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China's Reformed Science and Technology System: An Overview and Assessment

ABSTRACT

Starting from the establishment of the People's Republic of China in 1949, this article provides background on China's science and technology (S&T) system and the perceived growing urgency of reforming it in order to support continuing economic growth in China. The need for reform became even more pressing once China commenced its market-oriented economic reforms in 1979. Comparative data are provided on China's S&T sector, the processes of reforming China's S&T system is outlined and discussed as well as changing patterns in the source of funds for its S & T research. China's evolving technology market is given particular attention as well as its establishment of a patent system. The importance of closer ties between technology suppliers and users in China, as well as pitfalls, are given particular attention. Transition in the system has been gradual rather than of a 'big-bang' type. The process of reforming the system and the state of China's current S & T system are assessed.

Keywords: China, economic reforms, patents, research and development, science and technology policy, technology markets.

China's Reformed Science and Technology System: An Overview and Assessment

1. Introduction

There has been a growing preoccupation with the role of technology in the economic growth of modern industrial societies and with the conditions under which scientific and technological systems can be made to function more effectively from an economic point of view. The need for technologies to be integrated with economic prospects is now firmly established as a critical factor in modern economic development (Mowery et al., 1995, p.67).

Patterns of technological change, differ according to a country's specific situation, overall social environment and stage of economic development. Industrialisation, when launched today in a backward country, is likely to display different patterns to those previously experienced by today's advanced countries, not only as to the speed of development, but also in the productive and organisational structures of industry that emerge (Gerschenkon 1962, pp.7-8). When considering the processes of economic catch up, a country's technological capability/capacity always has been emphasised as a crucial factor in determining how efficiently domestic and foreign technology can be utilised and developed. Some studies (Lundvall 1992, Conroy 1992, Teubal et al. 1996) point out that a suitable productive science and technology system or framework is a pre-condition for improving a country's technological capability/capacity. This issue is important in understanding why China's technology was outdated in its pre-reform era and how it needed to be upgraded to assist China in its economic growth efforts.

The problem that China faced with science and technology when it commenced its reforms were similar to those of many former communist countries. Let us consider those issues generally before considering China's specific situation and its reforms of its science and technology system.

Several economists argue that the centrally planned system in the former communist countries was relatively ineffective in promoting innovation. Central priorities governed the items and quantities of commodities to be produced and determined their sources of supply. Consumer demands, input prices and market competition inroads played no role in these socialist systems. Thus, the impetus toward production and, even more, toward product innovation was not as compelling as in competitive market economies (Chiang 1990, pp.397-426, Malecki 1997, p.295).

Some of the principal reasons for this were 1) bureaucratic unresponsive structures that managed science and technology development and resulted in immobility of scientists and engineers (Sagdeev 1988); 2) at the firm or institute level, there was little incentive for managers to improve product designs, quality or efficiency beyond that demanded by planning authorities; and 3) the stumbling block for the system was not a lack of R&D funding or scientific capability. The S&T system's greatest weakness was poor linkage between research and production; e.g. factories without engineering facilities and R&D institutes that lacked production engineering capability or pilot production plants (Kassel 1989).

Gomulka (1990, p.96) points out that because of these weakness, the contribution of new innovations in central planned economies was negligible despite expenditure in these countries being large and equal to at least a quarter of world R&D expenditure. The structure, linkage and operating efficiency of R&D systems in these countries were badly in need of reform. But empirical studies record that change in these system was difficult and slow. Some economists call these types of phenomenon "institutional failure" (Jiang 1993, Wang 1997).

A country's development of S&T and R&D is also affected by its inflow of external technology. Foreign technology can play an important role in stimulating the development of LDCs. Debate focuses on foreign technology inflow and its long-term impact on a host country's economic, technological and social development. Some writers claim that foreign technology acts as a substitute for domestic technology, because it displaces existing local technological effort. In contrast, other writers consider that the linkage between foreign technology and domestic technical effort is complementary (Radosevic, 1999, p.115-120).

S&T systems in transitional economies needed to be reformed once economic transition began. There was a need for informal as well as formal changes (Murrell 1996). There was a need to reconstruct linkages between research organisations, universities and manufacturers;

improve R&D infrastructure; establish finance agencies for R&D; and promote dissemination of technology (Landesmann 1995).

Rapid 'Big Bang' transitional policies in Russia, based on neoclassical economics, ignored or downplayed the existence of the preceding pervasive nature of the state. The policy dismantled the old system without appreciating the strong connection between state ownership and the social obligations of the enterprise and the need to take time to foster new social obligations and institutional arrangements. Thus, the consequences of this policy were generally negative (Tsang 1996, Malecki 1997, p.297). Rapid privatisation and marketisation under the policy did not work as well as expected in Russia and some Eastern European countries. The consequences of this were that S&T funding was considerably reduced; large numbers of research projects were cancelled and the technological capabilities of several nations were weakened in their transition.

China's economic reforms proceeded more gradually under the leadership of Deng Xiaoping. While China's economic reforms began in 1979, reforms to its science and technology system did not get underway until 1985. These reforms were also market-oriented and gradual or evolutionary rather than in the form of a sudden large change. Let us consider, in turn, relevant comparative data on the development of China's S&T sector; the process involved in reforming China's S & T system and changes in the pattern of funding of China's S&T research. Then, attention will be given to the nature of China's evolving technology market, China's establishment of a patent system and its efforts in creating closer ties between technology supplies and users. Finally, there is an evaluation of China's reformed S&T system followed by concluding comments.

2. Comparative Data on the Development of China's S&T Sector

China's science and technology base was very weak when the People's Republic of China was established in 1949. Construction of its 'modernised' science and technology system was then initiated and developed, based on the Soviet model, but did not start until the commencement of China's large-scale industrialisation in mid-1950s. The economy relied largely for new technology on the adoption of foreign technology transferred from the Soviet Union and Eastern European countries. Its rate of domestic technology development was slow and its efficiency in utilising foreign technology sluggish during China's centrally planned economic system which did not begin to be reformed until after 1979.

In the early 1950s, the country's scientific and technological personnel amounted to less than 50,000 and there were almost no suitable research facilities available. After two and half decades of communist development, China's S&T efforts showed progress. In 1978, there were 1.37 million personnel engaged in science and technology (S&T) work. Subsequently, the number increased steadily, reaching 3.14 million in 2001 of which scientists and engineers (S/E) accounted for 2.07 million persons (Table 1). R&D personnel numbers rose from 781,000 in 1986 to 956,000 in 2000 (Table 1).

In absolute terms, China's number of R&D personnel and researchers ranked fourth largest globally, just behind Russia, USA and Japan in 1995 (Table 2). But in terms of researchers per million population, China's figure was 5 times lower than that of Japan, 3.1 times lower than that of the USA and 1.5 times lower than that for both Singapore and S. Korea in 1995 (Table 3) but well ahead of India and Malaysia.

