

OECD Reviews of Innovation Policy

CHINA

Synthesis Report



ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
in collaboration with
THE MINISTRY OF SCIENCE AND TECHNOLOGY, CHINA

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 30 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

Foreword

This synthesis report (August 2007 Beijing Conference version) summarises the main findings of the OECD review of the Chinese national innovation system (NIS) and policy. The review was requested by the Chinese authorities, represented by the Ministry of Science and Technology (MOST), and was carried out as a joint OECD-MOST project under the auspices of the OECD Committee for Scientific and Technological Policy (CSTP), as part of its new programme of country reviews of innovation policy.*

The review process involved several fact-finding missions to China by the OECD Secretariat and representatives from OECD member countries and an international workshop on indicators for measuring science, technology and innovation (held in Chongqing in October 2006), all organised with the generous support of MOST. It has benefited from the contributions of a number of experts from China and OECD countries (see the Acknowledgements below). A workshop on the international aspects of the Chinese NIS was also held in Paris in September 2006 in consultation with the Business and Industry Advisory Committee (BIAC) to the OECD.

This document has four parts:

- Part I highlights the role of science, technology and innovation in the context of China's need to shift from a sustained to a sustainable growth mode, and the importance of broad-based framework conditions for innovation for building an efficient market-based innovation system.
- Part II assesses the pace of development and analyses the main features of China's national innovation system, focusing on the key performers of R&D and innovation activities, namely, the business sector, the public research institutes and the universities, and the science-industry interface.
- Part III analyses China's policy for promoting science, technology and innovation, including the public governance of its innovation system.
- The final section offers some concluding remarks and provides policy recommendations.

Following the conference in Beijing in August, this version of the synthesis report will be revised – taking into account the results of the discussions - and published by the OECD as part of the full report on the detailed results of the review, including thematic chapters, annexes as well as full references.

* The other countries reviewed to date are Chile, Luxembourg, New Zealand, South Africa and Switzerland. The reviews of Greece, Hungary, Korea, Mexico, Norway, Russia and Turkey are under way and it is planned to launch a number of others in 2008.

Acknowledgements

This synthesis report (conference version) was prepared by the OECD Secretariat on the basis of a preliminary version of the full report on the detailed results of the review of the Chinese national innovation system (NIS) and policy.

This review was carried out in close partnership between the OECD Secretariat and the Chinese Ministry of Science and Technology (MOST). It has benefited from the contributions of a number of experts mobilised by MOST and the following OECD member countries: Australia, Austria, Finland, France, Germany, Japan, Korea, Norway, Sweden, and the United States. It has also been supported financially by the New Energy and Industrial Technology Organisation (NEDO) of Japan and the National Science Foundation (NSF) of the United States.

The overall co-ordination of the project was ensured by Jing Su and Jianing Cai (MOST) on the Chinese side, and by Jean Guinet, assisted by Gang Zhang and Gernot Hutschenreiter (OECD Directorate for Science, Technology and Industry) on the OECD side, with Fiona Legg providing administrative and organisational support and Shuxian Liu, Xiaodong Tang and Lin Wu providing research assistance. Joseph Loux provided assistance in preparing the report for publication.

The Chinese expert team was co-ordinated by Lan Xue; Gang Zhang co-ordinated the inputs of experts from OECD member countries. The work of the experts was organised in four modules: Policy and Institutional Analysis; Globalisation of R&D; Human Resources for Science and Technology; and Science and Technology Indicators.

The work undertaken under the Policy and Institutional Analysis module was co-ordinated by Xielin Liu, Graduate School of Chinese Academy of Sciences, on the Chinese side, and by Svend Otto Remøe, OECD consultant, Norway, on the OECD side.

Background papers on the performance of the Chinese NIS and on policy instruments and the governance of the Chinese NIS were prepared by: Svend Otto Remøe; Xielin Liu; Sylvia Schwaag Serger, Institute for Growth Policy Research, Sweden; Mireille Matt, Laurent Bach, and Patrick Llerena, Bureau d'économie théorique et appliquée (BETA), Université Louis Pasteur, France, and Mingfeng Tang, Chongqing Jiaotong University, China (contributed as a member of the French team); Jakob Edler, formerly Fraunhofer Institute for Systems and Innovation (ISI), Germany, and presently Manchester Institute of Innovation Research, University of Manchester, United Kingdom; Li Liu, Tsinghua University, China (contributed as a member of the ISI project team). Substantive inputs were also provided by Lin Chen, Tsinghua University, China; Can Huang, UN University-Merit, the Netherlands; and Rainer Frietsch and Jue Wang, ISI, Germany.

Irène Hors, Karen Maguire and Guang Yang under the guidance of Andrew Davies, all in the OECD Directorate for Public Governance and Territorial Development, prepared the background paper on regional dimensions of the NIS and Sung-Bum Hong, Science and Technology Policy Institute (STEPI), Korea and Deok-Soon Yim, formerly STEPI and currently Daedeok Innopolis, Korea, contributed a case study on the regional innovation system.

The work undertaken under the Globalisation of R&D module was co-ordinated by Lan Xue, China Institute of Science and Technology Policy (CISTP) and Tsinghua University, on the Chinese side, and by Heikki Kotilainen, consultant of the Ministry of Trade and Industry, Finland, on the OECD side.

The main contributors were Nannan Lundin, OECD consultant and Research Institute for Industrial Economies (IFN), Sweden; Sylvia Schwaag Serger; as well as Lan Xue, and Zheng Liang, CISTP and Tsinghua University, China. Substantive inputs were also provided by Martin Berger, Institute of Technology and Regional Policy of Joanneum Research, Austria; Jakob Edler; Li Liu; and Deok-Soon Yim.

Work undertaken under the Human Resources for Science and Technology module was coordinated by Rongping Mu, Chinese Academy of Sciences, on the Chinese side; and by Gang Zhang, on the OECD side.

Main contributors were Mu Rongping and Ester Basri, OECD Secretariat.

Work undertaken under the Science and Technology Indicators module was co-ordinated by Changlin Gao, National Research Center for S&T for Development, China, on the Chinese side, and by Rolf Lehming, National Science Foundation, United States, and Kazuyuki Motohashi, University of Tokyo, Japan, on the OECD side.

Main contributors were Nannan Lundin, Changlin Gao, and Martin Schaaper, OECD Secretariat, with substantive inputs provided by Rainer Frietsch and Jue Wang.

All contributions and support, financial and in kind, are gratefully acknowledged.

Table of Contents

Foreword	3
Acknowledgements	5
Part I. From Sustained to Sustainable Development: The Role of Innovation	9
The Chinese model of growth – successes and challenges	15
The role of science, technology and innovation policy	16
Framework conditions for innovation – large scope for improvement	17
Education	17
Competition	17
Corporate governance	17
Financing innovation	18
Intellectual property rights protection	19
Technological standards	20
Public procurement	20
Part II. China's Innovation System: Main Features and Performance	21
Benchmarking the size, growth and potential of China's innovation system	23
Human resources for science and technology	27
Main actors in the innovation system	29
Interaction within the innovation system	41
Part III. Promoting Innovation: The Role of Policy and Governance	43
Introduction	43
The evolution of post-reform S&T policy	44
The current focus of China's S&T policy	48
Governance of the S&T and innovation system	49
Governance at the central level	49
The central-local government dimensions of the innovation governance system	50
Chinese S&T policies – a policy mix perspective	51
R&D programmes - the single most important policy instrument	53
Strengths and achievements	53
Shortcomings of the current programmes	56
Main issues and challenges in the governance of the innovation system – hindrances in the learning process	56
Evidence-based policy analysis	57
Defining policy strategy and priorities	57
Designing policy instruments	58
Implementing instruments	58
Evaluation	58
Conclusions and Recommendations	59
Achievements and challenges	59
China's integration in the global innovation system: towards a positive sum game	60
Guiding principles and strategic tasks	61
Specific recommendations	62
Adjusting the role of the government	62
Improving the framework conditions for innovation	62
Sustaining growth of human resources for science and technology	63
Improving governance of science and innovation policy	63
Adjusting the set of policy instruments	64
Ensuring adequate support for public R&D	64
Strengthening the linkages between industry and science	65
Abbreviations	67

Part I

From Sustained to Sustainable Development: The Role of Innovation

China has maintained very rapid economic growth and development over several decades, but it now faces the challenge of ensuring that further progress – economic, social and environmental – will be both sustainable and comprehensive. This will require fostering innovation, which can play a major role in achieving that goal.

Economic reforms, including the launch of the “open door” policy, prepared the ground for the Chinese economy’s nearly three decades of extraordinary performance. China’s re-emergence as a major power in the world economy is one of the most significant developments in modern history.

- Over the past 15 years the Chinese economy has expanded by an average of around 10% a year (Figure 1.1), and its macroeconomic performance remains strong (Table 1.1). Today, China is the world’s fourth largest economy. It is home to about one-fifth of the world’s population and is regaining its former historic place in the world economy.
- Economic growth has led to a significant increase in income per capita, and an impressive reduction in poverty levels has given large numbers of people the opportunity to escape extreme poverty. Nonetheless, compared to the OECD average, China’s GDP per capita is still low.
- China is now a major destination for foreign direct investment (FDI). Inflows of FDI expanded very rapidly in the 1990s and increased again after the end of the Asian financial crisis (Figure 1.2). Today, China’s inward FDI stock relative to GDP is considerably larger than that of Korea and particularly of Japan and is comparable to that of Canada and the United Kingdom. Outward FDI stocks are still low but are beginning to pick up (Figure 1.3).
- China has become a trading nation of global standing and is on its way, if current trends continue, to becoming the world’s largest exporter.

Over the past two decades, output growth has largely been driven by capital accumulation (Table 1.2). Total factor productivity growth, which measures improvements in the overall efficiency of the utilisation of labour and capital, has been high by international standards. The increasing average level of education and the resulting higher quality of the labour force have also boosted output growth.

Structural change in the Chinese economy is broadly characterised by a shift from agriculture to services, with shares that are still significantly larger and smaller, respectively, than those of OECD countries. Unlike some developing countries, including some emerging economies, China has not started to de-industrialise but has strengthened its manufacturing base.

China has relied heavily on technology imported from abroad, and the development of its scientific and technological capability has until recently lagged behind its economic growth. This trend was reversed towards the end of the last decade and since then significant progress has been made towards developing the country’s innovative capabilities.

Table 1.1 China: Macroeconomic indicators

	2004	2005	2006	2007	2008
Real GDP growth	10.1	10.4	10.7	10.4	10.4
Inflation*	6.9	3.8	2.8	2.5	2.5
Consumer price index**	3.9	1.8	1.6	1.8	1.5
Fiscal balance (% of GDP)	0.0	0.2	1.0	2.0	1.8
Current account balance (% of GDP)	3.6	7.2	9.5	10.2	10.6

* Percentage change in GDP deflator from previous period.

