Toward a Market-based Open Innovation System of China

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1. Introduction

The National Innovation System (NIS) has become an increasingly useful tool when analyzing innovative capacity and providing inputs for policy making in developing countries, such as China, although the concept of NIS and its implications are defined in different ways (Freeman, 1987; Nelson et al. 1993; Lundvall, 1992).

For a long time in the past, the innovation system in China has been a more plan-based system. The government research institutes played a dominant role and the government acted as a core coordinator from idea creation to a final user of new products, by issuing the National Science and Technology Plans both annually and in every five years. Industrial enterprises played a trivial role in such a system (Liu and White, 2001). Even though the system was efficient for implementing some targeted R&D programs, such as the development of nuclear bomb and missile system, it was an inefficient system in terms of innovation.

Since the 1980s, China launched its economic reform and open-door policy toward a market-oriented economy of great openness. Industrial enterprises, with diversified ownerships have gradually become the main player of innovation during the reform process. A large number of State-Owned Enterprises (SOEs) were transformed into equity share or privately owned enterprises. Foreign invested /affiliated enterprises emerged also with a rapid growth. The market mechanisms thus, to a large extent, replaced the government plans as driving and coordinating forces of the Chinese innovation system. In a sense, the system has been heading for a market-based open innovation system.

In this paper we present the transformation process of the NIS in China. As China's political and economic systems are unique, the innovation system and policy making need to be grounded in this uniqueness. Therefore, we aim to give the presentation with emphases on key elements of the NIS in terms of actors and linkages as well as on country-specific factors, which are important determinants for both strength and weakness of the Chinese NIS.

The remainder of this paper is organized as follows. In Section 2 we provide a short review of how the Chinese innovation system has evolved over the last twenty years. In Section 3, key linkages in the system will be illustrated and discussed. The enterprise system will be presented in more detail in Section 4 and we will discuss the key country-specific factors in the Chinese innovation system, such as the role of government, foreign direct investment, globalization of innovation in China and regional diversity in Section 5. Finally, we conclude in Section 6.

2. From a research institutes- dominated to an enterprise-centered system

Since the economic reform, the Chinese innovation system has undergone significant changes, in terms of the relative importance of key actors and the mechanisms that drive the development of the innovation system. As shown in Table 1, the share of R&D expenditure by research institutes in the total R&D expenditure nationwide has gradually decreased from 50 % in 1990 to 21% in 2005, while the corresponding share for enterprises has increased from 27% to 68% in the same period. In this Section, from a historical perspective, we provide a brief description of the transformation process.

Table 1 **The relative importance of key actors in terms of R&D expenditure, %**

	1990	1996	1997	1999	2000	2001	2002	2003	2004	2005
Research institutes	50	41	43	39	29	28	27	27	23	21
Universities	12	13	12	9	9	10	10	11	10	10
Enterprises	27	37	43	50	60	60	61	62	67	68

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

2.1 A plan-based innovation system

In the socialist planned regime, the innovation system of China was dominated by a linear model of innovation with a clear-cut of division of labor. The government functioned as the key coordinator in the system and the government research institutes played a dominant role in performing innovation activities.

From the 1950s to the 1980s, Government Research Institutes (GRIs) were established at different administrative levels with various goals and orientations. The most important of them were at the national level, such as the Chinese Academy of Science (CAS). Most of basic/scientific research was done by the CAS and some large research universities such as Beijing University and Tsinghua University. There were also hundreds of industrial research institutes under a wide range of industrial ministries, focusing on applied research and developmental tasks. Regional GRIs conducted R&D tasks, which were defined as relevant for the regional development.

In addition, the higher education sector played a complimentary role for the GRIs. Most of universities at that time were not involved in research, except those large research universities as mentioned above. Many specialized universities focused on industry specific technology and education. For example, there were universities specialized in light industries, metallurgy and printing, etc.

In general, the role played by industrial enterprises in the innovation system was limited and they functioned as manufacturing and/or sales units. Most of them did not do any R&D, while only some large SOEs had their own R&D laboratories and their work focused mainly on experimental issues. Hence, the innovation system was constructed and driven largely according to a linear and hierarchical model.

Following this clear-cut division of labor in knowledge creation and product manufacturing, a key question is how to introduce the new technologies and products into the market? This was the task of the government. The main policy tools of the government were the annual and the five-year Economic and Science & Technology (S&T) plans. Even at the government level, there was a sophisticated division of labor in policy making. For example, the State Planning Committee (the current State Development and Reform Commission) was the central body of allocating production targets for enterprises and also responsible for introducing new technologies to the economic system. The Ministry of Science and Technology (MOST) was in charge of the annual and the five-year plans in the field of science and technology.

For a long time, S&T was considered of strategic importance to overcome shortages of supply of goods and services as well as to strengthen China's military position. The high priority was given to a few large national projects, in which involved thousands of scientists and engineers from a large number of government research institutes, universities, enterprises and hospitals across the country with a well planned division of labor. The successes of nuclear bomb, artificial insulin and other major discoveries were the results of this planning regime and they reinforced the impression that great success in S&T could be achieved, albeit with huge costs.

Despite the success in a few prioritized fields, the innovation system as a whole was less efficient. The enterprises were output-oriented, with little if any incentives to improve efficiency and enhance profitability and paid no attention to intellectual property rights (IPR). The research institutes and universities were funded by the government and produced project reports with limited industrial uses.

