Does Institutional Context matter in Building Innovation Capability?

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ABSTRACT

Our study investigates whether changes in China's reform policies had an influence on the national innovation capability building. Specifically, our study empirically examines the relationship between national innovation capability (national patent data as a proxy) and the roles of key drivers (i.e. industry actors, financial and human capital inputs, inward foreign direct investment, international trade and domestic technology transfer) from 33 administrative regions across the two periods of the reform (1991-1998 and 1999-2005) with time lag of four types of domestic patents during 1992-2009. The data is drawn from Government official statistics, using STATA for panel analysis. Overall findings demonstrate that the innovation environment was changed and consequently changed the impact of drivers on China's innovation capability differently between the two periods. The change of impact provides indications of which strategies or innovations worked better during a specific period, which in turn helps provide a better understanding of the effect of innovation system reform in each phase in China. We contribute to the literature by extending research on innovation capability to emerging economies like China and by enhancing our understanding of how the government policies shape a country's innovation capability through mechanisms of key innovation drivers in emerging economies.

Keywords: China, Reform, Foreign Direct Investment, Employment, Science and Technology, Patents

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1. Introduction

National innovative capability is the political and economic ability of a country to create technological innovation (Furman, Porter and Stern 2002). The national innovative capability framework draws on prior research of National Innovation Systems (NIS) identifying country-specific drivers of innovation (Sharif 2006; Li and Cantwell 2010). China's economic reform, which began in 1978, aimed to improve its Research & Development (R&D) system with a market-dominated economy by transforming its R&D system from a centrally planned one to a system that was more market-orientated (Baark 2001). Using descriptive statistics before and after the reform policies, prior research concluded that a number of key reform policies¹ influenced the key drivers of innovation capability, such as the expenditure on R&D activities, Foreign Direct Investment (FDI), numbers of new enterprises, and the development of human resources in Science and Technology (Chen, Chen and Vanhaverbeke 2011). Evidently, these studies suggest that China's innovation-related policies during the reform influenced these key drivers of innovation. However, we know context matters (Yang and Terjesen, 2007) and how the policy shifts during the different phases of the reform led to different impacts and outcomes to innovation capability. The question remains: How did changes in the institutional context in different phases impact on the national innovation capability in China?

The importance of studying innovation system in China has been widely acknowledged and researchers have conducted much research in regions of China. Zhong and Yang (2007) and Zhu and Tann (2009) investigated the long term reform process with a

¹ Such as the 1995 Decision of the Central Committee of the Chinese Communist Party on Accelerating Scientific and Technology Progress, and the 1999 Decision of the Central Committee of the Chinese Communist Party on Strengthening Technological Innovation and Developing High Technology and Realizing Industrialization.

qualitative approach, while Liu and Chen (2003) compared innovation system across 12 regions. There are also studies based on overall regions in China. Wu and his colleagues (2010) measured the performance of innovation capability across 30 regions in Mainland China (in the following, referred to as China for short) during 2001 and in 2005 employed a Data Envelope Analysis based model. Li (2009) focused on the impact of interactions between components of innovation capability between 1998 and 2005, covering 30 regions in China and using econometric models. Although there are many studies on innovation system in China, to our knowledge, none of them employ a quantitative approach to systematically investigate the differences between major drivers in different phases of the transitional process.

To fill this gap, our study thus aims to firstly explore these questions in twofold. Firstly, our study explains the context of China's reform policies. These policies lead to changing role of key enablers of innovation capability (such as industry sector (private enterprise, higher education), employment of scientists and engineers, funding in science and technology and foreign direct investment). Secondly, our study empirically examines the extent to which the changes of these enablers impact on China's innovation capability across two major periods of the reform.

The remainder of this paper is organized as follows. In section 2, we review the national innovation system framework and discuss the role of nation-based institutions in national innovation performance. In section 3, we review the economic growth and historical changes in the industry structure in China. In sections 4, we provide justification of using various types of patenting as a proxy of China's innovation capability and then we propose key drivers of China's innovation capability to be explored in section 5. The methods and results of panel data analysis are provided in sections 6 and 7. We then conclude our paper with a discussion of our results, future direction and limitations in sections 8 and 9.

