The evolution of high-technology in China after 1978: Towards technological entrepreneurship

M.J. Greeven

ERIM REPORT SERIES *RESEARCH IN MANAGEMENT*	
ERIM Report Series reference number	ERS-2004-092-ORG
Publication	October 2004
Number of pages	34
Email address corresponding author	mgreeven@fbk.eur.nl
Address	Erasmus Research Institute of Management (ERIM) Rotterdam School of Management / Rotterdam School of Economics Erasmus Universiteit Rotterdam P.O.Box 1738 3000 DR Rotterdam, The Netherlands Phone: +31 10 408 1182 Fax: +31 10 408 9640 Email: info@erim.eur.nl Internet: www.erim.eur.nl

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BIBLIOGRAPHIC DATA AND CLASSIFICATIONS		
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Library of Congress Classification (LCC) LCC Webpage	Mission: HF 5001-6182	
	Programme: HB 615-715	
	Paper:	HD 72 Economic development
Journal of Economic Literature (JEL) JEL Webpage	Mission: M	
	Programme : M 13, O 32	
	Paper:	L 2 Firm Objectives, organization and behavior L52: Industrial policy; sectoral planning methods M13: Entrepreneurship O32: Management of technological innovation and R&D O53: Economic country studies, Asia P31: Socialist enterprises and their transitions
Gemeenschappelijke Onderwerpsontsluiting (GOO)		
Classification GOO	Mission: 85.00	
	Programme: 83.82, 83.62, 85.00,	
	Paper:	83.30 Economische structuur, ontwikkeling
Keywords GOO	Mission: Bedrijfskunde / Bedrijfseconomie	
	Programme: Ondernemerschap, Innovatie	
	Paper: China, technologische ontwikkeling, ICT, netwerken, ondernemerschap	
Free keywords	Technological and institutional change, networks, evolution, high-technology, entrepreneurship, China	

The evolution of high-technology in China after 1978: Towards technological entrepreneurship

M.J. Greeven
Faculty of Business Administration
Erasmus Unversiteit Rotterdam

October, 11, 2004

To be presented at EURAM, May 4 – 7, 2005, Münich

Abstract

The purpose of this paper is to describe the development of China's science and technology, their related institutions and use in the business world since the reforms started in 1978. Special attention will be given to the re-integration of high-technology into the private sector and the accompanying new type of organization: the New Technology Enterprises (NTEs) – or *technological entrepreneurs* – in the Development Zones. In an historical analysis we identify several phases of institutional reforms and international technology transfer. The present state of Science & Technology is analysed in terms of information infrastructure, educational system and innovative capability. The analysis shows the still underdeveloped parts of a science and technology supporting environment. The analysis discusses the basic features of the high-technology industry and identifies the information and communication technology (ICT) sector as the most important sector of the industry. This sector is growing fast none the least due to the attention the reform policy has paid to its development since 1978. Specifically the role of NTEs – who are pre-dominantly ICT oriented – in Development Zones is interesting and important. We argue that the NTEs play a large role in the development of private high-technology. We propose a system for technological entrepreneurship and identify computer hardware and software as key sectors for NTEs and high-technology development.

Key words: technological and institutional change, networks, evolution, high-technology, entrepreneurship, China.

JEL: M10: business administration, general
M13: entrepreneurship
O53: economic country studies, Asia
O32: management of technological innovation and R&D
P31: socialist enterprises and their transitions
L2: firm objectives, organization, and behavior
D85: information and uncertainty, network formation
L63: microelectronics; computers; communications equipment
L52: industrial policy; sectoral planning methods

1. Introduction: heading for technological entrepreneurship

China started implementing policies of economic reform and opening-up in 1978. The government and Deng Xiaoping in particular became aware that a more efficient and productive economy was needed and that the role of the government needed to be lessened. The reforms play a large role in the development and advancement of the Chinese economy.

The capacity of a country to develop its technology is an important condition for economic development (Tidrick, 1986; Piek, 1998). Therefore, the reform of the Chinese economy has been accompanied by a major effort to raise the level of science & technology (Xiaojuan, 1997). It was insufficient to compete with world-class technology (Garrett-Jones, Xielin, 1997; Piek, 1998; Xiaojuan, 1997) and science & technology activities (e.g. R&D) were carried out in state R&D institutes and missed every link to the economy. The institutional environment did not support technological development in other than state-run institutes and foreign investment was not allowed. R&D activities were not commercialised. Furthermore, the educational system was irrational and resources were wasted. The number of highly-skilled workers was low and the average level of science and technology was far behind other countries. In an era of high-technology development, such as the minicomputer, personal computer, semiconductors, biotechnology and telecommunications, China needed to catch up. Market-based incentive mechanisms needed to be enhanced and institutional conditions improved, while reducing government interventions in order to foster self-sustainable development of the high-tech, knowledge-based industry (OECD, 1999; Baygan and Freudenberg, 2000). So, technological change and institutional change go hand-in-hand.

The purpose of this paper is to show the development of technology, related institutions and business since the reforms started in 1978. We are specifically interested in the emergence of high-technology development in the private sector and a new type of organization: the New Technology Enterprises (NTEs) – or *technological entrepreneurs* – in the Development Zones.

Since the reforms, programs and legal changes are crucial in understanding the development of science and technology in China, we will discuss this in the next part. We will show the search for the right way of upgrading and improving the technology and commercialising it through a high-tech industry. Phases will be identified and characterised according to the reforms and technology development. In the last phase of development, we will show the role of technological entrepreneurs – NTEs – and the importance of foreign investment.

Part Three will discuss the role of international technology transfer in the development of technology in greater detail. These two parts together give a historical and evolutionary overview of the development of the science and technology system and the connection between technology, institutions, and business.

The Fourth Part will show the current status of the science and technology system in more detail. Information infrastructure, educational system and innovative capability form the supporting environment for the high-technology industry (OECD, 2000) and ultimately the basis for private R&D and technological entrepreneurship.

The Fifth Part then discusses the main features of the high-tech industry. We identify the information and communication technology (ICT) sector as the most important sector of the industry. This sector is interesting because it is growing fast and got a lot of attention in the reforms and programs since 1978. Specifically the role of NTEs – who are predominantly ICT oriented – in Development Zones is interesting and important. A short introduction to the main parts of the ICT sector is then provided: telecommunications, computer hardware and software.

We will argue that the role of NTEs is important in the development of private high-technology (R&D). They operate in a network of R&D institutes, higher education institutes and CAS research institutes and get incentives from state plans and market demand. The current supporting (institutional) environment is a result of the evolution of technology and business policy and international technology transfer. In the conclusion we propose a system for technological entrepreneurship and identify computer hardware and software as key sectors for NTEs and high-technology development.

2. Evolution of technology and business in China: institutional change

The evolution of technology in China is strongly linked to the development of the reforms and programs that the central government initiated. We will argue that there are four phases of development to be distinguished after 1978. However, we start with a short historical note of the period before 1978 to understand the Chinese insatiable drive to reform.
After Mao took power in 1949, all economic activities were guided by a state plan. All research, development and engineering was controlled and coordinated by the State Development Planning Commission and the State Science and Technology Commission. The Cultural Revolution started in 1967 after Mao's disappointment of the intelligentsia in China. The consequence was a halt to science and technology development for 10 years. Mao died and Deng Xiaoping imposed a new regime by means of the promulgation of Zhou's Four Modernizations. The reforms started in 1978. **Table 2.1** gives a detailed overview of all relevant reforms, programs, and events and we will discuss the phases in the evolution of technology in China.

Table 2.1: The evolution of technology and business in China

Year	Initiative	Activities	Initiators (funds)
1949 – 1977	Planned economy	All research, development and engineering	Control and coordination by State Development Planning Commission and the State Science and Technology Commission (SSTC)
1967 – 1976	Cultural Revolution	All science & technology came to a halt, except for military	Central government
1978		*Initiation process of economic reform (agricultural sector first)*	
1978	"1978 – 1985 National Science and Technology Programme"	<u>Program for long-term development:</u> 8 S&T priority areas; rehabilitation and improvement of R&D institutions; elaboration of planning practice	National government
1980		*First education law: Regulation on Academic Degrees in the People's Republic of China*	*National People's Congres (NPC)*
1982	Key technologies R&D Program	Three main areas of focus: agriculture, high-tech development, and social development	MOST (Government budget)
1982	Tackle Plan	Solving technical problems raised by enterprises using resources at research institutions and universities	
1984	State plans for key laboratories & industrial experiments	Basic scientific research and technical development	
1984		*Reform of the industrial sectors*	
1985	'Decision on Reform of the Science and Technology Management System'	Creating a technology market with supporting institutions	State Council
1986 (adopted in 1984)	"1986 – 2000 Programme for Scientific and Technical Development"	<u>Program for long-term development</u>	National government
1986		*Compulsory Education Law*	*NPC*
1986	**"863" Plan**	7 key high-tech areas: biotech, IT, automation, energy, new material, 2 military areas	MOST (Government budget)
1986	Spark Plan	Agricultural technology	(Government funded, bank loans and self-raised funds)
1987	'Stipulations of the State Council for Furthering the Reform of the S&T Management System'	Urging industrial R&D institutes to enter into enterprises	State Council
1987		*Technology Contract Law*	*National People's Congress*
1988	**Torch Plan**	Creating a supportive environment for development of new technology enterprises; Establishment of national high tech industrial development zones; incubators of innovation	State Council, Ministry of Science and Technology (MOST) (Bank loans and self-raised funds)
1988	Zhongguancun	First high tech zone	Beijing, MOST