Table 1

Numbers of China's national S&T and R&D personnel (in 10000)

	1 (1) Total personnel engaged in S&T activities	1(2) Of which scientists & engineers	2 (1) Total R&D personnel	2 (2) Of which scientists & engineers	3. S/E engaged in R&D per 1000 labor force
1949	5	-	-	-	-
1978	136.9	-	-	-	-
1985	-	-	57.6	-	-
1986	-	-	78.1	32.0	-
1987	-	-	71.3	34.1	-
1988	209.4	108.5	75.3	36.2	-
1989	209.9	115.0	76.3	37.6	-
1990	209.9	118.2	75.7	38.9	-
1991	221.9	124.8	77.6	39.5	-
1992	220.7	127.7	70.7	38.8	-
1993	237.4	129.7	68.2	38.3	-
1994	243.7	134.7	64.4	37.4	-
1995	247.6	135.3	62.6	36.8	-
1996	290.3	168.8	80.4	54.8	7.9
1997	288.6	166.8	83.1	58.9	8.3
1998	281.5	149.0	75.5	48.6	6.8
1999	290.6	159.5	82.2	53.1	6.7
2000	322.3	204.6	92.2	69.8	9.8
2001	314.1	207.1	95.6	74.3	10.1

Note: - data not available.
Source: Statistical Yearbook of China and Statistical Yearbook of China on Science and Technology and Science and Technology Indicators in relevant years.

Table 2

Comparisons of numbers of R&D personnel (10000 persons) for selected countries

	All R&D personnel			Researchers			Technicians		
	1981	**1990**	**1995**	**1981**	**1990**	**1995**	**1981**	**1990**	**1995**
Russia	-	1079100	1113244	878500	593000	562070	-	200600	96922
USA	691400	949200(88)	962700(93)	691400	949200	962700	-	-	-
Japan	629172	863382	948088	463062	666393	673421	34007	104190	-
China	-	757000	804000(96)		389000	548000	-	-	-
Canada	78180	113550	129750	39060	63930	80510	22790	-	-
Australia	45211	67796	90519	24486	41837	60890	12284	16647	14133
India	218995(82)	322977	336589(94)	93698	128036	10505	60887	96737	98769
S. Korea	35805	125512	152247	20718	70503	100456	8815	42841	-
Taiwan	-	-	-	22184	65582	92113	6551	19511	25635
UK	312000	280000	279000	127000	133000	140000	-	-	-
France	249100	293031	318384	85500	123961	151249	163600	168852	165966
Germany	359419	431100	459138	124678	241869	231128	-	-	-
Italy	102836	144917	141789	52060	77876	75536	29385	40067	45701
Poland	221000	174000(87)	82852	89000	43000	49787	51000	62000	19553
Hungary	51512	36384	19585	22267	17550	10499	21719	14113	5207

Note: -- data is not available.
Numbers in the brackets are for the relevant statistics years.
Source: UNESCO 1999, China's data from the Statistical Yearbook of China 1994 and UNESCO 1995, Taiwan data are from Statistics Yearbook of Republic of China in relevant years.

Another indicator, R&D personnel per 10000 of the labor force, was even lower accounting for less than ten percent of that of developed economies and 20 percent of that of early NICs such as S. Korea. Thus China's average S&T and R&D personnel intensity were low in the mid-1990s. (Table 3).

Table 3

R&D personnel in selected countries: numbers and intensity

	1. Researchers per million Inhabitant			**2. R&D personnel per 10000 labor force**
	1981	**1990**	**1995**	**…**
Canada	1573	2301	2719	…
Australia	1661	2408	3185	…
USA	2973	3675	3676	…
Japan	3934	5395	5368	125 (1997)
Germany	1596	3029	2831	116 (1995)
Netherlands	2084	2693	2202	…
Norway	1830	2880	3664	…
Italy	921	1366	1318	…
U.K.	2254	2319	2504	95 (1993)
Russian	…	6697	3503	136 (1996)
Poland	2479	1083	1307	…
Hungary	2081	1694	1027	…
S. Korea	536	1645	2235	63 (1997)
Malaysia	182	88	93	…
Singapore	485	1426	2316	…
China	…	967	895	11 (1998)
India	131	151	149	…

Notes: … data is not available.
The number in the brackets is for the relevant statistical years.
Source: figures in 1 are from UNESCO 1999, China's figures were calculated using data from Statistical Yearbook of China in relevant years. 2 is from http://www.sts.org.cn/stsi_2/stsdata/data2000/debk26.html.

The main problems for China's S&T and R&D development in its pre-reform era were chronic shortage of funds, low average density of technical personnel in the population and labor force, a distorted R&D personnel distribution and a poor linkage between research and production. Thus, China's technological capacity was low, it experienced high technology transfer costs and difficulties in obtaining research results. All these weaknesses seriously hindered China's effort not only in developing domestic technology, but also led to inefficient utilisation of foreign technology. As a result, improved technology contributed very little to China's economic development during the pre-reform era.

Table 4

China's R&D expenditure (by value and as a percentage of GDP)

	R&D expenditure Yuan 100 million	R&D/GDP %
1985	48.1	0.58
1986	51.0	0.54
1987	56.7	0.51
1988	60.1	0.56
1989	112.3	0.70
1990	125.4	0.71
1991	142.3	0.72
1992	169.0	0.70
1993	196.0	0.62
1994	222.2	0.50
1995	348.7	0.60
1996	404.5	0.60
1997	481.5	0.64
1998	551.1	0.69
1999	678.9	0.83
2000	895.7	1.00
2001	1042.5	1.09

Source: Statistical Yearbook of China and Statistical Yearbook of China on Science and Technology.

Table 4 indicates that China's total nominal R&D expenditure increased six fold between 1990 and 2000 and its intensity doubled approximately in relation to its GDP. In total value terms in 1995, it was 5 percent of the level of USA, 6.3 percent of Japan, 16.4 percent of Germany, similar to Netherlands, Canada and S. Korea, double that of Taiwan and 2.5 times that of India. In 1995, Japan had the highest R&D per capita expenditure ($1176), followed by USA ($688), Germany ($651) and West European countries (See Table 5). China's figure was far behind these for developed countries and much lower than that of Asian NICs. No doubt, a fundamental reason for the lack of R&D funding and China's low average income level.

However, in Tables 4 and 5 may underestimate China's S&T and R&D expenditure as they were calculated using exchange rates based on traded commodities. LDCs, especially the previous planned economies such as China, principally traded in primary and low value added products. For LDCs, real purchasing power, parity rates should be larger than figures calculated according to the nominal exchange rates used in Tables 4 & 5. Nevertheless the figures given in the tables do highlight an overall T & D funding gap between the developed and developing countries.