2. China's innovation system through National Innovation System (NIS) lens

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

NIS was first formally defined by Lundvall (2007), focusing on knowledge and process of learning. Next it was redefined by Nelson (2008), focusing on the analysis of institutions and how countries set up their NIS, and finally by Edquist (2004). The first two definitions are based on an institutional perspective while the last uses an evolutionary perspective. Consequently, the two main definitions of NIS are:

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

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

From Lundvall's (1992) perspective, NIS is comprised of elements such as innovation actors and institutions, and their relationships in the production, diffusion and use of new knowledge within the borders of a nation. Nelson's (1993) definition focuses more on the role of institutions in innovation activities. Differing from the previous two definitions, Edquist (1997) argued NIS could be defined by identifying the determinants of innovations. Hence, in a broad way, NIS includes all parts and aspects of economic structure and the institutional set-up that may influence the development, diffusion, and use of innovations. In other words, NIS consists of several sub-systems, such as an education and training system, production system, marketing system, and financial system (Lundvall 1992). At the very least organizations and institutions involved in innovation should be included. Consistent with the sub-systems mentioned above, organizations can be, for example, governments, universities, R&D departments, firms, banks, and financial agencies (Aeron and Jain 2015; Plechero and Chaminade 2016). The major functions of these institutions are policy formulation, promotion of human resources, performing R&D activities, financing R&D, technology bridging, and promotion of technological entrepreneurship (Chang and Shih 2004). Accordingly, the NIS approach highlights the importance of interactions and the role of nation-based institutions in national innovation performance (Asheim and Coenen 2006).

NIS consists of all the factors that may affect innovation activities. A variety of components can be considered part of these factors (Sawang & Unsworth, 2011), but organizations and institutions are always considered to be the major ones (Edquist 2004). Organizations refer to firms, banks, universities, research institutes, and government agencies, and institutions are the "rules" (Scott 1995) organizations are embedded in (Hamilton and Biggart 1988) and have to conform to (North 1990).

3. Transition of China's Economy and China's Innovation System

It is worthwhile to provide a brief historical review of China's economy reforms here in order to understand the context and the justification of the two periods (1991-1998) in our analysis. Since its foundation, the People's Republic of China (PRC, referred to as China in the following) has undergone tremendous change. The crucial shift took place in 1978 by the reformists within the Communist Party of China, also known as Chinese Communist Party (CPC), led by Deng Xiaoping. Since then China has stepped into the market-oriented reforms and economic transition under the guidance of the central government, following both a top-down and bottom-up approach, which has led to extraordinary economic development.

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

The reform process of the economic and innovation system in China has been gradual (Chow 2004; Bagnai and Ospina 2009; Yang and Li 2004): the government undertakes experiments in a specific area and monitors the outcomes to decide whether to extend the

reforms nationally (Yang and Li 2004). Our study focuses on two critical periods of innovation policy changes: 1991-1998 and 1999-2005.

During 1991-1998, the government first implemented the outline of long and medium-term development of Science and Technology (1991-2000), leading China to a new era of the transformation of national innovation system. The role of government, both central and regional, in innovation was transferring from mandatory to directing, and the development emphasis was changing as well. Based on the outline of long and medium-term development of Science and Technology, the government put great effort into building up technology markets to facilitate technology transformation. During this period public research institutes and universities were also encouraged to set up their own high-tech enterprises. Researchers and teachers could take part-time or full-time jobs in the enterprises or establish their own high-tech companies while remaining in their positions in public research institutes or universities. Those activities led to 16,097 high-tech enterprises being established in national high-tech development zones all over the country by the end of 1998 (Zhong and Yang 2007).