1990	Dissemination Plan	Commercialization of R&D results	SSTC (government budget, bank loan, self-raised funds)
1992	Climb Plan	Basic research	(Government budget)
1992		*Deng's Southern Tour: Large inflow of foreign investment*	
1993	'Decision on Several Problems Facing the Enthusiastic Promotion of Non-Governmental Technology Enterprises'	Encouraging policymakers to form a new generation of technology firms: entrepreneurial **spin-offs** from universities or government research institutes	Chinese government
1993	Golden Projects: Golden Card, Golden Bridge, Golden Custom	Adoption of IT in key sectors: IT banking, national telecom backbone, computer networking for foreign trade	State Informatisation Expert Group
1994		*Company Law*	
1995		*Education Law (commitment to a universal education as well as to one that will produce both scientists/academics and skilled laborers)*	*NPC*
1995	'Decision on Accelerating Scientific and Technological Progress'	Promoting and developing high-technology; training workers, further opening-up.	State Council
1997	"973" Program	Continuation of the Climb Plan; promoting S&T development in relatively mature research environments	MOST (Government budget)
1997	National Center for Science and Technology Evaluation (NCSTE)	Established to provide an objective peer review of government-funded S&T research	MOST
1998		Ministry of Post and Telecommunications merges with the Ministry of Electronics and Information in to the Ministry of Information Industry	
1998	Venture capital	First venture capital funds set up by local governments.	A result of the 1998 establishment of the National Foundation for Technological Innovation in technology-based SMEs by the State Council.
1999		*Constitutional change to establish status of private and non state sector enterprises*	*NPC (the ideological shift was made at the 15th Party Congress in 1997 where the legitimacy and contribution of private enterprises was acknowledged)*
2001		*China enters WTO*	
2001	10th Five-Year Plan (2001 – 2005)	Software, computer manufacturing, telecommunications, lasers and aerospace identified as pillar industries	

Based on: Dahlman & Aubert (2001), Saxenian (2003), Yuan & Gao (1992), Gu (1995), U.S. Embassy (2002), Hendrischke (2003), Feinstein & Howe (1997)

1978- 1984: Restoration

The first period is a period of restoration. The process of economic reform in the agricultural sector was initiated to restore the Science & Technology system (S&T) to pre-Cultural Revolution state. The believe was that the success of the new economic development plans could be built upon pre-Cultural Revolution (Soviet) model. The "1978 – 1985 National Science and Technology Programme" was announced in 1978 to rehabilitate R&D institutions[1]. The program focused on long-term development and set eight S&T priority areas[2].

In the early 1980s, however, the government recognized the difficulties of the fulfillment of economic objectives. The focus soon became the elaboration of planning practices, the development of a Key Technologies R&D Programme by the Ministry of Science and Technology (MOST), and state plans for key laboratories and industrial experiments. The Key Technologies Programme was enacted in 1982 and put emphasis on the development of agriculture, new/high technology and social well-being. The Tackle Plan was also initiated in 1982, to solve technical problems raised by enterprises using resources at research institutions and universities.

Besides initiatives for restoring the technology system, there were also reforms in education. In 1980 the First Education Law was enacted to regulate academic degrees. The emphasis shifted from quantity to quality by introducing academic standards. Slowly the need for universal education became clear. The government recognized the need to reform this system to be able to fulfill their economic plans.

While the reforms in the industrial sector started in the mid-1980s, the government also started to recognize the deficiencies in the current system. The central concern was the lack of linkages between the S&T system and the economy.

1985 – 1986: Technology market

On March 1985 the "Decision on Reform of the Science and Technology Management System" was taken by the State Council. Recognizing the linkage problem, the program tried to forge horizontal links between research labs and enterprises to facilitate the flow of technologies from the state S&T system into industry (Lu, 2000). This was a turning point in the history of technology in China, because from now on the reform of the system itself was the focus. The goal of the 1985 "Decision" was to forge a technology market with supporting institutions. China tried to integrate the research system with the economic system in the 1980s to overcome the problem of the separate cultures of production and research. (Turpin, Xielin, Garrett-Jones, Burns, 2002).

In 1986 the "1986 – 2000 Programme for Scientific and Technical Development was impolemented. The program consisted of plans for basic and applied research, technical development and commercialization of the results, technological popularization and absorption of foreign technology (Feinstein & Howe, 1997). Furthermore, in 1986 the "863 Plan" was implemented by the MOST, which identified

[1] Most S&T activities are R&D activities which are carried out in R&D institutes

[2] Agriculture, energy resources, materials, computing, lasers, space science and technology, high-energy physics and genetic engineering.

seven key high-tech areas: biotechnology, IT, automation, energy, new materials and two other military areas. Since then the development of research on high technologies has entered a new stage in China. Besides catching up technologically, the strategic goals were: training scientists and engineers, promoting S&T in related areas, advancing a technical basis for economic and social development, and transforming results into productive force. The promotion of S&T in related areas is also supported by for instance the Spark Plan (1986) to upgrade agricultural technology. Furthermore, the Compulsory Education Law (1986) improved the quality of education since every child was required to fulfill nine years of education (six years primary, three years junior secondary, and three years senior secondary).

However, commercialization is a complicated process, and not easily reached by just creating technological markets. At the end of 1980s it became clear the technological market was insufficient and needed further reform. Gu (1995) identified several factors influencing the failing of the technology market: uncertainties of technological innovation, inexperience of users, and underdeveloped market institutions.

1987 – 1992: Institutions and industry: merging initiatives and spin-offs

The second turning point in the history of technology are the "Stipulations of the State Council for Furthering the Reform of the S&T Management System" in 1987. The State Council urged industrial R&D institutes to enter into enterprises, because the reforms of the 1980s failed to develop a consistent technology policy. Policy continued to focus on public research institutes in stead of the industry and the resources predominantly went to state-owned institutes rather than the potentially more innovative non-governmental enterprises (Saxenian, 2003). For instance, even though the 863 Programme rewarded China with world-level high-tech achievements, the program did not bring many new products to market(Saxenian, 2003). The links between commercial enterprises and research were still hard to find. Furthermore, since the educational system was not really advanced and developed yet, there was a problem of getting enough highly educated personnel. Many of the scarce highly-skilled students who had gone abroad since the reforms did not return (China statistical Yearbook, 2002).

The 1987 Stipulations encouraged R&D institutes to enter into enterprises by protecting the preferential position they enjoyed and provide incentives to merge (Gu, 1995). A major step to promote this process was the enactment of the Technology Contract Law (1987). This Law states that it is formulated – among other things – to "(…) protect the legitimate rights and interests of the parties to technology contracts(…)"

The merging of R&D institutions into enterprises proved to be harder than expected because it was difficult for the inexperienced enterprises to incorporate a R&D institute. In 1988 the MOST and State Council initiated the Torch Plan. This plan was introduced to further promote the linkage between science & technology research and commercialization. The main purpose was to create a supportive (institutional) environment for the development of *new technology enterprises*. There are two important aspects of this program.

First, the Programme supported the integration of R&D assets with commercial production within newly-created enterprises. These new technology enterprises – or NTEs – were basically spin-offs of R&D institutes (of e.g. universities)[3]. The Programme provided support in several ways: incentives, preferential stipulations and basic intellectual property rights (Gu, 1995), which lead to a special legal status of the NTEs. Second, the supportive (institutional) environment was created by the designation of Development Zones for New Technology Industries. The support was mainly financial and NTEs could tap into networks of finance: R&D institutions (for some venture capital), banks (for expansion funds), and Zones (for investment in infrastructure). However, it must be noted that venture capital was relatively underdeveloped, which is often seen as one of the major drawbacks in the development. 'Real' venture capital investment started with the local government initiatives in 1998.

Gu (1995) finds that the main initiators of NTEs were the institutes of the Chinese Academy of Sciences, R&D institutes belonging to central ministries, R&D institutes belonging to local governments and R&D institutes of higher education. The majority of NTEs were engaged in information technology related activities (Gu, 1995). The first high-tech zone was created in the Zhongguancun area in Beijing. In 2004, this area is dubbed "China's Silicon Valley" and is a world-class research and development center. It has more than 500 R&D centers, over 40 of which were set up by multinational corporations. There are over 4000 enterprises employing more than 200.000 persons and focusing on information and biotechnology. Many more Zones were set up: Shanghai, with 400 enterprises, 100.000 employees and Shenzheng, with 100 enterprises and 40.000 employees are among the largest.

In the early 1990s, the government introduced two other plans: Dissemination Plan (1990) and Climb Plan (1992). The first was to further improve and promote the commercialization of R&D results and the second was to promote basic research activities. However, the Torch plan can be seen as the major breakthrough of technology in China. It is for the first time that science & technology and commercial initiatives are successfully linked. The continued effort of the government in terms of supporting plans and projects is the basis for the success of their initiatives. However, even though succesful, it was insufficient to catch up technologically, as the government became aware.

1992 – onwards: Opening-up and technological entrepreneurship

A policy shift regarding foreign investment and increased encouragement and promotion of technological entrepreneurship are the characteristics of this phase. A major turning-point in the history of technology in China is marked by Deng Xiaoping's Southern Tour in 1992. Deng promoted liberalization, reform and foreign investment in the Southern provinces. Chinese government policy toward foreign investment shifted dramatically, offering for the first time significant domestic market access to firms that

[3] Although the Torch Programme was the formal support for spin-off enterprises, the emergence of them was already authorized by the 1985 Decision.

brought in advanced technology. One of the major reasons was the growing awareness that only indigenous, domestic technology development is not enough to catch up with the rest of the world (Naughton, 1999). The government provided more and more market access to foreign investors, among which were many multinational corporations. This policy shift led to a massive flow of foreign direct investment into China. Part 3 deals with international technology transfers and foreign direct investment in greater detail.

