5. NATIONAL INNOVATION SYSTEMS IN DEVELOPING COUNTRIES

Chinese National Innovation system in transition

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5.1 Introduction

The organization and effectiveness of innovation systems in transitional economies has become a very popular research topic (Lundvall et al, 2006). This is especially true since developing countries have become increasingly important in the international community, and China, boasting one of the world's fastest growing economies, is certainly no exception. After 30 years of opening up and reform, China has already established a unique economic and enterprise system, which is very effective for mobilizing resources for economic performance; however, it seems that the rate of development of the country's innovation capability has not increased as quickly. Therefore, the question is how to face the challenge of making China's innovation system more productive and integrative for the future welfare of the country.

There are many papers and reports on China's innovation system (Liu and White, 2000; Motohashi, 2007; OECD, 2008; Gu and Lundvall, 2006); The recent OECD review on the Chinese innovation policy (OECD, 2008) suggests that China needs more bottom-up decision making, the private sector should be given a more important role in innovation, and there should be more coordination among policy making and implementation agencies to promote innovation (OECD, 2008). According to the OECD's recommendation, the Chinese system must move towards a more open and market-based innovation system. However, in order to more effectively introduce innovation in China and pave a road of development leading to further innovation, many changes must be made. This chapter investigates the role of the Government supporting such transition.

Asia's situation is paradigmatic as the government plays a much more significant role in the innovation system compared to other countries. One can see that when Japan and Korea were catching up, the Government played a very important role. This is also the case in China. There are several key factors which have led to such a powerful government in China. Firstly, thousands of years of Chinese history and culture have created a government that is very influential in many aspects of Chinese people's lives. Secondly, China was formerly a socialist country with a powerful system in place controlling the economy. This regulation system has changed with several decades of market oriented reforms; however, the basic power structure has not changed that much, thus remaining a Government controlled economy. Thirdly, China is still a developing country. During the early stages of catching-up, the country's business system was relatively weak. The government therefore mobilized its limited resources, focusing on key industries and the development of a system of public research institutes and state own enterprises that have become the core of the system of innovation.

The next section of this chapter will briefly discuss the national innovation system in developing countries. Section 5.3 will look at the transformation of the innovation system in China exploring the role of the main actors in the Chinese Innovation System and evaluating the resulting changes. Finally, the paper will conclude with a discussion of the results.

Box 5.1. National Innovation Systems in developing countries: main terms used in this chapter

Broad definition of NIS = The Freeman and the 'Aalborg-version' of the national innovation system approach (Lundvall, 1985, 1992; Freeman, 1987), the so-called 'European tradition', aims at understanding 'the innovation system in the broad sense'. Thus, the definition of 'innovation' is more wide ranging. Innovation is defined as a continuous cumulative process involving not only radical and incremental innovation but also the diffusion, absorption and use of innovation. Moreover, a major source of innovation, besides science, is interactive learning taking place in connection with production and sales. Therefore, the analysis takes its starting point in processes of production and product development assuming, for instance, that interaction with users is fundamental for product innovation.

Narrow definition of NIS = A national system of innovation has been defined as follows:“ .. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.” (Freeman, 1987)

NIS in transition country = in developing and transition country, it is said that the system is more fragmented than that in developed country. Here learning activity is as important as innovation.

5.2. National innovation systems and developing countries

It is widely known that the idea of the National Innovation System was originally created by Christopher Freeman to explain Japan’s earlier economic success. He defined a NIS as “the network of institution in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies” (Freeman, 1987:1).

As Ostry and Nelson said, the growing proximity and potential tension among national systems brought about by globalisation is a factor increasing the demand for understanding nation-specific systemic differences between innovation practices that relate to international trade (Ostry and Nelson, 1995).

More recently, however, researchers have realized that there is a big difference between

NIS in developed countries and NIS in developing countries (Lundvall et al, 2006). In developing countries, the vast majority of firms lacks the minimum capabilities to engage in interactive learning and innovation (Chaminade and Vang, forthcoming). Overall, in developing countries, the systems of innovation are often fragmented (Intarakumnerd, et al., 2002), with some parts of the system well developed but with most firms and other organizations with low capabilities and weak linkages with the strong elements of the system. In some countries and regions one can even talk about two separate and coexisting systems of innovation. Some can be dominated by TNCs, indigenous global firms and world class universities, coexisting with a second one with a majority of firms with low absorptive capacity, weak linkages with other organizations in the system of innovation and low quality educational institutions.