From the 1950s through the 1960s to the 1970s, China imported foreign technologies with a large scale from the former Soviet Union, Germany and Japan. Those technologies laid the foundation for the Chinese chemical, automobile, steel, textile and many other industries. For many industrial GRIs, from 1949 to the early 1980s, their main tasks were to assimilate those imported technologies. In order to replace the imported technology and to save foreign currency, incremental innovations based on imported technology were also implemented. Many new industrial sectors were established in China in the 1970s around the same time when South Korea initiated its new growth path to target at automobile, ICT- and steel industry. However, the Chinese enterprises in these sectors have been lagging behind Korean enterprises in many years because of both the high degree of foreign technology dependency and the low level of absorptive capacity. Many Chinese enterprises have got stuck in the pattern of "Import, lag behind, import again, lag behind again".

2.2 The transition to an enterprise- centered system

In the previous plan-based innovation system, there was little space for curiosity-driven research. The share for basic research has been low and remained at a level around 5% of the total R&D expenditure during the period 1995-2005 (China Statistical Yearbook on Science and Technology, 2006). Since the economic reform was initiated in 1978, the S&T system of China was soon exposed to market competition. The objectives of the reform were twofold: to introduce competition-based funding system and to establish a new governance system of S&T institutions in order to more efficiently commercialize R&D results.

One of the key initial changes was to reform the funding system and make the governance of the S&T institutions more flexible. It meant that government reduced the direct funding for GRIs, and the funding of GRIs should be increasingly diversified and come from other sources than the government. While this change aimed to enhance incentives for innovation and to accelerate commercialization, it imposed also increased pressure on scientists and led to short-term research projects for pursuing more immediate economic returns.

In order to speed up the process from research to commercial products, the government also encouraged GRIs and universities to set up their own spin-offs and encouraged scientists to leave their research position and engage in commercial activities. Furthermore, a new institution called technical market was introduced. This new specialized market was supposed to facilitate technology transactions between suppliers and users of technology. Moreover, special economic zones were established across China to support the development of high-tech enterprises.[1]

In the 1990s, after more than ten years of reform, there was still a great gap between the research activities of GRIs and the needs of industrial sectors. In the meanwhile, the government system underwent a significant change as most of the industry-specific ministries were abolished. The new structural challenge was how to deal with the industrial GRIs, which were previously affiliated to those ministries? Toward the end of 1998, the State Council decided to transform 242 GRIs at the national level into technology-based enterprises or technology service agencies. This important structural change implied that the dominance of GRIs in the Chinese innovation system was changed and instead, the industrial enterprises were on the way to become the core of the innovation system. Since 2000, the enterprises performed more than 60% of total R&D in China (See Table 1). However, GRIs and universities are still the key players in frontier science and technological research. They still attract a larger number of talented scientists than enterprises do.

[1] More detailed information on spin-offs and special economic zones are given in Section 3.1 and Section 5.1.2.

3. Industry-science linkages

The intensity and efficiency of industry-science linkage are important indicators of innovation capability at the system level in a country. As there was a functional division of labor in knowledge creation and diffusion for a long time in China, strong barriers existed between the knowledge creation by GRIs and universities and the utilization of knowledge of enterprises. But since the introduction of economic reforms in China, under the strong competition pressures and supported by various institutional changes, the industry-science linkages have been improved greatly in last 20 years. In this section, we illustrate industry-science linkages in the Chinese innovation system in the following three aspects: spin-off, R&D outsourcing and co-publication.

3.1 GRIs and university spin-off

GRIs and universities were allowed and encouraged to set up their own spin-offs so that they could commercialize their technology directly. In this way, GRIs and universities could be more integrated in the economic activities. Spin-off companies could also provide GRIs and universities with some financial resources, which could compensate for budget cuts from the government. Although the size of spin-off industry in China is small compared to that of the Chinese industrial sector, it is very important for high-tech industries in China (See Table 2). Spin-off companies provided many scientists from GRIs and universities with good opportunities to access the market knowledge. The policy to encourage spin-offs gave also birth of many successful domestic high-tech companies, such as Lenovo, from the CAS, Beida Founder from Peking University, which are now leading companies in the Chinese ICT industry. Most of the Chinese biotech companies are also 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).

However, since 2000, as the government has continuously strengthened its support for research and higher education, many GRIs and universities no longer considered the development of spin-off companies one of their primary functions.

Table 2 **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.

3.2 The S&T outsourcing by industrial enterprises

GRIs and universities began also to conduct contract research for the industrial sector. This type of activity has been beneficial for the industrial sector, as most of the enterprises, especially Small and Medium-sized enterprises (SMEs) have limited innovation capabilities. To various extents, outsourcing of S&T to GRIs and/or universities has become an integral part of development strategy of industrial enterprises. For instance, for the period 2000 -2004, the share of universities' S&T funds from industrial enterprises has been increasing and it was about 38% of their total research funds in 2004 (See Table 3). In 2004, about 26% of industry's total S&T expenditure went to university (Table 4).