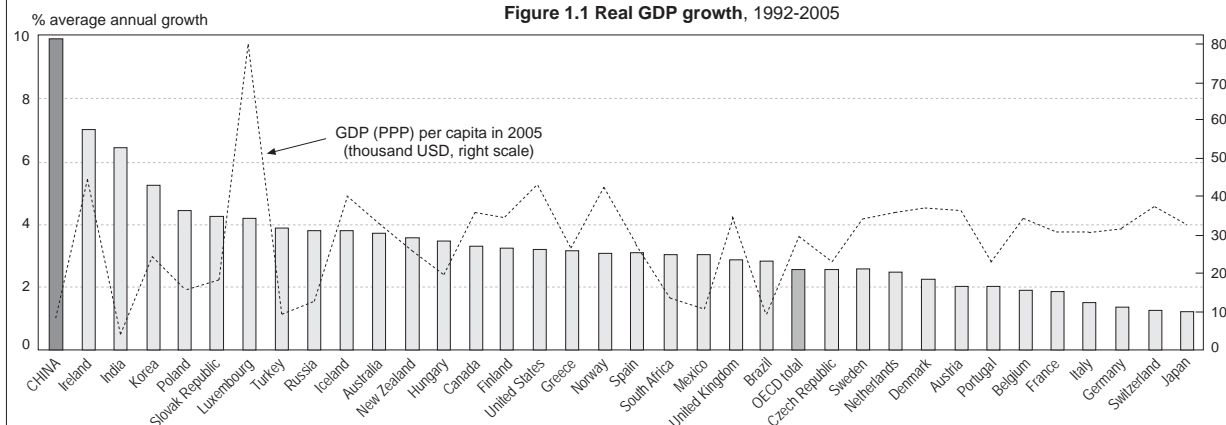
** Changes in Laspeyres fixed base year index (base year 2005).

Source: National sources and OECD projections.

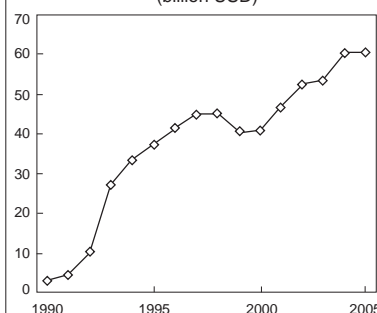
Table 1.2 China: Sources of output growth

	1983-88	1988-93	1993-98	1998-03	2003	1993 to 2003 relative to 1985 to 1993
Output growth	12.1	8.9	9.8	8.0	9.1	-1.5
Employment contribution	1.5	1.0	0.3	0.3	0.4	-0.9
Capital contribution	5.0	4.5	5.5	4.9	5.5	0.4
Residual factors	5.6	3.4	4.1	2.8	3.1	-1.0
<i>Sectoral change</i>	2.2	0.8	-0.3	0.5	0.7	-1.4
Education	1.0	0.9	0.9	1.1	0.8	0.0
Multi factor productivity	2.4	1.7	3.4	1.3	1.6	0.3

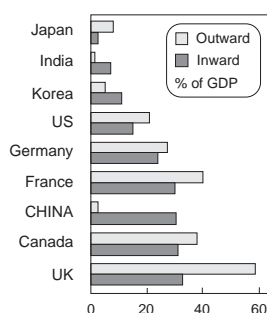
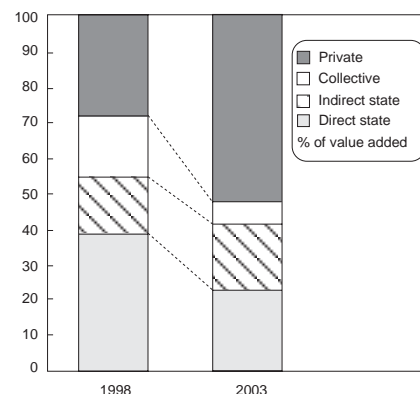
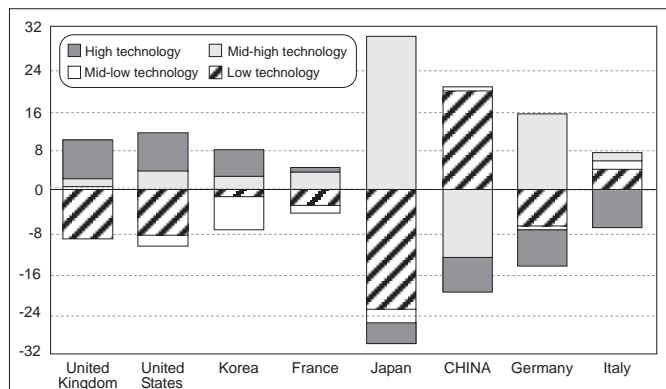
Source: OECD Economic Survey of China 2005.

Figure 1.1 Real GDP growth, 1992-2005

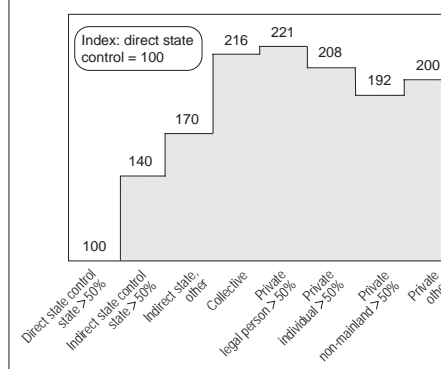
Source: OECD, IMF.

Figure 1.2 FDI flows to China (billion USD)

Source: MOFCOM FDI statistics; OECD.

Figure 1.3 FDI stocks in selected countries**Figure 1.4 The expansion of the Chinese private sector****Figure 1.6 China remains specialised in low-tech**
Contributions of industries to trade balance as % of manufacturing trade by technological intensity, 2005

Source: F. Sachwald (2006) based on data from SYSPROD-IFRI.

Figure 1.5 Relative levels of productivity depending on ownership

Source: OECD Economic Survey of China 2005.

Growth has been underpinned by economic reform...

Underlying China's economic growth has been a fundamental and ongoing reform of the entire economic system. Beginning with agriculture, the reform process was subsequently extended to industry and more recently to major parts of the services sector. Economic reform has contributed to far-reaching deregulation and the creation of new framework conditions which have helped to improve the functioning of markets and to create a unified domestic market. These changes, induced by economic policy decisions, have gradually transformed China into a more market-based economy and provided the basis for the emergence of a thriving private sector. New actors have been allowed to emerge alongside the state-owned enterprises (SOEs), further expanding the space for private firms.

Reforms directed at the state-owned enterprises aim to transform them into modern, market-oriented corporate entities, a process that is ongoing. Structural change in terms of ownership has been particularly pronounced in the industrial sector where – according to an OECD analysis – the private sector already accounted in 2003 for considerably more than half of value added (Figure 1.4). Rates of return on investment have also increased significantly since the 1990s. However, SOEs still record much lower levels of productivity than other firms (Figure 1.5), often appear to be less efficient knowledge producers and often lack the basis for R&D.

...as well as by international openness to foreign trade and investment

China's "open door" policy has been an integral part of economic reform. Adopted in 1978, it has resulted in a progressive opening to foreign trade and investment and culminated in China's accession to the World Trade Organization (WTO) in 2001. Through its acceptance of globalisation, China has become the most open of the large developing economies. In some respects, China today is more open than a number of significantly more developed market-based economies.

Along with China's opening to foreign trade, the increasing role of market forces and large inflows of foreign direct investment have facilitated the country's integration into the global economy and played an important role in the economic development of recent decades:

- Overall, openness has helped China make better use of its comparative advantages and become a major trading nation.
- Openness to international trade and FDI has allowed China to become a major export platform for multinational enterprises, in particular for manufactured goods ("workshop of the world"), but increasingly also for other activities.
- Openness has generally led to greater competition in product markets and increasingly in markets for services. More vigorous competition exerts discipline on Chinese firms, helping to lower prices and ensure better quality and variety of goods. It therefore tends to strengthen incentives for innovation in the Chinese economy.
- While the foreign-invested sector of the economy is relatively small in terms of its share in total employment, its labour productivity is high. As a consequence, it makes a large contribution to aggregate output, accounting for more than half of China's exports. Foreign-invested enterprises therefore contribute significantly to China's economic growth.
- FDI has provided access to technology, know-how and skills, although recent perceptions within China tend to see its impact as lower than expected.

Owing to differences in initial conditions – among others, the legacy of a planned economy, the absence of a suitable financial system and inadequate access to distribution networks – China did not replicate the strategies adopted earlier by countries such as Japan and Korea, but instead made international openness a cornerstone of its development strategy. China's opening to foreign investment was not motivated by a shortfall of domestic savings; rather, through the concept of a “market for technology”, FDI, foreign trade and technology transfer were expected to contribute to the modernisation of the economy.

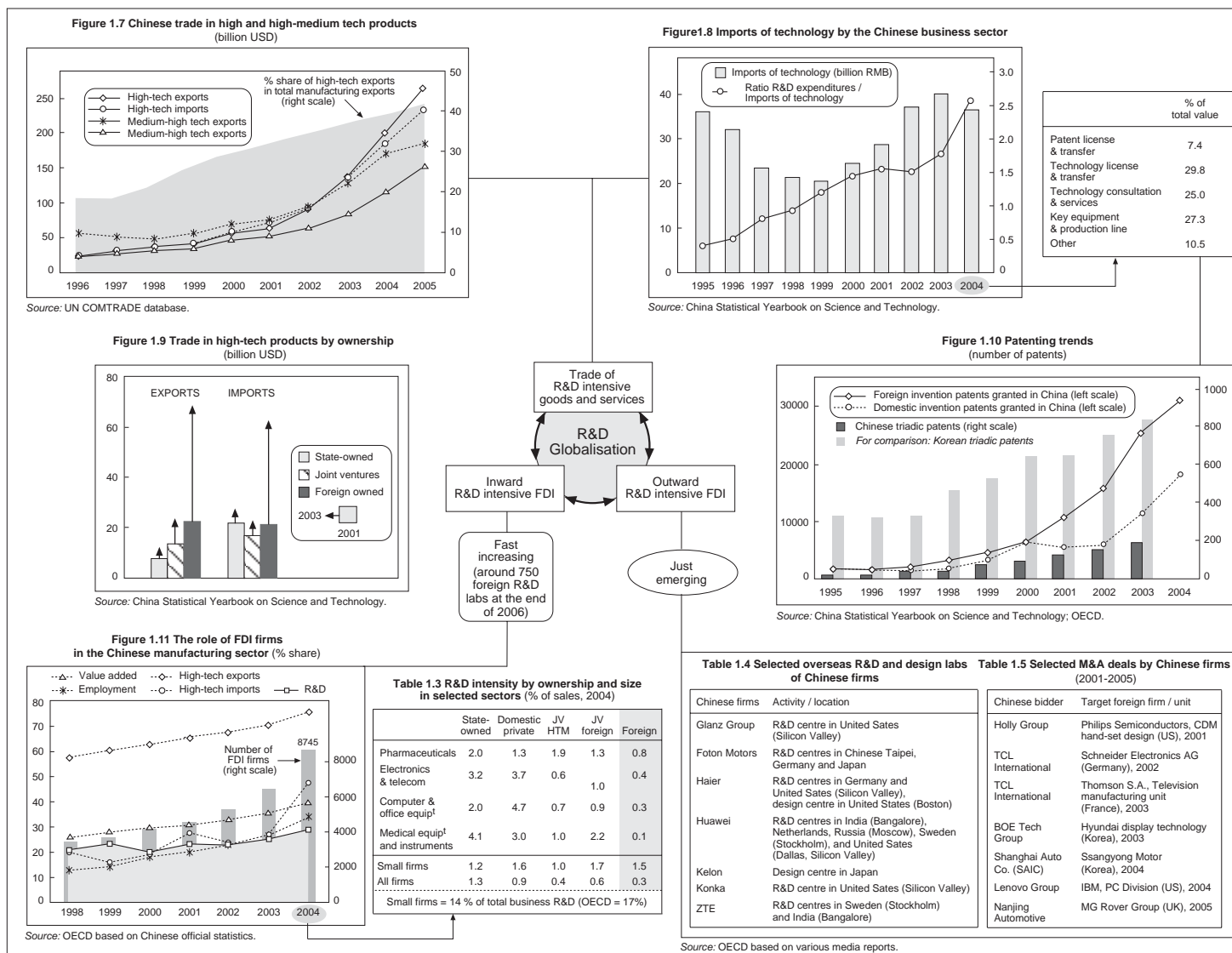
Technological knowledge can be transferred via imports of intermediate and capital goods. FDI projects and the operations of foreign-invested firms have also helped to improve China's access to advanced technologies, to management practices and to a wide range of skills. Foreign-invested firms have therefore served as a major channel of technology imports. At the same time, they have located aspects of an increasingly fragmented manufacturing process in China, but have performed little technological innovation or product design in the country. Core technologies mostly remain controlled by the foreign partners in joint ventures or by company headquarters abroad. Generally speaking, foreign-invested companies are less R&D-intensive than domestic firms, although this is not specific to China. There is quite a pronounced differential in R&D intensities in the Computer and office equipment and Electronics and telecommunication industries (Table 1.3 in Box 1.1). Overall, this has contributed to a perception that technology transfer to China and related spillovers to the domestic economy have not met expectations. Current patterns of specialisation, a lack of absorptive capacities in Chinese firms and shortcomings in framework conditions, such as a lack of effective intellectual property rights (IPR) protection may have limited the amount of spillovers. Improvements in these areas would allow China to better benefit from international technology flows. For more detailed analysis on this issue, see Part II.