Table 5

International comparison of R&D expenditure per capita in selected countries, 1981-2000 (US $)

	1981	1985	1990	1995	1997	2000
Japan	230	327	715	1176	…	…
USA	317	483	608	688	720	…
Germany	212	241	554	651	592	…
Norway	177	251	409 (1989)	559	…	…
Netherlands	200	203	406	511	…	…
Canada	150	202	308	302	312	…
Singapore	17	…	215	287	…	…
S. Korea	11	35	109	269	…	…
Italy	60	90	262	197	204	…
Hungary	53	49	53	26	…	…
Malaysia	…	12 (1988)	…	12 (1994)	…	…
China	…	3 (1988)	2	3	5	9
India	2	2	3	2	…	…

Note: … data are not available.
Number in the brackets are for the relevant statistics years.
Source: figures were calculated according data from Statistical Yearbook of UNESCO and International Financial Statistics of IMF into relevant years.

3. The Process of Reforming China's S & T System

China's economic reforms started in agriculture, then moved to industry, foreign trade and other areas. Reform in China's science and technology system dates from mid-1980s and includes all aspects of S&T (i.e. institute, management, S&T personnel and funding).

One of China's important reforms of its S&T system was a change in funding procedures so that research and trial production funds were split into three separate categories: applied and basic research, trial production and technological back-up activities. In the first category funds are distributed to research units through contracts. In the second category, funds are distributed directly to end-users, who then contract out trial production projects to units under the relevant industrial ministry and who thus have control over the implementation of the project. The third category funds are used to develop technological standardisation, information services and son and are distributed directly to research units by the relevant industrial departments.

Technology was identified by Chinese policymakers as a key to China's long-term economic, social and cultural development. From the early 1980s, China started to reconstruct its S&T system and began to reform the management of its research sector.

The new S&T development strategy that emerged in early 1981 includes several elements. Conroy (1992, p.78) considered the major element of the change was the insistence on making scientific activity subordinate to production needs. The main guidelines were that S&T should be mainly developed to accelerate economic development; research on production techniques should be strengthened and the production sector should participate more in research and use results more extensively.

In practice, the principal focus is on a few aspects. Subordination of S&T activities to economic needs is clearly the most important. This means, in the first instance, an increased emphasis on production technology and a strengthening of the capacity and mechanisms to transfer S&T results from the formal R&D sectors to production, as well as from military to civilian use, thereby, further diffusing technology. The second element is to adopt and absorb foreign technology aggressively, both for gaining access to advanced technological areas, in which China is currently lagging, and for strengthening domestic capability.

China's R&D reform was initiated to help it transform rapidly from an administrative command economy (with direct and pervasive state intervention) to a market-orientated system. In order to do so effectively, some barriers had to be removed. The Science and Technology Leading Group in the State Council was established in 1983 as an organisation capable of bringing together all major agencies involved in work relevant to S&T development. It was also been given the important task of integrating S&T policies for the civilian and military sectors.

The actual formulation and implementation of S&T policy is the responsibility of the State Science and Technology Commission (SSTC) [1] acting within the guidelines set down by the State Council. Its overall planning and financial support is worked out in co-operation with the State Planning Commission's S&T Bureau which in turn operates jointly with SSTC.

International experience suggests that a modern and efficient S&T and R&D systems should be enterprise dominated rather than government dominated (Figure 1).

[1] SSTC was renamed the Ministry of Science and Technology (MST) in 1994.

The separation of technology generation (mainly by public research institutes) and utilisation (mainly by enterprises) in China has seriously hindered technology transfer, diffusion and spillover, and made transfer costs extremely high. According to Yu's survey (1998, p.202), about 85 percent of all research results have never been utilised by enterprises and only 15 percent have been transferred into production and utilised to any extent; of these, only 5 percent of research results have been successfully commercialised.

Table 6

Comparison of international S&T model 1970 to early-1990s

	Developed countries	Early NICs	China
1. Scientist & engineer	Enterprise dominated	Enterprise dominated	Government dominated
2. Origin of R&D funding	Enterprise dominated	Enterprise dominated	Government dominated
3. Ratio of R&D/GDP	2.7% - 3%	1.8% - 2.0%	0.5% - 1%
4. Ratio of R&D expenditure/sale revenue	Over 3%	Around 3%	less 1%
5. Per scientist & engineer annual research expenditure	$150000	---	$3800
6. Ratio of basic research/applied research/development	1:2:5	1:2:4	1:4:15

Note: Ratio of basic research/applied research/development was calculated according to their value of expenditure.
Source: Yu 1998, p.140. Some data were re-calculated from relevant source material.

To strengthen firms' human resources, the Chinese government has adopted measures to encourage, stimulate and promote the transfer of S&T personnel from research institutes to enterprises. The government also changed the operational function of research, encouraging some institutes to merge with enterprises and to link their work directly with production. Research institutes were required to more actively link their research efforts closer to market requirements and receive feedback from customers enabling them to adjust the direction of their research.

These reforms have resulted in significant changes in the distribution of R&D personnel in China by institutional affiliation. Enterprises' technical human resources were relatively limited in the pre-reform era in terms of quantity and quality, but since the mid-1980s, the pattern has started to change. In 1990, research institutes employed 280 thousand R&D staff accounting for 45.3 percent of national R&D personnel while enterprises employed 154 thousand (24.9 percent of personnel) (Table 6). By 1999, the number of R&D personnel in institutes declined to 234 thousand (28.5 percent of total personnel) while enterprise' S&T personnel doubled to 351 thousands, 42.7 percent of the total. Universities R&D personnel increased slightly but there was little change in percentage terms (Table 7).

Figure 1
R&D scientists & engineers: their distribution pattern by institutions in selected countries 1990