The government encouraged and promoted technological entrepreneurship with several decision and programs. The "Decision on Several Problems Facing the Enthusiastic Promotion of Non-Governmental Technology Enterprises" in 1993 encouraged policymakers to form entrepreneurial spin-offs from universities or government research institutes. This decision recognized that non-state enterprises could play a role building a new, more market-oriented economy. The 1993 Decision was followed by the 1995 "Decision on Accelerating Scientific and Technological Progress" to promote and develop high-technology, train workers and further open-up. The Golden Projects in 1993 encouraged the adoption of IT in key sectors such as IT banking, national telecom backbone development, and computer networking for foreign trade. The Projects have played a major role in developing information networks and infrastructure. The "973 Program" (1997) was a continuation of the Climb Program to promote S&T development in relatively mature research environments. The further development and dissemination of technology was supported by the establishment of the National Center for Science and Technology Evaluation (1997), which provided objective peer review of government funded S&T research and the creation of the Ministry of Information Industry (1998). The MII is now a super-agency overseeing telecommunications, multimedia, broadcasting, satellites, and the Internet.

The enactment of the Company Law (1994), the Education Law (1995) and the important constitutional change in 1999 to establish the status of private and non state sector enterprises were crucial legal reforms. They show the commitment of the government to universal education and the ideological shift of the government in which the legitimacy and contribution of private enterprises was acknowledged. Finally, in 2001 China enters the WTO and the 10th Five-Year Plan (2001-2005) emphasizes the economic importance of the information and communication technology industry. The high-tech industry is now fully acknowledged and supported by the government.

From restoration to technological entrepreneurship

The evolution of technology and business in China is a process of learning. The development is guided by the policy decisions that set the institutional environment. The various stages in history show the evolution of and interaction between technological development and institutional development. The policies of <u>the first phase</u> (1978 – 1984) aim at restoring the technological system to pre-Cultural Revolution level. However, in the early 1980s it became clear that there were too many deficiencies in the system and that structural reform was needed. <u>The second phase</u> (1985 – 1986) is characterized by reforms to forge horizontal links between research labs and enterprises to facilitate the flow of technologies from the state S&T system into industry. The main goal of the 1985 Decision was to create a technology market with supporting institutions. The 863 Program was one of the most influential programs and determined focus for the following years. At the end of 1980s it became clear that the technological market was insufficient and needed further reform. The third phase (1987 – 1992) is characterized by additional attempts to urge R&D institutes into enterprises (1987 Stipulations) and the Torch Plan to create new technology enterprises in a supportive environment. High-tech spin-offs (NTEs) were formally supported and Development Zones for New Technology Industries were set up. Even though the last decision is successful, it was insufficient to catch up technologically. The final phase (1992 -) is characterized by the opening-up approach of Deng Xiaoping to attract foreign investment and advanced technology. Further decisions and programs characterized the encouragement and promotion of technological entrepreneurship by the government. Entrepreneurial spin-offs are further promoted, and education and training are further developed. Important decisions are the Company Law and the constitutional change which acknowledged the legitimacy and contribution of private enterprises. The role of foreign (direct) investment in technology development is increasingly large in this phase.

3. International Technology Transfer

The reform process started with the collapse of the Maoist doctrines of 'self-reliance' and was basically a strategy to achieve the Four Modernisations[4] through technology transfer (Howe, Kueh and Ash, 2003). Foreign technology transfer is also a way to built technological capability upon, besides indigenous knowledge and experience. The transfer of foreign technology to China helped the process of technology development. Foreign direct investment became the main vehicle of technology transfer in the 1990s.

International technology and domestic policy initiatives shaped – and continue to shape – the development of technology and its role in the economy. This section deals with the general opening-up, the phases of technology transfer and the utilization of foreign direct investment.

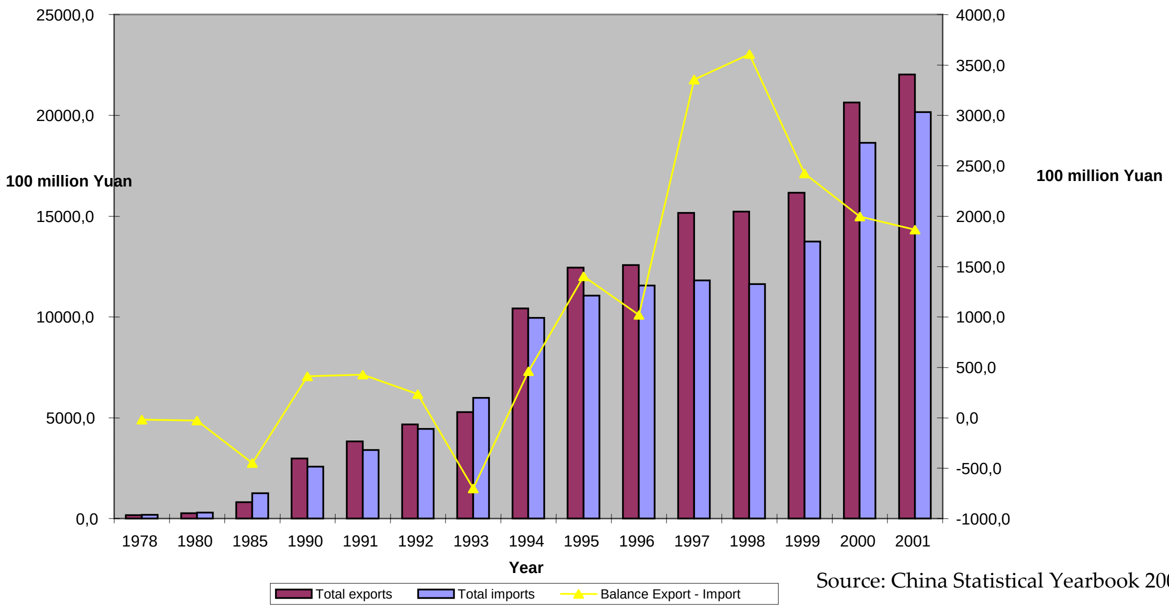
3.1 Import/export: opening up

The value of imports and exports and the balance between them show the accelerated opening-up of the economy (**Figure 3.1**). After the reforms were initiated both the value of imports and exports show a large increase. The values almost doubled in the first two years and more than tripled between 1980 and 1985. In the period between 1985 and 1995 it doubled again twice. This indicates the opening-up of the Chinese economy and is pre-dominantly influenced by Deng's Southern Trip in 1992. The balance of exports and imports is even more interesting. The value of imports is comparable or sometimes

[4] The Four Modernizations were first announced by Zhou (1973) and promulgated by Deng (1992). They stand for the upgrade and advancement of agriculture, industry, national defense, and science and technology.

even higher than the value of the exports until the early 1990s. This indicates an unfavourable balance of foreign trade, but actually is a strategy of the Chinese government – as will be shown in the following sections – to import products and knowledge. Later on, the exports are larger than the imports, which indicates a better balance of trade.

Figure 3.1: Value of imports and exports



Source: China Statistical Yearbook 2002

The reforms in the import/export policies are the main pillars in the development of the opening-up of China. Piek (1998) identified three major reform programs:

1. Open Door Policy – early 1970s: exchange visits between Chinese and Western specialists and academics, and students being sent abroad;
2. Special Economic Zones – 1980s: coastal provinces were given preferential treatment to attract foreign investors;
3. Breaking monopoly of state trading organisations and foreign exchange corporations.

During the process localities got more authority (decentralisation) and enterprises were given more responsibility. It created more opportunities for regions, localities and enterprises to establish their own links with the external world. There were many ways of importing new knowledge: investment, capital, joint ventures, and so on. This in turn led to a broad transfer of technology and the establishment of networks of relations and institutions to further develop technology. As Piek (1998, p. 35) observed 'decentralisation of institutions and lifting of state's monopoly in the foreign sector stimulates domestic enterprises to enter the world market'. The acquiring of a seat in the World Bank and the IMF in the mid-1980s and more recently entering the WTO influenced this development. Concluding, general reform initiatives of the government increased the cooperation between China and the world.

Table 3.1 shows the shares of high-tech imports and exports of total imports/exports (of manufactures). The shares of high-tech imports increased during the last decade. This indicates that the Chinese focused on high-technology development and used imports of high-tech manufactures as a way of gathering knowledge. The share of high-tech imports to total imports almost doubled in the last decade to one-third of the total manufactures imports. The export of high-tech manufactures doubled as well and became one-quarter of total manufactures exports in 2001. The increase in exports can be explained by the fact that China has developed products that are good enough for export, after two decades of learning.

Table 3.1: High-tech imports and exports as share of total imports and exports (of manufactures)

	1992	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
import	17,31%	16,61%	18,79%	18,15%	18,17%	20,90%	25,31%	28,57%	30,76%	33,05%
exports	12,33%	12,97%	14,05%	15,49%	17,20%	17,50%	19,81%	21,53%	23,42%	25,28%

Source: Adopted from Schaaper (2004)

3.2 Phases in international technology transfer

The import of technology can be understood in phases[5] and is defined as 'the transfer of the scientific knowledge and production technology related to a certain good' (Jiangping, 1997, pp. 82-83). There are different types of import: whole plant, licenses, technical services, consultancy, co-production, and foreign (direct) investment.

Since 1979, changes in the state management of importing technology took place. The newly formed State Commission for Imports and Exports intended to help the technology import but failed because it wasn't in line with the decentralisation and reform of the rest of the system. China's technology imports were managed under central authority. After 1982, the State Economic Commission decentralized part of this authority to local governments

1981-1987

Jiangping (1997) reports that the import of technology grew throughout the whole period. A large part of these imports (in value) came from Japan, the United States, and former West-Germany. Most of the imports were for the energy, raw materials, machinery, electronics, light and textile industries. The still large state-controlled imports of technology in this period were focused on two major programmes: the '3,000 item plan', aimed at renovating technology in existing enterprises, and the 'twelve production lines plan', aimed at importing twelve lines to develop production.