Are China's exports high-technology or not?

China's international trade has expanded rapidly over the past decades and has been particularly dynamic in recent years. Today, China is one of the world's three leading trading nations and may well become the world's largest exporter in the near future.

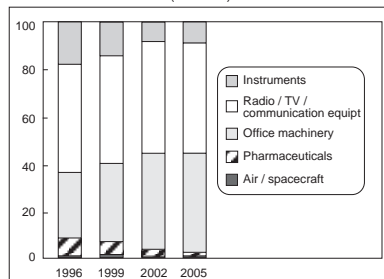
- China has greatly increased its market share in leading markets and exports a wide variety of goods.
- The structure of exports has changed fundamentally over the past 20 years. Today, the composition of China's exports resembles that of countries with a significantly higher GDP per capita and is more “sophisticated” than that of countries with similar endowments.
- In recent years, there has been a spectacular rise in China's high-technology exports. Their share in total exports increased from 5% in the early 1990s to over 30% in 2005 (Figure 1.14 in Box 1.2). These exports are heavily concentrated in two product categories: Office machinery and TV, radio and communication equipment; high-technology exports such as pharmaceuticals are relatively weak (Figure 1.12 in Box 1.2). As of 2004 China is the world's largest exporter of ICT goods (Figure 1.13 in Box 1.2).

Box 1.1 China and the globalisation of R&D



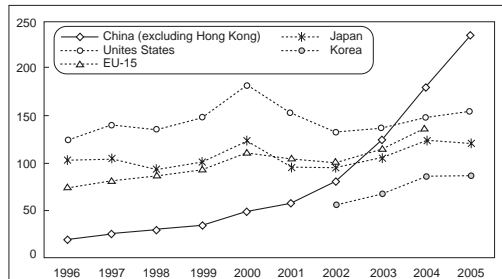
Box 1.2 Chinese high-tech exports

Figure 1.12 Electronic products and communication equipment dominate Chinese high-tech exports (% share)



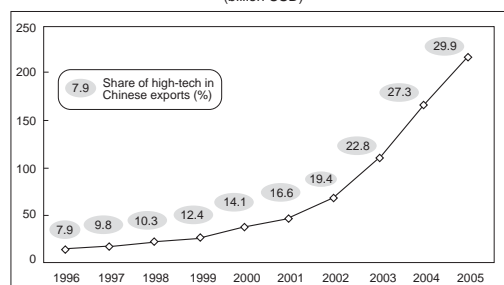
Source: MOST.

Figure 1.13 China is now the leading exporter of ICT (billion USD)



Source: OECD.

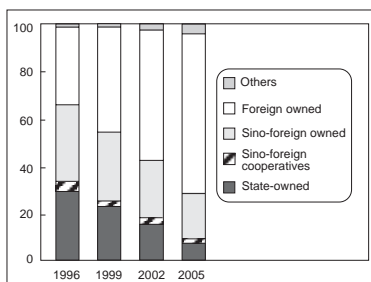
Figure 1.14 The surge of Chinese high-tech exports (billion USD)



Source: MOST.

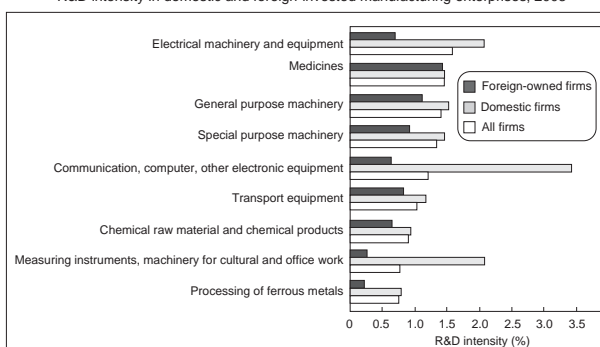
Figure 1.15 Foreign-owned firms are the dominant and increasing source of high-tech exports but are generally less R&D intensive than domestic ones

Chinese high-tech exports by ownership (%), 2003



Source: MOST.

R&D intensity in domestic and foreign-invested manufacturing enterprises, 2003



Source: China Statistical Yearbook on Science and Technology.

Nevertheless the positive contribution to the manufacturing trade balance overwhelmingly comes from low-technology exports (Figure 1.6). Moreover, China's position as a major exporter of high-technology products needs to be qualified:

- These exports mainly originate from foreign-owned enterprises (joint ventures and wholly foreign-owned firms, including those controlled from Hong Kong, China; Macau, China; and Chinese Taipei), which account for 88% (Figure 1.15 in Box 1.2). Wholly foreign-owned enterprises have significantly increased their share in high-technology exports during the past decade, while that of joint ventures and especially SOEs has decreased. They also account for most of the imports of high-technology products (Figure 1.9 in Box 1.1).
- High-technology industries, notably Information and Communication Technology (ICT)-related manufacturing, are primarily under foreign control, while traditional industries such as textiles and garments are largely domestically owned.
- High-technology industries are considerably less R&D-intensive in China than in advanced OECD countries. Industries in this category typically produce high-volume goods, often by assembling imported components. The share of value added in this activity tends to be relatively low. Imports of high-technology products, including components such as semiconductors and microprocessors, have risen rapidly in the present decade (Figure 1.7 in Box 1.1).
- Across all industries, exports from the OECD area sell for significantly higher prices per unit than Chinese exports. OECD machinery sells at prices that are, on average, nearly ten times those of Chinese machinery.

The Chinese model of growth – successes and challenges

The Chinese model of growth has produced impressive results in a very short time, yet China's income per capita remains low. Further improving the population's living standards will require high and sustainable economic growth. However, despite its recent success, the current pattern of growth may not be sustainable. Major challenges include:

- China's GDP is unevenly distributed, particularly between the wealthier coastal provinces and the less developed western parts of the country; in fact, income disparities between urban and rural areas have increased. In a number of rural areas, poverty remains a serious challenge.
- China is undergoing a fundamental demographic change, owing to a rapidly ageing population. It may be difficult to maintain its current high savings rate as the population ages, and indeed – in contrast to the developed world – China might be ageing before getting rich.
- China's export growth has been largely based on the expansion of low-wage manufacturing utilising imported components, equipment and technology.
- Large migration flows have contributed to rapid urbanisation and exert pressure on the social fabric and the environment.
- China's economic growth has induced high demand for energy and raw materials. Moreover, rapid economic growth, industrialisation and urbanisation are leading to environmental degradation and damaging the population's health. Ecological challenges may eventually limit China's further economic development.

The Chinese authorities are well aware of these challenges and – through concepts such as the “harmonious society” – have taken steps to achieve a more balanced pattern of development. Science, technology and innovation can contribute significantly to this objective.

China is already pursuing ways to shift to a growth path that is less dependent on low-skill, resource-intensive manufacturing. Human capital formation and the encouragement of capabilities in science, technology and innovation play a key role as potential engines of future growth. Accordingly, China appears committed to extending its present comparative advantages through accelerated formation of human capital and increased investment in science, technology and innovation.

To date, China has largely relied on the supply of foreign technology. However, it is now boosting investment in science and technology and has taken steps towards building a high-performing “enterprise-based innovation system”. While most Chinese enterprises are still far from being innovation leaders, some are developing their innovative capabilities and introducing global Chinese brands. The ratio of R&D to imports of technology has increased considerably over the past decade (Figure 1.8 in Box 1.1). Chinese enterprises have started to engage in mergers and acquisitions and are attempting to gain access to knowledge through overseas R&D and design labs (Tables 1.4 and 1.5 in Box 1.1).

The role of science, technology and innovation policy

In OECD member countries, including the most advanced among them, government policies play a significant role in fostering science, technology and innovation. Government tasks include:

- Setting framework conditions that are conducive to innovation. Some, such as well-functioning markets, sound corporate governance and financial institutions, may not be specifically aimed at fostering innovation but may have a significant impact. Others, such as the legal protection of intellectual property rights and the setting of technological standards, may have a more direct effect on innovation.
- Developing and implementing policies to encourage science, technology and innovation in the presence of market or systemic failures, such as provision of financial support for R&D.

In the Chinese context, the government’s role is augmented owing to the economy’s:

- Greater proclivity to market failure (*e.g.* in the financing of innovative business firms and projects in the small and medium-sized enterprise [SME] sector) than in more mature market economies.
- Wider disparities than in more developed countries between regions, between modern and more traditional sectors and between types of firm ownership (*e.g.* productivity is lower in SOEs – see Figure 1.5 – which also often lack innovative capacities).
- Distortions of incentives for research and innovation in the business sector (owing, for example, to decision-making mechanisms in the current corporate governance setting, see below) and, to some extent, in the public research system.
- Remaining uncertainties in the business environment regarding the interpretation and enforcement of legislation (*e.g.* in the area of IPR protection).
- The institutional architecture of a national innovation system that still requires adaptation to the requirements of a market-based, innovative economy.

- Insufficient interaction among actors (*e.g.* between business enterprises and public research organisations).
- Insufficient co-ordination in the national innovation system, with too little interaction between various parts and layers of government (*e.g.* between central and sub-national levels).
- A shortage of complementary assets (*e.g.* advanced specialised infrastructure) in certain areas of science and technology, notably in the area of the provision of public goods.

Recent policy initiatives show the government's determination to step up investment in science and technology and build a full-fledged, high-performing national innovation system. The 2006 "Medium- to Long-Term Strategic Plan for the Development of Science and Technology" (also referred to as "the S&T Strategic Plan 2006-2020" in this report) sets out the key objectives and priorities in science and technology. The overarching goal is to make China an "innovation-oriented" society by the year 2020 and – over the longer term – one of the world's leading "innovation economies". It emphasises the need to develop capabilities for "indigenous" or "home-grown innovation".