Table 3 **S&T outsourcing of Industrial enterprises to Universities**

		2000	**2001**	**2002**	**2003**	**2004**
Total S&T funds (billion RMB)		16.7	20.0	24.8	30.8	39.2
From industrial enterprises	**S&T funds (billion RMB)**	5.5	7.2	9.0	11.3	14.9
	Share (%)	33.3	36.2	36.2	36.7	38.0
From government	**S&T funds (billion RMB)**	9.7	11.0	13.7	16.5	21.1
	Share (%)	58.4	54.9	55.4	53.6	53.8

Source: Statistics of Science and Technology in Higher Education, 2000-2005.

3.3 Joint publications

Joint publishing of scientific papers between university and industry is another indicator of industry-science linkage. For IPR and other reasons, the industrial enterprises are typically reluctant to publish papers. But from Table 5, it is clear that researchers from universities, to an increasingly extent have engineers/researchers from industrial enterprises as their co-authors for joint publishing.

Table 5 **2000－2003 co-authored papers between industry and university**

First -Second author	**2000**		**2001**		**2002**		**2003**	
	Paper (Piece)	**Share (%)**	**Paper (Piece)**	**Share (%)**	**Paper (Piece)**	**Share (%)**	**Paper (Piece)**	**Share (%)**
Total	51079	100	53246	100	87688	100	100310	100
Enterprises-University	4499	8.8	1123	2.1	1381	1.6	1567	1.6
University-Enterprise	867	1.7	5301	10.0	6448	7.4	7421	7.4

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

4. The enterprise system

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 made enterprises have stronger incentives to invest in product development and innovation on top of exploiting cost advantages or diversification. Table 6 and Tables 7 show that, large and medium-sized enterprises gradually increased their R&D inputs and R&D intensity. Nevertheless the R&D intensity is still quite low, comparing to that of developed countries.

Table 6 **R&D expenditure and technology importation (unit: 100 million RMB)**

	Expenditure on R&D	Expenditure on technology import
1995	141.7	360.9
1998	197.1	214.8
1999	249.9	207.5
2000	353.6	245.4
2001	442.3	285.9
2002	560.2	372.5
2003	720.8	405.4
2004	954.4	367.9
2005	1250.3	296.8

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

Table 7 **Ratio of R&D/sales in large and medium sized companies, %**

Year	1995	2000	2001	2002	2003	2004	2005
R&D/sales	0.46	0.71	0.76	0.83	0.75	0.71	0.76

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. This is why 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 (See Table 8).[2] Furthermore, the patenting activities differ significantly between domestic and foreign firms and the difference is discussed in more detail in Section 5.2.

[2] Patents registered in China are classified into three categories: invention, utility model and design. The invention patents are presumably more R&D intensive than the other two types of patents.

Table 8 **The patents granted in China- by type of patents, unit: piece**

	1995	**2000**	**2005**
Total patents granted	45064	105345	214003
Invention patent	3393	12683	53305
Utility model patent	30471	54743	79349
Design patent	11200	37919	81349

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

Comparing international patents, such as invention patents granted in the U.S., the wide gap between Chinese enterprises with that of Korea and Japan becomes evident. In 2004, Korea's patents in the U.S. are about 11 times that of China (Table 9).

Table 9 **Chinese and Korean patent registrations in the U.S.**

		2000	**2001**	**2002**	**2003**	**2004**
China	**Number of Patent**	119	195	289	297	404
	Rank	26	24	21	22	20
Korea	**Number of Patent**	3331	3546	3755	4198	4590
	Rank	8	8	7	5	4

Youngrak Choi, Rise of New Asian R&D Forces，paper for New Asian Dynamics in Science, Technology, and Innovation, Copenhagen, Denmark, September 27-29, 2006.

The growth of small firms is a relatively new phenomenon. The market was opened for non-state owned small firms only after the 1980s. As most of them started their business by taking market opportunity and in general, their innovation capability is still low. But compared to large- and medium sized enterprises, as shown in Table 10, small S&T-based enterprises, which are defined as firms with S&T and/or R&D activities, have higher R&D intensities, but are less internationally oriented in terms of export of new products and import of foreign technology. 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 (Lundin et al, 2006a)[3].

Table 10 **A simplified comparison between 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	1.19	0.29	0.19	0.51	0.91	1.55	0.32	0.06
Joint venture: HTM	0.97	4.22	0.21	0.37	1.01	23.01	0.40	0.41
Joint venture: Foreign	1.64	4.22	0.64	0.42	1.30	6.44	1.18	0.74
Foreign	1.44	6.61	0.22	0.79	0.99	24.37	0.15	0.25
Private	1.55	3.21	0.13	0.66	0.74	5.90	0.05	0.90

Source: Lundin et .al, 2006a.

[3] 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.

5. The key country-specific characteristics of the innovation system of China

5.1 The Role of the Chinese government

The government plays an important role in the development of the Chinese innovation system, even through the market force has been increasingly strong. For example, the government agencies at the different levels still to various degrees, control land, large investment projects, infrastructure construction, and market accesses to some strategic industrial and service sectors, such as automobile industry and financial services. In terms of innovation, national R&D programs, various long-run and short-run plans are important instruments, through which the government policy influences the S&T development in China.

5.1.1 National R&D programs

China has developed a system of national R&D programs to support innovation activities. Table 11 gives a brief overview of the main programs controlled by Ministry of Science and Technology (MOST).

