubated enterprises largely increased from 378 in 2002 to 1098 in 2007. While Hubei has developed its S&T intermediary service system throughout the technology business incubators, the productivity promotion center has become the backbone of the Fujian’s intermediary system which plays an important role in promoting technological innovation of SMEs. In 2007, the total number of the productivity promotion centers in Fujian was 80, which was three times higher than that of Hubei (see Table 6.7). Of which six national demonstration centers were established. In 2007, Fujian Province, formulated the provision of "the implementation of provincial administrative rules for the Productivity Promotion Center" to further guide and regulate the province's productivity promotion centers.

6.2.5 Institutions of Promotion of Innovation Entrepreneurship

From the mid-1990s, Chinese government has promoted innovation entrepreneurship through the establishment of the venture capital system. The central government, especially MOST, legitimizes venture capital as well as private entrepreneurship by the regulations and creates an institutional environment conducive to investment for new ventures. Following the central government initiatives and guidelines, the regional governments are more directly involved in the developing new ventures and supporting infrastructure in their regions (White et al. 2002). While the central government's support for local enterprises (mostly state-own enterprises) has decreased sharply since the reform, regional government has increased incentives and opportunities to foster new technology-based ventures. For instance, the provincial departments of finance and S&T have established either government venture capital firms or government-backed guaranty companies to guarantee bank loans to local ventures. In addition, they have provided tax exemptions and reductions, physical space and rental leasing at low rates, and other preferential conditions to new technology venture especially within the high-tech zones. However, China still lacks the mature venture capital system and acceptable investment channels required to promote technological entrepreneurship effectively, due to the absence of mechanisms for withdrawing capital and the restrictive regulatory environment systems (Chang and Shih 2004).

Fujian and Hubei got a late start in developing S&T venture capital enterprises compared to other eastern provinces, such as Guangdong, Zhejiang, Shanghai, and Jiangsu which initiated it in 1991-93. In early 2000s, the venture capital enterprises were formally founded in two provinces. The number of venture capital enterprises founded in

Hubei was 31 in 2002 with the total registered capital of 2.4 billion Yuan. The investment of province's venture capital enterprises was highly concentrated in the hot industries, including optoelectronic, optical and electrical integration, biomedicine, new materials, and so on.

At the same time, the provincial S&T department of Hubei led to establish the industry self-regulatory organization, Hubei Venture Capital Association, in order to accelerate the development of S&T venture capital enterprises. Its major roles are to provide consulting services, promote communication between the government and members and between members for information exchange and collaboration, and actively participating in local legislation. By the end of 2007, the number of venture capital enterprises increased to 55 with the total registered capital of 4.5 billion Yuan. Despite substantial progress, however, Hubei's venture capital system is not mature yet, due to the shortage of private investment. Since the majority of the province's existing venture capital firms are founded by either the government or state-owned enterprises, the proportion of private investments is not only much lower than eastern provinces but also not sufficient to meet the majority of the financing needs of new start-ups.

Fujian first marked the start of venture capital industry in 2000. There were only two venture capital enterprises established by the end of 2002. The combined amount of the registered venture capital of two enterprises was 1.3 billion Yuan at that time. The Fujian's venture capital industry has lagged far behind as compared to Hubei and other eastern provinces owing to the lack of sound venture capital mechanism and policy environment. In recent years, however, Fujian begins paying attention to the development of the venture capital system in its policy planning. For example, the provincial government invests 30 million Yuan each year to guide a special venture capital fund, set up venture capital enterprises, and implement venture capital compensation. In 2007, there were 41 venture capital enterprises founded with the registered capital of 1.86 billion Yuan.

6.3 Interactions in the Regional Innovation Systems: A Case for the University-Industry Collaboration (UIC) in Hubei and Fujian

Universities have been perceived as one of key elements in the regional innovation systems with its substantial roles of technology transfer and interactions with industries which support economic growth through innovation. They are not only the major educational and training institutions producing human capital, but also the technology provider to domestic firms. Regional competitiveness and economic activities have been increasingly associated with partnership and collective learning between social actors, especially university-industry interactions during the process of commercialization and knowledge transfer. In this regard, it is frequently noted that university-industry collaboration (UIC) can help build and develop the capabilities of the innovation systems, contributing to sustain the competitive advantages of local firms (Azagra-Caro 2005; Edquist 2005; Dooley and Kirk 2007). This type of partnership can also be promoted by the government's supporting and incentive mechanisms which provide the innovation platforms facilitating the interface process between university and industry.

At the regional levels in China, these platforms have been designated at the particular areas ranging from broad high-tech development zones to more targeted university science parks and incubators (Chen and Kenney 2007; OECD 2008b). It has been found that the UIC has been notably increasing in China, while firm's collaboration with public research institutes has been lessened over the years. Motohashi's study (2008) reveals that rapidly growing UIC in China results in increasing share of university patents, while the share of co-patents between firms and research institutes drops sharply after the reform of the public institutes in the early 2000s. However, despite some progress, the development of university-industry linkages still lags behind advanced countries. Insufficient demand from firms, weak incentive systems, and an academic research culture that does not emphasize economic relevance are pointed to major impediments to strengthen those linkages in China (OECD 2007).

In order to evaluate and compare the interactions between key actors in two different regional innovation systems, this section explores the reality and pattern of the UIC in Hubei and Fujian through the analysis of the empirical evidence from the interviews. It investigates the motivations of both university and industry to engage in the UIC. The analysis can identify what encourages two actors to initiate and develop collaborative ties with each other in different regional contexts. Second, it focuses on regional communication channels established between universities and industry. The communication mechanism can be a crucial element to facilitate university-industry exchanges and interactions, serving as the platform to find new partnerships or to understand the needs of the desirable partners. The analysis can show what mechanisms are the most developed in each of two regions and how effective they are. Third, it examines the regional patterns of UIC and its evolution, particularly illuminating the prevalent forms of university-industry linkages and the general process and results of UIC. Finally, it assesses the factors either facilitating or obstructing the UIC in each province.

The empirical data were collected through in-depth interviews with four academic researchers and two industrial managers in both provinces.[40] All interviewees have carried out cooperative R&D projects in various fields over the years and sustained the collaborative ties with university or industry. The in-depth qualitative investigation on the nature and pattern of the UIC can provide an insight into the reality of university-industry knowledge transfer in the Chinese context. In addition, a comparison of two regions can tell the effective mechanism of interactions between university and industry in China and show how they are established, managed, and developed under the specific regional circumstances.

6.3.1 Motivation for Initiating the UIC

The motivation for university and industry to enter into collaboration is closely related to the institutional incentive systems and demands. Qualitative evidence from interviewees suggests that there are institutional and personal factors encouraging the actors to engage in the UIC. From the industry's side, new product development, production costs reduction, industrial research supports, and improvement of industrial technologies are identified as the primary reasons to start the partnerships with

[40] In case of Hubei, two university faculty members who participated in the interview by the author have been teaching and conducting research for 10 and 22 years at the two prestigious universities in Hubei: Wuhan University and Huazhong University of S&T (HUST). The industrial researcher interviewed by the author is working for the HUST spin-off as an engineer for five years. Their research areas are mainly satellite technologies, bio-medical technologies, and organic chemistry. Similarly, the author also interviewed two university faculty members working at the two leading universities in Fujian: Xiamen University and Fuzhou University. Also, they have been teaching and conducting research for 10-20 years. The industrial manager joined in the interview has been working for a small-sized light industry firm for five years. Their main researches are material science and engineering; however, one academic researcher was reluctant to release the information about his affiliated department and research area.

universities in both provinces. Aside from the institutional purposes, the following quote from the Hubei industrial researcher illustrates how he can also be personally more attached to the UIC by his unique backgrounds.

> In 2005, I participated in the research project in medical technology with my graduate advisor at HUST. I have conducted the medical research in our university research team for ten years. We used our research project as a stepping stone to establish the firm and HUST helped us by investing the funds. Our company has still close research collaboration with the university research team and I think that this collaboration will last a long time. I have participated in the UIC as a chief engineer responsible for technical parts in the project. Our firm is still small-sized one and HUST is a major stock holder of our firm. At this time, we attempt to translate our technologies into industrial products that can be competitive in the market. Through the constant collaborations, I personally hope that our firm grows further and become more privatized.

The above industrial researcher has built trust in a long-term relationship with university researchers in medical technology at HUST, through having the master-pupil relationship with a research director as well as working with the university research team for several years, since he was a student.[41] This is likely to make him more inclined to engage in the UIC research in accordance with his firm's demands and have better understandings of the academic research culture. To some extent, the example represents the important role of social capital, such as trust, commitment, and integration, in facilitating strategic alliances and partnerships between university and industry (Hitt et al. 2004; Plewa and Quester 2007).

[41] During the interview, the interviewee showed persistently his deep trust in a university research director who was his former academic advisor. Specifically, he comments that "my professor [university research director] is a very influential scholar in the bio-medical engineering field…He is not only an excellent expert but also a good teacher."

Table 6.8 Motivations of University and Industry for UIC in Hubei and Fujian

	Hubei	Fujian
University	• Understand the most urgent technological needs of industry • Obtain practical technical achievement • Build more reliable and stable research platforms • Receive a better faculty evaluation • Grant an job and internship opportunity to students • Improve lab equipments and facilities • Train graduate students • Receive financial rewards	• Need practical examples for teaching • Improve university research facilities and equipments • Test research results through the project • Increase both institutional and individual reputations • Respond to industry demand • Receive financial rewards • Boost self-fulfillment
Industry	• Develop new product • Pursue high-quality researches • Industrialize new technologies and knowledge	• Reduce production costs • Develop new product and process • Create new cutting-edge technologies • Need research supports

Source: results compiled from author's interviews

Academic researchers have a variety of motives for UIC that reflect both individual and institutional needs, as described in Table 6.8. All academic interviewees acknowledge the benefits from an inflow of industry research funds into university in the sense that it contributes to upgrade teaching and research environment through the improvement of lab equipment and facilities, student training, etc. In this respect, one academic interviewee illustrates the meaning of the UIC, stating that "the UIC is a mutually beneficial cooperation—in other words, it is a win-win situation since both industry and university can take an advantage from the collaboration."