Given the dynamism of China's economic development and the government's commitment to its strategic orientation it seems likely that China will make progress in developing its own innovative capabilities. This would allow China to emerge in time as a significant contributor to global innovation and to benefit better from international technology flows.

The following section briefly describes China's current situation in terms of the framework conditions that, on the basis of OECD countries' experience, have the strongest impact on innovation. Part II then analyses the current weaknesses of the national innovation system, and Part III shows how the Chinese government is addressing these weaknesses and accelerating progress through specific S&T and innovation policies.

Framework conditions for innovation – large scope for improvement

Education

The Chinese education system is oriented towards passive learning and exam-based performance. Apart from supplying the required skills, China's education system needs to give more attention to fostering students' innovative thinking, creativity and entrepreneurship.

Competition

Product market competition is an important stimulus for innovation. In China, various market imperfections still distort competition: administrative interventions interfere with the normal functioning of markets, and improper or even illegal conduct as well as some degree of local protectionism hamper or distort competition. Market institutions also remain underdeveloped and inadequate. As a consequence innovative activity may not be adequately rewarded. The transition to more innovation-driven growth based on stronger intellectual property rights also requires a modern, properly enforced anti-trust law.

Corporate governance

Raising the innovation capability and performance of the Chinese business sector is a core element of China's strategy. This is a difficult task given that most Chinese firms are unfamiliar with innovation activity. Corporate governance, which shapes the incentives of business executives and thus decision making within firms, has a significant impact on innovation performance in the business sector.

- The corporate governance, especially of SOEs, may give management insufficient incentive to undertake long-term, risky investment in R&D. A severe lack of competent professionals with experience in managing R&D projects creates an added disincentive.
- A top-down approach, by which authorities instruct SOEs to invest in R&D and innovation, is unlikely to produce the desired outcome. Instead, this may result in investment in R&D activities that are inefficient and only weakly related to demand. There is some evidence that SOEs are not very efficient producers and users of knowledge.
- Government policies focused on SOEs may have crowded out support to non-state-owned companies.
- As new enterprises have emerged alongside SOEs and the latter are restructured with a view to making them more market-oriented, incentives to invest in R&D and innovation will become more closely attuned to market signals.
- As the economy becomes more market-based, a modern system of R&D funding, which can address market failures when they occur, needs to be put in place to provide additional incentives for business sector investment in R&D.

Financing innovation

China's financial system is dominated by large state-owned banks. Their business largely consists of giving loans to large SOEs. As many of these SOEs have been operating at a loss, large amounts of non-performing "bad" loans have accumulated. The two most urgent tasks for China's financial system are to reduce the level of non-performing loans and to reform the governance of China's banking system in order to avoid the accumulation of new bad debt in the future.

The conditions for achieving this goal are improving with the ongoing reform of the SOEs, the gradual opening up of China's banking system to foreign competition in connection with the country's accession to the WTO, and measures to improve the governance and professional supervision of the banking system.

Some important constraints on China's financial system affect innovative activity in the business enterprise sector:

- China's financial system does not meet the funding needs of private firms, notably SMEs. The capital market is underdeveloped and SMEs find it difficult to secure loans since banks favour large companies, particularly SOEs. Smaller, privately owned firms thus largely depend on self-funding. Recent initiatives to address this issue propose funding mechanisms to support science and technology and innovation activities.
- There is a severe lack of capital for financing new ventures, which are one important source of innovation. China lacks both the expertise and the necessary legal and regulatory conditions for an adequately functioning venture capital system. Domestic venture capital firms have been set up by the government, at national or provincial level, and are run by government officials who do not always have adequate technical, commercial or managerial skills.

While there appears to be sufficient liquidity in the system – with a large number of wealthy business people and foreign venture capital firms looking for profitable investments – there seems to be a shortage of:

- Firms and professionals with the experience to identify and invest in high-risk ventures.
- Firms and business angels that are prepared to invest in sectors (such as biotechnology) in which an investment may take a long time to yield returns.

The number of private domestic and foreign venture capital firms has been increasing but funds are still short and there is too little management and business expertise of the sort offered by business angels available to small innovative firms.

The Medium- to Long-Term Strategic Plan for the Development of Science and Technology proposes to introduce several new funding mechanisms for “policy banks” and commercial banks, and several initiatives have been taken to increase access to funding for small high-technology SMEs and start-ups.

Intellectual property rights protection

Since China joined the WTO and signed the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS agreement), the Chinese patent system is in line with international standards and conventions. Applications to the Chinese Patent Office have picked up considerably since then (Figure 1.10 in Box 1.1). Nevertheless, the situation still falls short of the needs of both domestic and foreign-owned innovative enterprises operating in China. Infringement of intellectual property rights, particularly of copyright and trademarks, remains a concern.

With quite sophisticated IP regulations in place, the current level of infringement mainly points to weaknesses in the enforcement of IPR regulations. Both judicial and administrative decisions are difficult to enforce owing to the lack of appropriate infrastructure and mechanisms as well as of manpower.

While top leaders in the Chinese government have become aware of the importance of building a sound legal framework for IPR protection – which is already much improved – enforcement of the laws, especially at the local level, need to be substantially improved.

The lack of effective IPR protection affects innovative activity in China in various ways:

- Foreign firms hesitate to transfer technology to China; the threat of IPR infringement may even limit their willingness to produce in, or even to export goods to, China.
- Concerns about IPR protection have reportedly reduced Chinese inventors' propensity to commercialise the results of their R&D.
- IPR infringements, combined with low standards of quality, may also affect the national and international reputation of Chinese firms, notably when poor quality affects the health and safety of consumers.
- In contrast, sound IPR policies can facilitate the transfer of research results from public research organisations to business enterprises and from foreign firms to the Chinese economy.

However, China's move towards a more innovation-based economy can be expected to lead to improvements. As Chinese enterprises become more innovative, they, too, are adversely affected by a lack of effective IPR protection. Therefore, it is likely that awareness of this problem will become more widespread and lead to effective counter-measures. Tsinghua University, one of China's largest IPR applicants, vigorously pursues every instance of infringement. The Chinese Patent Office has conducted an active campaign to distribute information on IPR.

Technological standards

Technology standards have different aspects depending on their relation to competition. On the one hand, they have frequently been used to support “infant industries” or to otherwise protect domestic industries from foreign competition. On the other, they have played a significant role in enhancing competition, notably by making possible economies of scale and promoting interchangeability, compatibility and co-ordination.

Standards are increasingly seen as an important tool for promoting technological development in China:

- They have been gradually embedded in Chinese policy. They were initially seen as part of the industrial development strategy and were integrated in major R&D programmes. They increased in importance when China became a member of the WTO.
- The recent policy priority given to “indigenous innovation” has nurtured the idea of using technological standards to enhance China’s technological capabilities.

China is striving to promote its own technology standards and to transform Chinese standards into international standards, a goal that requires improving the ability of Chinese actors to take part in international standard-setting processes. China’s size, the dynamism of its domestic market and its rapidly developing technological capabilities give it a unique position. In China, it is widely seen as legitimate to make use of a standards regime that can help increase Chinese firms’ returns on investment in technology and can be instrumental in fostering innovation. At the same time, as far as technology standards are concerned interests vary widely. This calls for a pragmatic approach towards this issue. The challenge for China is to develop a standards regime that is in line with WTO regulations and does not eventually lead to distortions of national and international competition and thus stifle innovation.

Public procurement

Public procurement can also help promote innovation and accelerate the diffusion of innovative products and services in the economy. The size of the Chinese market, its dynamism and the important roles played by the central government and sub-national authorities in the Chinese economy point to the strong potential for promoting innovation via public demand. The volume of government procurement has been expanding rapidly, although, at about 2% of GDP, it is still far below the levels in more developed countries.

The Chinese government has recognised this potential and attempts to make use of it. The Medium- to Long-Term Strategic Plan for the Development of Science and Technology for the first time assigns public demand an important role in economic development and the promotion of innovation. This represents a policy innovation since the Chinese government traditionally relied entirely on supply-side policies to promote technology development.

The development and implementation of an innovation-oriented procurement policy is a demanding process in terms of the required expertise and the co-ordination of the government agencies involved. Innovation through public procurement cannot be “ordered”; rather, it has to be the result of a sophisticated articulation of demand for innovative products or services and of a transparent competitive process.

Precautions should be taken so that the new policies do not get in the way of China joining the WTO Government Procurement Agreement (GPA), on which China has declared that it will start negotiations in 2007. Integration into the WTO GPA would not just open up China’s public procurement markets to foreign companies, it would – following the principle of reciprocity – also provide new opportunities for Chinese companies to enter public procurement markets abroad.

Part II

China's Innovation System: Main Features and Performance

The concept of a national innovation system (NIS) encompasses the set of political and other factors that determine a society's ability to define creatively and achieve increasingly ambitious cultural, social and economic goals. The history of China, like that of any other nation, can be analysed from this perspective, but it is one that goes far beyond the scope of this report. In contemporary economic thinking, an innovation system is defined as the purposeful combination of market and non-market mechanisms to optimise the production, deployment and use of new knowledge for sustainable growth, through institutionalised processes in the public and private sector. Not so long ago it would have been hard to talk about China's innovation system from this narrower but more precise perspective.

Civil research and development (R&D) activities in China were for decades limited in scale, scope and depth and separated from production. In the early phase of the economic transformation prompted by the "open door" policy, new knowledge and innovation still played a modest and largely passive role in economic growth and were mainly embodied in the growing capital stock, including the first wave of foreign investment.

The origin of the Chinese innovation system can be traced back to the mid-1980s when reform of the science and technology (S&T) system was included in the broader agenda of economic reforms. S&T industrial parks, university science parks and technology business incubators were started under the Torch programme as new infrastructures to encourage industry-science relationships, and spin-offs from public research organisations (PROs) started to fill the gap. The maturing of this embryonic system was accelerated in the 1990s through the combined effect of continued international opening (*e.g.* accession to the World Trade Organization [WTO] in 2001), improvement of corporate governance and key framework conditions for innovation (*e.g.* protection of intellectual property rights [IPR]), as well as further reforms of the university and public research sectors.

By the turn of the century, a combination of experimental national policies in special zones, bottom-up initiatives supported by regional and local authorities, and top-down systemic reforms had given birth to what could be considered an NIS under construction, in the image of the entire Chinese economy.

It is a challenging task to characterise the current state of the rapidly evolving Chinese innovation system in terms of its structure, performance, integration into global S&T networks and potential for future development, not least because it involves international comparison and benchmarking. The task is rendered difficult by:

- *Size, heterogeneity and complexity.* On any measure, absolute numbers and per capita figures tell two different stories about China's NIS, both of which are true. Moreover, national averages can be particularly misleading because the geographical concentration of innovative activities is more pronounced in China than in almost any OECD country.
- *Lack of internationally comparable indicators and statistics.* Apparently comparable areas are not always measured according to the definitions used in OECD countries; this is particularly true in areas such as human resources in science and technology (HRST).
- *Idiosyncratic institutional features.* Areas that can be measured using international norms may not be readily compared to other countries; this is particularly true for R&D activities and the performance of firms whose forms of ownership and governance are peculiar to China.