From 1999-2005, the strategy of “building the nation with science and education” was reaffirmed and the objective of building China’s innovation system was highlighted. At this stage the reform focused on the macro level, which is different from the micro level from last period. The central government released the *Decision on Strengthening Technological Innovation, Developing High-Tech Firms, and Realizing Commercialization of New Technologies*, which highlighted the emphasis of this stage; strengthening China’s innovation system and accelerating the transformation of science and technology achievements. The decision recognized the complex relationships between reforms in the economy, science and technology, education, and innovation (Zhong and Yang 2007). Therefore, to realize the

objectives, innovation actors were encouraged to increase financial investment in innovation activities and collaborate with each other.

4. Patenting as a proxy of China's innovation capability

Domestic patents have been widely used to capture the national innovation activities in the literature (e.g. Li 2009; Acs, Anselin and Varga 2002). Patent statistics offer the best available output indicator for innovation activities (Freeman 2004). Because some innovative products or services may not be patentable, some studies thus used alternative innovation measures such as the number of new products (Fritsch 2002), new product sales (Liu and White 1997), and literature-based innovation counts (Acs, Anselin and Varga 2002), which still generate the similar pitfalls.

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

We adopted the domestic patents because they are more comparable and all the regions are subject to the same national patenting laws (Koo and Wright, 2010). Specifically, in China there are 33 administrative regions in PRC, including 22 provinces² ; five autonomous regions³ ; and two special administrative regions.⁴ Therefore, domestic patents are deemed to be appropriate for our study. Four types of domestic patents are used; (a) overall patent applications, (b) overall granted patents; (c) granted invention patents; and (d) granted utility model patents.

5. Key determinants of China's innovation capability

Our study identifies key determinants of China's innovation capability as (a) industry, including firms, research institute and universities; (b) financial input through science and technology funding; (c) human capital though numbers of scientists and engineers and employment rate; (d) inward foreign direct investment; (e) international trade and (f) domestic technology transfer. A proposed model is shown in Figure 1.

Figure 1 is about here

Firms, research institute and universities are the organizations that can generate innovations directly. Firms engage with productive activities; research institutes influence idea generation; and universities transfer knowledge and provide human capital (Sawang, 2011). In our study, we employ the numbers of universities, special colleges, such as medical schools and musical colleges, and professional technology colleges representing Higher

² Anhui, Fujian, Gansu, Guangdong, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Jiangsu, Jiangxi, Jilin, Liaoning, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang; four municipalities, Beijing, Shanghai, Tianjin, Chongqing (separated from Sichuan in 1997)

³ Guangxi, Inner Mongolia, Ningxia, Tibet, and Xinjiang

⁴ Macau and Hong Kong

Education Institutions (HEI) and the number of large and medium-sized industrial enterprises. We propose:

Hypothesis 1: Higher education institutions and industrial enterprises will have a positive influence on innovation capability (i.e. four types of domestic patents) in China.

Resource commitments such as funding for science and technology activities, R&D expenditure (Freeman 2004; Lundvall 1992; Park and Park 2003; Pan 2007; Evangelista et al. 2001), and numbers of scientists and engineers (Lundvall 2007) are considered as the most direct input factors to innovation activities. These key resources have also been reflected by the policy reform as previously discussed. Our study uses the funding for science and technology activities as a key indicator because it can be used for all science and technology related activities, including research and development (R&D) activities, purchase or construction of fixed assets and it may represent the effort put into innovation development better than R&D expenditure. Apart from funding, the number of scientists and engineers are also important for innovation capability building. However, scientists and engineers also need support from other staff with general administrative issues. This is why employment rate is also included. We propose:

Hypothesis 2: Financial input through funding for science and technology will have a positive influence on innovation capability in China.

Hypothesis 3: Human capability through number of scientists and engineers, employment rate will have a positive influence on innovation capability in China.

Inward Foreign Direct Investment (FDI) is one of the main channels transferring technologies from the source countries to the host countries (Zhu and Jeon 2007). During 1991-1998, China FDI grew rapidly, creating US\$45,463 million by 1998. However, the

inward FDI has been dropped during 1999-2005 periods, due to Asian Financial Crisis and the acquisition transactions. A part of inward FDI, the numbers of international trade and domestic technology transfer is likely to reflect the innovation building capability in China (Lin and Lin 2010; Chuang and Hsu 2004). Accordingly we propose broad hypotheses as following:

Hypothesis 4: Inward FDI will have a positive influence on innovation capability in China.