In most cases, university faculty members tend to be personally motivated to pursue academic activity and research. Fujian academic researchers express strong personal motives for engaging in the UIC. One of whom comments: "as a professor, I teach students and read and write research papers everyday—but these are mostly theory-based, not very practical works. The UIC provides a chance to conduct problem solving researches and I am very pleased to see the practical results from the real experiments."

Moreover, financial remuneration is found to be an influential factor in driving personal motives for pursuing collaborative R&D with industry.

While the research activities of universities faculties depend a great deal on personal motivation, institutional incentives appear to be an important accelerator. The institutional rewards are not necessarily limited to financial; it can be public recognition of achievement, granted by the university authorities as well as by the other peers. Comparatively, Hubei academic researchers are inclined to be more influenced by the incentive systems of the university than the Fujian researchers. They emphasize that the faculty evaluation system has a positive effect on their motivation for the UIC. To receive research funding and financial support from industry is considered as one of the important criteria in the faculty evaluation. This indicates that the establishment of internal incentive mechanism can be effective in motivating university research personnel to engage in university-industry relations. The rewards include the promotion and financial incentives; however, the reward systems can be different by institutions.

University faculties in two different regions differ in their motives for the UIC. Fujian academic researchers have a tendency to be more teaching oriented, addressing the pedagogical aspect of the UIC. The industrialization of research findings from the collaboration can be useful teaching examples and materials when faculties teach the classes. Some undergraduate and graduate students are also given the opportunity to participate in the research collaboration and this offers the students chance to have real research and practical learning experiences. Given this context, one Fujian academic researcher reveals the important weight of teaching in the academic culture, stating that:

> A few years ago, teaching was a major duty and responsibility of our faculty members, but today, many are getting involved in more research activities. In Fujian, however, university faculties are basically more occupied in teaching than research. In other eastern provinces, such as Jiangsu and Zhejiang, the situation indicates the opposite that academic research has greater weight.[42]

On the contrary, Hubei academic faculties see more value of the UIC in stimulating and promoting the university research. Building more reliable and stable research platforms within the university is important for them to increase their research productivity. In doing so, academic faculties are often motivated to initiate and develop collaborative ties in order to find and understand the urgent technological needs of the private sector.

6.3.2 Regional Communication Channels

Communication channels are crucial to establish the interactions between innovation actors, including enterprises, research institutes, universities, and the government. Various forms of the UIC, such as R&D projects, technology contracts and licensing, training, and consulting have been created through the specific channels built up in the region. In Hubei and Fujian, formal and informal communication channels are

[42] In the Chinese higher education system, there is no formal type of the 'research university' which is a prevalent form of higher education institution in the West. According to academic interviewees, most Chinese universities combine research and teaching but teaching function has a higher priority over research in general. The key universities at national or provincial levels designated by government through the 211 Program and the 985 Program may have more strength in research. Especially, 39 universities sponsored by the 985 program are considered as the top research universities in China, since they receive the substantial government's funding in expanding their research capacities and disciplinary scope, and developing new interdisciplinary research programs (Wu 2006).

found to coexist as the useful platforms where university and industry can find each other to start the partnerships. They also appear to vary distinctively from institution to institution and from region to region.

Table 6.9 Main Communication Channels for the UIC in Fujian and Hubei

	Hubei	Fujian
Formal Channels	Industry • Journal papers and other publications • Registered patents • Academic and professional conferences and forums • Government R&D projects • University joint research center	Industry • S&T department of provincial government • Local technology association • Professional and industrial associations
	University • Academic and professional conferences and forums • Government R&D projects • Provincial government's survey on industry's technological needs and demands • Conferences held by government and university	University • Academic and professional conferences and forums • S&T department of provincial government • Provincial government S&T online forum • S&T development department of university • Government R&D projects
Informal Channels	Industry/University • Personal networks • Personal contacts and visits University • Individually provide information online	Industry/University • Personal networks • Personal contacts and visits

Source: results compiled from author's interviews

Table 6.9 illustrates the main channels of communication for industry and university in two different regional contexts. As shown in the formal channels for industry, the Hubei firm employs research publications, including academic papers, reports, and books. When the firm finds relevant contents and topics in those academic publications, they directly contact the authors. Registered patents are also suggested as an alternative way besides publications in finding a possible university collaborator. By searching patents, firm can find not only academic researchers but also some hot research topics or new project themes. Although the academic conference and forum and government's R&D projects are referred to as other important channels of communication, the publications are considered as the most effective ones for the Hubei firm.

In the case of the Fujian firm, the different communication channels and mechanism prevail to establish a research partnership with university. Generally, Fujian industry has both informal and formal communication channels mainly through personal networks and local government's S&T departments. In a formal way, the provincial S&T department and local S&T association operated by the municipal government assist the industry by constructing partnerships with university in R&D projects. Those government agencies provide consulting services and introduce research projects and possible collaborators to industry. Additionally, professional associations are another formal channel used by the Fujian industry (e.g., Automobile Association, Rubber Association, Glass Association, etc.). These associations are made up of a number of firms in the same industry and form professional networks in which industry members can provide, share, and exchange information. Through the professional networks, the firms can find partnerships with either other firms or universities.

However, it is also revealed that the extent of government assistance can differ depending on the size of firms. As evidenced by interviews with the Fujian industrial manger, large sized firms receive the assistance more easily from the government than small-and medium-sized ones. The interviewee explicitly elaborates this point as follows:

> If it is the large-sized firms, they do not need to formally visit the government S&T agencies, because the government directly contacts them to recommend the channels or sources if there are some suitable collaborative partners. Some large firms also hire government officers or staffs in local government's S&T departments as their firm consultants, so that they can have more recommendations from the government......If your firm or firm's project is not large enough, your firm is not qualified, or your firm pays a relatively small amount of tax, the government S&T agencies are not willing to provide assistance. This actually reflects the current situation of China. While small-and medium-sized firms account for a large proportion of the economy, small sized firms generally have to stand on their own, because it is hard to expect the support from the government. Large-sized firms can get more government's attention.

In sum, large-sized firms are able to optimize both the informal and formal channels by getting broad government assistance and establishing direct interactions with the most prestigious universities in the region, whereas small sized firms tend to rely more on personal networks (e.g., friends, colleagues, alumnus, and former academic advisor).[43]

The main communication channels used by university researchers differ from those used by industry and it is distinct by region as well. Normally, academic researchers are often encouraged to visit conferences, forums, and workshops. It offers the researchers the advantage to be able to communicate directly with many specialists and create social networks of people within a certain field of S&T. As shown in Table 6.9, conferences and forums are one of the main formal channels for university

[43] As mentioned before, the Fujian interviewee from the industry is working for a small-sized firm. He usually finds university researchers by visiting the university where he graduated and meeting his former professor and colleagues. In other cases, his firm selects the local university based on its reputation and fame and then makes a direct contact with university researchers in the relevant field of S&T.

researchers in both Hubei and Fujian. Provincial and municipal governments have held conference several times each year inviting the local industry and university researchers as the platform for the UIC.

While the government conference becomes the common formal communication mechanism to facilitate university-industry relations in two provinces, its effectiveness is differently addressed. All Hubei interviewees consider this as the most effective communication channel in the province, whereas Fujian interviewees reveal the opposite regional trend. The Fujian academic researcher specifically comments as follows:

> In Fujian, many governmental conferences are held after most research contracts are made in private. Thus, what we [university researchers] actually see in the conference is the agreement already done by two sides of negotiators…If there is prior contact or connection with industry, the conference would be very effective. Without that, there would be less chance to get involved—so the effectiveness is reduced by half……This is China's characteristics….Although most contracts are made in private, government still holds the conference, because they need to make some noticeable accomplishments or results. The government's accomplishment is shown and assessed mainly by the numbers, rather than quality.

Similarly, the ineffectiveness of public UIC support mechanism, in terms of government conferences and events is evidenced by the interview with a Fujian industrial manger. For the Fujian industry firms, the professional conferences and meetings are not preferred channels over the others, as described in the following quotes:

> We receive many conference flyers often by fax. Some firms are not willing to participate in the conference or meeting, because they either think that it is ineffective or do not see any benefit or profit

> from attending the conference. Basically, we prefer using more familiar channels [personal contacts and networks]. We end up not going to the meetings or conferences we are not familiar with….There are only a few government organizations arranging the meetings and conferences. Government usually deals with large-scale projects and works, but do not focus on the small projects. They coordinate interventions at the macro level.

While conferences and forums are frequently held by regional governments, the Fujian industry firms seem less likely to deem them as reliable and efficient communication channels. As the part of reason, the government conferences tend to be designated in favor of large-sized firms or large-scale projects. This tendency is also verified in the interview with the Fujian academic researcher: "If collaboration or partnership successfully occurs between university and industry at the government conferences, it would be a large-scale investment project. Even if the actual investment is not that large, nominally it would appear to be large-scale investment." The evidence indicates the lack of efficiency and clarity regarding government intervention to establish effective UIC platforms.

Besides the conference and forum, diverse public UIC support mechanisms are found as the formal channels for academic researchers in Hubei and Fujian. Commonly, participation in cooperative projects within government research programme is considered as a useful way to meet new industry partners, to understand their technological needs, and to learn about their networks. In the case of Hubei, provincial and municipal governments conduct the surveys for technological needs and demands of the industry nearly 15 times each year and inform university researchers of the survey results. Based on the survey findings, governments offer a numbers of research grants to the university for fostering the researches which meet the industry's needs, and funds for the R&D cooperative projects. In addition, the government representatives visit the university every year and hold the conferences and events inviting local industries. These vigorous public efforts contribute to establish the efficient UIC platform in Hubei.