[5] This section draws heavily on Jiangping (1997)

1988-1991
In 1988, the State Economic Commission was abolished during the increasingly fast transformation of state-owned enterprises. The State Planning Commission took over. More authority was given to local governments to manage the imports to their own plans. However, the diversity of plans of local government made it increasingly difficult for the central government to get a full picture. The number of technology imports declined significantly as a consequence of China's contractionary macroeconomic policy. However, the value of the contracts increased. *The structure of imports changed towards more whole-plant imports, largely because the 1986 Law on Foreign Enterprises which formally granted legal rights to wholly owned foreign enterprises in China*. The imports focused mainly on energy, oil and petrochemicals. These imports were mainly obtained from the Commonwealth of Independent States and Italy.

1992-2001
In 1992, the management of technology imports was transferred to the State Economic and Trade Commission and transformed the system from "technology import control" to "scale of funds control". The changing role of the government was crucial in this period of institutional reform and focused on the establishment of the socialist market system. Whereas the government was the main actor in technology imports in the 1980s, in the 1990s enterprises became more independent and were themselves responsible for the import of technology and the associated risks. The macro-targets had to be set by the government, but the micro-control and content of the imports became the responsibility of the enterprises. In this period, there was a decline in technology imports. The focus of imports changed in favour of electronics, textiles, motor vehicles, machinery ad light industry. In the 1990s, many imports were closely related to foreign direct investment. Due to bold liberalisation of the policies of Deng Xiaoping after his 1992 Southern China Trip, many foreign investors set up joint ventures and imported advanced technology. The technological progress was promoted through foreign investment, because foreign investment in China did not only bring capital but also management skills, technology and equipment.

2001 - onwards
The accession to the WTO is one of last big contributors in this process and meant a new phase. China's accessed the WTO on December 11, 2001, and committed to eliminate various regulatory measures which imposed restriction to foreign technology transfer. Along with the country's accord with the United States (1999) and European Union (2000), Howe, Kueh and Ash (2003), expect that China is as open as many newly industrialised countries by 2005. The main implications of China's WTO accession Jiang, 2002):

- with deregulation of FDI, many export-oriented FIEs (foreign invested enterprises) are likely to target output to the domestic market;
- automobiles, chemicals, and electronics are likely to restructure due to the dismantling of import tariff and non-tariff barriers, since these were highly protected;

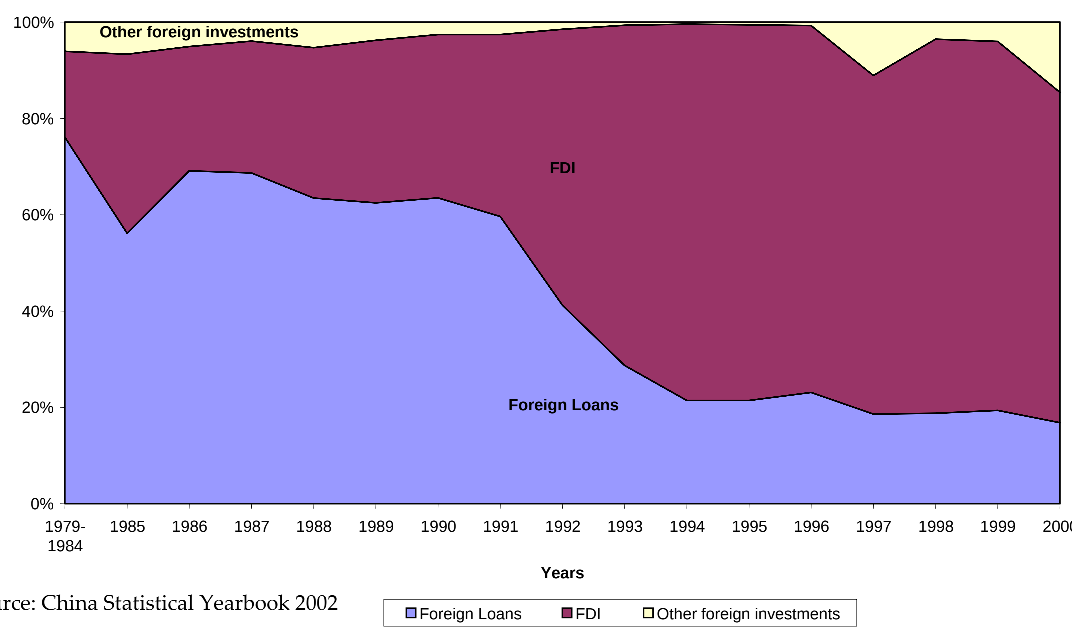
- the newly emerging industries – telecommunications, banking, insurance, and professional services and commercial distributions – will be flooded with foreign investment and MNCs;
- with the accession, many MNCs entered and will enter China

On January 1, 2002, a new post-WTO regulatory framework was promulgated by the State Council: 'Regulations of the PRC on Import and Export of Technology'. The MOFTEC and other relevant departments under the State Council started to provide detailed guidance for technology import, such as contract registration, catalogues of restricted technologies, et cetera. This marks an important step for individual enterprises and is conform WTO requirements. Although many uncertainties continue to exist the terms of contract are becoming increasingly clear for both foreign and domestic investors and technology transferors (Jiang, 2002). For these reasons the 2001 WTO accession could be regarded as the start of a fourth phase of international technology transfer and the development of the Chinese economy.

3.3 Utilization of foreign capital

Since foreign (direct) investment became increasingly important in the 1990s, we take a closer look at the foreign capital figures (**Figure 3.2**). The turning point is in the early 1990s. Even though approximately 30% of the foreign capital is still from loans or other foreign investments, foreign investment has become predominantly direct investment (FDI).

Figure 3.2: Utilization of foreign capital



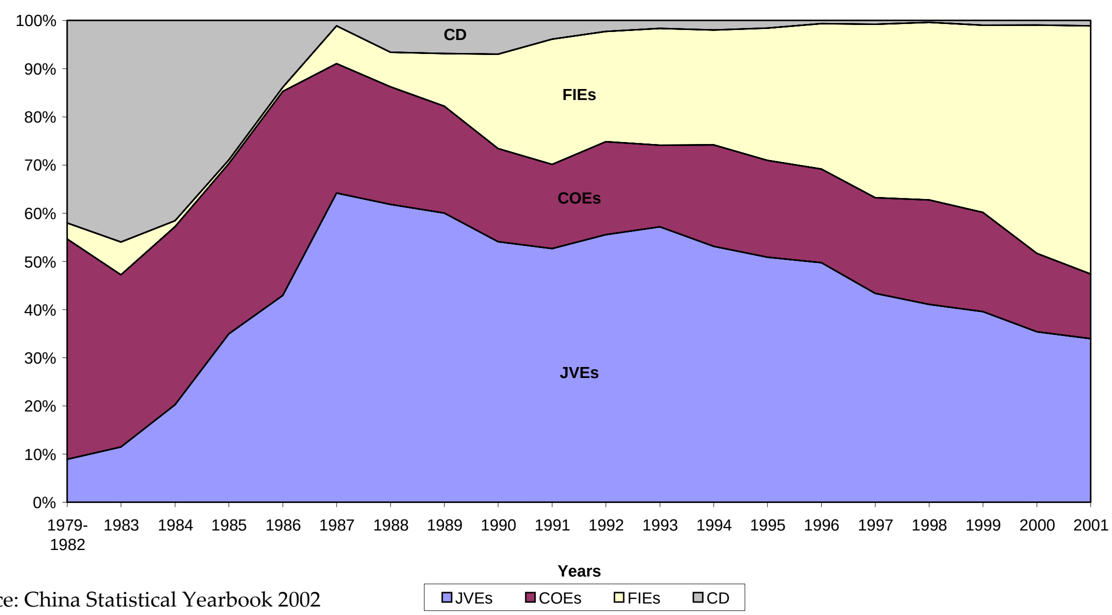
Source: China Statistical Yearbook 2002

According to Sun et al. (2002, p. 82), FDI is conventionally defined as 'a form of international inter-firm cooperation that involves a significant equity stake in or effective management control of host country enterprises'. Based on Sun et al. (2002) and Yi et al.

(2004)[6] we suggest two phases of FDI flows, based on industry categories. The *first* phase is between 1979 and 1991. In the first half of this phase FDI concentrated only on national industries and coastal zones; later also on manufacturing industries and more central zones. During this phase, the Open Door policy was predominantly restricted to the coastal region, foreigners had limited access to the Chinese domestic market, and the range of industries in which foreigners could invest was restricted. The *second* phase started in 1992, when the scope was broadened to large infrastructure and manufacturing. This last period the opening up was extended to all regions, the pace was accelerated, the domestic market has been further opened, the direction shifted from a regional to an industry based orientation. In general, most of FDI flows from Asian countries, in contrast to most of the technology imports during the first stages of technology imports (Jiangping, 1997).

Yi et al. (2004) identified four ways in which FDI enters China: joint-venture enterprises (JVEs), cooperative operation enterprises (COEs), foreign investment enterprises (FIEs) and cooperation development (CD). The amounts of actually used FDI by entry mode shows structural changes (Yi et al., 2004) (**Figure 3.3**).

Figure 3.3: Actually used amount of FDI by entry mode



Source: China Statistical Yearbook 2002

Until 1992, the total amount of FDI was small and the only entry modes used were COE and CD. The turning-point is in the early 1990s. From this point onwards the amount of foreign investment enterprises increases to a share of almost 50% of total FDI. The share of COE and CD declined when more structural investments were allowed and foreign investors made stronger commitments. The development of FDI and types of FDI entry modes is strongly linked to the regulatory reforms regarding foreign firms (**Table 3.2**).

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[6] Even though they suggest three phases, we believe that the only real turning point can be in the early 1990s, based on the figures and policy shifts.