- *Rapid and ongoing transformation.* The pace of change is such that accurate monitoring is very demanding for the Chinese government and even more so for outside observers. Information gaps tend to be filled by a proliferation of information, mostly anecdotal evidence, which may be misleading but can have a strong impact on public opinion and even policy making worldwide.

Based on an admittedly limited set of quantitative indicators, complemented by qualitative information and expert judgements gathered during the course of the OECD-MOST (Ministry of Science and Technology) project, this part assesses the pace of development of the key players, processes and infrastructure in China's innovation system. It focuses on the performers of R&D and innovation activities, mainly the business sector, the public research institutes and the universities. The role of government in providing guidance, basic incentives, institutional frameworks and support measures for R&D and innovation will be examined in Part III.

The main findings, which are documented below, are the following:

- China has excelled in mobilising resources for science and technology on an unprecedented scale and with exceptional speed, and is now a major R&D player.
- This impressive investment in resources has contributed significantly to the rapid socio-economic progress registered in China in the last decade, but it has not yet translated into a proportionate increase in innovation performance.
- One reason for this gap is that the capabilities for making productive use of accumulated investment in R&D, HRST and the related infrastructure have developed at a much slower pace, especially in the business sector, despite an increasing contribution from foreign investment in recent years.
- Foreign investment in R&D is expanding rapidly and its motivation and content are changing. Access to human resources has become a more important driver than market access or mere support to export-oriented manufacturing operations. In parallel, and even more recently, a first wave of innovative Chinese firms have developed a global brand and expanded their operations abroad, in some cases with a view to tapping into foreign pools of knowledge through mergers and acquisitions and the establishment of overseas R&D.
- Some framework conditions are insufficiently conducive to market-led innovation, especially those relating to corporate governance, financing of R&D and technology-based entrepreneurship, and enforcement of IPR (see Part I). Their improvement could create the necessary conditions for the operation of an open innovation model in which indigenous innovation capabilities and R&D-intensive foreign investment could be mutually reinforcing.
- The public support system for R&D and some aspects of the institutional arrangements of the NIS do not yet sufficiently encourage the deepening of R&D efforts and their translation into innovative outcomes (see Part III). Except in some targeted areas, such as nanotechnology, there is still a wide gap between a relatively small basic research sector and massive technological development activities.
- China's NIS is not fully developed and still imperfectly integrated, with many linkages between actors and sub-systems (*e.g.* regional *versus* national) remaining weak. To the outside observer it appears as an "archipelago" or very large number of "innovative islands" with limited synergies between them and, above all, limited spillovers beyond them. Spreading the culture and means of innovation beyond the fences of S&T parks and incubators by promoting more market-based innovative clusters and networks should now be an important objective.
- Regions have played and will continue to play a key role in the advancement of S&T in China. However, current regional patterns of R&D and innovation activities are not optimal from the perspective of the efficiency of the national innovation system. For example, they create too great a "physical" separation between knowledge producers and potential users. They are also not optimal from a social equity perspective as innovation systems in lagging regions are underdeveloped.

- Despite the rapid growth of all components of the HRST pipeline, from university enrolments in undergraduate studies to PhD programmes, and even taking into account the large potential for improving the productivity of HRST, the bottlenecks that will mainly constrain the future development of the Chinese NIS may come from shortages in the specialised human resources that are needed at various stages of innovation processes. This also has important global implications given the current role of Chinese students in international flows of human resources.

Provided that the government properly addresses these shortcomings, following international best practices, China has the potential to develop an NIS that will provide a powerful engine for sustainable growth while also facilitating the smooth integration of China's expanding economy into the global trading and knowledge system (see the final section "Conclusions and Recommendations" below).

Benchmarking the size, growth and potential of China's innovation system

The national dimension

Figure 2.1 provides a snapshot of the Chinese innovation system, comparing its size and growth to certain OECD countries using a mix of input and output indicators. Figures 2.2 and 2.3 provide detailed information regarding the R&D component.

- China is already a major S&T player in terms of inputs to innovation. Since 2000, it has ranked second in the world after the United States and ahead of Japan in number of researchers. R&D spending has increased at a stunning annual rate of almost 19% since 1995 and reached USD 30 billion (at current exchange rates) in 2005, the sixth largest worldwide.¹
- China's innovation system looks smaller when considered from the output side, but the relevant indicators are growing much faster, thus indicating increasing systemic efficiency and pointing to areas in which the country is focusing its leapfrogging efforts, such as nanotechnology. For example, Chinese patent applications filed under WIPO's Patent Cooperation Treaty (PCT) accounted in 2005 for only 3% of total PCT applications, a share comparable to that of Sweden and Canada, but they are doubling in number every two years.
- The R&D/GDP ratio has more than doubled in a decade and reached 1.34% in 2005 compared to only 0.6% in 1995. This is a spectacular achievement but does not mean that the innovation capabilities of the Chinese economy are already on a par with those of OECD countries which have a similar R&D intensity of production.

In aggregate, the social and economic returns to R&D investment, as measured by available input and output indicators, are currently lower in China than in advanced OECD countries, for three main reasons.

- Much more "D" than "R". R&D efforts are mainly oriented towards experimental development. Only about one-quarter of gross domestic expenditure on R&D (GERD) is devoted to basic research (6%) and applied research; more than 70% corresponds to experimental development (Figure 2.3). The lack of basic and applied research implies that little research is likely to lead to patentable inventions.

1. In an international comparison, assessing the level of Chinese R&D expenditures based on current exchange rates (USD 30 billion in 2005) obviously leads to underestimating the relative size of China's R&D system. However, using the conversion rate for GDP to calculate R&D expenditures at purchasing power parity (PPP) (USD 115 billion in 2005) is also misleading because the relative prices of research equipment and the relative wages of researchers are very different from average relative capital costs and wages, although available statistics does not allow for an accurate quantitative estimate.

Figure 2.1 The relative size of the Chinese innovation system

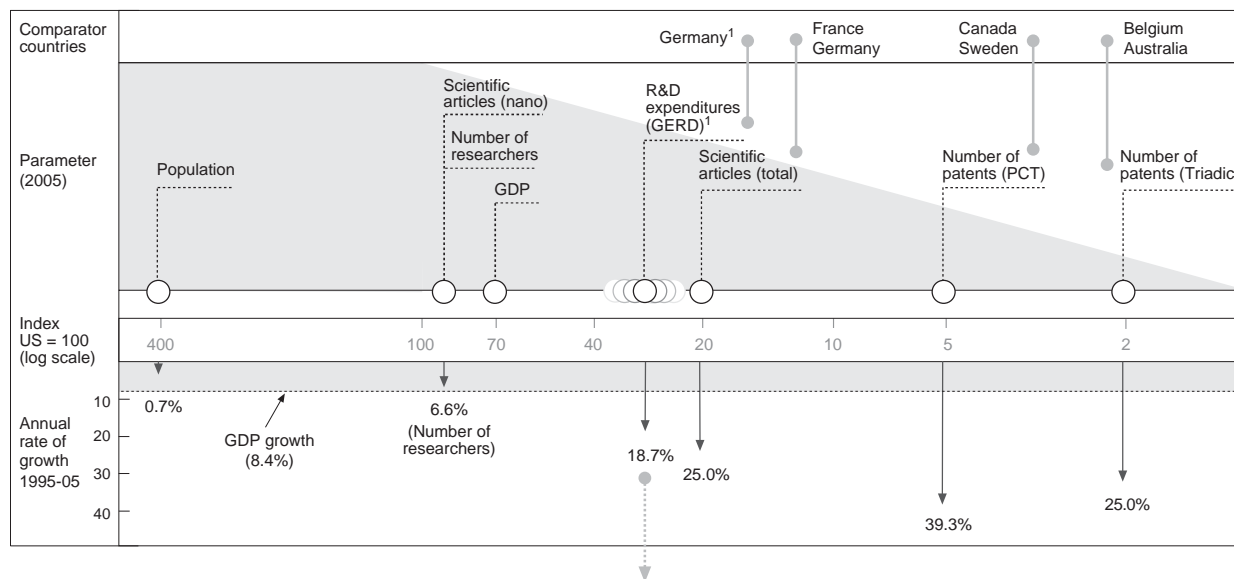
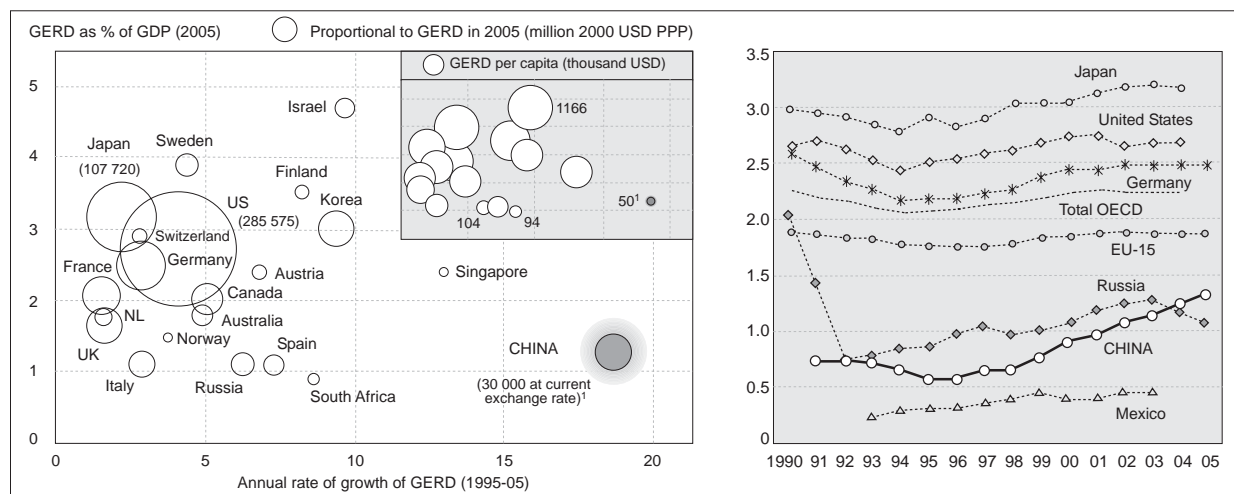
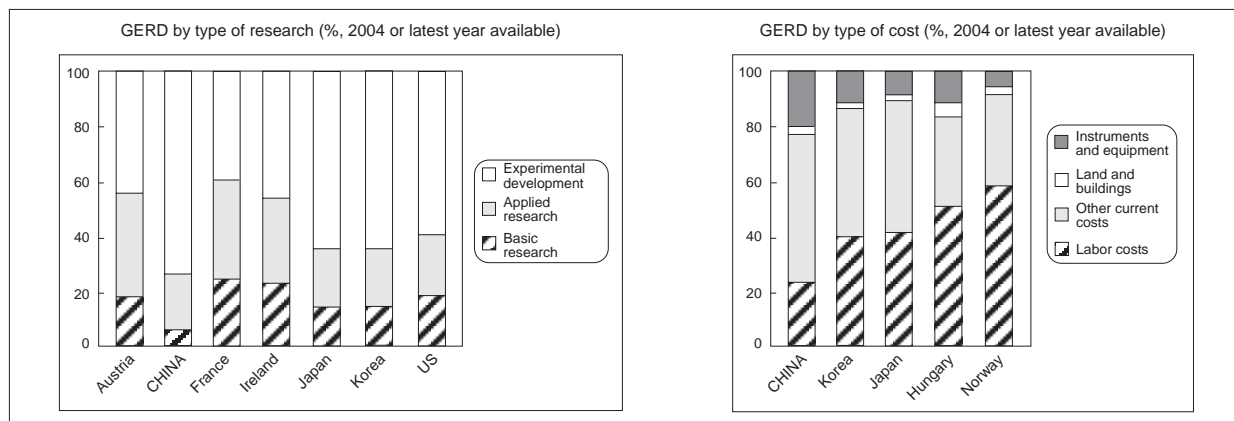


Figure 2.2 Chinese R&D expenditures and R&D intensity are growing very fast



1. The calculation of Chinese R&D expenditures at Purchasing Power Parities (PPP), in order to allow meaningful international comparisons, raises a number of problems. A wide variety of alternative estimates for PPP conversion rates exists for China's GDP. In addition, in the case of China the conversion rate for GDP cannot be applied to R&D expenditures without a significant adjustment for which however there exists no agreed methodology. For illustrative purpose these charts show an interval of possible values instead of a single value.