In Fujian, the provincial government also plays a role of a bridge between university and industry. The S&T online forum designated by the provincial department of S&T serves as the E- platform for the UIC, publishing information on technology supply and demand. When the firms post their technological needs online, it is directly notified to the university S&T office. Then, the university office provides faculty members with information on its own website. Reversely, when university researchers have appropriate research subjects and problems, they are able to contact firms through the university office and government S&T agency for research collaboration.

Stimulated by the regional government's support, universities have been tapped to develop collaborative ties with industry. The academic interviewees in both provinces denote that universities pay a great attention to the UIC in recent years. This is addressed in the statement by the Hubei respondent: "Our university is now putting an emphasis on the UIC. University functions at multiple levels and this is one of the university functions providing social services other than education and training."

Given the context, the university not only provides funding for the UIC, but also holds conferences or forums for facilitating communication with local industry. In the Fujian case, university S&T office plays an important role as the most effective formal channel for university researchers. The S&T office frequently communicates with industry and regional governments and assists researchers in finding partnerships with industry.

However, the evidence suggests that Hubei university researchers have a higher propensity to establish collaborative ties than their Fujian counterparts. According to respondents, the UIC in Fujian is usually initiated by industry, whereas, in Hubei, it is most likely to occur by both demand and supply sides. Hubei university researchers are found to be entrepreneurial-oriented and active in seeking partnerships with industry, as exemplified in the following interview excerpts:

> If university faculty members carry out the cutting-edge research or have particular research topics in the promising field, they attempt to sell their research findings to industry or to find the support for their research projects. To this purpose, individual faculties publish their research results online, so that firms are able to directly contact them.

If the university has a higher reputation, more positive responses come from the industry. The respondent indicates that researchers at prestigious universities frequently receive the industry's requests for collaboration. For example, the CEO of the company sends representatives to the university every year, or he regularly visits the famous labs and meets star researchers who have a reputation in the certain field.

In short, informal and formal channels of communication between industry and university are constructed in Hubei and Fujian. Most formal communication channels are made by regional government intervention, through conferences, cooperative projects, surveys, and online forum. In addition to the formal channels, informal communication is achieved via alumni networks, colleagues, and friends. Comparatively, Hubei respondents show a high contentment with both types of communication channels, while Fujian respondents consider informal channels as the most effective communication mechanisms in the province. Hubei seems to have better public UIC communication platforms which induce both industry and university to engage in more active collaboration activities. Fujian, in contrast, exposes some efficiency issues in the government UIC support mechanisms which consequently make two institutional actors to rely more on personal networks to find the partnerships.

6.3.3 Regional Patterns of the UIC

6.3.3.1 Collaborative Forms

In general, the UIC takes a variety of collaboration forms, such as joint R&D projects, technology licensing, consulting, internships, services, and other partnerships to develop a new product or technology. Hubei and Fujian certainly have different preferred forms of the UIC and the extent to which the UIC is prevalent in each region appears to differ as well. While a joint R&D project is considered as the general form of the UIC in both provinces, it is found that two regions display a distinctive preference for the certain type of the UIC.

In the case of Hubei, both university and industry favor the contract R&D projects over the others. For industry, the contracts manifest the legal right and responsibility of stakeholders in the collaboration more clearly. Another reason is revealed that it provides the firms with an opportunity for training employees on-site:

> During the research collaboration, it is common for firms to send employees to the university for training. They can be part-time

> graduate students as well as researchers in the joint projects at the same time…This is not only to nurture human resources for the firms, but also to support our research project. In this respect, training and education are not merely employee benefits. With our investment funds, university faculties train our employees as well as conduct the research which meets our interests. As a result, the joint project is more likely to be successful. This is a sort of investment behavior.

The above quote from the industrial researcher illustrates how industry appreciates the value of the collaborative research with university. In the same manner, the university also puts priority on research contracts aiming at developing new products among the forms of the UIC. Aside from the joint research project, joint venture is also found to be another form of the UIC that Hubei universities prefer.[44] In the joint venture, the university not only participates in a cooperative research but takes a share of technology. Unlike other forms of the UIC, the relationship between university and industry can continue after the technology-transfer to industry, since both parties are the technology shareholders. Hubei interviewees imply that as regional capabilities of R&D and technology absorption grow stronger, the preference for the certain UIC forms as well as the UIC patterns change accordingly.

All Hubei respondents view the UIC as prevalent in the province and is becoming more widespread. The UIC is especially developing around the high-tech development zones, such as the optics valley development zone in Wuhan City, and its degree is getting increasingly intensive. The interview with a university researcher unveils that a

[44] A joint venture here takes the form of a short-term partnership in which university and industry equally invest in a particular project in terms of money, time, and effort. Undertaking a transaction for mutual profit, each stakeholder contributes assets and share risks.

lot of central and provincial government research programs have led to the development of the UIC in Hubei: "if the university solely applies for the government project, they would be less likely to be accepted. However, if university and firm work together, there would be more chances to get the project successfully. This trend has resulted in intensifying the UIC after all."

However, the Fujian case somewhat differs from the Hubei one. While the joint research project and professional consulting are identified as the general forms of the UIC in Fujian, the latter seems to be actually preferred more by industry and university than the former. It is found that both industry and university face more difficulties when they participate in the joint research project. According to the Fujian industry interviewee, it is sometimes hard for the firm to work with university researchers for the R&D projects, because most researchers are less concerned about industrial applications of the research. From the Fujian industry's perspective, many university researchers have an interest in doing the basic research, which let them pay relatively little attention to the applied research, such as the product development and modeling. This raises the conflict of two different perspectives, when the industry engages in the joint research project with university researchers. For this reason, industry tends to be more likely to use the consulting rather than the joint research project, as the industry respondent describes: "the contract research project is the last consideration followed by the consultation."

Likewise, evidence from an interview with the Fujian university researcher demonstrates that the joint research project is a complex and difficult form of the UIC for university faculties. It suggests that there is much pressure placed upon researchers to engage in the cooperative research project as compared to the consulting case. Because the joint research collaboration deals with complicated problems to be solved, it requires much more energy, financing, time, and people in repeated research works. Under the circumstances, university researchers relatively receive less pressure from consulting works with industry. As the academic respondent specifically demonstrates, "I usually provide consulting to the firms, because there is a time management issue. I also have to spend much time for teaching, so that I am not able to spend a lot of time for the collaboration research."

In contrast to the case of Hubei, Fujian interviewees see that the UIC is not so prevalent in the province. As for industry, there are too much uncertainty and risk to enter research collaboration with university. Because there are always possible changes in research direction and investment in the course of the research collaboration, it is hard to predict whether research results can be successfully achieved. The other reason revealed by the university researcher is a shortage of supply to meet demands. The Fujian industry often faces a difficulty to find suitable university partners for research collaboration because of the following regional context:

> This is somewhat related to the Fujian history. Fujian has been considered as a battlefield frontline in a potential war with Taiwan for a long time. Due to this reason, the industry base was not well-established previously. The main role of the university also has concentrated on teaching rather than research. The development of research capability has been largely overlooked.

For the solution, some large enterprises have built their own research center and undertook R&D on their own. Given the industrial R&D is very confidential, those with its private research center tend to be less likely to collaborate with university due to the secrecy. The SMEs with a lack of own R&D capabilities are more willing to engage in the research collaboration.

Although two Fujian academic interviewees have different views on the prevalence of the UIC in the province, they agree that it will become more common and even stronger in the near future. While the governments promote the UIC and encourage the implementation of the cooperative R&D projects, university researchers are increasingly aware of the importance of the UIC in facilitating technological progress.

6.3.3.2 Collaborative Process

On the whole, the UIC partnership is composed of a single university research group and a company only. Though there are multi-party research collaborations in which diverse organizations involve in the project at once, it is not the common cases in Hubei and Fujian.[45] With respect to the joint R&D project, the funding, duration, process, and number of researchers vary in response to the demand and requirement of each project. In most cases, funding comes from either only industry or both industry and university. The project can proceed in two different ways: first, industry researchers directly work with the university research team and second, university researchers solely pursue a research project. In this study, the former appears more common in both provinces.

[45] The Hubei academic interviewee points out the issue of the joint ownership of intellectual property rights, such as patents, among the participants in the large-scale, multi-disciplinary, and multi–party collaborations. Thus, the bilateral relationship between industry and university is more preferred form of the UIC in general (Barbolla and Corredera 2009).

The process of collaboration in the joint R&D project is divided into three stages in common. First, the initial stage involves the collaboration start-up, which is a crucial part to establish and keep up a positive working relationship between the collaboration partners. At this stage, it is essential to have an open and ongoing interaction to clarify the goals and maintain a consistent understanding of the project objectives. As one academic interviewee mentions, this is a relatively difficult part in doing the joint research, so that collaborators need to carefully carry out collaborative R&D works. Information sharing and idea exchange are often regarded as to successful research collaboration (Philbin 2008).

The second stage involves the process of reporting for the delivery of research results. There is a periodic communication between industry and university to review the collaboration progress through meetings, conference call, and email. Research progress is often delivered and monitored by regular reports—it can be either monthly, quarterly, or annual reports. During this stage, there may be some disagreements over the project deliverable; for example, the industry feels that the research results or analyses are not good enough to meet their expectations. In this case, an effective conflict resolution procedure is needed, so that both parties can lead to a more satisfactorily situation.

The final stage contains the process of post-delivery review that can bring some outcomes, such as contract renewal and joint publications (e.g., patents, journal articles, conference proceedings, etc). As demonstrated in the interviews, many issues can unexpectedly happen after the evaluation. The continuation and extension of the collaboration depend on the feedback to the previous stage. Both collaborators can decide not only to shift the direction and priority of the research but also to suspend or terminate the project when they no longer see the merits in working together further.