Table 3.2: Phases in regulations for foreign firms

Phase	**Regulatory reform**	**End of phase**
1979 - 1985	Law of the PRC on Joint Ventures Using Chinese and Foreign Investment	High inflation
1986 - 1991	PRC Law on Foreign Enterprises	Tianman Square Incident
1992 -	- 1990 Amendments to the Joint Venture Law - 1991 Income Tax Law for Enterprises with Foreign Capital and Foreign Enterprises - 1992 Deng Xiaoping's South China tour	

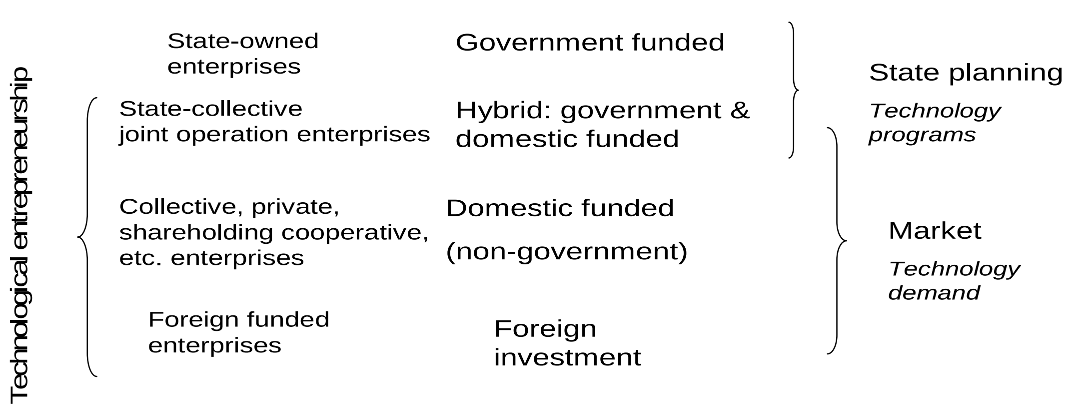
What is interesting, however, is that the turning point in the early 1990s was actually not caused by a specific regulation – although supported by – but by Deng Xiaoping's liberalisation quest. What is also striking is the learning path that the Chinese government took. The reforms followed political – economic incidents and they are the motor behind the step-by-step establishment of a foreign enterprise friendly environment. The foreign investments meant an efficient way of importing technology and related experience and skills.

To sum up: In the 1990s the technology imports declined, but the foreign direct investments increased. The foreign investment enterprise becomes the main vehicle for MNEs to use FDI to enter China. FDI became a new channel for technology import beside capital accumulation and importing management skills

3.5 System of technology development, institutions and business

We investigated the evolution of technology and business in China (part 2) and the international transfer of technology (this part). One of the observed developments was that liberalization, opening-up and various reforms favouring (private) entrepreneurship lead to a more market-oriented technology system. The role of private initiatives is increasingly valued, as is the role of foreign investment. **Figure 3.4** shows the current system of organizational forms for technological development. It is this system in which technological entrepreneurship is possible.

Figure 3.4: Organizational forms for technology development



4. Infrastructure, education and innovativeness: the basis for private R&D

Along with years of domestic reforms and international technology transfer, the supporting environment developed. Having a dynamic and efficient information infrastructure is key. Education is another key element for a knowledge intensive industry. Furthermore, the number of skilled workers and S&T activities undertaken are indicators for the innovative capability. This part presents key figures on information infrastructure, the educational system and gives and discusses indicators for the innovative capability of China.

4.1 Information infrastructure

The information infrastructure are the physical conditions for the development of technology. Infrastructure comprises of fixed telephones, mobile telephones, networks, computers, Internet connections, etc. A good information infrastructure contributes to trade, investment and growth. It helps firms, institutions, and entrepreneurs to reduce costs, increase market coverage and achieve economies of scale (Dahlman, Aubert; 2001). The information infrastructure in China has grown more than three times as fast as the total economy (Dahlman, Aubert; 2001). **Table 4.1** shows key figures of the development of the information infrastructure.

Table 4.1: Development of information infrastructure

	1990	1995	2000	2001	2002
ICT expenditure (% of GDP)		2,90	5,40	5,70	5,85
PCs (per 1,000 people)	0,43	2,27	15,90	19,04	27,64
Local telephone subscribers (10.000)	685,0	4070,6	14482,9	18036,8	
Mobile telephone subscribers (10.000)	1,8	362,9	8453,3	14522,2	20700
Internet users (per 1000 persons)		0,049	17,37	25,67	46,01

Source: China Statistical Yearbook 2002, World Development Indicators, World Bank, EVD

The total ICT expenditures as a percentage of GDP rose from 1,91 % (1992) to 5,85% (2002); an increase of almost 300% in 10 years. The Chinese expenditures are only slightly lower than UK and US (6,12% and 6,49%, WDI) and even higher than France or Germany (5,19% and 5,18%). So, with respect to investment in ICT, China is doing very well.

The availability of personal computers rose from 0,43 per 1000 people in 1990 to 27 per 1000 people in 2002. Although this growth seems impressive, it must be noted that there is a long way to go. Compared to EU and US, with 340 – 650 per 1000 persons on average, it is far behind. One of the major reasons is the fact that a large group of the population is still living in poverty in the rural areas.

China's fixed-line and mobile phone networks are the world's second largest and the paging network is the world's largest. There are four fixed-line carries: China Telecom, China Unicom, China Railcom, and China Netcom. The first two are essentially controlled by the Ministry of Information Industry. China Netcom is also owned by the state for a large part (Ministry of Railway and State Administrator for Radio, Film and Television). In 1999 China Telecom was broken into four companies focusing on fixed-line, mobile, paging, and satellite services. China Mobile and China Unicom provide mobile telephone services. Internet access is provided by China Telecom, China Unicom, China Netcom, China Mobile, China Railcom and China Satellite (satellite telephone).

The first connection from Mainland China to the Internet was established in 1993. The World Bank reported 33,7 million Chinese online in 2001 and Internet use is heaviest in the Beijing, Shanghai and Guangdong areas. China has nine interconnected Internet backbone networks and these networks are the only ones authorized to connect to the global Internet. Internet connectivity is growing really fast from 2000 users in 1993 to 33,7 million in 2001 (as reported by the World Bank). Again, it must be noted that this figure is still low with (approx.) 2.8% of the total population is an Internet user. In China there are 46 Internet users per 1000 persons in 2002. This is not much compared to US and EU, where rates vary from 330 – 550 users per 1000 (WDI). However, the growth rates are remarkable and boom the demand for fiber-optic cables, switches, routers et ceteras. The Internet backbone development business is the prime target of new investment in 2001 according to Dahlman & Aubert (2001).

Dahlman & Aubert (2001) compared the growth of the information infrastructure with other countries in the East Asia and Pacific Region. They report (p. 83-84) that China 'has the highest growth rate of fixed main telephone lines and PCs per 100 inhabitants'. Furthermore, the growth in mobile phones per capita was among the fastest growing countries in the region. Summing up, the ICT expenditures are comparable to advanced countries and the growth rates are phenomenal, but China is still behind in most respects.

4.2 Education

During the Cultural Revolution, the educational system of China was non-existent. After 1978, there was a lack of trained talent, an irrational higher education system, uneven and unequal development rates to satisfy the needs of an economic and technological boom. The main goal was to revitalize the educational system and many reforms were initiated. Deng Xiaoping recognized that the Four Modernizations could help to develop science, technology, and intellectual resources and to raise the population's education level. In 1980 the First education law was enacted to regulate academic degrees and set 'achievement' as the basis for admission and promotion in education. The commitment to modernization was reinforced by the 1986 Compulsory education law, which meant 9 year compulsory education and good quality higher education. In 1995 the Education Law was enacted, which meant a commitment to a universal education as well as to one that will produce both scientists/academics and skilled labour.

China's education system is composed of 4 components: 1) basic education, 2) occupational/polytechnic education, 3) common higher education and 4) adult education. Basic education comprises of pre-school education, primary (6 years) and junior (3 years) and senior (3 years) middle schooling. Adult education comprises of schooling education, anti-illiteracy education and other programs oriented to adult groups. Common higher education comprises of junior college, bachelor, master and doctoral degree programs.

Up to 1999, there were 1,071 common colleges and universities countrywide offering 2,754,500 seats to those applying for junior college and bachelor programs, 19,900 seats to those applying for doctoral programs and 72,300 seats to master program applicants, and accommodating 54,000 doctoral candidates and 179,500 master candidates (CERNET). Although China has made substantial achievements in the science education, it still cannot meet the needs of science development and construction of the country. Programs like "211 Project" for education development, the 21st Century Education Revitalization Plan, Technology Innovation Project and Knowledge Innovation Program continue to reform the educational system.

Table 4.2 shows the basic features of the educational system. The number of schools decreased on all levels. Probably many schools were closed because they were inefficient or obsolete. The number of teachers increased on all levels. More new students enrolled in higher education and secondary schools and more students graduated on all levels.

Table 4.2: Features of educational system

		1985	1990	1995	2000
Schools:	Higher education	1016	1075	1054	1041
	Secondary schools	104848	100777	95216	93629
	Primary schools	832309	766072	668685	553622
Teachers:	Higher education	34,4	39,5	40,1	46,3
(full-time, 10.000 persons)	Secondary schools	296,7	349,2	388,3	472,3
	Primary schools	537,7	558,2	566,4	586,0
New student enrollment:	Higher education	61,9	60,9	92,6	220,6
(10.000 persons)	Secondary schools	1789,8	1815,8	2354,1	3103,2
	Primary schools	2298,2	2064,0	2531,8	1946,5
Graduates	Higher education	31,6	61,4	80,5	95,0
(10.000 persons)	Secondary schools	1279,1	1497,5	1636,9	2302,3
	Primary schools	1999,9	1863,1	1961,5	2419,2
Number of students studying abroad		4888	2950	20381	38989
Number of returned students		1424	1593	5750	9121
Education funds (in brackets: state share)	*1990 = 1991*		7315028 (84%)	18779501 (75%)	38490806 (67%)

Source: China Statistical Yearbook 2002

It is interesting to look at students studying abroad and the number of returns. This is related to the so-called brain-drain. The trend since 1995 is that more students go abroad than that return. This is a disturbing situation, because the idea of the government is that the students return with superior knowledge. In turning this trend, the government enacted a program to reward 100 returning students.