The objective of this chapter is to analyze the transition of a National Innovation System, by looking at the transformation of the different components of the system (particularly organizations and its relationships). This chapter will explore the evolution and interaction of Chinese actors in the last thirty years, to see what kind of institutions need to be created and further improved to increase the production of China's national innovation system. The chapter highlights the role of the Government steering this transition and how different policies impacted the innovative performance of the different actors in the national innovation system.

5.3. The transition of the NIS in China

5.3.1. Stage 1 – Planned economy (1949-1980)

In 1956 the government launched its 1956–67 National Science and Technology Long-Term Plan, which focused on developing Chinese research and production capabilities in atomic energy, electronics, semiconductors, automation, computer technology, and rocket technology. The objective of this program was for China to reach the level of developed countries, both in defense and advanced civil technologies. At the same time, several specific mission projects were initiated and ultimately quite successful, such as the development of atomic and hydrogen bombs (by 1964 and 1967, respectively), and launching satellites (by 1970).

In the period of the planned economy (1949-1980), State Own Enterprises (SOEs), which were the exclusive form of enterprise in the country, were extremely weak in terms of innovation and they usually did not have perform R&D. Rather, the government told firms when, where, and how to introduce new technology, while research was mainly performed by government research institutions. Even at the government level, there was an elaborated division of labor. For example, the State Planning Committee (now State Development and Reform Commission) was central in allocating production targets for the enterprises and also had the power and obligation to introduce new technologies to the economic system, while the Ministry of Science and Technology would make five-year and annual plans in the area of science and technology.

Overall, however, the whole system was less than efficient. The enterprises were only motivated to produce high levels of output, with few if any incentives for efficiency and profit, and absolutely no consideration for IPR. Research institutions and universities were funded by the government and typically produced project reports with limited industrial use. Therefore, the level of innovation at that time was very low, although reverse engineering made a great impact in some sectors. Many new industries, such as the automobile industry, ICT industry, and steel industry, began to develop around the same year that Korea initiated its new growth strategy; however, these industries still lagged behind Korea decades later. "Import, lag behind, import again, lag behind once more" was the rule of that period.

For a long time, SOEs operated as manufacturing units with few if any R&D activities or formal R&D centers. Their production capability was maintained and upgraded mainly through technology imports, on which they spent more money than their own R&D during the period before the 1980's.

From 1949 to the 1980s, the main tasks of many industrial GRIs was to work on the assimilation of imported technology from the former Soviet Union, Germany, Japan, and other countries. In order to replace the imported technology and to save foreign currency, incremental innovations based on imported technology were implemented according to the principles of a planned economy.

During this plan-based innovation system, there was little space for curiosity-driven research. The share for this type of research, out of R&D as a whole, had been low and remained at a level around 5% of the total R&D expenditure during the period from 1995 to 2005 (China Statistical Yearbook on Science and Technology, 2006). China's economic reform and opening up was initiated in 1978, and the country's S&T system was soon after exposed to market competition. The objectives of the reform were twofold: to introduce a competition-based funding system, and to establish a new governance system of S&T institutions in order to more efficiently commercialize R&D results.

5.3.2 .Stage 2- Catching up (1980-2006) – The growing up of enterprises ,attracting FDI and investing in defense and strategic civil technologies

The role of enterprises in NIS

For a long time, enterprises have typically operated as manufacturing units with few if any R&D activities or formal R&D centers. Their production capability was maintained and upgraded mainly through technology imports and enterprises spent more money on technology imports than on their own R&D during the period before 1998. Since the 1980s, SOEs were given more autonomy to invest and innovate based on their own strategic decisions. Also, enterprises with different ownerships such as private and foreign enterprises have also, to a larger extent, engaged in innovation activities. This wave of privatization and competition has given enterprises strong incentives to invest in product development and innovation.

The contribution to the total economy of private companies, mainly in retail and service industries, is currently about one sixth of GDP.

Table 5.1 Number of companies with different ownerships 1994 - 2004 in million

	1994	2004	Annual growth rate
Number of private companies	0.43	3.65	29.79%
Number of SOEs	2.17	0.92	
Number of collective companies	5.46	1.39	-12.79

Source: Heixiu, 2006

Table 5.2 shows the pattern of how large and medium-sized enterprises gradually increased their R&D inputs and R&D intensity. Nevertheless the R&D intensity is still quite low, compared to that of developed countries.