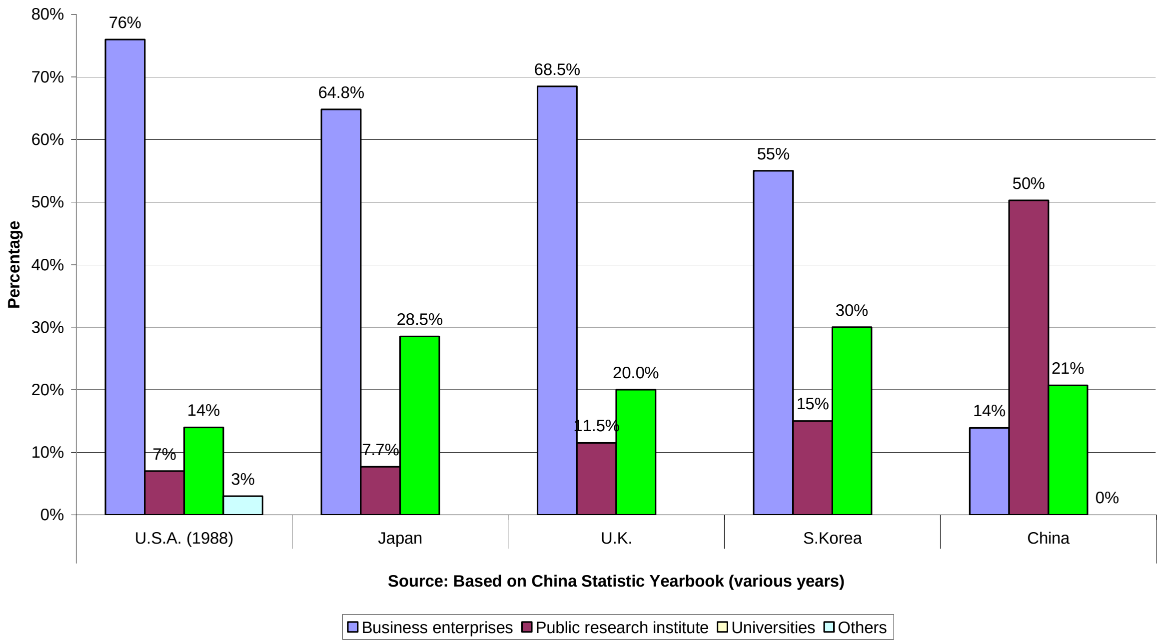


Table 7
Distribution of R&D personnel
in China by institutional affiliation 1990-99

	Research institute	Enterprise	University	Research institute	Enterprise	University
	1000	**1000**	**1000**	**%**	**%**	**%**
1990	280.0	154.0	128.0	45.3	24.9	20.7
1995	206.1	260.2	139.2	31.0	39.1	20.9
1999	234.0	351.0	176.0	28.5	42.7	21.4

Source: Figures were selected and calculated using data from Statistical Yearbook of China and China Science and Technology Indicator.

China's scientist/engineer (S/E) pattern of distribution showed a similar changing trend. The number of enterprise S/E tripled from 56.5 thousand (13.9 percent of total S/E) in 1990 to 171.9 thousand (32.4 percent) in 1999 while the number of institute personnel fell from 205 thousand (50.3 percent) to 166.8 thousand (31.4 percent) (Table 8).

Table 8

Distribution of scientists and engineers engaged in R&D (1990-99) in China by institutional affiliations

	Research institute	Enterprise	University	Research institute	Enterprise	University
	1000	1000	1000	%	%	%
1990	205.0	56.5	118.2	50.3	13.9	29.0
1995	157.8	103.8	132	37.3	24.6	31.2
1999	166.8	171.9	168.4	31.4	32.4	31.7

Source: Figures were selected and calculated using data from Statistical Yearbook of China and China Science and Technology Indicator.

The quality of enterprises' S&T and S/E personnel also improved. Previously the best-qualified S/E were only willing to work in public research institutes because these provided better research facilities, and the government could pay higher salaries and living subsidies than were available working for business enterprises. After China's reforms, funding for institutes was reduced, or disappeared altogether, due to the reduction of government appropriations. Other sources of funds for research institutes also became more limited. At the same time, production, sales revenue and income of business enterprises increased considerably. Enterprises were now willing and able to pay higher salaries and provide research opportunities to R&D personnel and S/E engaged in S&T development of new products, as the market became more technically demanding.

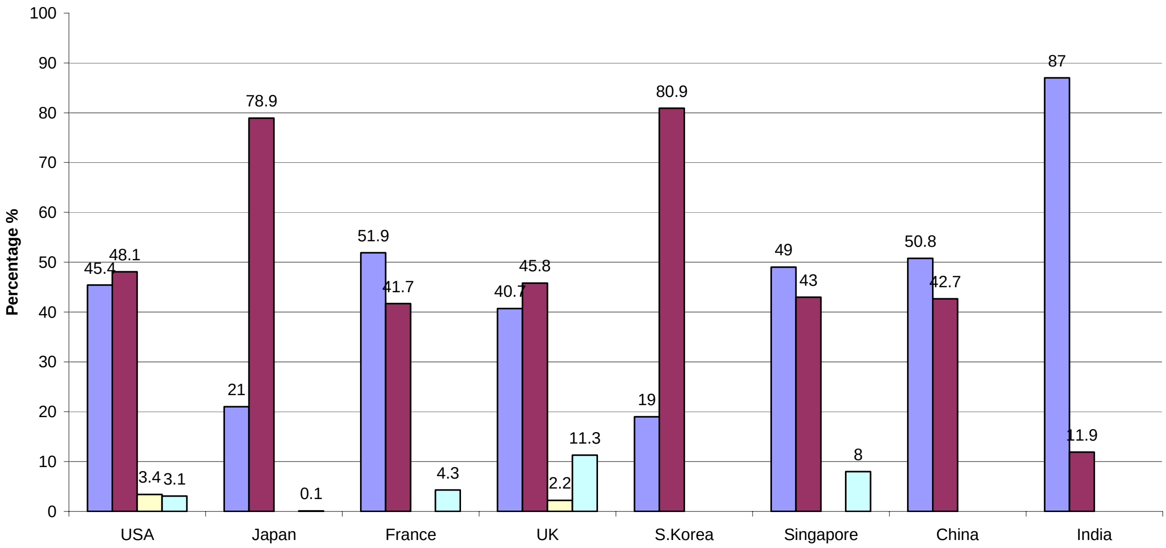
Consequently, increased movement of high quality S&T and S/E personnel into business enterprises occurred. This significantly strengthened China's industrial human technical resources, and has played an important role in generating domestic technology. At the same time, it has also greatly improved the ability of China's businesses to utilise imported technology and has strengthened the international competitiveness of China's businesses.

4. Sources of Funding for China's S&T Research - Changing Patterns and International Comparisons

Policy measures involving deregulation and decentralisation of the economy adopted as part of China's market-oriented reforms have reduced the government's financial resources. Limited government resources now have to be shared between defence, social and public affairs. This partially explains the government's dilemma: emphasis on science and technology is a primary productive force yet fewer public financial resources are available to distribute to this sector.

The funding pattern of science and technology in selected nations shown in Figure 2 for 1985 indicates that in most of the developed countries and in some early NICs most funding for R&D effort was obtained from business by enterprises. In China, contrary to this pattern, the government was the main funding source. Its funding in R&D, especially basic R&D was low, because of the budget constraints that followed deregulation and decentralisation in the reform period.

Figure 2
Sources of R&D funding of selected nations 1985



Source: Based on statistics Yearbook of UNESCO and China Statistics Yearbook

Before China's economic reform commenced, government appropriations, as in other centrally planned economies, provided virtually the entire funding for China's R&D. Under that system, some basic sciences were developed, but the linkage between R&D and its end-users was very weak. Additionally, the transformation rate of R&D results to production was very sluggish and high costs were involved.

The proposals for reform included:

- Diversifying of sources of funding away from sole dependence on the government towards the business sector;
- Undertaking paid commercial research;
- Introducing research performance as a criterion for allocating funds;
- Encouraging borrowing from the banking sector.