Hypothesis 5: International trade will have a positive influence on innovation capability in China.

Hypothesis 6: Domestic technology transfer will have a positive influence on innovation capability in China.

6. Methods

Our study employs secondary data to uncover the longitudinal impact of key drivers on innovation activities in China. The data were drawn from the official documents and statistics. Official statistics are permanent, and less time consuming or costly (Bryman and Bell 2003; Emory and Cooper 1991). They can also result in unforeseen discoveries (Saunders, Lewis and Thornhill 2003). What is more important is they are suitable for longitudinal studies (Saunders, Lewis and Thornhill 2003; Bryman and Bell 2003) and they can be used to make powerful comparisons between different groups, societies and nations (Smith 2008). Moreover, official statistics, such as statistic yearbooks, are not based on samples, so a complete picture can be obtained.

Our data samples are 33 administrative regions in China across two phases: Phase One starts in 1991 and extends to 1998, which corresponds to the fourth stage of the reform.

Phase Two extends from 1999 to 2005, which aligns with the fifth stage in the long run. Considering time lag between input and output, the time range for dependent variables is from 1992 to 2009.

Our dependent variables (proxies of national innovation capability) are the number of (DV1) total patent applications (DV2), overall granted patents, (DV3) granted invention patents and (DV4) granted utility model patents per million people as our dependent variables (innovation activities). Our determinants of national innovation capability are the number of higher education institutions (HEIs), industrial enterprises (IE), GDP per person, (GDP) funding for science and technology activities (FUND), full-time employed scientists and engineers per million persons (SCI-ENG), employment rate (EMPLOY), inward foreign direct investment (FDI), international trade (TRADE) and domestic technology transfer (TECH).

7. Results

As discussed earlier, the time frame of this study is divided into two phases according to the reform process of innovation system. Phase One is 1991 to 1998 and Phase Two is 1999 to 2005. To explore whether there are any differences in China's innovation drivers between the two stages, the two stages were analyzed separately using panel data regression with fixed effect models.

The comparison of means between the two phases is depicted in Table 1, which shows the mean of each variable was higher in Phase Two than in Phase One, except for FDI. Considering IVs, the difference between number of higher education institutions (HEI) is the greatest, followed by skilled labor (SCI-ENG), domestic technology transfer (CONTRACT), and financial input (FUND).

Table 1 about here

7.1. Estimated results

In the following, the estimated results from fixed effect models for the two phases are elaborated. We firstly present the results main effects (Table 2) of key drivers on the innovation activities (DV1 to DV4). -----

Table 2 about here

Testing hypothesis 1: the role of higher education institutions and industrial enterprises

Higher education institutions: The estimated results showed the impact of HEI differed between Phase One and Phase Two. In Phase One the impact was negative and significant on overall granted patents ($\beta = -.378, p < .001$), granted invention ($\beta = -3.466, p < .001$) and utility model patents ($\beta = -.325, p < .001$), while in Phase Two it was positively significant on granted utility model patents ($\beta = .487, p < .001$) (as highlighted in the table 2). The comparison of coefficients confirmed the difference in impact between the two phases. Hence the positive impact during the whole period may be mainly influenced by the effect in Phase Two.

Industrial enterprises: The impact of IE differed between the two phases as well. In Phase One, the estimated coefficient was only negatively significant on granted invention patents ($\beta = -3.669, p < .001$). In Phase Two, it was positively significant on overall applications ($\beta = .202, p < .001$), but negatively significant on overall granted patents ($\beta = -.263, p < .001$).

Comparing its effect during the whole period, the significantly negative impact on granted invention patents was mainly from the impact in Phase One, while the positive impact on overall applications and negative impact on overall granted patents in Phase Two were weakened in the long term.