Figure 2.3 Chinese R&D mainly consists of experimental development



Source: OECD.

Figure 2.4 Regional GDP per capita and regional shares of total R&D expenditures

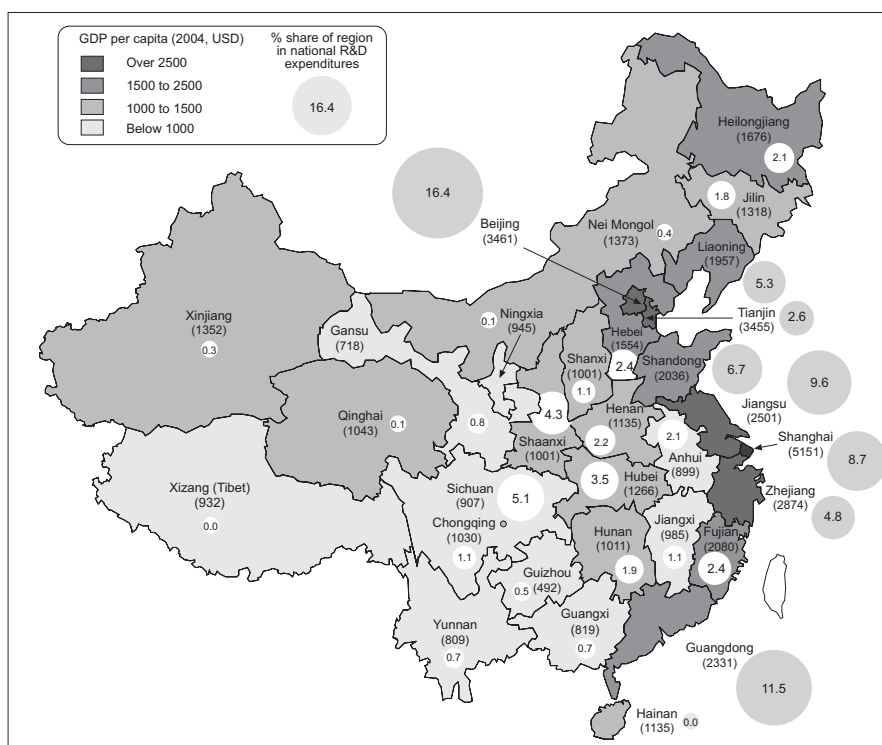
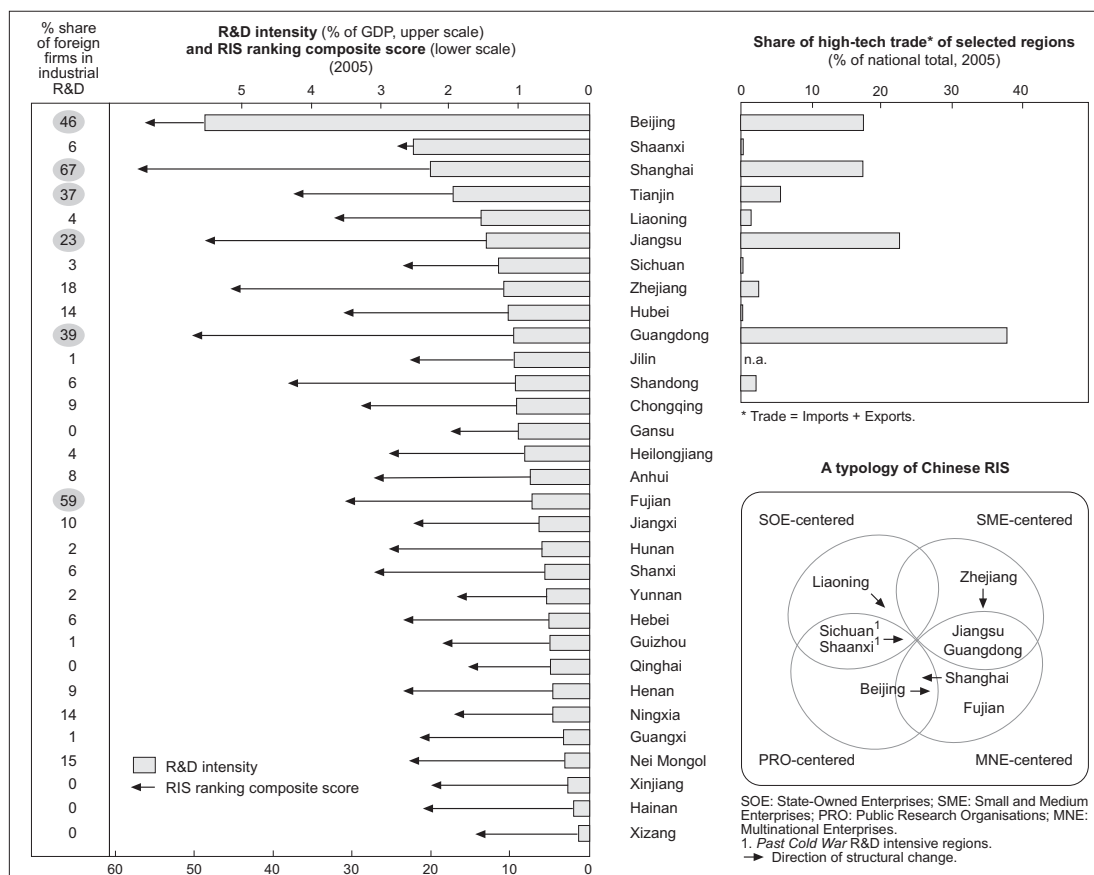
Source: National Bureau of Statistics (2005), *Chinese Statistical Yearbook 2005*; MOST.

Figure 2.5 Chinese regional innovation systems (RIS)

Source: MOST online database. S&T Development Strategic Research Team (2006), *Annual Report of Regional Innovation Capability of China 2005-2006*, Science Publishing, Beijing. OECD based on Xieliu Liu.

- So far a large proportion of the resources invested in R&D have been devoted to building the “hardware” of the innovation system (Figure 2.4). The capital-intensive nature of R&D investment is particularly striking in the case of public research organisations, which have renewed their equipment and facilities on a large scale. However, the stock of intellectual capital does not grow as quickly. This creates overcapacity in the use of some research infrastructures, which in many cases should only be temporary.
- It is possible to identify several sources of inefficiencies in the innovation system. Some are inherent in the position of Chinese actors on the learning curve of best practices; these will be removed gradually and automatically as collective and individual experience accumulates and newly trained highly skilled workers replace older staff. Here the challenge is for all types of organisations (universities, businesses, government bodies) to ensure a good compromise between the speed and depth of learning. Other sources of inefficiencies stem from structural imbalances within the system and defective incentive structures for actors; these can be corrected by appropriate government decisions (see Part III).

These limitations illustrate China’s large unexploited potential for further development and innovation, even at the present level of R&D expenditure. However, China plans to continue to increase R&D spending while at the same time promoting more market-led innovation. To do so without widening the efficiency gap will present a challenge since the level of business R&D will be increasingly determined by the profitability of such investment. If only for this reason, predicting the future through a simple extrapolation of recent trends is unwarranted. As the innovation system matures, demand-side factors will play a growing role in determining the scale, allocation and impact of S&T investment.

The regional dimension

The Chinese innovation system is too large and complex to be summarised with a single model; the regional dimension should not be overlooked. Beyond some broad common features the system includes several regional systems characterised by different levels and dynamics of development. Over the past two decades regional initiatives have played an important role in shaping the new S&T landscape.

The regional dimension also needs to be taken into account in international benchmarking since several Chinese provinces or even municipalities are now larger R&D performers than several OECD countries.

Significant disparities exist among Chinese provinces in terms of R&D intensity and innovation performance; a clear group of top performers far surpasses the others (Figures 2.4 and 2.5). In general, the provinces and municipalities with provincial status on the east coast are more innovative than the provinces in the central and western parts of China. Regional levels of innovativeness are highly correlated with their GDP per capita and their contribution to high-technology exports, but less with their shares in national R&D expenditures.

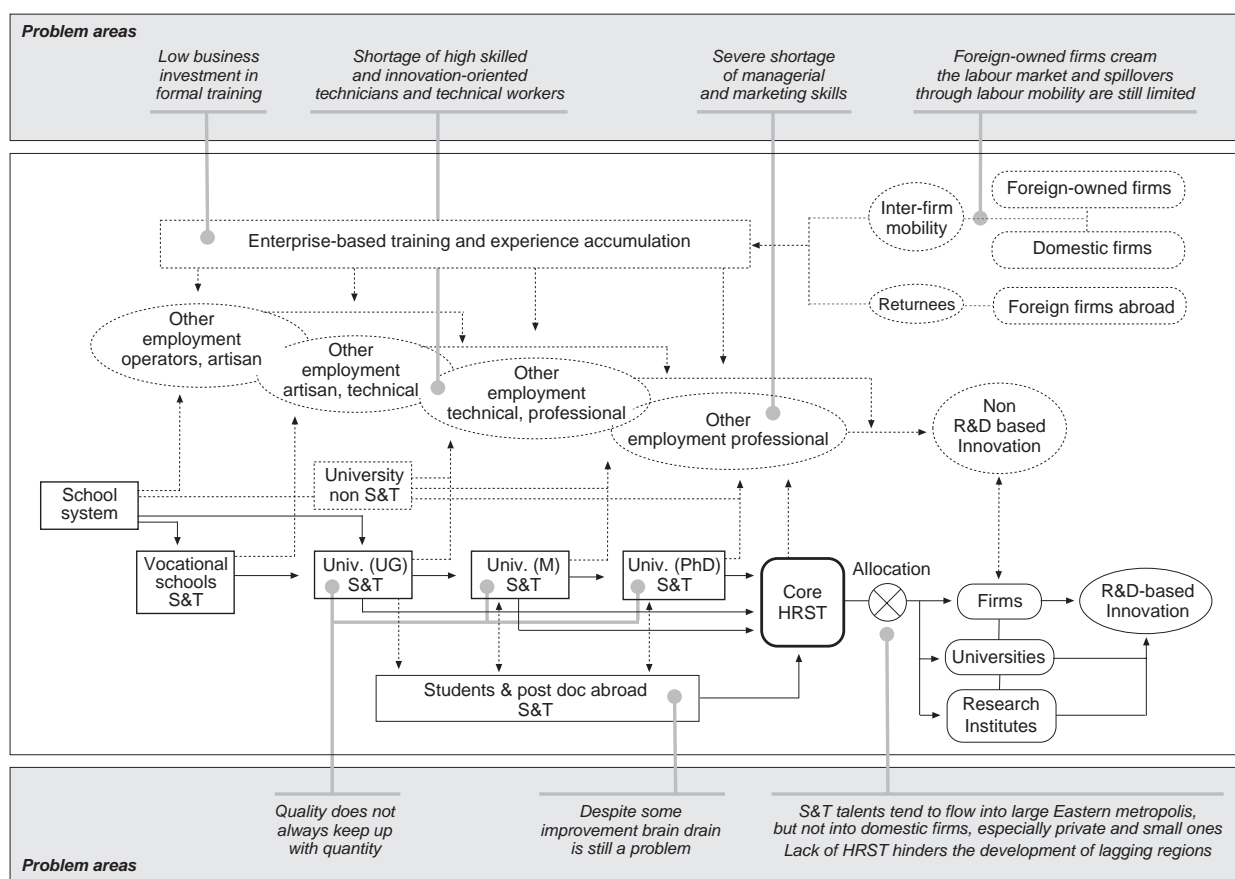
The regional mismatches between R&D and innovation have historical roots but should today be a source of concern. For example, the Sichuan and Shaanxi regions have inherited quite large R&D facilities which were located there for strategic reasons during the Cold War. The conversion of such facilities remains a difficult challenge in an environment that is less supportive of innovative activities than eastern China. Beijing concentrates the lion’s share of basic research in public institutes but may not have an industrial base able to commercialise the results. The reverse is true for Shanghai, where an active business sector is to some extent deprived of a strong, application-oriented basic research infrastructure. Such mismatches have been corrected in part by the emergence of new technology-based firms from university science parks and technology incubators but the problem persists for small and larger incumbent firms.