The major funding reform regulations were promulgated in early 1986. Funds for post-laboratory development work, the trial production of new products and key research projects were put under the joint management of the Ministry of Finance and the SSTC, and it was stipulated that the rate of increase of these state allocations would be greater than the rate of increase of state revenues. Contracts were now to be drawn up between successful bidders and the department in charge of a project. The banking sector was drawn into the new system for the first time by being given responsibility for supervising fund disbursement and repayment on the completion of projects.

In April 1986, the State Council introduced a policy to promote the new R&D system. It encouraged research units to further develop their academic work and to co-operate closely with other research units, enterprises and institutes. Each research unit now has the right to keep any income earned subject to the requirement of completing any research project required by the state. The units also have been made relatively independent with the authority to choose their own staff and research projects (State Council, 1986).

In recent years, direct funding from government has considerably increased but the ratio to total S&T funds has decreased. Government appropriations fell from 50.8 percent in 1988 to 25.1 percent in 2000 while self-raised funds increased from 42.7 percent in 1989 to 55.7 percent in 2000 (Table 9). Commercial bank loans are still relatively limited. The organisation and operational function of the Chinese banking system is very outdated and does not have an established, effective risk assessment system to appraise R&D borrowers for new products as is the case in many developed economies.

Table 9

Funding for S&T research (100 million Yuan) 1988- 2000, China

	1988	1989	1990	1992	1994	1996	1998	1999	2000
S&T funding	282.5	343.5	403.3	556.1	718.5	1043.2	1289.8	1460.6	2370.0
:Government funds	143.4	114.4	124.1	149.4	204.4	272.0	353.8	473.0	594.8
:Enterprises self-raised funds		146.7	174.4	240.4	288.7	434.2	655.1	745.9	1319.5
: Loans		40.9	49.0	80.7	108.9	149.8	171.0	123.0	194.9
: Other		41.5	55.7	85.1	116.4				
Percentage of S&T funding(%)	100	100	100	100	100	100	100	100	100
:Government funds	50.8	33.3	30.8	26.9	28.5	26.1	27.4	32.4	25.1
:Enterprises self-raised funds		42.7	43.3	43.2	40.2	41.6	50.8	51.1	55.7
: Loans		11.9	12.2	14.5	15.2	14.4	13.3	8.4	8.2
: Other		12.1	13.8	15.3	16.2				

Source: 1988 data from China Statistical Yearbook on Science and Technology 1994, 1989-91 data from China Statistical Yearbook 1992, 1992-94 from China Statistical Yearbook 1995

However, the funding pattern has changed to some extent. S&T non-government funds (self-raised funds + bank loans + others) amounted to 22.9 billion Yuan (49.2 percent) in 1989 and 177.5 billion Yuan (74.9 percent) in 2000 (Table 9).

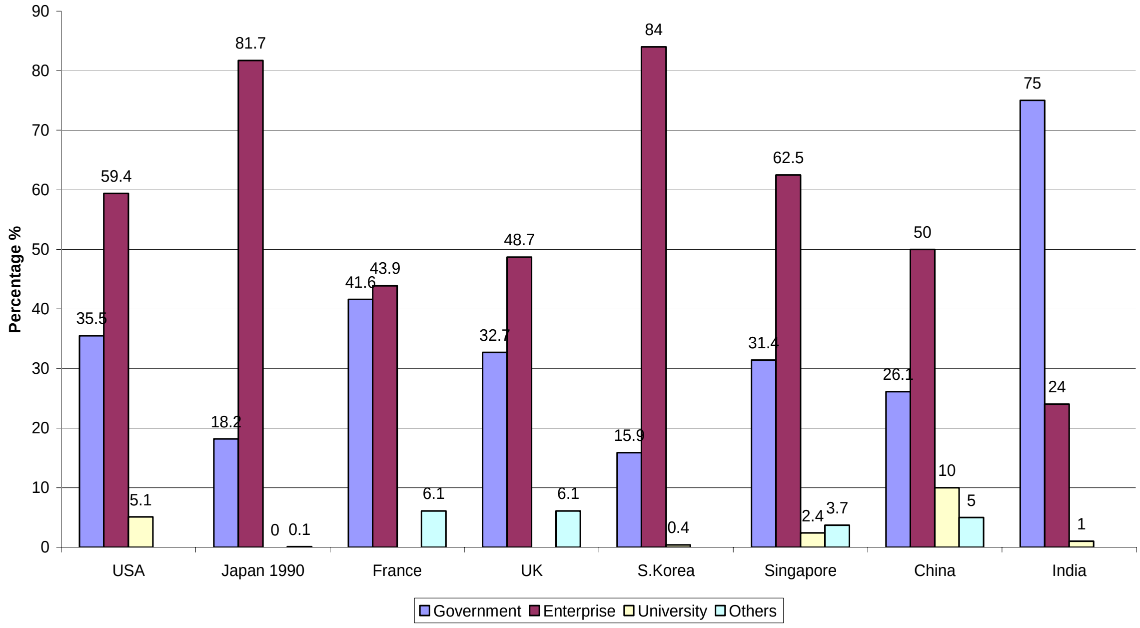
Table 10

Sources of R&D funds by origin for selected nations

	Government				Enterprise				University				Others			
	1980	1985	1990	1996	1980	1985	1990	1996	1980	1985	1990	1996	1980	1985	1990	1996
USA	46.5	45.4	44.8	35.5	46.7	48.1	48.7	59.4	3.5	3.4	3.8	5.1	2.4	3.1	3.5	…
Japan	27.9	21	18.2	…	72	78.9	81.7	…	…	…	…	…	0.1	0.1	0.1	0.1
Canada	38.7	40.5	35.8	30.1	36.6	40.6	41.2	50.7	16	11.8	12.6	8.4	8.7	8.1	9.8	10.8
Germany	…	…	…	36.7	…	…	…	61.4	…	…	…	0.3	…	…	…	1.6
France	…	51.9	48.3	41.6	…	41.8	43.5	48.7	…	0.3	0.7	1.4		5.9	7.5	8.3
Italy	45.3	54	51.5	50.2	52.1	41.7	43.7	43.7					2	4.3	4.8	6.1
U.K.	47.7	40.7	35.8	32.7	42.7	45.8	49.4	51.9	2.6	2.2	3.3	3.7	6.9	11.3	11.5	11.7
Australia	73.9	64.1	55.3	48.1	20.5	31.7	39.6	45.7	2.1	1.9	3.8	4.2	3.5	2.3	1.3	2
Switzerland	23.3	21.9	28.4		76.7	78.1	67.4	…	…	…	…	…	…	…	…	…
S. Korea	49.8	19	15.2	15.9	48.4	80.9	80.6	84	…	…	…	0.4	…	…	…	
Singapore	…	49	38.8	31.4	…	43	59.6	62.5	…	…	1.6	2.4	…	8		3.7
China	…	50.8	33.4	26.1		42.7	43.3	50(98)	…	…	13.8	10	…	…	13.8	5
India	82.7	87	87.4	75	13.4	11.9	12.6	24	…	…	…	1	3.9	…	…	…

Note: China's R&D data were substituted by S&T data as the former are not available.
Sources: figures were selected and calculated using data from Statistics Yearbook of UNESCO in relevant years.