Table 11 **National R&D Programs of China,（unit: billion RMB）**

	1996	1997	1998	1999	2000	2001	2002	2003	2004
973 Basic Research	-	-	0.3	0.4	0.5	0.6	0.7	0.8	0.9
863 National High Tech R&D program (from 1986)	0.45	0.51	-	-	-	2.5	3.5	4.5	5.5
Key Technologies R&D program (from 1983)	0.52	0.54	1.04	1.17	1.03	1.06	1.06	1.25	1.61
Torch Program (from 1988, for high technology)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	-
Spark Program (from 1988 for rural SMEs)	0.04	0.04	0.04	0.04	0.04	0.1	0.1	0.1	-
Key S&T Diffusion program	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-

Source: MOST, China Science and Technology Development Report, 2006.

In addition, there are the National Innovation Fund (INNOFUND) for S&T based SMEs (about 0.5 billion RMB a year), and the National Science of Foundation mainly for basic research. The national programs are very important not only for funding. Universities and GRIs give very high priority on governmental projects and many talented scientists are involved in these projects as main researchers. Furthermore, many other regional and industrial funds often follow those national projects, in terms of topics and fields of study.

5.1.2 Policy instruments

The Chinese government has adapted various important policy instruments to encourage innovation activities and to promote transfer and commercialization of R&D results. One of the important policies is to establish high-tech zones and incubator to promote high-tech industries in China. This policy started in the end of 1980s, learning from the Silicon Valley model of the U.S. There are 53 high-tech development zones at the national level. The first high-tech zone, Zhongguancun high-tech zone was established in Beijing in 1988. The core of the high-tech zone policy covers following aspects:

- To establish well-functioning infrastructure so that the high-tech zones serve as a platform for innovation activities and interactions.
- To provide preferential treatments to high-tech firms in forms of a broad range of tax incentives.
- To create a new governance model, which is characterized by "small government, but big service" to reduce transaction costs.
- To establish cluster structure in order to promote active interactions and close co-operation among the firms.

In the past two decades, these high-tech zones have expanded rapidly in terms of their size and scope of activities and therefore played an important role in promoting the development of high-tech industries in China. Up to now, more than 90% of high-tech firms and incubators are located in these high-tech zones and most of them are spin-offs from universities and GRIs, new private and FDI firms. In 2004, the total value-added of these high-tech zones reached 550 billion RMB, accounting for about 8.8% of the GDP, their exports were about 82.4 billion US dollar, making up about 12% of the total exports of Chinese industrial sectors (MOST, 2006).

The first business incubator in China was established in 1987 in Wuhan. By 2005, more than 490 incubators had been created across the country and most of them are located in Beijing, Shanghai and Shenzhen. The ICT and biomedical industries are the two most favored areas, but the number of incubators specialized in ICT industry is much larger than the biomedical industry.

Regarding the ownership of IPR, the following important steps have been taken to facilitate the commercialization of R&D results:

- Firstly, inspired by the Bay-Dole model form the U.S., the first step taken by the Chinese government is to allow IPR resulting from government-funded R&D projects to be commercialized.

- Secondly the ownership of IPR resulting from government-funded R&D projects could be transferred to the university or GRI who conducted the projects, instead of being government-owned intangible assets.

- Thirdly, since 1998 individual inventors involved in government-funded R&D projects are allowed to obtain a royalty of at most 35% of the license fee when the research results are transferred.

5.1.3 Long-term plan: indigenous innovation

The "National Plan 2006-2020 for the Development of Science and Technology in the medium and long term" is the current long-term S&T policy framework of China. The most interesting element of the new plan is the declared intention to strengthen "independent" or "indigenous" innovation.

Why indigenous? There are, at least three different factors behind this concept. Firstly, the economic growth of China has been strongly dependent on foreign technology and foreign invested firms. 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 factor that "market for technology" policy has not resulted in the immediate and automatic knowledge and technology spillovers from foreign to Chinese enterprises that policymakers had hoped for. Secondly, a culture of imitation and copying is common not only in product development and design, but also in the field of scientific research. Hence innovations from domestic knowledge bases and intellectual property rights are acutely needed in China. Thirdly, the high growth rate of the Chinese economy during the last twenty years will not be sustainable without a change in the 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.

There are three main policies selected to pursue the indigenous 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 as in the past two decades, the increase of R&D to GDP ratio implies a huge increase of R&D expenditure in absolute terms. Already today, China has the second-largest expenditure on R&D in terms of purchasing power parity, trailing only the US, but has surpassed Japan (OECD, 2006). Secondly, various fiscal policy instruments to enhance innovation capability are assumed as the most important ones. The new tax policy will make R&D expenditure 150 % tax deductible, thus effectively constituting a net subsidy, as well as accelerated depreciation for R&D equipment worth up to 300 000 RMB (Source ???). Also, the public procurement of technology will be adopted to promote indigenous innovation activities. The purpose of current public procurement practice is to cut costs rather than promote indigenous innovation. The new public procurement policy aims to give priority for indigenous innovative products in public procurement in terms of price and volume in various forms.

5.2 Foreign Direct Investment (FDI), high-tech industries and R&D

Since the open-door policy was implemented in China twenty years ago, FDI firms have become increasingly important in production as well as in R&D in China.