Human resources for science and technology

China has made tremendous and largely successful efforts to mobilise its abundant human resources in order to upgrade the technological level of its economy and more recently to enhance the creativity of the labour force. The lack of comparability of available statistics is an obstacle to international benchmarking in this area. However, some main trends and issues can be highlighted (Figures 2.6 to 2.9).

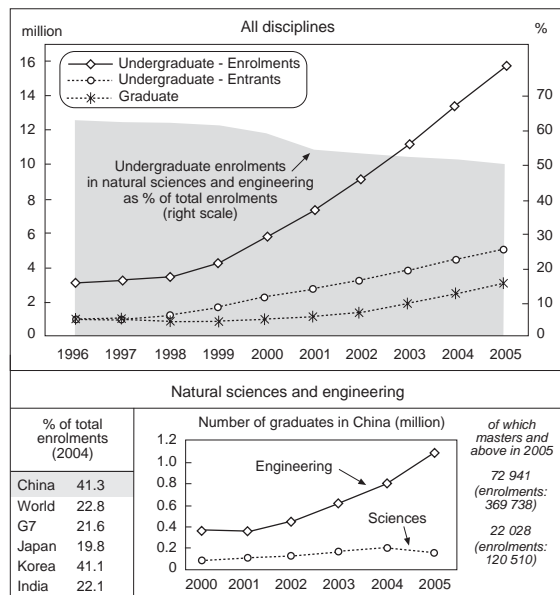
- Since the early 1990s China has made substantial progress in developing HRST. However, in terms of HRST as a share of the population, China significantly lags OECD countries, and building a more innovative economy will require sustained growth in numbers.
- Undergraduate and postgraduate enrolments in science and engineering remain stronger than in OECD countries, with the exception of Korea. However the share of science and engineering degrees in the tertiary education system has been falling since 2000. In recent years, undergraduate degrees in science have even fallen in absolute terms; this is worrying given China's ambitions in the area of R&D.

Figure 2.6 Main features of and bottlenecks in the Chinese HRST pipeline and market



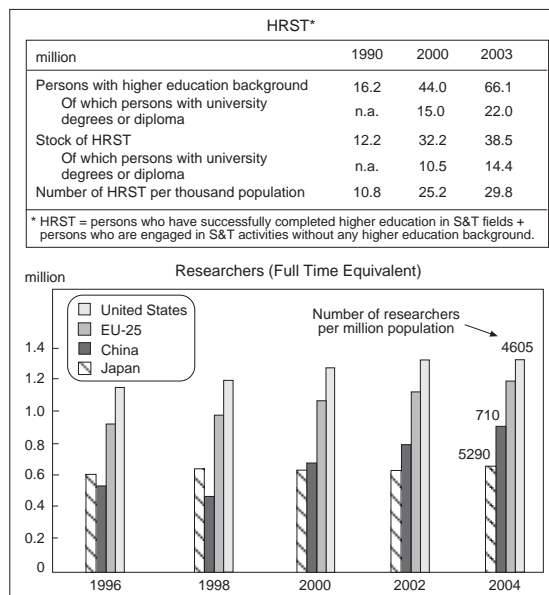
Source: OECD.

Figure 2.7 The expansion of the Chinese higher education system



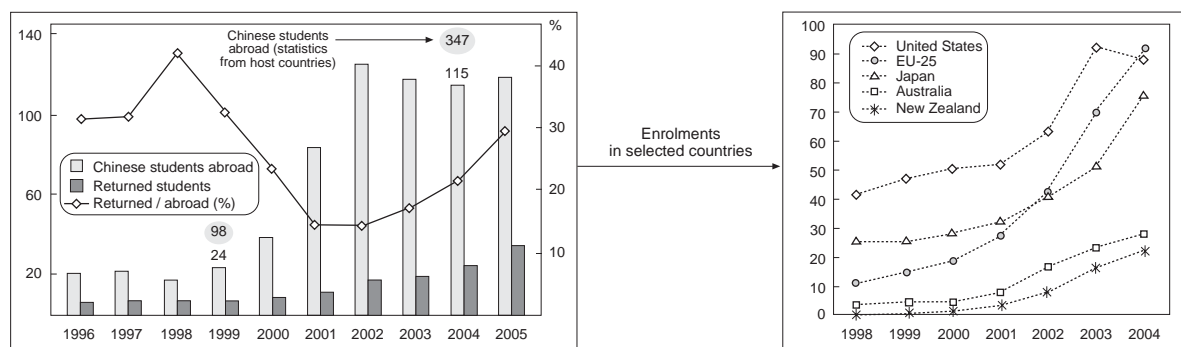
Source: National Bureau of Statistics, China statistical yearbook 2006; World Bank.

Figure 2.8 The stock of Chinese HRST and researchers



Source: Estimates from China's National Census data and education statistics; OECD.

Figure 2.9 Overseas Chinese students and returnees (thousand, %)



Source: National Bureau of Statistics, China statistical yearbook 2006.

Source: OECD and UNESCO-OECD-Eurostat data.

Although China has succeeded in building a major stock of R&D personnel, there are questions about the efficiency of the current workforce. The main available indicators in this respect are the numbers of science and engineering articles published per thousand researchers (on the basic research side), and patent applications per thousand researchers (on the applied and experimental development side). On both measures, China lags significantly behind the advanced economies. There are also tensions in several segments of the labour market for various levels of S&T-related skills, which reveal human resource bottlenecks in the innovation system and challenge the responsiveness of the education system:

- Domestic firms, especially private ones, have difficulty competing with foreign firms in recruiting scarce talent with managerial competencies or highly qualified researchers in industry-relevant fields.
- Highly skilled and innovation-oriented technicians and technical workers seem to be in short supply in many industries, owing to insufficient business investment in training and deficiencies in vocational training, the effects of which are magnified by the extremely rapid industrial expansion.

Although vocational training is a priority for the government, many initiatives are left to the local authorities and information about their effectiveness is scarce.²

- A shortage of innovation managers is apparent in many areas.

International mobility is an important aspect of the Chinese HRST pipeline and market, given the large number of students enrolling in courses abroad. China is a key player in the global competition for talent, mostly on the supply side. The government has actively tried by various means to transform the current “brain drain” into a “brain circulation” that would help to achieve national goals:

- Relaxing regulations. Since 2000, the government has taken a series of initiatives to make returning more attractive by loosening restrictions, such as granting special permits for entering and leaving the country so that returnees can continue to work abroad and also work in China. They may also be allowed to remit their after-tax earnings, a right otherwise reserved to foreigners working in China.
- Development parks and incubators. For example, in 2003, 45 incubators dedicated to returned overseas scholars hosted about 3 000 enterprises employing more than 40 000 persons.
- Tax incentives and project funding. There is some interregional competition, especially between Beijing, Shanghai, Shenzhen and Guangzhou, to attract returnees through tax reductions or exemptions, favourable import regulations and/or financial support to start-ups.
- National programmes to attract high-level scientists such as the “100 Talents” programme of the Chinese Academy of Sciences and the recent similar initiative by the National Natural Science Foundation of China.³

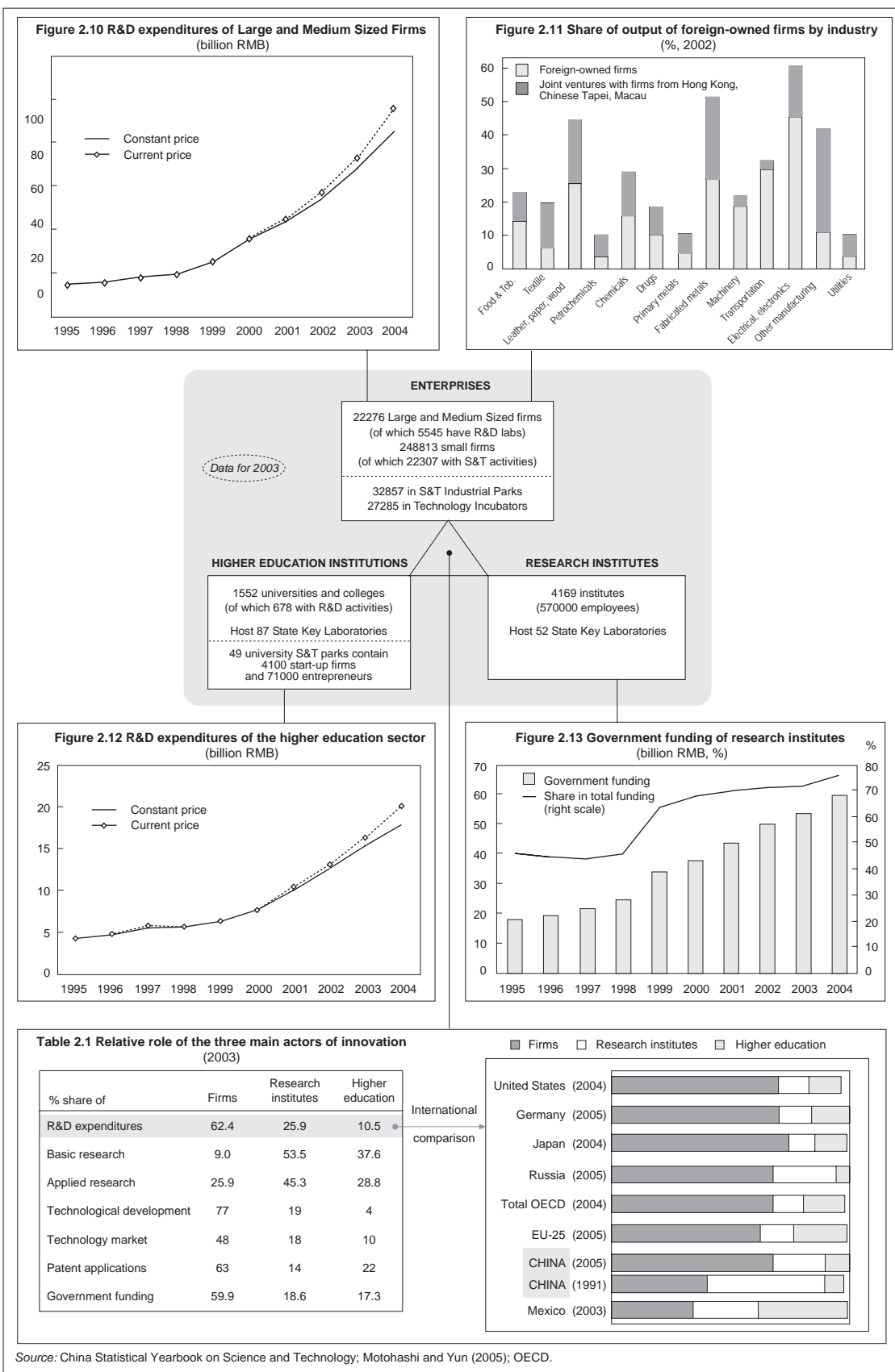
To date the results of these initiatives appear rather mixed. The extent to which the recent increase in the number of returnees can be attributed to government incentives is questionable since opportunistic behaviour to enjoy windfall benefits cannot be ruled out. In any case, the number of returnees falls short of what would be needed to reduce significantly the current and prospective shortages of certain types of skills. In the foreseeable future the main determinants of inflows and outflows of highly qualified Chinese labour will continue to be international differentials in wages, working and living conditions and entrepreneurial opportunities.