Figure 3
Sources of R&D funding for selected nations, 1996



Some production-related and development-oriented R&D institutes have become increasingly competent in funding much of their own operating expenses and have become almost financially independent. However, those R&D institutes carrying out basic research are, of necessity, are still highly dependent on government assistance. Nevertheless, Chinese government funding of R&D decreased from 50.8 percent in 1985 to 26.1 percent in 1996, as is apparent from a comparison of Figures 2 and 3.

5. China's Evolving Technology Market

Under the pre-reform system, R&D results had no exchange value and were normally transferred from one research unit to another or to the production factory by the relevant administrative bureau at zero cost. Technology was therefore a "free good" or a "public good". Consequently, there was neither incentive for innovation nor efficient transfer or diffusion between research institutes and the R&D users.

Following the support for market directed reforms, there were moves to treat research results as marketable commodities, and the view that the revenue received would be used to provide incentives for further research. The practical steps for this commercial transition in technology started in the mid-1980s and are still ongoing. The establishment of a unified open technology market has been seen as a significant shift in China's S&T system, helping to break vertical and horizontal institutional barriers and accelerate technology transfer and diffusion.

The departments administering S&T activities now have greater responsibilities to see that funds are better used and managed. Various R&D projects are funded in different ways and sources of funding have been expanded. Funds provided for some research projects now require repayment. Attempts have been made to remove the barriers between departments and regions, introduce competition into the research system, and focus funding support on those who can best carry out the required work.

According to available data, China's trade in technology has grown very rapidly since the mid-1980s. In 1985, it accounted for 230 million Yuan increasing to 8146 million Yuan in 1989. There was further expansion in the 1990s. After one and a half decades of development, the value of the annual technology trade reached 65.1 billion Yuan (Table 11) by 2000.

Table 11

Technology trade in domestic market 1991-2000, China

	Number of projects	**Value (Yuan 10000)**	**Value Yuan/Item**
1985	9932	23000	23150
1986	87084	206000	23655
1987	131617	335213	25469
1988	265017	724881	27352
1989	262161	814639	31074
1990	206748	750969	36323
1991	208098	948054	45558
1992	226460	1456182	64302
1993	245967	2075540	84383
1994	222356	2288696	102929
1995	221182	2683445	121323
1996	226962	3002045	132271
1997	250500	3513713	140268
1998	281782	4358227	154667
1999	264523	5234126	197870
2000	241008	6507508	270012
2001	…	7830000	…

Source: Statistical Yearbook of China on Science and Technology in relevant years and some unpublished data from the Information Centre of Ministry of Electronics Industry.

Following expansion of the Chinese technology market, its nature has changed greatly changed, especially in terms of its structure. In the early and middle 1980s, most buyers in this market were small rural enterprises that were not part of the state-owned system and had no way of obtaining “free technology goods”. The major type of trade with those customers involved service arrangements to improve their outmoded production facilities. Most of the projects were small, and involved relatively unsophisticated technologies. About 77 per cent of all contracts were of this type with an average value of less than 20,000 Yuan (Science and Technology Daily, October 24, 1996).

In 2000, technology service was still the main part of the technology trade, but the value per contract had increased to 270012 Yuan (Table 11). Since 1993, large and medium-large enterprises have become the major segment of buyers in the market purchasing 65.6 percent of total traded technology in 1990 and 73.6 percent in 1999 [Table 3.12 (c)]. This demonstrates that technology on offer in the market has become relatively more sophisticated and of higher value. As expected, R&D units are the main suppliers. They had a market share of 37.5 percent by 1996. Technology trade companies are the second main direct sellers they accounted for 20.6 percent of the market in 1990 by value and 25.7 percent in by 1996 [Table 12]. Enterprises themselves have the advantage that the items they transfer are often more mature and appropriate than those developed by research units. They also have a more flexible funding pool than “pure” research institutes. The main purchasers from technology market were industrial firms accounting for 76.1 percent of total transaction value [Table 13]. Table 14 indicates that large and medium sized enterprises dominate purchases of technology by industrial firms and that they are becoming relatively more important as purchasers. A further development has been the gradual evolution of a national information and trading network although this still remains a weak link. Some moves have also been made towards constructing a more effective legislative framework by which trade in technology can further develop.

Table 12

Sellers in domestic technology trade 1990-96; market statistics

	Number of contracts				Value of contract (10000 Yuan)			
	1990		**1996**		**1990**		**1996**	
	Projects No.	**%**	**Projects No.**	**%**	**10000 Yuan**	**%**	**10000 Yuan**	**%**
Research institute	59235	30.9	58935	26.0	268184	36.5	1126799	37.5
University	13475	7.0	23848	10.5	66104	9.0	321591	10.7
Enterprise	31563	16.5	36370	16.0	144279	19.7	442530	14.7
Technology trade company	61841	32.3	81628	36.0	151561	20.6	772656	25.7
Private company	6403	3.3	7656	3.4	13256	1.8	69941	2.3
Others	18923	9.9	18525	8.2	90648	12.3	268525	8.9
Total	191440	100	226962	100	734032	100	3002042	100

Source: Absolute value is from China Statistical Yearbook on Science and Technology in relevant years; Funding percentages were calculated from the same sources. 1999 data from http://www.sts.org.cn/stsi_2nbsjj/DATA99/Abt18_1.hmml.

Table 13

Buyers in China's domestic technology trade

(1991-99, in percentage terms); market statistics

	1991	**1995**	**1999**
	%	**%**	**%**
Research institute	7.6	4.9	…
Government	9.6	9.8	…
Enterprise	63.9	63.3	76.1
Technology trade company	2.8	3.9	…
Private & others	0.5	1.3	…
Total	100	100	100

Source: The figures were calculated using data from China Statistical Yearbook on Science and Technology in relevant years. 1999 data from http://www.sts.org.cn/stsi_2nbsjj/DATA99/Abt18_1.hmml.

Table 14

Industrial buyers in China's domestic technology trade

(1991-99, value & percentages); market statistics

	Number of contract				Value of contract (10000 Yuan)					
	1991		**1996**		**1990**		**1996**		**1999**	
	Projects No.	**%**	**Projects No.**	**%**	**10000 Yuan**	**%**	**10000 Yuan**	**%**	**10000 Yuan**	**%**
Large & medium enterprise	71235	52.2	73997	11.3	326867	65.6	1259850	66.7	1889022	73.6
Small firm	43731	32.0	373565	55.4	129448	26.0	372565	19.7		
Rural firm	21583	15.8	255746	33.4	42296	8.5	255746	13.5		
Total	136549	100	656809	100	498611	100	1888161	100	2493016	100

Source: Absolute value is from China Statistical Yearbook on Science and Technology in various years, The percentages were calculated using absolute value in the table.