During the period of 1998-2004, the number of large- and medium-sized FDI firms has been steadily increasing. While the shares of value-added and exports of FDI firms in the Chinese industrial sector have reached a relatively high level (40% and 76%, respectively in 2004), the shares of R&D expenditure and employment are still relative low (29% and 34% respectively in 2004). It implies that, FDI firms' production in the Chinese industrial sector has been more capital-intensive, but not really R&D-intensive manufacturing (See Table 12).

Table 12 **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 LMEs	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.

Beyond the manufacturing and with the focus on the high-tech industries, the internationalisation in the high-tech industries is of significant importance, but it also has some controversial characteristics. On the one hand, the increased trade volume shows the international competitiveness of the high-tech industries of China. But on the other hand, the dominance of FDI firms and the large share of processing of imported materials as well as the reliance on foreign technology raise the questions: Are China's high-tech industries really high-tech? And are the high-tech industries in China really Chinese? Nevertheless, there are also substantial cross-industrial variations in the high-tech industries. As a well-known fact, the ICT sectors are the most internationalized high-tech industries, in which value-added, technology imports and exports are dominated by FDI firms. Regarding R&D expenditure, the share of FDI firms in the computer and office equipment industry has the most remarkable increase and 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 13).

Table 13 **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 LMEs	R&D expenditure	Tech Import	Export	Employment
1998						
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 &	28	20	11	41	40	14

instrument						
			2004			
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.

In addition to the relative importance of FDI firms at the industry level, another important, but also somehow controversial question is, if FDI firms are more R&D-intensive than domestic firms in China. While the R&D intensities across different ownerships all have increased during the period 1998-2004, so far domestic firms, both stated-owned and private have higher R&D intensity than FDI firms. The implications of these observations are the follows:

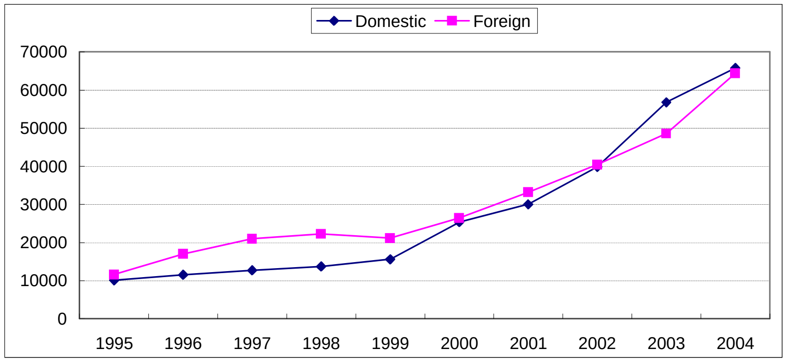
- Domestic firms in China are strengthening their innovation capacity through increased R&D investments. This is achieved not only by the increased R&D investments in the SOEs, but also is driven by an increased number of entrepreneurial and S&T-based private firms.

- The lower R&D intensities in FDI firms may be explained by two types of FDI activities in China. For the first, some of FDI firms' activities are still capital- or labour intensive manufacturing in the high-tech industries. For the second, while some foreign firms are increasing their R&D effort in China, the R&D activities are still home-based in the OECD countries.

- Even though the R&D intensities in the high-tech industries have increased over time, they are still at a much lower level compared to the high-tech industries in the OECD countries. From a long-term perspective, the R&D intensities need to, and will be further boosted, driven by continued indigenous R&D efforts and intensified competition between domestic and FDI firms when the technology gaps between them are being narrowed. Furthermore, the narrowed technology gap can also facilitate strategic alliances among firms with various ownerships and thereby boost R&D investments in both domestic and FDI firms.

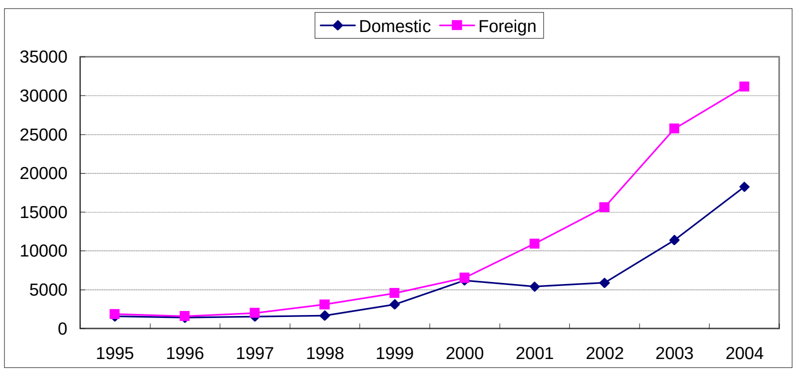
In terms of innovation output, one of the largest differences between domestic and foreign applications is the structure of the application. For domestic firms, the majority of their patent applications are utilization model or design, although the number of invention applications has been increasing as well. For foreign applications, the invention application is the main category. The number of invention applications by domestic firms exceeded for the first time their foreign counterparts in 2003 (See Figure 1). However, the foreign firms still outperformed their Chinese counterparts significantly in terms of the numbers of granted invention patents in the past years (See Figure 2).

Figure 1 **Domestic and foreign applications for invention patents**



Source: China Statistical Yearbook on Science and Technology, 2005.