Testing hypothesis 2: the role of financial input through science and technology funding

Science & Technology fund: The estimated results show science and technology effort was only significant and positive on granted invention patents ($\beta = 3.465, p < .001$) in Phase One and none of the effects were significant in Phase Two.

Testing hypothesis 3: the role of human capital through scientists and engineers and employment rate

Scientists and engineers employed full time: According to the results shown in Table 2, differences exist in the impact of scientists and engineers employed full time. In Phase One, all the coefficients were positive and it was significant on overall granted patents ($\beta = .436, p < .001$) and granted utility model patents ($\beta = .426, p < .001$). In Phase Two, it was only positively significant on granted invention patents ($\beta = 1.152, p < .001$). The results indicated skilled labor drove incremental innovations in Phase One, but radical innovations in Phase Two.

Employment rate: The estimated coefficients of employment were only negatively significant on overall granted patents ($\beta = -.753, p < .001$) in Phase One and were positively significant on granted utility model patents ($\beta = .656, p < .001$) in Phase Two.

Testing hypothesis 4: the role of inward FDI

FDI: The impact of FDI was quite different between the two phases. In Phase One, FDI was significantly and negatively related to all four DVs ($DV1 = \beta = -.112, p < .001$; $DV2 = \beta = -.141, p < .001$; $DV3 = \beta = -2.069, p < .001$; $DV4 = \beta = -.167, p < .001$). In Phase Two, the effect became significantly positive on overall granted patents ($\beta = .135, p < .001$). Therefore, the strong negative impact over the whole period was mainly because of Phase One.

Testing hypothesis 5: the role of international trade through import-export

International trade: The impact of international trade was greater in Phase Two than in Phase One. The estimated results showed the impact of international trade was negative and significant on granted invention patents ($\beta = -2.804, p < .001$), but was positive and significant on granted utility model patents ($\beta = .238, p < .001$) in Phase One. In Phase Two, the coefficients were positive and significant across all four DVs ($DV1 = \beta = .319, p < .001$; $DV2 = \beta = .411, p < .001$; $DV3 = \beta = .603, p < .001$; $DV4 = \beta = .467, p < .001$). This indicates the negative effect of international trade on granted invention patents over the whole period was mainly during Phase One, and the strategy of enhancing international trade worked better in Phase Two than in Phase One.

Testing hypothesis 6: the role of domestic technology transfer

Domestic technology transfer: The impact of domestic technology transfer was weaker than the impact of international interactions in both phases. In Phase One the estimated coefficients were positive and significant on overall applications ($\beta = .040, p < .001$) and granted invention patents ($\beta = .890, p < .001$), but are negatively significant on granted utility model patents ($\beta = -.049, p < .001$). However, in Phase Two, they are positive and significant on overall granted patents ($\beta = .108, p < .001$) and granted utility model patents ($\beta = .082, p < .001$).

8. Discussion and conclusion

Our study elaborates on the role of drivers in increasing innovation activities within China via fixed effect panel data modeled across two phases. The results in this part revealed the impacts of the drivers changed over time, as did the interactive effects between science and technology investment and interactions.

We found that both higher education institutes and industrial enterprises showed a negative impact in Phase One, while in Phase Two higher education institutes exerted a positive effect on incremental innovations and industrial enterprises exerted a positive effect on applications but a negative impact on overall granted patents. The different impact of the two phases may be explained by the reform of higher education institutes in China. The reform of higher education institutes started with the open door policy in 1978. With the reform of science and technology system, the importance of higher education institutes in science and technology development was re-emphasized. The progress of the reform led to higher education institutes having different impacts on national innovation capability, as shown in the analysis. In Phase One the national government asserted that, other than the responsibility of educating, higher education institutes should expand their role in improving science and technology by putting more effort into applied research (Zhou 2009). Although they made great achievements in technology innovation during 1991 and 1998, most achievements were in theoretical research, which largely resulted in published papers rather than patent counts. Therefore, analyzing the impact on patent counts would impair the impact of higher education institutes on the improvement of overall China's innovation. However, with the progress of reform, higher education institutes engaged more in technology innovation and industry development in Phase Two than in Phase One (Zhou 2009), which makes patent counts a better proxy of innovation capability than in Phase One. Hence, the

impact of higher education institutes on patent counts better reflects the impact of higher education institutions on China's ability to innovate in Phase Two.