6. China's Establishment of a Patent System

Patents are one of the most extensively discussed topics in the theoretical literature on innovation, and opinions differ about the economic benefits of patent systems. According to Beije's (1998, pp.147-64), the patent system provides a valuable compromise between private and public interests in R&D and innovation. From the private point of view, individual firms are stimulated to undertake R&D when the profits from successful innovation projects can be appropriated by them and therefore, should be favorably disposed towards strong protection for intellectual property rights. From technology 'users' or the public's perspective, however, full disclosure and availability of R&D results of all firms is often seen as most desirable (David, 1997, p.25).

In R&D investment, there are two main uncertainties. One is the uncertainty of solving the technological problems faced; the other, is concern with the possibility of imitation by competitors. A patent offers legal protection to an innovator against imitation. A patent therefore, reduces market uncertainty thereby increasing incentives for R&D and innovation firms. As a result, R&D investment may rise. Governments must seek a balance between the stimulating effect on R&D of a temporary monopoly position for the innovating firm and the disadvantage of actually establishing a monopoly for a single firm.

China's centrally planned economic system did not have a patent system. There was a lack of incentive for local innovation. Furthermore, extensive reverse engineering of foreign technology occurred without permission and this caused several technical and legislative problems.

Following market reforms and commercialisation, the Chinese government started to establish a patent system. This has become the cornerstone of science and technology development in China, and has enabled China to participate in the world's intellectual property market.

The promulgation of China's patent law in 1985 was the first step in establishing a legal basis for ownership of intellectual property. This was followed by laws on technology contracts, the first of which came into force in 1987. However, the law was framed in very general terms and did little to clarify the rights and responsibilities of parties to the contract.

Copyright law was also gradually implemented. The process was stimulated by China's application for membership of WTO in the 1990s.

The rapid increase in the number of patents granted reflects the change in policy. In 1985, only 138 patents were granted and of these, just 40 were for inventions, with the balance being for utility/applied and design patents. Patents granted in 1999 totalled 100,156 including 7637 invention patents (Table 15). China ranked 22nd in terms of world invention patents granted by 1998 (Table 16). Given the fact that China's patent system only started in 1985, growth in patenting has been rapid.

China's patent structure is similar to that of other low-income NICs. The percentage of invention patents is relatively small; with the majority being utility model and design patents. This pattern indicates that China's innovative capability (especially in high technology areas) is still limited and its patents mostly relate to the absorption and adaption imported new technology.

Table 15

Patents granted in China by types 1985-99 (Project)

	Total	Inventions [3]		Utility model		Designs	
	Project	Project	%	Project	%	Project	%
1985	138	40	29.0	60	43.5	38	27.5
1986	3024	56	1.9	2530	83.7	438	14.5
1987	6811	422	6.2	5768	84.7	621	9.1
1988	11947	1025	8.6	10191	85.3	731	6.1
1989	17129	2303	13.4	13508	78.9	1318	7.7
1990	22588	3838	17.0	16952	75.0	1798	8.0
1991	24616	4122	16.7	17327	70.4	3167	12.9
1992	31475	3966	12.6	24060	52.8	3449	11.0
1993	62127	3883	6.3	32819	75.8	6595	10.6
1994	43297	3883	9.0	32819	67.8	6595	15.2
1995	45064	3393	7.5	30471	67.6	11200	24.9
1996	43780	2976[3]	6.8	27171	62.1	13633	31.1
1998	67889	4733	7.0	33902	49.9	29254	43.1
1999	100156	7637	7.6	56366	56.3	36151	36.1
2000	105345	12683	12.0	54743	52.0	37919	36.0
2001	114251	16296	14.3	54349	47.6	43596	38.2

Source: Figures were calculated using data from China Statistics Yearbook, Statistical Yearbook of China on Science and Technology and China Science and Technology Indicators in relevant years.

[3] **Inventions** refer to the inventions as specified by the patent law and its detailed rules and regulations for implementation. They refer to the new technical proposals to the products or methods or their modifications. **Utility models** refer to the utility models as specified by the patent law and its detailed rules and regulations for implementation. They refer to the practical and new technical proposal on the shape and structure of the product or the combination of both. **Designs** refer to the designs as specified by the patent law and its detailed rules and regulation for implementation. They refer to the aesthetics and industry applicable new designs for the shape, pattern and color of product, or their combination (China Statistical Yearbook 2000, pp.709-10). Because the data sources in Tables 15 and 16 are different, so there is a slight variance in the figures.

Table 16

Invention patents granted in selected countries, 1998

	China	Japan	USA	Germany	France	UK	Russia	S. Korea	Mexico
Domestic	1655	80292	125704	39500	19271	122068	4838	14497	112
Foreign	3078	67228	15744	16990	32414	34145	38343	10082	3832
Total	4733	147520	141448	52890	51685	46213	43181	24579	3944
Rank	22	1	2	3	4	5	6	8	24

Source: World Intellectual Property Organisation (WIPO), Industry Property Statistics 1998

7. Creating Closer Ties Between Technology Suppliers and Users

In most of the developed economies, continuing innovation is an essential factor in sustained growth at the firm, sectoral and national levels, mechanisms for promoting innovations are well integrated (Pavitt 1984, pp.343-73). Compared to these close and organic relationships, China's technological links between research institutes-firms, universities-firms and firms-firms have been weak and fragmentary. This made domestic and international technology transfer very inefficient in the pre-reform era. Even within the same ministry, traditional vertical transfer results largely depended on top-down administrative apparatus rather than direct interaction between the units concerned.

The Chinese government has introduced a number of measures in an effort to improve links between research and production. These comprise:

1) Promoting co-operation between research institutes and firms that have achieved some success in the past, under special conditions. State plans for developing key products and important technical innovation programs all require intra- or inter-sectoral co-operation between the research and the production units organised by the relevant state organisations. Such co-operation however is mainly encouraged on sectorally important projects involving technology innovation, transfer, utilisation, assimilation and further refinement.

2) Stimulating establishment of closer links between the R&D and production sectors by adoption of the so-called "contract system": The government granted research institutes greater autonomy to encourage them to develop their own research projects and permitted them to keep any profit in order to improve staff welfare and research facilities. While this was a useful way to make the research sector more responsive to technical needs of production, overall the total volume of contract work was relatively small in 1980s, a lot

of it was consulting for small factories and most transferred technology was of a low value, "one-off" nature. However by the 1990s, these types of arrangements grew considerably. The majority of research institutes now depend mainly on funds from their own research projects rather than government finances.