Figure 2 **Domestic and foreign invention patents granted**



Source: China Statistical Yearbook on Science and Technology, 2005.

Among foreign patent applicants, the multinational enterprises from Japan and the U.S. are the most active applicants, while German, Korean and French companies are also applying for a large number of patents in China (Table 14). The distribution by field of technology reflects to a large extent the competitive strengths of these multinationals in the Chinese market.

Table 14 **Top ten foreign enterprises in applications for invention patents in China (2003)**

Ranking	Country	Enterprise	Number of applications
1	Japan	Matsushita Electric Industrial Co., Ltd.	1817
2	South Korea	Samsung Electronics Co., Ltd.	1560
3	Japan	Canon Co., Ltd.	820
4	Japan	Seiko Epson Corp.	781

5	South Korea	LG Electronics Corp.	624
6	Japan	Toshiba, Inc.	583
7	United States	IBM Corporation	581
8	Japan	Sony Corp.	560
9	Japan	Mitsubishi Electric Co., Ltd.	556
10	Japan	Sanyo Electrical Motors Co., Ltd.	541

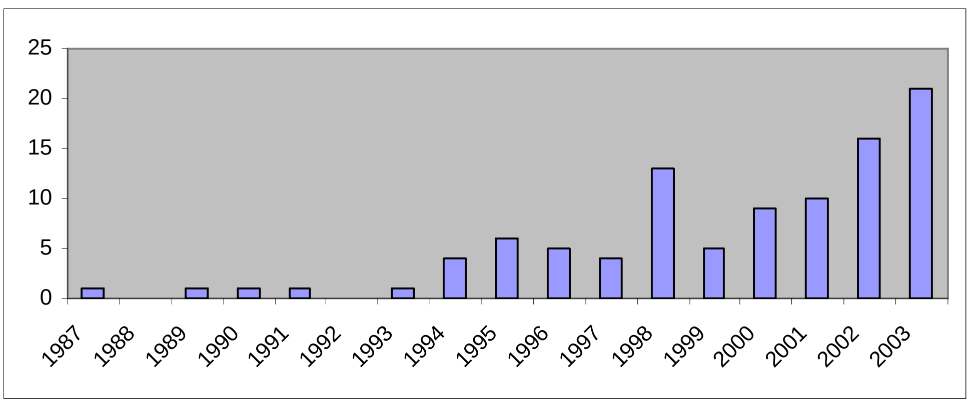
Source: China Science and Technology Indicators 2004.

5.3 Globalization of R&D and China

In the recent years, the number of R&D centres of multinational enterprises in large cities, such as Beijing and Shanghai has increased rapidly. The purposes of these establishments are mainly twofold: to take advantage of abundant and relatively cheap R&D human resources in China and to locate R&D units near to their (exiting) manufacturing units in the Chinese market.

According to von Zedtwitz (2006), there were 199 foreign R&D facilities in China in the beginning of 2004. The number has increased rapidly since then and possibly amounted to 250-300 currently.

Figure 4 **Number of new establishments of foreign R&D labs in China, (1987-2003)**



Source: von Zedtwitz (2006)

The globalization of innovation in China can also be observed from the co-operation between foreign enterprises and Chinese universities and research institutes (See Table 17). This new type of co-operation is in an initial and immature stage and it is still very difficult for foreign enterprise to find original ideas and sufficiently innovative projects through this kind of co-operation. At the current stage, foreign enterprises do not buy ready-made projects or research, rather they utilize the existing R&D research capacity and facilities (which were often purchased by the support of governmental funding and of very high standard) to carry out research projects, which are defined by the foreign enterprises themselves and modified during the working process to adapt to the local conditions.

Nevertheless, the mutual benefits generated through such co-operative efforts should not be underestimated. It will not only provide local universities and research institutes with additional funding and more advanced equipment, more importantly, it will also generate positive demonstration- and spill-over effects to the universities and allow them to get more informed about the international research frontier. Finally, it can be an efficient way for foreign firms to identify research units and personnel with high research capacity.

Table 17 **Select list of research co-operations between domestic research institutes and multinationals in the biomedical industry**

Foreign partner	Chinese partner	Details
GlaxoSmithKline	Shanghai institutes of Materia Medica (SIMM).	Chemical compound database.
Roche	Chinese National Human Genome Centre.	Diabetes and schizophrenia.
Novartis	Shanghai institutes of Materia Medica(SIMM).	Herbal compounds, Chinese traditional medicine.
AstraZeneca	Shanghai JiaoTong University.	Gene linked to schizophrenia.
DSM	Joined lab with Fudan university in Shanghai. JV with Chinese vitamin makers.	Nutritional products activities.
Novo Nordisk	Collaboration with Tsinghua university in Beijing.	Diabetes

Source: Liu & Lundin (2006a).

In recent years, a few Chinese enterprises, in particular in the electronics and ICT sectors have indeed initiated there international R&D activities, by either acquisition of foreign enterprise/units or through setting up R&D organisations in OECD countries. The high profile Merger and Acquisition (M&A) deals involving Chinese enterprises in the high-tech sectors have caused huge attention worldwide. In these M&A deals, the access to R&D centres of western sellers is one of the key elements. For example, in the TCL- and Thomson deal, it included Thomson's R&D centres in Germany, Singapore and the U.S. Similarly, in the Lenovo-IBM deal, Lenovo took over IBM's R&D centres in Japan and the U.S. (See Table 18).