Table 6.10 Challenging Issues in the Collaboration Process

	Hubei	Fujian
University	• Slow progress • Insufficient time to fully focus on research works due to teaching assignments • Industry's breach of the contract • A expectation and understanding gap in research	• Poor technological capabilities of industry • Lack of industry understanding for technological innovation • Industry's breach of the contract • Too much cost expected by industry • Timing issues
Industry	• Disagreement about research directions and requirement in the process • Lack of understanding of practical usability and technology standard	• Delayed process • Too much demand for funding from university • Unsatisfactory progress • Lack of funding

Source: results compiled from author's interviews

Table 6.10 illustrates the list of challenging issues emerging at each stage of the collaboration process from two different perspectives. In the initial stage of the joint research, collaborators experience a few problems which obstruct the collaboration process. For instance, the industry often fails to fulfill the contract by suspending the funding or providing only partial funding for the project. This exerts a negative effect on the partnership between industry and university, making the collaboration hardly successful.

The interviews with Hubei university faculty members point out the heavy duty of teaching and research as the difficulty to concentrate on research tasks during the first stage. Because developing new products take considerable much energy and time, it is really hard for university researchers to fully engage in research tasks in addition to teaching. Especially, for some tasks requiring emergency treatments and constant attentions, researchers are unable to respond at the right time. This consequently causes a delay in the process, so that project priority is often set to developing the profitable products rather than new products. As for the solution, firms should be aware of the issue in advance and coordinate the tasks with university researchers during the collaboration process.

Fujian university researchers demonstrate different issues, particularly related to the work with the firms which have weak technological capabilities. It is reported that firms poorly equipped with technological knowledge tend to provide little information and ideas on site. Consequently, it is sometimes difficult for university researchers to carry out the joint R&D. Those with a strong technological strength, however, are more enthusiastic about innovation and technological equipments that make the collaboration process proceed smoothly.

In all the processes, most concern for industry is the project funding. If there requires too much demand for funding from the beginning stage and the industry is no longer able to provide financial investment, the project is either suspended or cancelled by industry. The Fujian industry interviewee addresses the difficulty in finding outside funding especially for the small projects:

> If it is a relatively small project, it is harder to get the financial loan. Although there are some incentive systems in the university in the way that university researchers apply for some funding to the S&T department, the funding is usually too small to support the project.

The Hubei interviewee, however, indicates that the firm also has a communication problem with university researchers at the initial stage, when they have a disagreement about the requirements for the process and the development of the goal. Nevertheless, the problem can be usually solved through the coordination between two parties.

In the second stage, respondents experience the expectation gap with their partners in delivering the research results. The Hubei interviewees point to this gap as the main problem to prevent a successful UIC. The gap reflects a perceived difference between what the firms expect to accomplish and what university researchers want to obtain from the joint R&D. The firm prefers seeing practical and applied research results that can be immediately transferred to new products, or industrialized in a short period of time, whereas university researchers are more concerned about new discoveries with an emphasis on originality in carrying out the research. From the industry side, originality is not a major concern for industry, because even if the product is not new but the same as others in the market, the cost could be much lower. Thus, the practical abilities of the project can be regarded as a good result and many firms prefer doing this way. In short, conflict is often created between two parties in the sense that university researchers have a lack of interest in the practical usability and applicability of research, while industry is unable to understand academic culture. It is suggested that more direct and open communications between two parties are required to solve this issue during the process.

However, the gap exerts a different impact on the firms with different sizes as evidenced by the Fujian academic researcher:

> For the large firms which have its own R&D department and labs, the gap can be narrowed by firms, since they are able to industrialize the technology by themselves. In contrast, small-sized firms have to rely on the university from the beginning to the end. Given that firms desire to have complete product which can be commercialized

> immediately, if university is not able to make it to this level right on time, collaboration always fails.

The Fujian respondents also demonstrate similar experiences at the second stage of the collaboration process. From the university perspective, the CEOs of the firms often seem very short-sighted by pursuing quick and short-term pay-offs and avoiding risk-taking. Although the university researchers solve the problems which the firms encountered, the firms do not want to proceed if the costs are expected to be higher. As Fujian university researcher describes, if industry and university co-invest the project at the very beginning and make an effort to participate in R&D together, the collaboration is more likely to be succeed.

From the industry perspective a delayed process is problematic to continue the collaborative research with university. Considering fierce competition in the China's market, there is always possibility that firms can lose its market share. As a project takes longer than expected, a firm might lose its interest in the research, because other competitors already commercialize the same product. Moreover, the delay of the process can miss the best time to apply the research results in that some technology can only be usable in certain seasons. In either case, the firm calls off the collaboration, since the research is no longer meaningful.

In the final stage, an unsatisfactory and slow progress can lead to the termination of the collaboration. If one or both of collaborators no longer recognize further benefits or progress, there would be no continuation and extension of the research contract. This is found to be the common practice in both provinces.

6.3.3.3 Results of the UIC

Whether the UIC is success or not is determined based on the final results of the collaboration. In most cases, the best result of the UIC ends up with the new product/service development which has a great market potential. This greatly helps the firm not only make profits but also enhance its competitiveness in the market. University researchers, on the other hand, receive a distinctive social benefit besides economic one. As the Hubei academic researcher illustrates:

> Financial reward is just one part of the benefits obtained from the successful UIC. The central and provincial governments offer invention rewards to university researchers who have developed new products with high commercial value through the UIC. This fruit of the collaboration is very important for university faculties, since it is one of the important evaluation criteria for academic achievements. Thus, what I receive from the successful UIC is not just about the money, but the qualification for my accomplishment.

Followed by the new products and services, co-patents and co-publications are found to be preferred results of the UIC. In particular, both university and industry pay a great deal of attention to patenting the research results. If the collaboration successfully achieves the development of new products and services, it is usually accompanied by the patent. For the industry, patent registration represents the competitiveness of product and its price, while for university, it is considered as an intellectual property right which can be a possible economic source. The interviewees show familiarity with patenting, but the value of the patents differently perceived by the region. In both Hubei and Fujian, universities have a strong willingness to co-patent with the industry through the UIC, since they can gain profits from new product development as well as share the legal rights. However, as contrasted with Hubei, the Fujian industry respondent reveals the reality of weak patenting enforcement which makes the firm become less attached to patent:

> Our firm is interested in patent, but we register not many patents. Last year, we wanted to apply for design patent but after careful consideration, we decided not to, because IPR protection is not strong enough. Even though patents are issued to the firm, others are still able to easily imitate and copy our technologies. In addition, there are high annual fees for registered patents, so that it is not worth having many…We can sue people or firms for patent infringement, but lawsuits usually cost way too much…Patent laws seems very perfect but the enforcement does not.

Asked what type of patents is most preferred, the Fujian respondent answers that the firm is more inclined to apply for utility patent over invention patent. As compared with the utility model, the invention patent takes a longer time to be approved and requires paying higher annual fees. From the industry perspective, the annual fee seems to be expensive relative to the degree of legal protection and this is the high cost of possessing the patent. In contrast, universities tend to have more interests in the invention patent, so the majority of patents held by the university is invention one. All the Hubei respondents show a tendency to prefer the invention patent over others due to two reasons: first, the technological contents of the invention patent contain the highest economic value; and second, the invention patent has a relatively strong legal protection. However, it should be noted that the patent preference depends on the research project outcome and technology field. For example, the utility model patent will issue faster for some processing products, such as design and aesthetic modifications. Also, such pharmaceutical and mechanical researches are more related to the invention patent rather than the utility patent.

6.3.4 Factors Promoting the UIC

All interviewees in this research acknowledge the progress of the UIC and its contribution to the development of innovation in their regions during the past few years. The Hubei case suggests that both university and provincial government have promoted the UIC to foster technology-transfer in the region. First, a number of high-tech parks established by the government have become the important base and carrier for indigenous regional innovation. For instance, Hubei provincial government recently has invested 15 billion Yuan for three years to build the bio-lake park (e.g., biotechnology park) in Wuhan, a capital city of Hubei. Many large firms and universities are encouraged to move into the park. At the same time, this especially stimulates local universities to develop their own research center and engage in industrial R&D within the park. Hubei university researchers can introduce venture capital to industry and also set up the small high-tech firms like Silicon-Valley. Many university alumni become entrepreneurs establishing the high-tech firms as well as researchers participating in R&D projects.

Second, the leadership of the university is so important to develop closer ties with the industrial sector. The example is illustrated by the Hubei industry interviewee as follows:

> The former president of my university made a great contribution to the development of the UIC research, focused on the applied R&D at our university. During his ten year tenure, the university found two or three high-tech listed companies. Subsequently, our university

> park was established and many high-tech companies were located there…These are all his ideas. For example, he first introduced the idea of the 'three incubation stages' for creating university spin-offs. This forms the mechanism connecting industry with learning and research. Unlike the traditional systems, the university takes care of everything, including making products. All the stages of industrialization are considered by him. As a result, it promotes the learning process through the research and forms the channel between industry and university. This is very successful. Such practices, which are his pioneering work, lead him to have political success as well.

Therefore, vigorous efforts made by the university leadership could motivate their institution to move closer to the industry sector and encourage university faculties to be enthusiastic about the collaborative research with industry. From this development pattern of the UIC, Hubei has some advantages of: 1) cultivating talents through training and educating people in both the public and private sector; and 2) accelerating technology transfer to the industry through the UIC. A lot of talent has become the backbone of industrial technology innovation and scientific research and technology applications have spawned a number of large industries, such as optoelectronics.

The Fujian case also shed light on the effects of the UIC on the development of regional innovation and local economy. The growing UIC activities have facilitated the changes in the business direction, the structure of local industry, and the need of local human resources. The innovation outcomes from the UIC, such as new products and technologies, stimulate the entrepreneur ideas for innovation that has led to the transformation of local economic structure from labor-intensive industry to knowledge-intensive one. This change is also associated with the demand for new human resources, and local governments need to implement new human resource strategies. In this respect, the Fujian government plays an effective role in promoting the innovation entrepreneurship and enhancing the level of the local S&T workforce. As evidenced by the Fujian industry respondent:

> Local governments are holding professional conferences twice a week as well as job fairs for the college graduates each year. The talent-exchange fairs are also held each year for the large companies. When there are some demands from the industry, the government takes the initiative in organizing talent-exchange conferences, too. Those events held by the government are not just for the certain or single industry, but for the overall industry to attract specialists and talents.