3) Establishing technology alliances such as "research/production combines" (R/P). These combines include objective alliances, organisational alliances and technological alliances. An objective alliance is where a research unit becomes a constituent part of a large corporation to form a research-based production unit. Alternatively a large research institute integrates with an enterprise to form a trial production-research unit. The second organisational type of R/P entity is a research institute with some manufacturing capabilities which develops, produces and markets its own products such as when a R&D unit links up with an engineering company to participate in large civil engineering projects. A technological alliance comprises those research institutes with technology development centres for specific industrial sectors. They focus on supplying technology for small/medium enterprises; or involve several small R&D units merge to form a R&D centre; or where a research unit controls a small production enterprise, concentrate on using its facilities to develop those research results to the commercial stage.

8. An Evaluation of China's Reformed S&T System

Despite the initial progress achieved, problems remain in China's S&T system and some new ones have also emerged.

1) The "contract system" adopted in S&T has led to some negative short-term behavior, for example, an emphasis on cash flow rather than on research or fundamental commercialisation of research results. The pressure on research units to generate their own income has created a tendency to ignore state-assigned projects in favor of independently contracted projects with other companies, especially with private or collective-owned ones (Guongmin Daily, 8th June 1994, p.2). The institutes receive most of their income from sales of their own innovatory new products rather than from the commercial sale of R&D results. The latter is very difficult in China's technology market and domestically generated technology is always underpriced. The economic benefits of many R&D units are in fact linked to production outcomes rather than R&D achievements..

2) Compared to earlier figures (see Table 6), the utilisation ratio of China's research results has improved but external transfer/diffusion is still limited. Results of a sample survey (Table 17) indicates that 51.1 percent of research results (1+3) were self developed, produced and sold or were adopted by the innovators themselves to ensure a temporary monopoly. Joint research and production accounted for 20.1 percent; external transfer 17.1 percent and another external resources 11.7 percent. This suggests that China's environment for external technology diffusion is not favorable and existing transfer mechanisms are also not effective.

Table 17

Structure of obtaining and utilising research results 1997 in innovations

Chinese sample of enterprises

	Number	%
1. Self-developed, produced and sold	1969	30.1
2. External research, self-produced and sold	763	11.7
3. Produced by innovation firm	1372	21.0
4. Develop and utilise by cooperation of institute & firm	1313	20.1
5. External transfer with payment	1118	17.1
6. Total	6535	100
7. Firms having long-term technological co-operation with research institutes	952	14.6

Source: Figures were calculated using data from documents of Ministry of Science and Technology Commission.

3) Some research, especially basic research, appears to have been neglected despite efforts made to encourage it. At a broader level, the measures designed to substitute independently sourced income for state grants, in practice often penalises the more successful research units. In many areas of the economy, "soft budget constraints" still operate in the S&T system. For example the repayment of funds provided through a state organisation via low interest loans is able to be negotiated. Banks are usually mere conduits for funds and the agents for local or central organisations rather than independent parties lending funds through set evaluation procedures.

4) The tendency for research units to become much more involved in their own manufacturing activities has had both positive and negative results. The pressure to become financially independent has led to some units becoming *de facto* production units. This is especially true of income derived from technology transfer. Of the 144 transfer projects surveyed in 1994 (SSTC), transfer fees did not cover research costs in over 50

percent of the cases. This trend may damage the research sectors' R&D capabilities as it has forced the research institutes to operate their own manufacturing facilities. There is, however, an obvious role for them in producing and manufacturing trial products embodying advanced technology.   Research resources tend to become tied to production and research units and, as such, the unit rarely has the capacity to achieve economies of scale. The diffusion of new technology is retarded as research units try to protect their market position and competitive advantage by retaining sole possession of their new technology.

5) There are also continuing problems about the desirable balance between administrative intervention, market forces and the need for further adjustment. In addition, the lack of skilled labor and well regulated capital markets are seen to have a significant constraining effect on the development of the technology market. One problem is that newly developed technology is often "immature", needing further work before the product/process can be put into production. The weak link is seen to be due to a lack of intermediate experimental or pilot plant facilities. Hence, the encouragement for research units to linkup with production units. A second problem is the very uneven distribution of the technology trade throughout the country.   A number of issues relating to production appear to be the major limiting factor in the expansion of commercialised technology trade. Until the late/1980s, China's booming demand for producer and consumer goods reduced pressure on enterprises to develop new products. However, since the early 1990s, competitive pressure has increased and the market has become much more technically demanding.

6) The existing contract S&T system concentrates on the short-term, and desire for quick results. Hence, basic research work also appears to have been hit by funding reforms, despite government commitments to increase investment in basic research as a proportion of total expenditure.

After seventeen years of reform in China's S&T system, some progress has been made. S&T and R&D personnel numbers have increased, a more efficient distribution pattern of resources has emerged, funding sources have diversified, its volume of R&D output has considerably increased and R&D results have been more efficiently utilised. However, China's average R&D outlay from the personnel and financial perspective is still lower than in developed countries, and in the early Asian NICs. In recent years, rapid overall economic growth has been largely due to economic reform, capital accumulation (from domestic saving and foreign borrowing), labor (released form the rural area), inflow of foreign technology with some contribution from indigenous technology.

9. Concluding Comments

China's modern science and technology system was established in the 1950s based on the Soviet model. For a number of reasons, including an inappropriate S&T system and funding shortages, China's S&T and R&D personnel were not efficiently utilised, mainly because of the administrative separation between research and production. Its scientific and technological development was sluggish, its technological capability was limited and China's scientific and technological advance contribution growth in China's economy in the pre-reform era.

China's experience generally confirms that a centrally planned S&T system is less productive in generating, utilising, transferring and diffusing new technology than a market-oriented system. Science and technology systems play an important role in influencing how efficiently a country utilises its scientific resources. Therefore, restructuring the science and technology system is essential in transitional economies if they are to obtain greater economic benefits from the S&T efforts.

China's pre-reform era, all research institutes and most enterprises were not profit-seekers, and resource allocation was under administrative control. Market signals did not play any significant role. China's pattern of science and technology development was incapable of explanation by market pull and technology push theories (see for example, Mowery and Rosenberg, 1979; Von Hippel, 1979; Conroy, 1992; Malecki, 1997) and was largely institutionally determined. However, following the reform, the system has been transformed into a market or partially market-oriented one and some relevant legislation has been enacted to enable this to occur. Therefore, market push and technology pull approaches may become relevant in explaining China's S&T development.

Restructuring the S&T system not only brings about technical change, but also involves a series of systematic institutional changes, including human resource, financial_and social measures. The construction of a more productive social framework for technology innovation and development was shown to be very important as a part of China's economic transition and is necessary for it to support its economic growth. Reforms to China's S&T system have market-oriented, and have been introduced in order to reduce negative effects in the process of transition. Reforms have been gradual so as to maintain necessary social, economic and political stability. They lagged China's initial market reforms and are still continuing.

The reconstruction and reform of China's S&T and R&D systems has improved its domestic technological capability. Even more significantly it has provided a technological platform/framework to stimulate economic growth by more efficiently generating indigenous technology as well as transferring and utilising foreign technology to implement its catch-up strategy. Nevertheless, as observed, the current system is far from perfect.

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