Table 18 **Selected M&A deals by Chinese firms (2001-2005)**

Chinese bidder	Target foreign firm / Unit	Industry
Holly group	Philips Semiconductors, CDM hand-set reference design (US), 2001	Telecommunication
TCL International	Schneider Electronics AG (Germany), 2002	Electronics
TCL international	Thomson SA, Television manufacturing unit (France), 2003	Electronics
BOE Technology Group	Hyundai display technology,(South Korea), 2003	Electronics
Shanghai Auto Industry Corporation (SAIC)	Ssangyong Motor (South Korea), 2004	Automotive
Lenovo group	IBM, PC Division (US), 2004	IT
Nanjing Automotive	MG Rover Group (UK), 2005	Automotive

Source: Wu (2005), The Boston Consulting Group (2005) and various press reports.

In addition to the acquisition of R&D centres, some Chinese firms have made green field investments in the form of R&D units in foreign countries. China has a total of 37 R&D operations abroad, which are concentrated in the ICT sectors and 24 of them are in developed OECD countries (FIAS, 2005)(See Table 19).

Table 19 **Selected Design, R&D labs of Chinese firms overseas**

Chinese firms	Location	Industry
Huawei	R&D centres in Sweden (Stockholm), the U.S. (Dallas, Silicon Valley), India (Bangalore) and Russia (Moscow).	Telecom
ZTE	R&D centres in Sweden, (Stockholm), India (Bangalore).	Telecom
Glanz Group	R&D centre in the U.S. (Silicon Valley)	Electronics
Konka	R&D centre in the U.S. (Silicon Valley)	Electronics
Haier	R&D centre in Germany, the U.S. and India, design centre in the U.S. (Boston).	IT and electronics
Kelon	Design centre in Japan.	Electronics
Foton Motor	R&D centre in Japan, Germany and Taiwan	Automotive

Source: various press reports.

In a recent report from Boston Consulting Group (BCG, 2006), among the top 100 emerging global companies from developing economies, 44 are Chinese firms and 18 of which are in the ICT sector and a few from the automobile industry (See Table 20). Even though the number of such Chinese firms is very few and the scale of their international R&D activities is still small, a new generation of Chinese firms seem to emerge as important players in S&T-intensive (instead of labour-intensive) segments of the global market. The innovation capacities of these Chinese firms and their ability to tap into the global network have therefore generated large interests, from both research- and policy-making perspectives. In other words, will these emerging Chinese multinationals become global players in the near future?

Table 20 **Selected list of Chinese firms with globalization potential**

Stated-owned enterprise		Privately-owned enterprise	
Company	**Industry**	**Company**	**Industry**
Haier	White goods	Midea Group	White goods
SAIC	Automobile	Huawei	Telecom equipment
BOE	Electronics	Wanxiang	Auto parts
Lenovo	Computer	SVT Group	Electronics
TCL	Electronics	CHINT Group	Electronics
ZTE	Telecom equipment	Galanz	White goods
Chery	Automobile	People Electric	Electronics
		Aux Group	White goods
		Lifan	Motorcycle
		Geely	Automobile

Source: IBM Global Business Service, 2006. The assessment of the globalisation potential is based on multiple criteria such as key firm characteristics related to size, export and innovation capacity and industrial characteristics such R&D intensity - and competition.

5.4 Regional disparity in innovation capacity

China, as a large country has different regions with different cultures, geography and resources. This diversity is also very important for innovation. Historically, the northeast part used to be the core industrial base of China with heavy industries and important technologies imported from the former Soviet Union.

In the western region, there were some isolated industrial bases following the three-frontier construction in the 1960s and 1970s, i.e. the mass transfer of defense industry from the coast to the west region. This made Xian, Guizhou and other western cities centers of heavy industries. Currently, Chongqing, Xian and Chengdu are the three examples of innovative cities in the western region.

The coast region used to be, and is still the most developed region in China. Even though the government in the planned economy era invested very little in provinces in the coast regions, such as Fujian, Zhejiang and Guandong provinces and there were few large SOEs there, these provinces used to be commercial centers and they adapted to the market economy much faster than other regions. Private SMEs with great entrepreneurship flourished and Guangdong, Zhejiang, Jiansu and Fujian have become the most prosperous regions of the new Chinese economy.