With respect to the management of the educational system, a lot has been changed. The previous irrational and segmented education structure, overlapped disciplines and waste of resources has been changed. Universities are no longer funded exclusively by the government. The government also allowed privately-funded educational institutions. Furthermore, private schooling on the other levels is also allowed. As Table 4.2 shows, the share in educational funds of the state is declining. However, this does not mean that the government invests less in education but that there is more investment from other sources (the total funds more than double every 5 year the last decades). China also received educational aid from UNESCO, UNICEF, UNFPA, UNDP, World Bank and many other international organizations. Another large change is the new two-level management system consisting of central and local governments with the latter as the main management body. The local government is playing a key role in compulsory education, while central and provincial government are dominant in higher education. In occupational and adult education, social partners including industrial organizations, businesses and public institutions are playing a more and more important role. However, the local governments are increasingly stimulated to develop higher education and enhance the relationship between education and regional economic and social development.

4.3 Innovative capability

The innovative capability of the Chinese economy is a determinant of the potential of the Chinese economy to develop and market innovative new products and services. To determine this potential we look at two things. On the one hand you have the labour market: how many highly-skilled workers are there? On the other hand you have the scientific and technological activities carried out by skilled workers. Science and Technology activities refer to 'organized activities which are closely related with the creation, development, dissemination and application of the scientific and technical knowledge' (China Statistical Yearbook indicators, 2002). Science and Technology activities are classified into: R&D activities, application of R&D results, and related S&T services. R&D activities are those activities that aim at increasing the knowledge and using the knowledge for new application of science and technology by systematic and creative activities: basic research, applied research and experiments and development. The results of these research activities are published in journal articles, result in patents or new products/services.

Table 4.3 shows basic statistics on highly-skilled workers. Overall, there is a steady increase in researchers and S&T personnel. With respect to the number of researchers per thousand persons employed, China is far behind other countries. In the EU were 4,7 researchers per thousand on average in 1991 and 5,9 in 2001. Singapore has 8,2 researchers per thousand in 2001 and Japan even more: 10,2 per thousand (Schaaper, 2004). If you compare the number of researchers in R&D, China is far behind as well. For instance, Germany has over 3.000 researcher in R&D and Japan even more than 5.000 researchers per million people (World Development Indicators).

Table 4.3: Basic statistics on highly skilled workers

	1994	1995	1996	1997	1998	1999	2000	2001
Researchers per thousand persons employed	0,8	0,8	0,8	0,9	0,7	0,7	1	1
Persons engaged in S&T activities (10.000 persons)	265,5	270,1	273,2	288,6	281,4	290,6	322,3	314,1
Researchers in R&D (per million people)	353,0	350,8	453,6	473,2	387,2	419,9	545,1	
S&T personnel in higher education (10.000 persons)				32,6	34,5	34,2	35,2	36,6

Source: China Statistical Yearbook 1998, 2002; World Development Indicators, World Bank; Schaaper (2004) OECD database

Table 4.4 shows the basic statistics on scientific and technological activities. The funding for S&T activities was increased: between 1997 and 2001 the total funds more than doubled. S&T funds consist of labour expenses, purchase of fixed assets, R&D expenses, fundamental research, applied research and experimental development. The state is responsible for one-quarter to one-third of the funds. Furthermore, the proportion of R&D expenditure to GDP is increasing: it almost doubled between 1997 and 2001. What is also interesting to see it the large increase in transaction value of S&T activities in the technical market. The total value more than doubled in 5 years (1997-2001). Altogether, on average the funding, expenditures and value doubled in 5 years, indicating a large growth of S&T activities.

Table 4.4: Basic statistics on scientific and technological activities

	1997	1998	1999	2000	2001
Funding for S&T activities (100 million yuan; in brackets: state share)	1181,9 (26%)	1289,8 (27%)	1460,6 (32%)	2346,7 (32%)	2589,4 (25%)
Proportion of R&D expenditure to GDP (%)	0,64%	0,69%	0,83%	1,00%	1,09%
Transaction value in technical market (100 million yuan)	351	436	523	651	783
Funding for S&T (100 million yuan; in brackets: state share) *In higher education*	73,076 (50%)	84,957 (48%)	102,946 (48%)	166,778 (58%)	200,000 (55%)
Proportion to total S&T funding	6.18%	6.59%	7.05%	7.11%	7.72%
Total patents certified	50992	67889	100156	105345	114251

Source: China Statistical Yearbook 2002

Within higher education - the most important source for highly skilled workers - the S&T funding is structured differently. More than half of the total value is obtained from the state, since most universities rely on government funding. It also implicates, however, that approximately 45 % of the funding is from non-government sources, e.g. business enterprises, foreign investment, international institutions, etc. This is in line with the previous observation that higher education is becoming less dependent on state funds. The proportion of S&T funding in higher education to total S&T funding shows that S&T funds that go to higher education S&T research activities is increasing.

The results of these activities are for a part captured in the number of patents. In the last 5 years (1997-2001) the number of patents certified more than doubled, with the largest increase between 1998 and 1999. Besides patents, journal articles are also results of science and technology activities and thus an indicator for innovative capability. **Table 4.5** shows the basic statistics on published journal articles in China, EU and US.

Table 4.5: Basic statistics on published journal articles

	1990	1995	1999
China	4999	6995	11675
France	21584	26265	27374
Germany	27317	34442	37308
United Kingdom	36671	39980	39711
United States	179978	179051	163526

Source: World Development Indicators, World Bank

What is striking is the steady increase of the number of journal articles published in China and the constant (EU) or even decreasing (US) stream of articles. Although China is still far behind with respect to the number of articles published per year, the growth trend implies that China is able to catch up.

Summing up, the funding side of the innovative capability of China is sufficient. However, there are still too few skilled workers and China is behind in terms of publishing/commercialising results. The government is aware of this and focuses on higher education and the related funding of S&T activities.

5. The High-Tech industry

In the past sections we described the evolution of technology, institutions and business in China, the role of foreign investments, the supporting infrastructure and technological entrepreneurship. The high-tech industry became increasingly market-oriented and is crucial in the development, dissemination and application of technology in the China. Being one of the fastest growing industries and recently ear-marked as a pillar industry, the high-tech industry in China is interesting. We will identify the most interesting sectors and argue the large role of NTEs.

5.1 Technology organizations: players, initiators and regulators
Several institutions are active in promoting and regulating the high-technology industry and science & technology development. The Ministery of Science and Technology (MOST) is responsible for many promotion programs. The 'Key Technologies R&D Program', the '863 Program', and the 'Torch Program' are all initiatives of the MOST. The programs funded S&T projects in institutes of higher education, R&D institutes, enterprises and companies.

The Chinese Academy of Sciences (CAS) is China's famous natural science and technology research organization. It has 123 research institutes, employing over 60,000 scientific and technical personnel. Research focuses on mathematics and physics, chemistry, earth sciences, biology and technology. In 2000, *the CAS increased its market-orientation by transforming more and more of its institutions of technology development into business enterprises*. At the end of 2001, 13 CAS institutions had been transformed (CAS, 2004): 12 became limited-liability firms and one merged into a state-run company. The firms performed well and reached a total turnover of 81 billion Yuan (USD 9.7 billion) from 2000 to 2001. The CAS (2004) website also reports to have provided job opportunities for about 40,000 people outside the Academy.

The following six companies are directly under CAS (CAS, 2004): China Sciences Group; China Investment Corporation For Sciences & Technology – CICSTD; Oriental Scientific Instrument Import & Export Group; Huajian Group Ltd.Co.; Kejian Group; Legend Group (in 2003 renamed Lenovo Group Ltd.). As the names suggest most of these companies consist of many other companies. We take the China Sciences Group and Huajian Group Ltd. Co as examples.

China Sciences Group (CSG): CSG has 30 wholly or partially owned member enterprises. China Da Heng Corporation, the Beijing Hope Computer Corporation and the Beijing San Huan New Materials High-tech Corporation are the most important ones. CSG employs 2700 persons (70% professionals and 12% managers). The website reports that in 2000 turnover reached nearly RMB 2.31 billion, including RMB 170 million profit income. Their business focuses on 'researching , developing , producing and marketing electronic data devices, computer and its software, medical instrument, new materials, new energy, and biomedicine' (CSG website, 2004)[7].

Huajian Group Ltd.Co. : This company focuses on computer language information processing, trade oriented systems, online information integrated processing systems and embedded application software. Directly under supervision of the Group are three companies: Huajian Machine Translation Co. Ltd., Huajian Huizhi Science & Technology Co. Ltd., Huajian Digital Technology Co. Ltd., and several other companies. These companies together have nine other companies to supervise.

Besides the companies directly under the CAS there are many other companies linked to the CAS: Beijing Zhong Ke San Huan High-Tech Co.; Daheng New Epoch Technology; etc. The Chinese Academy of Engineering (CAE) and the State Natural Science

[7] Although real estate, technical consulting and service , and patent agent services for clients in and outside China are also within business scope.

Foundation Committee (NSFC) are two other important institutions in the technology sector. The CAE was established in 1994 and is a key advisory institution for the engineering community. The NSFC was established in 1986 to promote and finance S&T research.