Table 5.2: R&D expenditure and technology import (unit: 100 million USD)[1]

	Expenditure on R&D	Share of total sales, %	Expenditure on technology import	Share of total sales, %
1995	17.1	0.46	43.4	1.17
2000	42.7	0.71	29.6	0.49

2005	152.7	0.76	36.2	0.18

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

In terms of output, the innovation capability of Chinese enterprises is still relatively low. Their innovation capability is mostly focused on incremental innovation with little radical innovation, which can be observed from the patenting activities of the enterprises. Patents registered in China are classified into three categories: invention, utility model and (appearance) design. The classification of patents differs from the international standard. For instance, design refers to new appearance and utility model refers to functionality modification or improvement, without substantial technological contents. The invention patents are thus presumably more R&D intensive than the other two types of patents. Chinese enterprises have relatively high patenting activity in utility model and design, which account for the largest increase in the total number of patents, but low in invention patents. However, since 2000, the number of invention patents granted has also increased more rapidly than before (see Table 5.3). Furthermore, the patenting activities differ significantly between domestic and foreign firms in China. For instance, even though both domestic and foreign firms have rapidly increased their patent applications, the largest increases in both applications for invention patents and invention patents granted are from foreign firms. Moreover, the technological sophistication and the claims required in patent applications by foreign firms, in general, are more advanced than in domestic firms.

Table 5.3: Patents granted in China- by type of patents (unit: number)

	1995	2000	2005
Total number of patents granted	45064	105345	214003
Share of invention patent, (%)	7.5	12.0	24.9
Share of utility model patent, (%)	67.6	52.0	27.1
Share of design patent, (%)	24.9	36.0	38.0

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

Growth of small firms is a relatively new phenomenon in the Chinese enterprise system. The market was opened up for non-state owned small firms only after the 1980s. As most of them started their business by taking advantage of market opportunities, their innovation capability is still low, despite the rapidly rising importance accorded to entrepreneurship and small firms in economic growth. If China is to make rapid strides in building up innovation capacity, it is crucial to bring small firms into this process. Firstly, small firms play an important role in job creation in China and absorb a large number of new entrants into the labor market as well as those former large SOE employees who were laid off during the structural reforms. The enhanced innovation capacity will not only increase the potential of small firms to grow, but also help them to create better jobs. Secondly, while FDI and globalisation of R&D have been highly MNC-dominated phenomena, in recent years it has been observed that small foreign firms are making greater efforts to enter the Chinese market and to participate in the process of globalisation of R&D.

At present, the share of R&D conducted by small firms is still low in China (accounting for 14% of total R&D expenditure in the business sector in 2004, which is slightly lower than the OECD average of 17%). However, their innovative potentials, indicated in terms of R&D intensity and patent output should not be underestimated. As shown in Table 5.4, the comparison of key S&T indicators of large- and small S&T-based firms, across various ownerships suggests that small firms have, in general, a higher R&D intensity (measured by R&D/sales ratio) than large firms. Small foreign firms are particularly active in invention-related patent applications. However, due to various resources and institutional constrains, small firms have also limited access to foreign technology and low capability to enter foreign markets. Furthermore, there are also substantial differences across ownerships among both small and large- and medium-sized enterprises in their inputs and outputs of innovation activities(Table 5.4) (Lundin et al, 2006a)[2].

Table 5.4: Comparison of key S&T indicators of small and large S&T-based firms (%), (2004)

	Small S&T based enterprises				Large S&T based enterprise			
	R&D/ Sales	Export of new products /sales	Tech import /sales	Patent/ 100 persons	R&D/ Sales	Export of new products/sales	Tech import /sales	Patent/ 100 persons
SOE	1.2	0.3	0.2	0.5	0.9	1.6	0.3	0.1
Joint venture: HTM	1.0	4.2	0.2	0.4	1.0	23.0	0.4	0.4
Joint venture: Foreign	1.6	4.2	0.6	0.4	1.3	6.4	1.2	0.7
Foreign	1.4	6.6	0.2	0.8	1.0	24.4	0.2	0.3
Private	1.6	3.2	0.1	0.7	0.7	5.9	0.1	0.9

Source: Lundin et .al, 2006a.

Overall, private enterprises in China are still relatively weak. Government research institutes (GRIs) and universities are the main actors working towards and achieving the national goals. Enterprises' lack of leadership in terms of innovation can be seen from Table 5.5, which shows that the amount of patents granted to private enterprises is no more than those received by GRIs and universities. Large foreign firms dominate patenting activity in China, accounting for roughly two-thirds of all invention patents granted in China in 2004 (Miller, 2006).