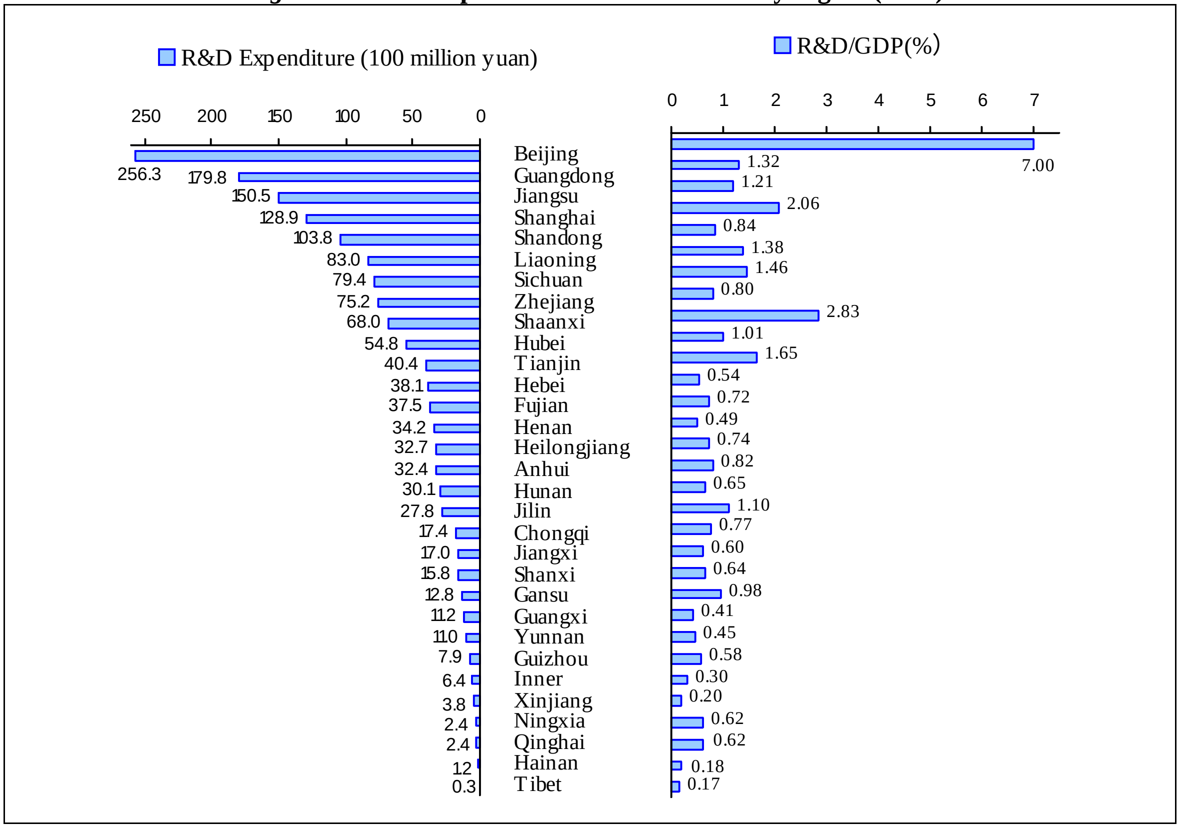
The diversity of innovation capacity across China has also owned to the decentralization of decision-making over both resource allocation and operational decisions from 1980s. One result, but also a serious challenge in R&D activities after decentralization is the large regional disparity. The gap among east, middle and western regions in terms of R&D can be seen in Table 15. Encouraged by an unbalanced growth approach and uneven FDI inflows, the Eastern region has become the hubs for R&D activity in China (See Figure 3). According to the Scoreboard of Regional Innovation Capacity (Liu et. al. 2006) and based on indicators of knowledge creation, diffusion, company innovation, infrastructure and performance, Shanghai, Beijing, Guandong, Jiangsu, Zhejinag and Shandong are the top 6 most innovative regions in China and they all come from east and coast regions. In addition to innovation, there are large regional disparities in a broad range of aspects, e.g. human resource, high-tech industries and openness of the regional economies in general (Liu & Lundin, 2006). Being aware of the divergence among regions and the risk that the gap will further increase, the central government launched the “go west” strategy in 2000, aiming at energizing the less developed regions through various combined efforts in forms of fiscal, regional, FDI- and S&T policies.

Table 15 **Regional gap of R&D inputs (2003)**

	East	**Middle**	**West**
Share of national GDP	58.9%	24.6%	16.5%
Share of national R&D	71%	17%	13%

Source: China Science and Technology Statistical Yearbook, 2005.

Figure 3 **R&D expenditure and R&D/GDP by region (2003)**



Source: Science and Technology Indicators, 2004

6. Conclusion

Similar to the Chinese economy, in which both the plan- and market mechanisms coexist, the Chinese innovation system has undergone great changes in the last twenty years and has become a very dynamic one with great potentials. It is still in a process of transformation from a GRI-dominated to a more enterprise-centered innovation system. Hence GRIs and universities are still very important in R&D activities as well as in terms of R&D human resources. In the industrial sector, SOEs have undergone reforms of governance; many large non-state-owned enterprises have been emerged, such as Huawei, Lenovo and Haier. SMEs have also become more important players in the Chinese economy as well in innovation, driven by competition and entrepreneurships. The increasingly open innovation system, spurred by FDI in both high-tech manufacturing and R&D has created significant incentives for structural changes and provided mutual learning opportunities among domestic and foreign enterprises. However, the emerging innovation-oriented enterprise system is still weak in terms of innovation capacity and their innovation activities are mostly focused on incremental innovations. The government has also strong influence on the emerging new innovation system through various policy, strategy and investments. However, in this transition process, the specific Chinese characteristics, such as innovation gap across ownerships and regional disparities are serious challenges for the future development. In sum, there are two major forces that will jointly shape the future development of the Chinese innovation system: the first one is national strategy of indigenous innovation, which focuses on how to promote domestic innovation capability building by favorable policy for domestic innovators. The second is an open innovation approach, which is based on knowledge creation and technology acquisition through global linkages and partnership.

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