In Fujian, both provincial and municipal-level governments have made an effort to promote the UIC by holding a certain number of conferences and setting the number of research contracts as a goal at the beginning of each year. Through the UIC, universities could obtain research fundings from both industry and government and gain research strengths at a time which can solve the problems of industrial technologies and products and produce new techniques, products, and patents. This stimulates the technological demands from the local industry.

However, the interviewees from both regions also point out that the UIC has not reached the desirable scale and intensity yet. Since only a few cities become the headstream of regional innovation, innovation resources and activities tend to be distributed in an imbalanced way. For example, the UIC activities are mostly developed and clustered in Wuhan City of Hubei and Xiamen City of Fujian. In addition, while the industrial restructuring of the regional economy has been in transition toward knowledge-intensive industry, the labor-intensive industry still accounts for a large proportion of the local economy. This means that there is little demand for technological innovation from the private sector.

Table 6.11 Key Factors Promoting the UIC in Hubei and Fujian

	Hubei	Fujian
University	• Local industry restructuring • High degree in practical application of university technologies • University incentive systems • Innovation capabilities of industry • Innovative and venturesome thoughts of entrepreneurship • Government's effective management of its funded R&D projects.	• IPR enforcement • Industry's demand for innovation • Open communication and credit between collaborators • Commercial potential of joint research projects • Research capabilities of university faculties • Innovation capabilities of industry
Industry	• Finding suitable university partners • University's understanding of practical usability of academic research	• Government supports for innovation resources

Source: results compiled from author's interviews

Table 6.11 describes a number of factors that have influenced the development of the UIC, from the perspective of the interviewees. At the macro level, the respondents in both regions mention that the transformation of local industry into a knowledge-intensive one is essential in order to facilitate the UIC. If the regional economy mainly relies on resource endowments and is highly labor-intensive, there would less demand and supply for the UIC.

According to the Hubei interviewees, it is important for both industry and university to make an effort to enhance its R&D capabilities to develop the UIC. University needs to increase its research capabilities to apply the academic research close to industrial technologies and product, so that industry can trust the university to cooperate with. In order to do so, the academic evaluation system for university faculties with regard to their technological achievements is found to be an important institutional incentive mechanism which promotes the UIC as well as develop the university. Given that finding the right academic experts in the specialty field is, from the industry's point of view, a key success factor for the UIC, the university should have capabilities to meet this demand.

A successful collaboration is often ascribed to innovation capabilities of the firm and venturesome spirits of the CEO. As the firm has more technological strengths, the CEO tends to have a more specific long-term planning for R&D and is more willing to participate in the UIC. Given that quick success and instant benefit of the UIC is rarely realized in general, entrepreneurs are required to understand the innovation process, think outside the box, and not to afraid of failure, that is, the important key to successful UIC. This leads to a higher chance of success in the collaboration process. This type of entrepreneurship is often found in the coastal provinces with high innovation capacities. As exemplified by the Hubei respondent, "entrepreneurs in the coastal region are more progressive, insightful, and ambitious with the adventurous spirit compared to others in inland provinces." In some coastal provinces such as Guangdong, where high-tech industry is well-developed with a relatively small number of universities, local industries try inter-regional collaborations through establishing close ties with universities in other provinces which have strong research strengths for collaboration.

It is also revealed that the redundant longitudinal government research funding without entrepreneurship impedes the enthusiasm of the UIC. While the national and regional government R&D funding rises every year and the number of government-funded projects keep increasing, the industry's demand for joint R&D project is relatively less. Given the situation, university faculties are certainly willing to participate in cooperative R&D projects within the government research programme rather than those with industry. This indicates that the governments need to manage the quality of the projects better and coordinate the overall allocation of R&D funding within the province more effectively.

In the similar manner, Fujian interviewees point to the importance of strengthening the R&D capabilities of both industry and university in order to develop the UIC in the province. An academic respondent describes the situation, "we [university faculties] are used to mainly engage in teaching and not involve a lot in applying our knowledge to produce industrial technology and products. Although the situation is slowly changing now, a lack of applied research experience becomes a difficulty for university faculties to work with industry." Thus, the development of the UIC will be not realized as long as university has no R&D experiences and achievements. It is also suggested that the university needs to understand the industry's technological requirements and development prospects. In fact, if the firm has technological strengths or certain levels of technical capabilities, the technical issue facing the industry is more clearly delivered to university researchers. In the case that both parties have the technology demand in common, the collaboration is more likely to succeed. A lack of common understanding of technical issues could potentially lead to breakdown in communications between collaborators that would not be conducive to the successful UIC. This does not mean that both collaborators need to have the same level of technical understanding but they do at least have a certain level of R&D capabilities to understand the underlying technical issues. It is all about the issue of trust between industry and university which is considered as one of the most important factors facilitating the UIC.

Government's supports for innovation resources are also viewed as the factor which promotes the UIC. If specific industries are promising and optimistic or the industrial R&D projects contain high commercial potentials, the governments are willing to provide financial supports. Beyond this, the governments create the innovation environment such as high-tech parks and industrial clusters through integrating the financial and human resources for the development of local industries with advantages. However, the respondent also addresses the enforcement issue of IPR legal protection that governments should take into consideration in order to foster the UIC activities.

With regard to the public support mechanisms, both Hubei and Fujian interviewees state several S&T strategic policy implementations. Basically, the governments of two provinces have implemented the preferential policies regarding to the development of high-tech industry. The firms which move into the high-tech parks are given the free workshop space for a certain period, free loans, and tax incentives in order to promote R&D activities of the private sector. The governments also provide some financial supports, including research grants and patent subsidies.[46] Other regional S&T policies are designed to build infrastructure such as public research facilities in order to attract oversea talents and to help oversea scholars and experts establish their own firms. In most cases, it is found that the firms can benefit from tax concession for conducting joint R&D projects with university and receive government's support funds as long as the project is considered to be consistent with the government interests.

[46] According to the interviewees, the government subsidy for patents is different based on the technical quality of the patent. The subsidy amount is relatively less for the design and utility model patents compared to the invention one. The subsidy is made through applications.

Respondents also address the issues in the regional S&T policy implementations regarding to the UIC. The Hubei interviewee responds that a sufficient attention has not yet been paid to the UIC in the regional policy-making process. It is proposed that the priority of the government S&T policy should be placed on upgrading industry's technical capabilities and promoting the commercialization of academic research at a time. The respondent also signifies the need to build the government's management system in the light of the UIC. To some extent, it is necessary for the regional government to resolve some conflict issues between industry and university in the UIC; for example, setting regulation on the profit share between the collaborators after the successful UIC.

Another issue is the inefficiency of the government funding system. The regional government has encouraged the industry to set up the cooperative R&D project funds and provide a partial funding to support the approved projects. When the firm applies for the government funding, project proposals are carefully reviewed by the experts to determine whether the research has some merits or reflects the government's preference for certain research areas. However, the Hubei industry interviewee indicates that the evaluation is sometimes not fair and meaningless: "The government funding is allocated based on the personal networks and reputation of the applicants. This results in the inefficiency of the government spending on S&T and the waste of money." In this regard, the regional government should focus on reasonable allocation and efficient use of the government resources in order to accelerate the UIC.

The Fujian respondents underline more active involvement of the regional government in facilitating, managing, and coordinating the UIC. First, it suggests that the regional governments should focus on the urgent need to stimulate the UIC demand by developing industry- and government-funded R&D projects. This can be the way of increasing the technical capabilities of both industry and university. As evidenced by the interview, if the university has little experience in pursuing the industrial R&D, the industry tends to be unwilling to collaborate with university.

Second, from the university faculty's perspective, it is difficult to obtain information about the industry's demand for the UIC within the university, since faculties engage in both teaching and research at a time. Given the condition that information flow from outside the university is not very smooth, there is much room for the role of the government. The regional governments should encourage the industry to report their technical problems, gather technological information of the private sector to exchange of the substantial information with the university. It is critical to build effective communication channels between university and industry. In the same manner, the industry interviewee points to the difficult access to government policy information. The firms are neither very familiar with nor do understand the government policy programs. This means that there is the lack of communication between government and industry.

As suggested by the interviewees, the UIC process requires the government intervention. Because there are often conflicts or problems between industry and university during the collaboration process, the contracts can be easily fragile and broken by either side. The regional governments, therefore, should come forward to coordinate the collaboration process to guide better research cooperation between industry and university.

6.4 Discussion of Study Findings

Two provinces have distinctive historical, geographical, cultural, social and economic characteristics. Comparative analysis shows how two RISs are differently constructed and function in two unique regional contexts. Fujian, situated on the east coast of China, enjoys a high level of economic development and larger amounts of FDI compared to Hubei. By contrast, Hubei, located in the central part of China, has benefited from sufficient human resources and strong higher education system. Table 6.12 shows the distinctive characteristics of two regional innovation systems and also comparison of internal dynamics of the RIS regarding its functions and interactions.