The different impact of industrial enterprises between the two phases was closely related to the progress of enterprise system reform, especially the reform on enterprises with funds from government, which include state-owned, collective-owned, state joint ownership and collective joint ownership enterprises). Although the government funded enterprises were given more autonomy for operations, to a great extent they still relied on the order of government directive (Zheng 2004) and had low incentives to initiate innovation activities. With the deepening of reform, the ownership structure of the government funded enterprises has been changing and most small and medium sized government funded enterprises have been privatized (Zheng 2004). With the change of ownership structure, the government funded enterprises may have improved their incentives to innovate (Li and Zhou 2008), and the innovation capability of industrial enterprises has improved (Ye 2009), which can be seen from the positive impact on overall applications in Phase Two. Although the impact of industrial enterprises on overall granted patents was significantly negative, the change of the impact between the two phases showed signs of improvement of contribution of industrial enterprises to innovation development in China.

Financial capital and human capital did not display a great impact on overall innovation activities in either phase. Considering the strong effect across the whole period, it suggests financial and human capitals have an accumulated effect in the long term. Our study also illustrates that FDI negatively influenced innovation activities in Phase One and exerted a positive effect in Phase Two, while the impact of international trade depended on the type of innovations in Phase One and it was positive on overall innovation activities in Phase Two. These results imply that, with the improvement of innovation activities, domestic innovators

benefit more from international interactions, and the positive effect of the strategies to attract FDI and enhance international trade emerges.

Overall, it is useful information for government and other key stakeholders to understand the key determinants of innovation in building national capability and how the strategies related to that factor worked in the past prior to developing new strategies or adjusting policies to improve its innovation capability. The changing impact also indicates governments should modulate innovation strategies and policies in terms of the change of the time and impact. Specifically, the impact of higher education sector in the two phases suggests it is good for governments to continue encouraging universities to take advantage of the research resources they have and exert spin-offs to serve the development of industries. Developing further incentives for enterprises to put more effort into innovation activities will help achieve the objective of developing an enterprise-oriented innovation system. The accumulative impact of our proposed key determinants implies that to improve China's innovation capability, financial inputs need to be increased and human capital investment is also required. The improved impact of FDI in the second stage suggests that, in addition to putting effort into enhancing inward FDI, governments also need to improve absorptive capability and other conditions to gain more positive spillovers.

9. Limitations

Even though the study was carefully designed, there are some inevitable limitations. The first limitation relates to the data source. When using secondary data, the quality of the data cannot be controlled (Bryman and Bell 2003), and measures of the variables have to be adjusted if the information available does not meet the requirements of the study (Emory and Cooper 1991). This being said, the fit of the data to the research question is a common concern (Saunders, Lewis and Thornhill 2003). The next limitation refers to counted patents

as the measure of innovation capability. However, not all innovations are patentable (Griliches 1990) and patents are not the ultimate goal of enterprise and higher education institutes (Bai and Li 2011). Thus, patents at most can be used as a proxy of research and development capability. Besides, a large number of patents are applied for and granted to individuals in China, which measures the innovation capability of individual residents within a region, but the financial and human resource inputs for those activities are unknown. Our study did not consider the ownership of patents, which may have led to some biases in the results. To overcome the disadvantages of secondary data in the future, researchers can design studies, collecting primary data to meet their specific needs and controlling the quality of the data. To better measure national innovation system, alternative indicators can be employed in future research, such as the number of new products (Fritsch 2002), new product sales (Liu and White 1997), and literature-based innovation counts (Acs, Anselin and Varga 2002).