Table 5.5 Invention patent granted in China (1987-2004)

Year	Total	Universities(%)	GRIs(%)	Enterprises(%)
1987	250	48	43	9
1990	863	38	38	24
1993	1514	33	38	29
1996	654	34	38	29
1999	1430	30	38	32
2002	3065	23	30	48
2003	6789	25	25	50
2004	12018	29	20	51

Source: Yearbook of China S&T Statistics (1988-2005). China Press of Statistics.

Role of FDI

One important event influencing the development of China's NIS in this period is the emerging role of multinationals in the private sector. During the period from 1998 to 2004, the number of large- and medium-sized FDI firms steadily increased. While the shares of value-added and exports of FDI firms in the Chinese business sector had reached a relatively high level (40% and 76%, respectively), the shares of R&D expenditure and employment were still low (29% and 34% respectively). This implies that FDI firms' production in the Chinese business sector has been more capital-intensive, with very little R&D-intensive manufacturing (Table 5.6).

Table 5.6. The importance of FDI firms in the manufacturing sector, 1998-2004 (Share in the manufacturing sector, %)

Year	Number of FDI firms	Share of number of large and medium enterprises	Value -added	R&D Expenditure	Tech import	Export	Employment
1998	3489	22	26	21	20	58	14
1999	3764	23	28	23	16	61	16
2000	4221	25	30	20	19	63	18
2001	4585	27	31	23	28	66	20
2002	5327	29	33	23	24	68	23
2003	6512	31	36	25	27	71	27
2004	8745	36	40	29	48	76	34

Source: Lundin et .al, 2006b.

The ever-increasing presence of FDI firms in China has made a great contribution to the country's economic growth. For example, in the automobile industry, without FDI, China would find it impossible to produce enough cars to meet demand in such a short period. This is also true for technology-intensive industries. It is well-known that, as a result of FDI, the ICT sectors in China are the most internationalized high-tech industries in which value-added, technology imports, and exports are dominated by FDI firms. Regarding R&D expenditure, FDI firms in the computer and office equipment industry have made the most remarkable increase; FDI firms in the medical equipment and instruments industry have also noticeably increased their contribution to the R&D investment at the industry level (Table 5.7).

Table 5.7 The importance of FDI firms across high-tech industries, 1998 & 2004 (Share in the high-tech industries, %)

	Number of FDI firms	**Share of number of large and medium enterprises**	**R&D expenditure**	**Tech Import**	**Export**	**Employment**
Pharmaceutical products	83	16	20	4	19	11
Electronics & telecommunication	349	52	41	77	86	42
Computer & office equipment	70	59	37	94	94	51
Medical equipment & instrument	28	20	11	41	40	14
Pharmaceutical products	158	21	22	20	21	16
Electronics & telecommunication	1145	72	42	93	93	73
Computer & office equipment	336	86	82	98	98	91
Medical equipment & instrument	105	38	27	33	88	36

Source: Lundin et .al, 2006b.

Role of government research institutes (GRIs)

There are five layers of public research institutes: the central, ministry, provincial, city, and county level. In the central level, which includes institutions such as the Chinese Academy of Science, GRIs focused mostly on basic and applied research. At the ministry level, GRIs specialized mostly by industry. From the 1950s through the 1960s to the 1980s, GRIs were the main agencies to realize the national S&T strategies and goals. For a long time, they were responsible for more than half of the total R&D expenditure in China (Table 5.8).

Table 5.8: The relative importance of key actors in R&D expenditure (%)

Performers	1990	1996	2000	2005
Research institutes	50	41	29	21
Universities	12	13	9	10
Enterprises	27	37	60	68

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

Since 2000, private enterprises have accounted for more than 60% of total R&D in China (See Table 5.9). However, GRIs and universities are still the key players in cutting edge science and technological research. Compared to private enterprises, they attract a larger number of talented scientists.

Table 5.9 The allocation of government R&D (2003 - 2005) (unit: 0.1billion yuan)

Year	2003	Share（%）	2004	share（%）	2005	share（%）
Total government R&D	460.6	100.0	523.6	100.0	645.4	100.0
GRI	320.3	69.54	344.3	65.76	425.7	65.96
Enterprises	47.3	10.27	62.6	11.96	76.5	11.85
University	87.7	19.04	108.8	20.78	133.1	20.62
Others	5.2	1.13	7.8	1.49	10.2	1.58

Source: China Statistical Yearbook on Science and Technology, 2004, 2006.