5.2 Features of the High-Tech industry: ICT as key sector

The industry grew at an average annual rate of 21.2 percent in the 1996-2000 period (CERNET, 2004). The total industrial sector grew 11% less. The same story holds for the exports of high-tech products: The total exports grew by 10.4 %, whereas the total high-tech exports grew by 38.4%. The proportion of high-tech manufactures exports rose from 17.2% to 25.28% of total manufactures exports and among total exports from 8.4% to 14.9%. There are 24.293 enterprises in high-tech development areas, employing 2.761.433 persons generating USD 22,7 billion in export value (China Statistical Yearbook, 2002). The regional distribution of high-tech activities is unequal. The best performing and largest high-tech areas are: the Yangtze River Delta, the Pearl River Delta, the Bohai Sea Rim, and areas along the Shenyang-Dalian expressway. Beijing, Shanghai, Shenzhen and Xi'an the country's four best-known high-tech cities. Beijing has - by far - the largest high-tech area with 7911 enterprises, 282.720 employees generating 17% of all High-Tech enterprises' gross output value and 13% of all high-tech exports.

But what exactly comprises high-technology in the Chinese context? According to Article 4 of the "Conditions and Measures on the Designation of High and New Technology Enterprises in National High and New Technology Industry Development Zones" (CERNET), high and new technology is divided into:

(1) microelectronics and electronic information technology;
(2) space science and aerospace and aeronautical technology;
(3) optoelectronics and optical, mechanical and electronic integration technology;
(4) life science and biological engineering technology;
(5) material science and new materials technology;
(6) energy science and new energy, high efficient energy conservation technology;
(7) ecology and environmental science;
(8) earache science and ocean engineering;
(9) basic matter science and radiation science;
(10) medical science and bio-medical engineering;
(11) other new process or new technology applicable in the traditional industries.

Source: CERNET (Ministry of Education, China)

Furthermore, the 10th Five-Year Plan (2001-2005) identified software, computer manufacturing, telecommunications, lasers and aerospace as pillar industries. Taking both together, we have a good idea of what high-technology means in the Chinese context. We identify the microelectronics and information technology sector as key sectors. Besides the central governments focus, we also believe it is one of the most dynamic and vibrant sectors of the last two decades. The China Statistical Yearbook provides data on large and medium sized industrial enterprises in the High-Tech industry, which corroborates our choice. **Table 5.1** provides basic statistics on S&T activities in 2001.

Table 5.1: Large and medium sized industrial enterprises in the High-Tech industry (2001)

	Technological activities personnel	Scientists and engineers	Expenditure technological activities (10.000 yuan)	Total revenue (10.000 yuan)	Export	invention
1) Electronics and Communication Equipment	113217	39606	1599800	52220694	4240727	902
% of total	*41%*	*48%*	*62%*	*59%*	*60%*	*74%*
2) Electronic Computers and Office Equipment	18249	5992	261554	15540968	2457322	78
% of total	*7%*	*7%*	*10%*	*18%*	*35%*	*6%*
Totals of medium and large industrial enterprises	*273668*	*81875*	*2588452*	*87865003*	*7078571*	*1223*
1) and 2) together of total	48%	56%	72%	77%	95%	80%

Source: China Statistical Yearbook, 2002

The figures show that these categories are responsible for a large part of the High-Tech industry's activities and output. Together they employ 48% of the technical personnel, 56% of the scientists and engineers. Furthermore, they generate 77% of the total revenue and are responsible for almost all exports (95%). They are also the most innovative sectors as they have 80% of the inventions. Although the first category is responsible for most of these figures, the second category has large revenues and export figures. This indicates that the microelectronics and information technology sectors are the most important sectors within the high-tech industry. This result is in line with Meng & Li (2002) review of the growing importance of the ICT industry in the Chinese economy. The next section show the features of the ICT sectors.

5.3 Telecommunications

The telecommunications market witnessed an incredible growth and the prospects are good. According to the EVD report (2004) on China's ICT sector, the telecom market had a total sales of USD 60,5 billion in 2002; a growth of 32,2 % compared to 2001. The market has the attention of the government's policies.

The growth of the mobile telephone market is remarkable and surpassing the fixed line market. The total number of mobile telephone subscribers increased to 207 million in 2002. In the same year the production of mobile telephone was increased to 120 million per year. Market leaders in production are Nokia, Motorola and Siemens[8] but in 2002 more than 30 % was produced by domestic manufacturers (coming from only 2% in 1999). The major domestic producers are: TCL, Bird, Keijan, Haier, Amoisonic, Konca,

[8] Besides Nokia, Motorola and Siemens, Alcatel and Ericsson are foreign investors in telecommunications.

Shouxin, Nanfangshouxin and Dongfangtongxin (EVD, 2004). With respect to the services and network providers, the Chinese enterprises are in control. Six companies provide the basic services and 4400 companies deliver value added services. In 2002 China Mobile had the largest market share with 37,4%, followed by China Telecom (32,5%), China Netcom (16,6%), China Unicom (12,2%) and others (1,4%).

Although there is foreign investment in China's telecommunications market, it is mostly in manufacturing equipment to supply the operating companies. Foreign investment in these operating companies is prohibited. There are, however, long-term plans for opening up the telecommunications market. As of 2003 there were no limitations for services with added value and basic services as paging. For the mobile services, the opening-up is planned in 2006 and for the fixed net in 2007. For both mobile and fixed services there are several cities that do allow foreign investment; slowly China raises the number of 'open' cities (EVD, 2004).

The major problem in this sector is that is relatively closed to market competition. Although attempts are made to open up specific sectors within the telecommunication market, many crucial services and operations remain under state supervision. Furthermore, foreign investment is difficult, especially in the operations side of the telecommunications market. World Bank analysis (reported in Dahlman & Aubert, 2001) shows that there are several sector that need to be liberalised and deregulated. The market structure is shown in **Table 5.2**.

Table 5.2: Market structure

Segment	**Structure**
Local calls	Duopoly: China Telecom, China Unicom
Long-distance calls	Limited competition: China Telecom, China Unicom, China Mobile
International calls	Monopoly: China Telecom
Mobile (GSM)	Duopoly: China Mobile, China Unicom
Data communications	Limited competition: China Telecom, China Unicom, Jitong, Netcom
Radio paging	Competition: > 2000 operators
Satellite services	Competition

(adopted from Dahlman & Aubert, 2001; source: World Bank analysis)

5.4 Computer hardware

The computer hardware industry in China has its roots in the late 1950s. The first Chinese-made computer was completed in 1958. However, subsequent development was slow and hindered. In the 1980s it was crucial for China's independently developed computer industry to catch up with the world. China increased its imports of large and mid-range computers from the US and Japan (IBM, DEC, Unisys, Fujitsu, Hitachi and NEC). It's main activity was the assembly of imported kits. With the opening-up, starting in 1992, China's computer industry entered a period of rapid growth and intensified competition. The government's desire to catch up technologically is also the leading element in the computer industry strategy.

The late 1990s are characterized by a change in composition of the computer market, indicating the success of the government's policy. Whereas the foreign PC makers had 60% of the market in the early 1990s (Chung, 1999 in K&D, 2001), domestic companies have 80% of the market in 1998 (Kreamer & Dedrick, 2001). In the last years, the largest shares belong predominantly to Chinese firms and new players are Chinese (**Table 5.3**).

Table 5.3: Market shares of largest PC makers in China (in %)

	1997	1998	1999	2000	2001	2002	2003
Legend	10,7	14,4	21,5	26,4	27,5	27,3	27
IBM	7,5	6,5	6,2	4,8	4,2	4,6	4,7
HP	6,5	5,7	5,6	3,7			
Compaq	6,7	4,3	2,9				
Founder	3	3,7	5,9	8,4	8,9	9,1	10,7
Great Wall	1,6	1,9	3,5	4,6			
Dell				2,9	3,9	5	6,9
Tongfang				1,5	3,8	4,9	7,1

Source: Annual reports Lenovo (formerly Legend)

At the forefront of the Chinese firms is Legend, an Science & Technology Enterprise. As a results of reforms and programs in the 1980s, the Science & Technology Enterprises came onto the scene. Legend is one of the four leading Science & Technology Enterprises (Lu, 2000). They were the focus in the government's framework to promote high-tech industry development. The set-up of the organizations was close to Western high-tech ventures. The main purpose was to commercialize the technological knowledge of the state S&T sector.

Legend was a spin-off of the Institute of Computing Technology under CAS. It has become the largest PC maker in China. The other leading enterprises were: *Stone*, the first to commercialize a Chinese word processor; *Founder*, became the leader in pictographic-language electronic publishing systems after it took over a government project ('Project 748'); and *China Great Wall Computer*, a spin-off of the Computer Industry Administration Bureau under MEI. It is one of the top, domestically developed PC makers and largest supplier of OEM components and peripherals in China. All have in common that they are non-governmental (except Great Wall, who accepts state budget), young, competitive, and among the first joint-stock companies listed. However, it must be noted that all enterprises are still controlled by holding companies of the government[9].

Taiwanese firms play a leading role in the industry (Kreamer & Dedrick, 2001). In the early 1990s, Taiwanese PC makers entered China with low-end operations. The main prupose was the use of low-cost production. Since 1995, the competition from US firms grew and Taiwan increased its investments. Most investment is directed to Jiangsu

[9] Stone is officially a collectively-owned enterprise and the other three are still state-owned enterprises.

Province, Shanghai and nearby cities. Between 1999 and 2001 Acer, Twinhead, Inventec, Compal, Quanta, FIC and Arima invested in China. The level of technology is increasing, with notebooks, LCD monitors, scanners and motherboard production. Besides producing for foreign multinationals in China, the Taiwanese firms also manufacture for China's domestic companies (Kreamer & Dedrick, 2001).