In sum, our study illustrates the roles of the main drivers that can influence innovation capability in China during the transitional phases, which are divided into two phases according to the reform process of innovation system. The differences found between the two phases reveal significant impact of institutional environment on innovation capability through changing key innovation drivers. The change of impact in two phases provides indications that the alignment between government innovation policies and innovation drivers could be the key to improving China's innovation capability.

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Table 1: The comparison of key drivers of innovation during the two critical periods of innovation policies during the China's reform (between 1991-1998 and 1999-2005) from 33 administrative regions.

Key drivers	Period One (1991-1998)		Period Two (1999-2005)	
	Mean	Std.	Mean	Std.
No. of higher education institution	2.981	0.240	3.070	0.240
No. of industrial enterprises	1.200	0.281	1.230	0.281
No. of scientists and engineers (fulltime)	3.084	0.349	3.16	0.349
Employment rate	0.517	0.060	0.520	0.060
Funding for science and technology	1.193	0.305	1.25	0.305
Inward FDI	1.302	0.524	1.30	0.524
International trades	2.202	0.434	2.21	0.434
Domestic technology transfer	0.556	0.477	0.620	0.477

Note: To ensure distributions are approximately normal, the logarithm transformation of most metric variables was used.

Table 2: The main effects between key innovation drivers and patents as a proxy for innovation capabilities from 33 administrative regions.

		Overall patent applications (DV1)		Overall granted patents (DV 2)		Granted invention patents (DV3)		Granted utility model patents (DV 4)	
		Phrase One	Phase Two	Phrase One	Phase Two	Phrase One	Phase Two	Phrase One	Phase Two
No. of higher education institution (HEI)	β	-0.046	-0.117	-.378***	0.05	-3.466**	-0.103	-.325***	.487***
	SE	-0.09	-0.104	-0.14	-0.184	-1.704)	-0.268	-0.12	-0.117
No. of industrial enterprises (IE)	β	-0.167	.202***	-0.132	-.263**	-3.669*	0.207	-0.053	-0.05
	SE	-0.107	-0.064	-0.165	-0.113	-2.017	-0.164	-0.142	-0.072
No. of scientists and engineers (SCI-ENG)	β	0.117	0.126	.436**	-0.012	2.173	1.152***	.426***	-0.043
	SE	-0.117	-0.091	-0.182	-0.162	-2.218	-0.236	-0.156	-0.103
Employment rate (EMPLOY)	β	0.017	0.093	-.753*	0.05	-0.921	0.955	-0.436	.656*
	SE	-0.246	-0.349	-0.381	-0.618	-4.65	-0.899	-0.326	-0.394
Funding for S&T (FUND)	β	0.048	0.083	-0.113	-0.038	3.465**	0.224	-0.074	0.023
	SE	-0.076	-0.066	-0.118	-0.116	-1.434	-0.169	-0.101	-0.074
Domestic technology transfer (TECH)	β	.040*	0.037	-0.034	.108**	.890**	-0.029	-.049*	.082**
	SE	-0.021	-0.028	-0.033	-0.05	-0.399	-0.073	-0.028	-0.032
Inward FDI (FDI)	β	-.112***	0.028	-.141***	.135**	-2.069***	-0.021	-.167***	0.054
	SE	-0.023	-0.035	-0.036	-0.062	-0.438	-0.09	-0.031	-0.039
International trades (TRADE)	β	-0.034	.319***	0.135	.411***	-2.804***	.603***	.238***	.467***
	SE	-0.053	-0.08	-0.083	-0.141	-1.012	-0.205	-0.071	-0.09
_cons		0.059	-2.770***	-1.470**	-3.330***	-34.514***	-11.343***	-1.459**	-4.792***
se		-0.422	-0.251	-0.655	-0.445	-7.99	-0.647	-0.561	-0.283
Within R-sq		0.4892	0.7883	0.6983	0.6291	0.6799	0.7938	0.6711	0.8645

Note: β = Standardize coefficient, SE = Standard errors, ***p<0.001, **p<0.01, *p<0.05

Figure 1: A conceptual model for innovation capabilities in China