It is a fact that most public money goes to public research institutes and universities. From 2003 to 2005, out of the amount of money distributed by the government, public research institutes received 67.09%，universities received 20.15%，and businesses only received 11.36%. This kind of R&D expenditure structure shows that most of the time, the government relies on GRIs and university to realize its S&T ambitions.

One of the key changes of this period was to reform the funding system and make the governance of the S&T institutions more flexible. This meant that the government reduced direct funding for GRIs, instead, increasingly diversifying the source of funding for GRIs. While this change aimed to strengthen incentives for innovation and to accelerate commercialization, it also imposed increased pressure on scientists and, in order to pursue more immediate economic returns, led them to replace long-term research projects with ones which would last a significantly shorter amount of time.

In order to speed up the process from research to commercial production, the government also encouraged GRIs and universities to use their results to create spin-offs, and scientists to leave their research positions to engage in commercial activities. In the 1980s, spin-off policy was introduced by MOST with the intention of pushing universities and GRIs to be more entrepreneurial in the high-tech industry.

Though the size of the spin-off industry (Table 5.10) in China has been small compared to the Chinese economy as a whole, it was valuable for the country's high-tech industry. Spin-off companies gave many scientists in universities and GRIs good opportunities to access the market knowledge. From the end of the last century on, however, as the government has continuously accelerated its support for research and education, universities and GRIs no longer consider developing spin-off companies as their primary function.

Table 5.10 University spin-offs

	Number of spin-offs	Revenue (billion RMB)	Profit (billion RMB)
1999	2137	26.7	2.2
2000	2097	36.8	3.5
2001	1993	44.8	3.1
2002	2216	53.9	2.5
2003	2447	66.8	2.8
2004	2355	80.7	4.1

Sources: Statistics of University's industry in 2004 in China, Center for S&T for Development, Ministry of Education, 2005.

The result of the policy to encourage spin-offs led to highly capable domestic high tech companies, such as Lenovo, from the Chinese Academy of Sciences, and Beida, from Peking University. Lenovo is now one of the leading companies in the IT industry in China. Most biotech companies are also the result of spin-offs. For example, Shenyang Sunshine Pharmaceutical Co. Ltd., Beijing Shuanglu Pharmaceutical Co. Ltd., and Anhui Anke Biotechnology Co. Ltd. were all founded by former researchers from research institutes (Liu and Lundin, 2006). In general, universities and GRIs are key factors in improving China's domestic high-tech industry.

Once implemented, the abovementioned policy gradually met new challenges. Firstly, spin-off companies are generally not motivated or lack the structure to further innovate. Secondly, there is a conflict between the profit-seeking and public goals of universities and GRIs, which puts them in a risky position. Therefore, universities are increasingly reluctant to encourage the creation of spin-offs.

In the 1990s, after more than ten years of reform, there was still a large gap between the research activities of GRIs and the needs of industrial sectors. In the meantime, the organization of China's government underwent a significant change as most of the industry-specific ministries were abolished. The new structural challenge was dealing with the industrial GRIs, which were previously affiliated with those ministries. Toward the end of 1998, the State Council decided to transform 242 national-level GRIs into technology-based enterprises and technology service agencies. This important structural change implied that the dominance of GRIs in the Chinese innovation system was over and instead, industrial enterprises were becoming the core of the innovation system. Thus, the number of GRIs in 1991, which was close to 6,000 institutes with around 1,000,000 employees, shrunk to less than 4,000 with approximately 560,000 employees in 2004 (NBS 2006).

After the transformation of applied GRIs, some have been operated quite well, but some of them are not, mainly because it is difficult to make good managers out of scientists. Additionally, some transformed GRIs were unable to find a position in the market; they lost their technological edge and became common companies. In this process, however, the largest GRI, the Chinese Academy of Science (CAS) has been strengthened by a special new program called the Knowledge Innovation Engineering Program which was specifically created for CAS.

Role of government

During this reform period, the government had introduced many new tools to promote innovation in China.

In 1980s, a new institution called technical market was introduced. This new specialized market was constructed to facilitate technology transactions between suppliers and users of technology. It is now one of the important ways for transaction of technology for China.

In the same time, special economic zones were established across China to support the development of high-tech enterprises. High-tech zone policy is a mixed result of open policy, institutional reform and governmental action. Zhongguancun high-tech zone was the first one in China and there are now 53 national high tech zones in China. The purpose of creating high-tech zones was to establish well-functioning infrastructure to serve as a platform for innovation activities and interactions among universities, research institutes, and firms.