Table 6.12. Comparison of the Innovation Systems of Hubei and Fujian

	Hubei	Fujian
Main Characteristics	More Government-led System	More Market-oriented System
Institution Functions		
Financing R&D	-1.18% of GDP -Ratio of R&D investment: government (26%), Industry (64%), Financial Institution (3%), Overseas (0.3%)	-0.90% of GDP -Ratio of R&D investment: Government (9%), Industry (88%), Financial Institute (2%), Overseas (1%)
Performing R&D	-Research institutes and enterprises are the primary performers. -Universities performing 12% of total regional R&D spending.	-Enterprises are the primary performer. -SMEs play an important role in performing R&D
S&T Workforce Development	12.5 R&D researchers per 10,000 labors	7.58 R&D researchers per 10,000 labors
Policy Formulation	-Following the basic S&T policy framework at the national level. -Policies more focus on establishing government procurement and incentive mechanism, government incentive programs, human resource development, etc.	-Following the basic S&T policy framework at the national level. -Policies mainly emphasize the international S&T cooperation (especially with Taiwan), SMEs development and government management systems for S&T resources.
S&T Intermediates	-Number of technology business incubator and productivity promotion centers: 79	--Number of technology business incubator and productivity promotion centers: 102
Innovation Entrepreneurship	-Number of venture capital enterprises: 55 -Total registered capital: 4.5 billion Yuan	-Number of venture capital enterprises: 41 -Total registered capital: 1.9 billion Yuan
Interactions in the RISs		
Motivation for Interactions	-Faculty evaluation systems motivate academic researcher to engage in the UIC -Academic researchers are more research oriented.	-Academic researchers are more teaching oriented emphasizing the pedagogical aspect of the UIC.
Communication Channels	-UIC actors rely on both formal (e.g., government conference) and informal (e.g., alumni networks, colleagues, and friends)	-UIC actors rely more on informal channels.
Regional Pattern of Interactions	-Joint R&D project as a preferred form of the UIC -New products and services and co-patenting (invention patents) as preferred results of the UIC.	-Professional consulting as a preferred form of the UIC -New products and services and co-patenting (utility patents) as preferred results of the UIC.
Main Factor promoting the interactions	-Strong research-oriented universities -Effective governments' intervention -Increasing industry's demands for innovation -Strong human resource in S&T	-Increasing industry's demands for innovation -Government support for innovation resources

1. Comparatively, Fujian's economic and innovation systems are market-oriented with the development of the SMEs, whereas the Hubei case is more government-led systems. Fujian's enterprises, especially SMEs, are not only major R&D investor but also performers. However, it should be noted that Fujian heavily relies on foreign investors in the high-tech sectors. Foreign-funded firms have played dominant role in the development of high-tech sector in Fujian in that they take nearly 80% of total high-tech industrial output value. Universities and research institutes are the smallest R&D spenders in Fujian, sharing less than 10% of total regional R&D expenditure. In contrast to Fujian, research institutes and enterprises play a major role in R&D financing and performing in Hubei. Research institutes basically follow government's policy and resources allocation. Universities are also important R&D performer, sharing 12% of total regional R&D expenditure. The share of foreign-funded enterprises in the Hubei high-tech sector is below 5%.

2. Hubei enjoys a relatively large pool of human resources in S&T, while Fujian has faced a shortage of the human workforce due to a small number of college and universities and less public investment in S&T higher education. With the government's strong policy programs for the development of S&T human resources, Hubei has a strong base for S&T workforce, ranking the 8^{th} among 31 provinces in terms of R&D personnel.

3. Innovation policy formulation of two provinces can be more or less homogenous. In the early 2000s, Hubei and Fujian similarly followed the basic lines of the national S&T plan, creating a conducive policy environment for S&T development. While the innovation strategies of two provinces mainly focused on building the innovation environment and infrastructure as the strategic basis of S&T development in

the first phase (2000-2003), they laid more emphasis on enhancing independent innovation capabilities in the second phase. Hubei was more concerned about establishing government procurement and incentive mechanisms, and human resource development, while Fujian made much effort to strengthen the international S&T cooperation and exchange and management system for provincial S&T projects.

4. Both provincial governments similarly provide direct guidance and support for the construction of an innovation environment, building technology bridges between SMEs, provincial government agencies, research institutes, higher educational institutions, and other financial institutions. However, two provinces also have lack of mature entrepreneurial infrastructure due to the shortage of private investment and the absence of sound venture capital mechanism and policy environment.

5. Through the comparison of the UIC pattern and trend as the interactions between the components of the RIS, Hubei's innovation system seems more dynamic efficient than that of Fujian. In the Hubei case, the effective government intervention policies in building effective formal channel between innovation actors, innovation demands from universities and industry, academic internal incentive systems, and research-oriented academic culture are crucial to promote the interactive learning between industry and university. However, the Fujian reveals the issues in fostering interactions between industry and university, including the inefficiency of the government support programs, ineffective formal communication channels between innovation actors, weak technical capabilities of both universities and private sector, more teaching-oriented universities, and weak institutional regimes.

Therefore, the comparative analysis shows similarities and differences between two distinct RISs. What makes differences in innovation productivity between Hubei and Fujian are the active and effective interactive learning between local innovation actors. In this respect, the study indicates that the role of regional government, research-oriented academic culture, institutional incentive systems for innovation, sufficient capabilities of domestic innovation actors to perform innovation activities, and innovation demands from both private and science sectors are important factors contributing to the development of the RISs in China.

CHAPTER 7

SUMAMARIES, IMPLICATIONS, AND CONCLUSION

7.1 Summary of the Main Findings

The present study investigates the underlying factors influencing the large variances in innovation performance among the Chinese regions. What is specified in the study is the issue of the knowledge divide in China as existing regional inequalities have appeared in conjunction with the production of knowledge and innovation in its transformation into an innovation-driven economy. Empirical and comparative analyses reveal the trend of increased regional disparity in the innovation activities and provide a clearer, more complete picture of the determinants of regional innovation capacities to understand the major reasons for the divergence trend in innovation competencies in the Chinese context.

7.1.1 Unequal Distribution in Regional Innovation Capacity

While the Chinese innovation system has achieved some promising developments at the aggregate level over the years, looking at the breakdown by regions unveils a different story behind the success. The study found that the inequality between the coastal and inland regions are widening with substantial disparities in the level of innovation activities. Along with the rapid growth in the number of domestic patents, there was a large discrepancy in the geographic distribution of patent activities over the period from 1998 to 2007. The top five most patenting provinces—Beijing, Shanghai, Zhejiang, Guangdong, and Jiangsu—accounted for over half of the total domestic patents granted to thirty-one Chinese provinces (NBS 2008b). The high degree of concentration in the geographic distribution in the east-coastal region is consistent with regard to the different types of patenting activities, such as the invention and utility-models. The regional inequality in patent production rose after 2000 and increased to a large degree in case of invention patents.

Likewise, the similar patterns of regional divergence are also shown in terms of the R&D intensity and resources during the same period. Although some central and western provinces had a notable growth rate in S&T expenditure per capita, a group of top performers on the east coast far surpassed them. In 2007, the R&D spending in the east-coastal provinces was seven times higher than that in other parts of China (MOST 2008a). The development of human resources devoted to R&D activities has been also largely concentrated on the group of east-coastal provinces with high innovation capacity. The S&T personnel per capita increased sharply in those provinces, whereas the others remained the low-level with no growth over a decade.

Innovation resources and infrastructure has been developed in an imbalanced way among the regions. In fact, regional levels of innovativeness are highly correlated with the infrastructure for innovation. The most innovative group mainly consisting of the east coastal provinces has a higher GDP per capita and a larger pool of well-educated and skilled workforce than the provinces in the central and western parts of China. In addition, the majority of both international trade and FDI have been heavily clustered in only a handful of the provinces in the group; Guangdong, Jiangsu, Shandong, Shanghai, and Zhejiang receive nearly 60% of total national FDI (NBS 2010a).

It was also found that more innovation resources and better government supports had been allocated to the east-coastal region. The regional government's S&T funding has maintained higher than the national average in the region since 1998 (NBS 2008b). Undoubtedly, educational and research strengths have been given exclusively to those provinces with better socio-economic infrastructure for innovation. The linkage between the industry and science sector for collaborative R&D seems more developed and strengthened in the east-coastal region over time, since many prestigious universities and national R&D institutions are clustered on the coastal areas. This is, in turn, a serious challenge which is evident in other lagging regions (especially the underdeveloped western regions) with the poor infrastructure as well as the lack of resources, public supports, and the openness of regional economies in the Chinese knowledge-based economy.

Meanwhile, the east coastal provinces have established better innovation environments where the fine industrial base is established and the market economy operates together, making enterprises the center of technological innovation. The coastal areas such as Bo-Hai rim, Yangtze River Delta, and Pearl River Delta, have been especially designated as a main driver of the high-tech industries development, producing about 70 percent of total national high-tech outputs (MOST 2008b). In the inland areas, however, the weak R&D capabilities with the absence of market mechanisms become the double agony leading to further marginalization in both domestic and international markets. The western provinces had the lowest contract trading values in the domestic technology market, accounting for less than 10% of total technology contract deals from 2000 to 2007 (NBS 2008b). This poor integration of innovation in the regional economy creates another ‘Matthew effect’ which gives to those that already have, as a consequence of increasing returns to scale from technological innovation.

All these confirm that there is the increasing trend of regional inequality in innovation capability in China. This inequality is not only reflected in economic and social structures of Chinese society but also in the distribution of knowledge and innovation, the new source of competitive advantage. The uneven distribution of innovation competences, therefore, can be significant contributors to persistent socio-economic inequality among Chinese regions.

7.1.2 Determinants of Regional Innovation Capacity in China

The complementarity between quantitative empirical results and qualitative comparative case studies is manifested in the full picture of the determinants of regional innovation capacity in China. While the quantitative analyses identify the underlying factors that affect the level of regional innovation activity, the detailed case study supplements those aggregate findings with the specific cases of Hubei and Fujian in a comparative perspective. The overall results suggest that while the Chinese regional innovation systems have evolved over time, increasing human and capital resources in innovation and accumulated knowledge stock/the level of economic development, together with the development of innovation-enhancing policies, industrial cluster environment, and linkages between innovation actors, are all crucial determinants of regional innovation capacity.

Based on the econometric analysis of the specific factors that influence regional patenting activities, the level of R&D inputs and knowledge stocks/the level of economic development appear prominent. Accumulated knowledge stocks and the level of economic and technological development represented by GDP per capita have the largest positive impact on the level of patenting activities. The S&T personnel and expenditure significantly contributes to the regional patent productivity. The importance of the scale of resources on innovation activities is also addressed by the significant and positive effect of the high-educated population. Thus, the proposition of endogenous (idea-driven) growth theory that innovation productivity depends on the stock of previous knowledge and R&D efforts has been strongly supported in the Chinese regional contexts.