In the process China has become a large player in the global PC production network. Almost no computers were produced in 1990, but in 2001 China produced almost 9 million microcomputers. (China Statistical Yearbook, 2002) The growth is (partly[10]) driven by domestic demand. The number of computers grew rapidly from 500.000 in 1990 to over 7 million pruchases in 2000. The domestic vendors have two-thirds of the PC market, since the high tarriffs on imported PCs and peripherals drive foreign competitors to build production facilities in China (as for instance IBM, Dell, HP and Acer did). Most of the hardware production is done in the southern coastal regions. The Shanghai area, Suzhou Industrial Park and Beijing's Zhongguancun high-tech development zone are the other major production sites. Many high-tech enterprises in these zones are spin-offs and operate in an innovation network of institutes, foreign enterprises and other spin-offs.

Software[11]

The industry emerged later than the hardware industry, as in many other countries (Zhang & Wang, 1995). In the 1980s most software products were sold together with the computer hardware and were very specific. There were some software projects scattered around various institutions but hardly any commercial R&D existed. Furthermore, the legal infrastructure was (and is) too weak to protect intellectual property. In the late 1980s some firms were authorized to commercialize software products and in the 1990s the software market started to emerge and develop. The Internet hype brought money to the software industry and the industry started to expand. From 1992 to 2000 there was an average annual growth rate of over 30%. In 2000 the government published one of the most important policies for the software industry: 'Notice of certain policies to promote the software and integrated circuit industry development'. This document meant: reduced effective VAT (17% => 3%); no enterprise income tax for the first two years; a tax rate of only 10% for 'key software enterprises'; shortened approval periods for foreign stock markets; no tariffs and VAT for all imports of technology; direct export rights for all firms with over USD 1 million in revenues; and the right to set salary levels and grant bonuses to inventors (Saxenian, 2003). The result was a more open and competitive software market.

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[10] According to Dedrick & Kreamer (2001) China also has become a major export platform for components and peripherals.

[11] We refer to Saxenian (2003) for a detailed overview of the software industry in China. In this section we focus on the most important features.

The domestic market is dominated by software services (54% in 2000, Saxenian 2003), followed by products (40% in 2000, idem) and exports (only 6% in 2000, idem). Tschang & Xue (2003) report that the industry shows high growth rates in all sectors (>30%). At the end of 2002, EVD reports (2004) that China has over 4700 software producers, 644 of which are financed with foreign capital. This is close to the IDC (2000) estimation of 2000 registered companies and 3000 software related companies. **Table 5.4** lists examples of Chinese software firms and foreign software firms in China. The market is extremely fragmented with thousands of small enterprises. Furthermore, many of the largest software developers are diversified firms, since it is difficult to be a specialized software producer in China (Saxenian, 2003). The reason for this is that more than half of China's total software output is in software services (primarily systems integration). Due to the weak property rights regime, many companies choose for the integrated services, since they do not face the risk of piracy.

Table 5.4: examples of Chinese software firms and foreign software firms in China

Chinese software firms	**Foreign software firms in China**
Beijing Legend Software Co. Ltd.	IBM
Peking University Founder Group Co.	Microsoft
Beijing UFSoft Group Corporation Ltd.	Orcale
Kingsoft Company Ltd.	Sybase
Kingdee International Software Group	Computer Association
Shanghai Huateng Software Systems Co.	Novell
Shenzen Zhongxing Telecom Co. Ltd.	Lotus

Source: adopted from Saxenian (2003) and IDC (2001)

The software parks house many software spin-offs of universities or CAS institutes. The Torch Plan (1988) of the MOST resulted in the establishment of at least eight Software Industrial Parks at the end of the 1990s:

- Shengyang East Yuan (1995)
- Chengdu West Park (1997)
- Chengsha Park (1997)
- Jinan Park (1997)
- Beijing Park (1998)
- Tianjing Park (1998)
- Wuhan Park (1998)
- Hangzhou Park (1998)

Furthermore, the software industry has ties to the older hardware sector. Many hardware producers, such as the Legend Group, developed software 'arms'. The Legend Group separated its software arm and renamed it as Digital China. The software clusters are highly innovative and operate in a network of institutes, other enterprise, universities and (foreign) cooperators. The so-called guanxi-networks thrive (Saxenian, 2003) in this dynamic and innovative environment. Furthermore, the weak intellectual property rights force entrepreneurs to rely on more informal, social networks.

However, despite the fast pace of development there are shortcomings. The literature (e.g. Tschang & Xue, 2003; Saxenian, 2003; Zhang & Wang, 1995) identified the following: 1) insufficient venture capital; 2) insufficient intellectual property rights protection; 3) weak English language abilities; 4) shortage of skills as a result of the slow growth of the number of software professionals. These shortcomings ask for further industrial restructuring and institutional change. The development of human resources has the full attention of the government since it focuses on (higher) education policy reform.

6. Conclusion: innovation system for technological entrepreneurship

The evolution of high-technology and business in China is a process of learning, guided by the policy decisions of the government, domestic technology development and international technology transfer through foreign investment. The interaction between the institutional and economic environment shaped the development of high-technology.

Reform initiatives and many programs and plans fostered the domestic development of technology and forged linkages between research and business. Technology imports in the 1980s helped China to catch-up. In the late 1980s, the government became aware that further opening-up of the economy would help to upgrade and improve technology. Several reforms favoring entrepreneurship and foreign investment made the market more open. Foreign direct investment became the main vehicle for technology import, capital accumulation and importing management skills. Institutional reforms made more organizational forms possible and networks of relations emerged while transferring technology. In little more than two decades the link between R&D and business became stronger and the government no longer controls all scientific and technological development. The reforms in Science & Technology, education, foreign policy and enterprise laws have led to a system in which *technological entrepreneurship* is made possible.

A key example of technological entrepreneurship is the New Technology Enterprise (NTE). The Torch Program (1988) supported NTEs in Development Zones for New Technology Industries. These NTEs are mainly spin-off enterprises from R&D institutes or universities and they aim at commercializing technological knowledge. The strong relations and interaction with research institutes, universities, foreign enterprises and other NTEs in the Development Zones make these enterprises innovative and enable commercialization. The majority of these NTEs is operating within the ICT sector.

Figure 6.1 shows the resulting *innovation system for technological entrepreneurship*. The central government sets a general framework and initiates technology programs, whereas the local government implements the policies, interacts with the enterprises and provides budgets. A good example of an innovation system is a Development Zone for New Technology Industries. The R&D institutes – some are part of a government program but others are free-standing – interact with the enterprises and other parts of the system. Together with the institutes of higher education and the Chinese Academy of Sciences, they provide the knowledge base of the system. Many NTEs are spin-offs of these institutions and the computer hardware and software sectors provide good examples. The programs and policies provide incentives for private technology development in the NTEs. Furthermore, the NTEs experience competition from the market, co-operate with other enterprises and receive demand-incentives from consumer. The transfer of technology within this system (both domestic and foreign) leads to a network of relations and institutions to further develop high-technology.

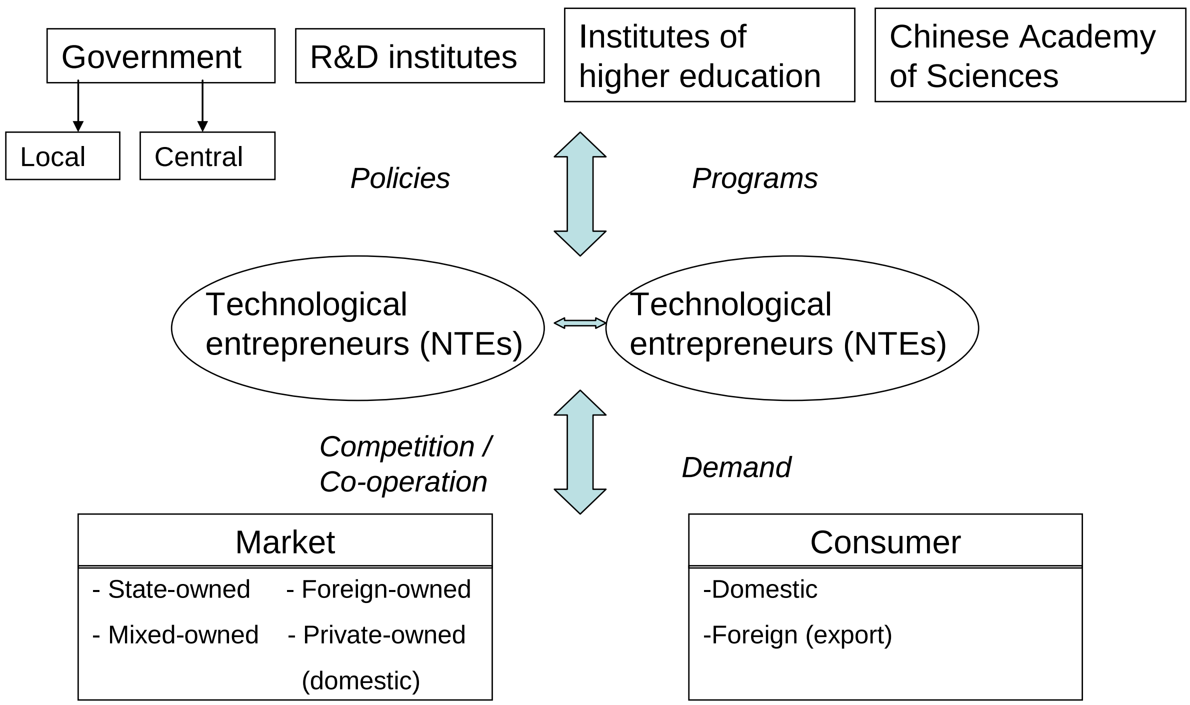

Figure 6.1: innovation system for technological entrepreneurship

However, even though market competition is enhanced, entrepreneurship is fostered and SMEs are promoted, China is still far behind in the development and commercialisation of technology. There are still too few highly-skilled workers, the information infrastructure is too weak and the capability to innovate is still to low. Furthermore, the state still has many shares in many sectors and thus keeps controlling parts of the economy.

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