In the past two decades, these high-tech zones have expanded rapidly in terms of size and scope of activities, therefore they have played an important role in promoting the development of the high-tech industry in China. Up to now, more than 90% of high-tech firms and incubators are located in these high-tech zones. Most of them are spin-offs from universities and GRIs, new private firms, and FDI firms. In 2004, the total value added by high-tech zones was 550 billion RMB, or about 8.8% of GDP, and its exports amounted to about $82.4 billion, about 12% of the national value (MOST, 2006). It is true that some high-tech zones have became a real estate investment for local authorities and private enterprises. Some of them have also attracted much FDI. Overall, however, it is still a good policy for China's high-tech industry.

The most important policy tools used to implement the national innovation strategy in this period are the specific national S&T programs controlled by MOST. Table 5.11 gives a brief overview of these programs. Among them, the national high-tech program (863) was launched in 1986 with the specific goal of catching up and has been one of the most important programs launched for this purpose.

Science and technology programming and planning are the main instrument for the government to intervene in innovation and S&T activity, promote technological and innovative capabilities and catch-up to developed countries.

From 2001-2005, about 15 billion RMB was spent on civil technology development with a focus on high technology. Most local high technology industries benefited greatly from this expenditure which planted the seeds of China's high-tech industry and, in large part, resulted in the development of high-tech zones (Table 5.11).

Table 5.11 National S&T programs

	1996	2000	2001	2002	2003	2004
973 Basic Research		5	6	7	8	9
863National High Tech R&D program(from 1986)	4.5		25	35	45	55
Key Technologies R&D program(from 1983)	5.2	10.3	10.6	10.6	12.5	16.1
Torch Program(1988, for high technology)	0.51	0.5	0.5	0.5	0 . 5	
Spark Program(1988 for rural SME)	0.39	0.4	1	1	1	
Key S&T Diffusion program	0.19	0.2	0.2	0.2	0.2	

Source: MOST (2006)

The linkage between universities, GRIs and industries

1. S&T Outsourcing by Industrial Enterprises

Since 1980s on, as an integral part of the establishment of science-industry linkage, GRIs and universities began to conduct contract research for the industrial sector. This type of activity has been beneficial for the industrial sector, as most Chinese enterprises, especially Small and Medium-sized Enterprises (SMEs), have limited innovation capabilities. Outsourcing of S&T research to GRIs and universities has become an important development strategy for industrial enterprises. For instance, the share of universities' S&T funds from industrial enterprises was about 31.3% of their total research funds in 2004 (Table 5.12).

Table 5.12 R&D outsourcing for university and R&D institutes from large and medium-sized industrial enterprises

	2000	2001	2002	2003	2004
Total R&D expenditure(Billion RMB)	35.4	44.2	56.0	72.1	95.4
Funds for university (Billion RMB)	5.5	7.2	9.0	11.2	24.9
Share of total business' R&D (%)	15.5	16.2	16.1	15.5	26.1
Funds for R&D institutes(Billion RMB)	3.8	2.5	3.6	4.7	5.0
Share of total business' R&D(%)	10.7	5.6	6.4	6.5	5.2
Total outsourcing for domestic Univ.and R&D inst.(%)	26.2	21.8	22.5	22.0	31.3

Source: MOST, 2006c; China Science and Technology Statistical Yearbook, 2005. Beijing: Chinese Press of Statistics.

2. Joint Publications

Another indicator of industry-science linkage is the number of joint scientific publications by researchers from universities and the industrial sector. Currently, however, the majority of published scientific papers in China are submitted by individual researchers from either the higher education sector or from research institutes, while those published jointly are still relatively small in number. Because of IPR and several other reasons, the S&T researchers from industrial enterprises are typically reluctant to publish papers. Recently, however, researchers from universities have increasingly co-authored science and technology publications with engineers and researchers from industrial enterprises. For instance, as seen in Table 5.13, the number of jointly published papers has rapidly increased from 867 articles (1.7% of the total number of scientific papers published) in 2000, to 7,421 (7.4% of the total) in 2003 (Chinese Institute of Information, 2005). This intensified interaction and co-operation may promote innovation capacity in both sectors as well as enhance the mutual understanding of their different but closely related innovation activities.

Table 5.13 Co-authored papers between industry and university (2000-2003)

First –second author	2000		2001		2002		2003	
University-industry	867	1.7	5301	9.96	6448	7.35	7421	7.39
	Paper	Share	Paper	Share	paper	Share	Paper	share
Total	51079	100	53246	100	87688	100	100310	100
Enterprises-university	4499	8.81	1123	2.11	1381	1.57	1567	1.56

Source: Chinese Institute of Information, China Science Paper and Citation Analysis, 2005.