Regional government policies appear to play an important role in determining the innovation productivity but they have the distinctive effects on the different qualities of the innovation outputs. In contrast to the public education investments, which have a considerable influence on the level of invention patenting, the impact from government S&T support is highly significant in the case of the utility model patenting. These findings imply that regional policies which shape human capital investment have created a conducive environment to increase technologically intensive innovation activities, whereas the impact of government S&T supports is limited to the generation of marginal innovations. Given that the governments have largely increased their spending on S&T since 1998, this trend raises the inefficiency issue regarding to the public S&T support systems which lower the quality level of innovation outputs.

The knowledge spillover effects of the FDI inflow and international trade are found to be insignificant in all regional patenting activities. The negative impact of FDI on the domestic innovation is supported by the crowding-out hypothesis that foreign-invested enterprises with superior technological skills may crowd local firms out of domestic market. The crowding-out effect can result in decreasing the market share of domestic firms as well as the number of domestic entrepreneurs (Chen 2007). The insignificant effect of overall FDI also indicates that a majority of inward FDI in China contains the least technology components since it has flowed mainly into more labor-intensive sectors.

The present analysis has also shown that the cluster innovation environment is essential to advanced technological innovation. Industry S&T funding is positively and significantly associated with the levels of invention patenting, but not to utility patenting. In fact, the significant influence of private S&T investment on the major innovation is reflected in a rapid increase in the firms' share of institutional invention patent grants during 1998-2007. Although Chinese firms hold a dominant share of utility model patents grants, the result does not support their prominent role in generating utility model patents. Rather, it denotes that industry is a major source of technologically intensive innovation in related to invention patents.

The interactions or linkages between the private and science sectors are found to be more prominent in producing utility model patents than invention patents. The S&T performance of universities and research institutes has a significant and positive impact on utility model patenting, whereas the financial supports from firms to S&T activities in universities and research institutes are neither effective nor efficient in all patenting activities. This indicates the positive role of knowledge spillovers from the science sector on marginal innovation, while industry plays a favorable role in technologically sophisticated innovation process.

The analysis by regional groups displays a more specific picture of different patterns of regional innovation activities. The development of innovation infrastructure has been the most important factor that contributes to the enhancement of the capacities of the regional innovation systems. GDP per capita and R&D related resources appear highly significant in invention patenting in the developed regions, whereas it has a marginal impact in the less developed regions. This indicates that the efficiency and quality level of R&D are low in the western inland region. Public S&T supports are ineffective in all patenting activities in the less developed regions, but public educational investment is prominent in the production of invention patents. Although the east-coastal regions are generally larger recipients of the public S&T financial supports, the results show that the effects are only limited to marginal innovation.

Since 2000, all Chinese regions have experienced a sharp rise in the private R&D investment. Industry's S&T funding is found to be important sources of invention patenting in both developed and underdeveloped regions. This may reflect the fact that the private S&T investment is the sole source of S&T activities in the absence of appropriate infrastructure and public supports in most western inland provinces, while the developed coastal regions have enhanced the innovation environment by developing industrial clusters and innovation infrastructure. The rise of the private innovation resources influences the evolvement of the linkages between the industry and science sector, but the linkage is found to be weak and ineffective in all regions, lowering the efficiency of the regional innovation systems.

The detailed comparative case study of Hubei and Fujian complements the empirical results, highlighting the importance of the government's policies and the interactions or links between industry and university. The contrasts between the two regional innovation systems reveal that the establishment of the strong knowledge base and learning culture for innovation, along with the effective government intervention is a determinant factor leading to differences in the innovation performance of the two regions.

Comparatively, Hubei province, the central region of China, has the strengths in a large pool of the S&T human resources and relatively well-developed knowledge institutions (e.g., key universities and public research institutes) which serve as a stepping stone for strengthening regional innovation capacity. The science sector has played a significant role in performing R&D and contributed to developing high-tech industry as well as facilitating knowledge spillovers through creating many high-tech spin-offs. However, Fujian, located on the east coast of China, has built strong innovation infrastructure and industry base by receiving massive inflows of FDI and government's supports. The firms are the major performer of R&D, but the large share of the foreign-funded enterprises in the high-tech sector has been the serious problem in developing indigenous regional innovation capabilities. In addition, weak R&D capabilities of the science sector have become the bottlenecks for effective technology transfer as well as S&T human resource development.

The comparative case analysis proposes that the effective government intervention policies, institutional incentive systems, S&T capabilities of industry and university, and research-oriented academic culture are crucial to promote the interactive learning between industry and university. The Hubei case illustrates that all these components induce the active learning trends that has contributed to the development of the capacity of its regional innovation system. By contrast, the Fujian case exposes the issues in fostering interactions between industry and university, including the inefficiency of the government support programs, weak technical capabilities of the private sector, more teaching-oriented universities, and weak institutional regimes.

Therefore, overall findings from the mixed analyses suggest that innovation inputs, knowledge stock/the level of economic and technological development, the role of government, cluster innovation environment, and strength of linkage are important determinants of RIC. In the quantitative analysis, the role of government and strength of linkage are found to be less prominent in producing major innovations. However, quantitative indicators for those two variables, such as the public financial investment in S&T and financial flows between science and private sectors, may only capture a single dimension of the regional government's roles and interactions between innovation actors. For example, interactions between science and private sectors can be more multi-dimensional, involving the flows of information, knowledge, technology, financial and human capitals, etc. In addition, regional government's role of supporting R&D also contains not only financial investment but also government's planning and incentive programs.

In this respect, the detailed case study of Hubei and Fujian, to some extent, can alleviate these measurement issues and provide more specific and multi-dimensional aspects of two variables, using qualitative indicators that can describe the subjective opinions on joint R&D projects and collaboration, government programmes or policy impacts. This mixed research design in the present study can provide stronger and more valid evidences, overcoming the weakness in quantitative method by adding qualitative method and data.

The comparative case study of the UIC patterns and trends in two provinces reveals the regional government's role and linkages between innovation actors are important factors enhancing RIC. Hubei province with a relatively high institutional invention patent-intensity has more active learning interactions between innovation actors and better formal communication channels which is effectively established and managed by the regional government than Fujian province. While the regional government plays a key role in building the innovation platform for the UIC, the Hubei case also addresses that the institutional internal mechanism such as academic faculty evaluation system is another important factor promoting interactions between university and industry. This, in turn, encourages university faculty members to be more research-oriented and motivates them to engage in the UIC more often than those in Fujian. In the Fujian cases, however, the absence of the effective formal communication channels indicates inefficiency of the government intervention policies, and also weak research capabilities of both industry and university are found to be the major hindrance to facilitating the interactive learning between regional innovation actors.

The findings of the qualitative comparative analysis capture more than one dimension of the regional government's role and linkages between regional innovation actors that may be ignored by the quantitative analysis. Therefore, the qualitative case study complements the empirical results, highlighting the importance of the effective regional government's policies and incentive mechanisms and strong interactive learning between innovation actors in enhancing regional innovation performance.

7.2 Policy and Research Implications

The above results describe the current regional patterns of innovation activities and identify the factors underlying the large disparity in regional innovation capacity in China. The present study can draw out some important implications for responding to this divergence trend. First, the study set out to illuminate the issue of the knowledge divide related to innovation competence-building in the Chinese regional context as the new type of social inequality. Despite the rapid progress that has been made in the construction of the regional innovation systems, the RISs are not optimal conditions from a social equity perspective in that lagging regions are underdeveloped and far behind the developed regions. This addresses the importance of the construction of more human and social development-oriented innovation systems, combining innovation efforts with social concerns and interrelated development issues. While new knowledge or innovation is widely recognized to be essential to promote economic development and competitiveness, it also needs to address its role for reducing inequality and promoting social inclusion. In this respect, China should foster interlinking between social and innovation policies further in order to achieve a more balanced and innovation-driven development pattern. In fact, this can also be the important lesson for other developing countries which are highly unequal societies to build more socially oriented innovation systems for their sustainable developments.

As far as the underdeveloped regions are concerned, a shortage of human resources, knowledge, and education institutions is the urgent problem to reduce the gap of socio-economic development and innovation capacity with the developed regions. Many of China’s key universities and public research institutes as well as S&T human resources largely concentrate on the east coastal region. The efforts need to be made by both central and regional governments in order to attract S&T talents from overseas and other developed regions in China to the western inland regions. This is very crucial because young outstanding S&T talents who have been educated and trained in research intensive institutions in the Western countries such as the U.S. or the eastern regions (e.g., Beijing and Shanghai) can inspire enthusiasm for innovation and research activities. In order to do so, vigorous incentive policies should be devised and implemented by the governments, offering a variety of benefits to qualified S&T researchers.

The S&T policy implementations in some leading countries that address the issue of regional balance can provide useful suggestions to improve R&D capacity and competitiveness of underdeveloped regions. For example, in the U.S., the similar structural inequalities are also identified at the regional level, in that the federal R&D resources are unevenly distributed and highly concentrate on the top four states with high research capacity and strong human resources, including California, New York, Virginia, and Massachusetts. Given the situation, the NSF has developed the Experimental Program to Support Competitive Research (EPSCoR) with the objectives of strengthening research and education in S&E throughout the country and avoiding undue concentration of such research and education in a few states (NSF 2006). NSF's EPSCoR has become a strategic program to support academic research in the states with a relatively weak R&D capacity as well as low share of federal research funding. Several empirical studies found that many EPSCoR states have benefited from the program in building their research capacity and competitiveness (Hauger 2004; Melkers and Wu 2009; Wu 2010). The EPSCoR case suggests that the particular efforts of China's central government are needed to effectively tackle undue concentration of S&T sources and supports.

Alternatively, promoting inter-regional research collaborations can be one of the ways to overcome the shortage of knowledge institutions in the less developed regions. For instance, through the inter-regional research collaboration, the firms in the western region can take benefits from the partnership with the key universities in other regions. The interviews with academic researchers confirm that inter-regional collaborations are already happening in some places of China, especially eastern regions where many prestigious universities are clustered. This implies that beyond regional boundaries, the regional innovation activities can be not only limited to the region but more extended at the national and global levels in the future.