3. Venture Capital

The venture capital system also has a very important role in promoting links between universities, GRIs, and industries. It was introduced in the end of 1990s. the first wave of the VC was driven by the government. Later on, private and international VC firms have recently started to emerge in China.

Recently, China's venture capital market has been developing rapidly. In the year 2001, the overall amount of venture capital in China is only 518 million dollars; however, just by the end of the second season of 2008, this figure has raised to 3845.04 million dollars, nearly 8 times that in the year 2001. Especially in the recent two years, the number and amount of venture capitals both maintained high growth rate, reaching an average rate of more than 50 percent. See table 5.1 and figure 5.1

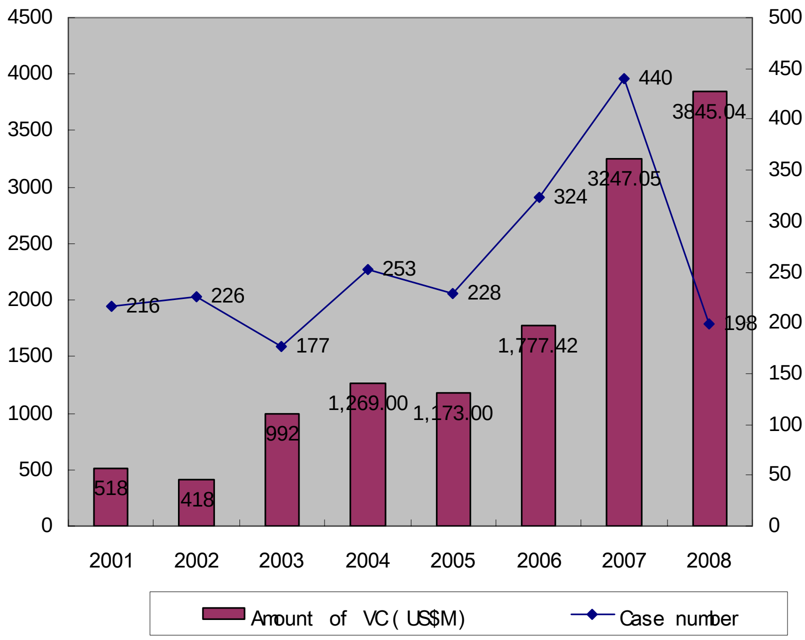
Table 5.1 Annual amount of venture capital in China, 2001 to 2008 August

Year	Number of Cases	Growth rate	VC amount (US$M)	Growth rate
2001	216	—	518.00	—
2002	226	4.6%	418.00	-19.3%
2003	177	-21.7%	992.00	137.3%
2004	253	42.9%	1,269.00	27.9%

2005	228	-9.9%	1,173.00	-7.6%
2006	324	42.1%	1,777.42	51.5%
2007	440	35.8%	3247.05	82.7%
2008 (up to August)	198	—	3845.04	—

Data source: zero2ipo research center, www.zero2ipo.com

[figure 5.1 about here]



Data source: zero2IPO research center, www.zero2ipo.com

Figure 5.1 Variation trend of annual VC amount and case number, 2001 to 2008 August

With regard to VC by sector, we see that IT industry, traditional industry, bio-tech/health industry and service industry, which together take up 84% of VC number and 85% of overall amount, are the ones attracting most VCs.

As White said, China's venture capital system is still immature in terms of the resources and capabilities of most of the constituent organizational actors, as well as the institutional environment in which they operate. Currently, venture capital firms do not have the expertise or operational mechanisms to adequately select and manage new technology ventures, nor have they been able to add much value beyond financing. Because their incentive structure creates a bias towards late-stage investment projects, these venture capital firms are not acting as a channel of funds to true start-ups, despite the government's intentions for the promotion of venture capital (White, Gao and Zhang, 2005).

5.3.3 Stage 3. Building domestic innovation capabilities (2006-present)

Though China had achieved rapid economic growth, but innovation capacity of China is still quite poor.

Firstly, China's economic growth has been highly dependent on foreign technology and foreign investment. Since 2000, foreign-invested enterprises accounted for more than 85% of all high-tech exports (China Statistics Yearbook on high-tech technology industry, 2004- 2006). In recent years, there has been an increasing frustration among domestic actors, caused by the fact that a "market for technology" policy has not resulted in immediate and automatic knowledge and technology spillovers from foreign to Chinese enterprises that policymakers had hoped for.

Secondly, a culture of copying and imitation is common not only in product development and design, but also in the field of scientific research. Hence, innovations based on domestic knowledge bases and intellectual property rights are extremely necessary for China to change this behavior.

Thirdly, the high growth rate of the Chinese economy during the last twenty years will not be sustainable without a change in the current development strategy. China needs, for example, more energy-efficient and environment-friendly technology, new management skills, and new organizational practices to ensure sustainable growth in the near future.

Fourth, lots of investment policies in some sense are more favorable to foreign company in China than domestic company.

In this background, the document of “National Programming 2006-2020 for the Development of Science and Technology in the medium and long term send out a strong voice to strengthen domestic innovation capability.

The objective of the new national program is to make China an innovative country by implementing domestic innovation strategies.

There are three main policies selected to set the framework of the domestic innovation strategy. Firstly, the government plans to increase R&D by 2020 to 2.5 % of GDP (from the current level of 1.3 %). Since GDP growth is projected to increase at a similar pace, increasing R&D expenditure as a share of GDP implies a huge increase in absolute terms. Secondly, fiscal policy will be changed to stimulate innovation at the company level. The new tax policy will make R&D expenditure 150 % tax deductible, effectively constituting a net subsidy, as well as accelerated depreciation for R&D equipment worth up to 300,000 RMB. The third policy is the public procurement of technology, which is taken from USA and Korea's best practices. Public procurement in China today is significant, but the policy tool itself is relatively new to China. The purpose of current public procurement practice is to cut the costs rather than promote domestic innovation. Under the new policy, government agencies will have to patronize innovative Chinese companies even if their goods and services are not as high quality or cost-efficient as those of other (both Chinese and foreign) companies. With this new policy, the government prioritizes domestic innovative products in public procurement. The policy requires that over 30% of technology and equipment purchasing will go towards domestic equipment if public money is used. It will also give domestic innovative products some price advantage (State Council, 2006).

5.4. Conclusion and discussion

Organizations and institutions involved with innovation in China have been improving in the last thirty years. The private sector has emerged as one of the most important innovation actors in China and diverse enterprise ownership structures have been formed. Private and foreign related companies are responsible for about two thirds of

GDP and employment in China. However, private companies in China still meet many barriers to enter the market.

Market demand is the main force mobilizing economic resources, although the government can still control the direction of the market by using land and infrastructure investment. It is a fact that a high government intervention model is not an efficient way to promote innovation. So, the Chinese government has created a specific goal: to establish an enterprises-centered innovation system in China. The progress of establishing an enterprises-centered innovation system is very slow, however, so it is too early to say whether China will be the next superpower of science and technology (Jefferson, 2004; Sigurdson, et al.2005).

In China, competition in the domestic market is very fierce. Real estate, automobile, and infrastructure and resources-based industries are the fastest growing industries. Those industries attract the highest investments and provide high returns. Therefore, financing agencies invest little in innovation based industries. Liu and Zhang (2002) have demonstrated that both R&D expenditure and new product sales are inversely related to SOEs' performance. This means that high R&D expenditure and greater new product sales will reduce the SOE's return. Lack of intellectual property rights may contribute to a lack of appreciation of innovation.

The link between GRIs, universities and industries has been established, although it is usually pushed by government programs (Motohashi and Yun, 2007). Spin-off companies do play a very important role, but in order to have more university-industrial cooperation, trust building is important for commercializing R&D results in China.

In western countries, industrial associations can play an important role in the introduction of new technology. In China, however, the industrial associations are at a level of under-development. Most of those associations play the role of a quasi-government. Therefore they cannot take an independent role in evaluating the technology and promoting GRIs and public interactions.

In the future, as the government will spend an increasing amount of money on R&D following the high growth rate of the economy, institutional reform and construction will be badly needed for a more efficient reward system regarding the increasing inputs in China. China needs a more efficient, transparent, and market based rewarding system of innovation to become a real innovation-driven economy.

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NOTES

[1] The nominal values of R&D expenditure and technology import in RMB were converted to USD using the annual average exchange rates in 1995 (1USD = 8.31 RMB), 2000 (1 USD=8.28 RMB) and 2005 (1 USD= 8.19 RMB).

[2] The industrial enterprises in China can be divided into the following ownership categories: SOE, joint venture with enterprises from Hong Kong, Taiwan and Macau (HTM), joint venture with foreign enterprises, wholly foreign-owned and private enterprises.

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