It is also important for the less developed regions to improve the quality and efficiency level of the innovation systems. Compared to the developed regions, the productivity and quality of the innovation outputs tend to be lower in the less developed ones. Beyond simply increasing the level of R&D resources, the government should devise the policies that reflect the characteristics and specific needs of regional economy and focus on improving the links between the components of the innovation system. In addition, the market-driven cluster innovation environment and the establishment of a healthy market economy are essential to the enhancement of the regional innovation capacity in the western region.

The findings of the present study calls into question the efficiency of the government's policies and S&T support programs. In all regional innovation systems, the public S&T expenditure has an insignificant and negative impact on major innovations. The redundant longitudinal government's R&D funding and lack of transparency of funding allocations are pointed to the problems increasing the government waste and inefficiency. Therefore, the regional governments should pay careful attention to the reasonable allocation and effective use of regional S&T resources. In order to do so, it is required to strengthen the management and monitoring systems for public spending on S&T to prevent the scattered allocation and waste of resources. The policy-makers also need to make an effort to develop the policy evaluation systems to achieve more sound regional policies that improve the planning and implementation process.

The linkage between the private and science sectors are still weak in most regional innovation systems in China. The study found that knowledge spillovers from the science sector only have limited effects on marginal innovations. In other words, the efficiency and quality of R&D are low, in that both quantity and quality of innovation outputs do not rise in proportion to the R&D inputs. Although the government has launched a number of programs to strengthen the linkage, sufficient attention has not yet been paid to it in the regional policy-making process. Thus, the regional policy practice needs a more systematic approach in making and implementing the dynamic interactions between university and industry. The following are among the more important suggestive points, which are called for by the present research.

First, it is urgent to enhance the R&D capabilities of both industry and university for fostering the collaborative ties between them. The study indicates that not only the firms but also universities have few R&D experiences and weak research capabilities. Since not many universities are research-oriented in China, the efforts need to be put on intensifying the market-orientation of universities and public research institutes. The university internal incentive systems can motivate university faculties to participate in the R&D collaborations with industry. In addition, the industry- and government-funded cooperative R&D projects can stimulate the demand for joint research and collaboration, as the way of increasing the technical capabilities of both industry and university.

Second, the information communication system of the supply and demand is not working smoothly. The study found that both academic researchers and firms have a difficulty in obtaining information about the demand and supply aspects for the research collaborations. Thus, it is important to build effective formal communication channels between the private and science sector in order to activate their interactions. Moreover, the government should facilitate the communications with both innovation actors in terms of policy formulation and implementations for the collaborations. This helps producing effective public policies in response to their actual needs and the effects of the policy implementations can be maximized when the policy information is well delivered to them.

Third, the direct government intervention is sometimes necessary to promote the successful collaboration process. Because there are often conflicts or problems between collaborators, the partnership can be easily dissolved. The regional governments, therefore, might come forward to coordinate the collaboration process to resolve some conflict issues and guide better cooperations.

Lastly, innovation entrepreneurship should be further promoted to increase the success rate of research collaboration between the private and science sector. Given that quick pay-offs and instant benefits of the research collaboration are rarely realized in the field of innovation, entrepreneurs are required to understand the innovation process, think outside the box, and not to afraid of taking a risk. The governments should make efforts to establish a sound venture capital market and strengthen enforcement of IPR protection conducive to a favorable environment where the technological new ventures or innovation entrepreneurship can be nurtured and developed.

7.3 Limitations and Further Studies

Several limitations of the study must be acknowledged. Main limitation is the accuracy of patent data as an innovation output proxy. As discussed earlier, patents may not be a complete indicator that measures the regional innovation activities, because not all inventions are patented and also the quality of patents can differ by the technology fields. In some regions where the IPR enforcement is weak, there would be less patenting activities, because the firms may be more reluctant to apply for patents due to the concerns about the possible patent infringement. This tendency is actually confirmed by the interviews with the industry manager in the present study. In addition, patents can be differently valued across the technology fields—for example, the invention patents are highly preferred by the pharmaceutical and mechanical fields, while utility-model and design patents are more likely to be issued to some processing technologies and products, such as design and aesthetic modifications. Patent data also represent the novelty of a technology, but not its economic values. In the regions with the well-developed high-tech sector, the patents may be often translated into the new products with the high economic profits.

Another concern for patent indicators is that the Chinese domestic patent data used in the study include patents issued to both foreign-invested enterprises and Chinese domestic firms. In the Chinese patent system, if patent applications are filed to SIPO using Chinese address, it is hard to separate domestic firms completely owned by Chinese investors from those funded or owned by foreign investors and multinational corporations. Since the foreign investors and multinational firms take a large share of domestic invention patents, the patent data may pose some drawbacks to examine Chinese indigenous innovation capabilities.

In order to reduce measurement errors and potential bias, further researches need to employ other indicators to complement patent data to capture a more precise picture of the Chinese technological innovation. Other alternative indicators beside patent data include new product sales, LBIO, and the number of patent citations, which can be a possible measure of either technological significance or economic values of technological inventions.

Another limitation is related to the validity of the Chinese official statistics published by the NSB. Although the Chinese official statistics are widely used in many social science research published in refereed journals, there is still a controversy regarding the data reliability. Despite the consistency of the data, using only single source of official data can produce inaccurate and biased results. In this regard, diverse secondary sources of statistical data should be supplemented to the further study for improvement in the validity of the empirical results.

In addition, industry-specific circumstances as well as the characteristics and structures of regional economy have not been fully considered in this study. The relative specialization of regional economies in specific technological fields, which captures the strength of an industrial cluster, may have a meaningful impact on regional innovation activities. For example, key high-tech industries in Hubei province, such as optoelectronics and telecommunication, have played a leading role in stimulating regional innovations and economic growth. Given that many regions have attempted to shift their economic structures from the labor-intensive industry to the high-tech industry, the composition of industrial structures can also affect the rate and performance of the regional innovation systems. Moreover, the degree of market orientation of regional economy and the revitalization of technology market can be important measures of the macro environment influencing regional innovation activities. Further advances in the research may take into consideration the importance of both micro and macroeconomic environments on regional innovation.

Notwithstanding these limitations, the interplay between the detailed qualitative cases study and empirical analyses in the present research may contribute to a better understanding of the scope and extent of 'knowledge divide' as a new social problem emerging in the context of the China's knowledge-based economy. The study, furthermore, can be extended in several directions for future research, stipulating some of the most salient structural implications. First, a more interesting question emerges: how to build the socially-oriented innovation systems. In other words, how to re-invent innovation policies and practice to reduce social inequalities rather than reproducing them? Second, the study of the China's regional innovation systems should not be limited to administrative regions, such as province and municipal cities. The grass-root development of the regional innovation systems in rural areas or counties deserves more research attention. Third, since the inter-provincial research collaboration tends to increase in China, the cross-regional collaboration between the western and eastern regions can be an attractive research topic for regional innovation. Finally, more empirical and qualitative investigations require further efforts to explore the dynamic and complex interactions among various components of the regional innovation systems, such as the triple helix of university-industry-government relations.

APPENDIX A

APPENDIX A

SUPPLEMENTARY INFORMATION AND STATISTICS

Notes: The three regions have different social and demographical characteristics. The share of national population in the eastern, central, and western regions is 37%, 27%, and 28% respectively. As for the ethnic composition of each region, Han Chinese is largest native ethnic group in the eastern and central regions, constituting about over 90% of its population, whereas in the western region, 67% of the population is ethnically Han. Other ethnic groups including Huis, Tibetans, Manchus, Uighurs, Yi, Monglos, Mioas, Kazakh, etc, represent minority population. Almost half of the China's high-learning and research institutions are located in the eastern region, while the central and western regions account for each quarter of the other half. Geographically, many of key universities are located in the eastern regions of China, such as Beijing and Shanghai. The number of scientist and engineers per capita in the eastern, central, and western regions is 0.004, 0.002, and 0.001 respectively.

Figure A.1 Regional Division of China

Table A.1 China's Top 15 Universities, 2009

Number	University Name	Location	Regional Division
1	Tsinghua University	Beijing	East
2	Beijing University	Beijing	East
3	Renmin University of China	Beijing	East
4	Beijing Normal University	Beijing	East
5	Shanghai Jiao-Tong University	Shanghai	East
6	Fudan University	Shanghai	East
7	Zhejiang University	Zhejiang	East
8	Nankai University	Tianjin	East
9	Tianjin University	Tianjin	East
10	Sun Yat-sen	Guangdong	East
11	Nanjing University	Jiangsu	East
12	Harbin Institute of Technology	Heilongjiang	Central
13	China University of Science and Technology	Anhui	Central
14	Huazhong University of Science and Technology	Hubei	Central
15	Xian Jiaotong Unversity	Shaanxi	West

Source: The Chinese Academy of Management Science (2010)
Notes: The selected universities were evaluated as the top research universities in the fields, including engineering, science, medicine, management, literature, economics, agriculture, law, history, education and philosophy. The number does not indicate the ranking of the university.

Table A.2 Correlation Coefficients between Explanatory Variables

	FTE	GEST	GDP	HIGHED	OADR	ED	PUBST	OPENNESS	FDI	PRIVATE	LINKAGE	UNIVIN
FTE	1.000											
GEST	0.910	1.000										
GDP	0.579	0.753	1.000									
HIGHED	0.341	0.532	0.760	1.000								
OADR	0.470	0.506	0.602	0.385	1.000							
ED	0.166	0.052	-0.090	-0.224	0.140	1.000						
PUBST	0.613	0.649	0.677	0.466	0.326	0.081	1.000					
OPENNESS	0.599	0.725	0.817	0.656	0.456	-0.113	0.760	1.000				
FDI	0.778	0.792	0.568	0.216	0.404	0.169	0.597	0.655	1.000			
PRIVATE	0.238	0.275	0.332	-0.001	0.265	0.216	0.160	0.168	0.450	1.000		
LINKAGE	0.405	0.307	0.349	0.089	0.496	0.090	0.400	0.236	0.391	0.330	1.000	
UNIVIN	-0.051	-0.109	-0.126	0.131	0.034	-0.165	-0.162	-0.084	-0.358	-0.757	-0.089	1.000

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