Main actors in the innovation system

The institutional profile of the Chinese NIS has undergone fundamental changes since the start of the reform of the S&T system in 1985. These changes have transformed each of the main components of the NIS, as well as their relationships.⁴ Most strikingly, the business sector has become the dominant R&D actor, now performing over two-thirds of total R&D, up from less than 40% at the beginning of 1990. At the same time, the share of public research institutes has declined from almost half of total R&D to less than one-quarter over the same period. The relative weight of higher education institutions has changed little. Box 2.1 portrays the three main R&D performers.

-
2. There are approximately 872 institutions offer tertiary education vocational training, of which 25% are private and 75% are public under local authorities.
 3. The NSFC programme offers annual grants of up to RMB 1 million (USD 120 000) for four years to overseas Chinese scientists willing to return.
 4. Chinese experts in S&T and innovation policy distinguish between five main sub-systems: the knowledge system, the technological innovation system, the regional innovation systems, the intermediary agencies and the dual-use knowledge and technologies. This synthesis report adopts a simpler, player-based approach to highlight major changes in the Chinese NIS.

Box 2.1 The three key R&D performers



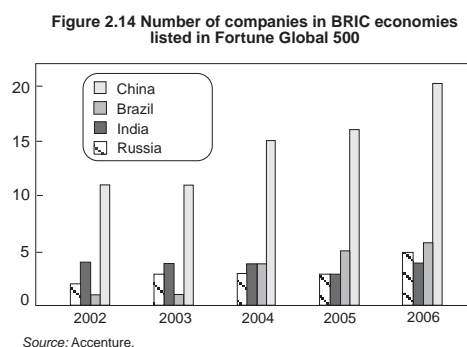
Domestic business sector

It would be wrong to conclude from these figures that firms already form the backbone of the Chinese NIS, as they do in the OECD countries with a similar distribution of R&D expenditures between types of performers (Table 2.1 in Box 2.1). In reality, enhancing the innovation capability and performance of the business sector has been one of the most difficult challenges, and the past reforms and transformations have been relatively unsuccessful in addressing it.

To a significant extent, the rapid increase in business sector R&D has resulted mechanically from the conversion of some public research institutes into business entities, often without creating the conditions for them to become innovation-oriented firms. From 1998 to 2003, 1 050 public research institutes were converted into business entities. The 204 000 employees, of which 111 000 S&T personnel, transferred to the business sector were on average older and less qualified than those who stayed on in research institutes.

But as mentioned in Part I, there are other reasons why the vast majority of Chinese enterprises, even those active in R&D, have both limited capabilities and a low propensity to innovate. Key factors include an emphasis on quantity rather than quality, which is a legacy of the planned economy, the availability of cheap but insufficiently skilled labour, the lack of managerial know-how, a mode of governance that does not encourage managers to take the risk of innovating, the persistence of a government support system that tends to crowd out rather than encourage business investment in risky projects, and a financial system that is not supportive.

However the combination of gradually improving framework conditions, accumulated experience in managing market-driven organisations, a steady supply of new graduates with enriched training and fresh ambition, and accelerated learning about good management practices from the large number of foreign firms active in China have started to generate a steady flow of success stories, and emblematic cases exert a strong demonstration effect. Indeed, China is far ahead of all other catching-up economies in creating large, successful companies (Figure 2.14)

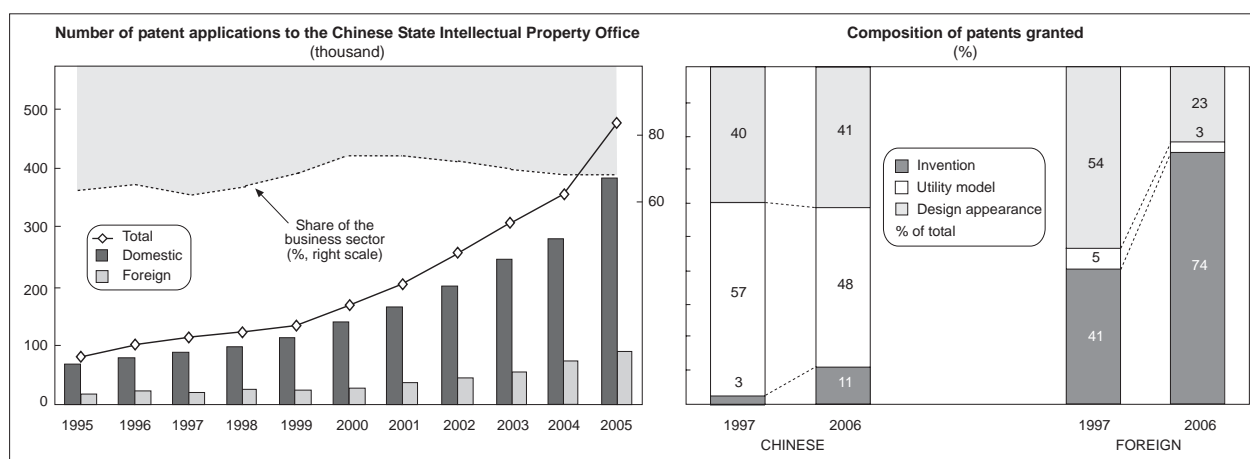


Some of the firms that have already acquired global visibility and market presence, such as Huawei, TCL and Lenovo, are in high-technology sectors, while others, such as Haier, need to be innovative to excel in their market segment. The most R&D-intensive firms have usually emerged from the public research sector. This is the case for three leading Chinese producers of personal computers: the predecessor of Lenovo, Legend, was nurtured in the Institute of Computing Technology of the Chinese Academy of Sciences, Founder Electronics is a spin-off from Beijing University and Tsinghua Tongfang from Tsinghua University. Some of these large successful companies are now investing abroad in R&D. By complementing the role of foreign investment in China, they help to accelerate and balance the process of China's integration into global knowledge networks.

Another encouraging trend is the rapid development of small technology-based firms, which is partly a pay-off from the huge investment China has made in the development of science parks and incubators. In fact, between 2000 and 2004, the number, value added, R&D and patent applications for inventions of S&T-based

small firms have increased by 52%, 141%, 121% and 221% respectively. In 2004, as much as 20% of the R&D personnel employed in domestic firms (excluding joint ventures with foreign partners) were in small enterprises (fewer than 300 employees). Many of these small firms remain dependent upon the various forms of public support granted by the different levels of government to tenants of science and technology parks. But the recent period has seen the emergence of more purely market-based innovative networks of small firms in some regions, notably Zhejiang, Jiangsu and Guangdong.

Figure 2.15 Trends in patenting at the Chinese State Intellectual Property Office



Source: MOST.

The fact remains that the innovation outcomes of the domestic business sector are much lower than what one would expect given its share in total R&D and HRST. A telling indicator is the nature of patenting activities at the Chinese Intellectual Property Office (Figure 2.15). Although the share of inventions in the total number of patents granted to Chinese actors has doubled in recent years, it is still very modest when compared with those of foreign firms.

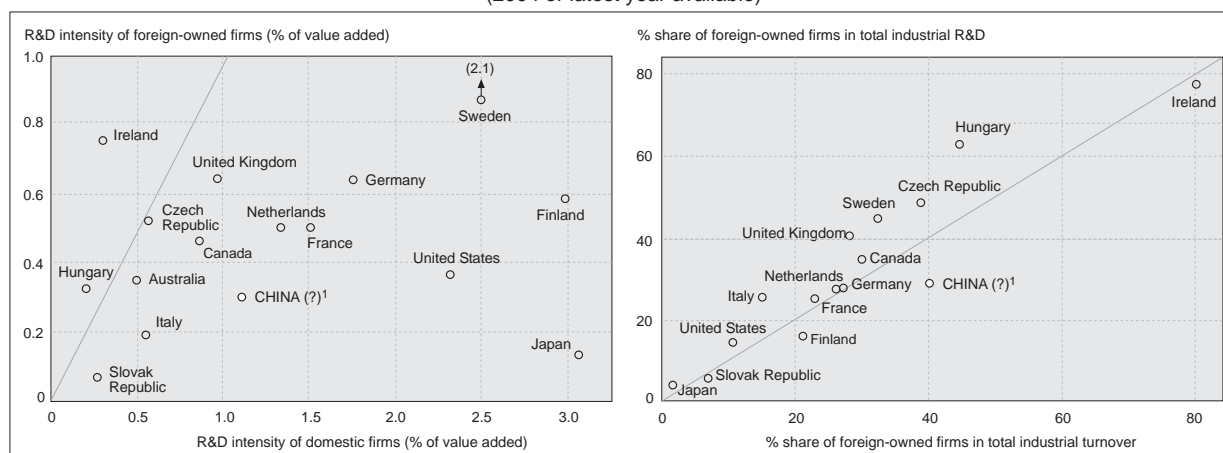
Foreign firms

The time when active foreign investors almost all originated from OECD countries and invested in China only to take advantage of cheap manufacturing platforms is over.

- First, inward foreign direct investment (FDI) increasingly includes R&D operations. As a best guess, given the limitations of available data, foreign R&D⁵ now accounts for 25-30% of total business R&D in China (Figure 2.16). Foreign R&D organisations established by multinational firms (MNEs) are highly concentrated in the information and communication technology (ICT) industries (including software, telecommunication, semiconductors and other IT products) but equipment and components, biotechnology and drugs as well as automotive industries also attract a significant amount of foreign R&D investment. Beijing and Shanghai are the preferred locations, but more recently Guangdong, Jiangsu and Tianjin have appeared on the map of foreign R&D investors (Figure 2.17).

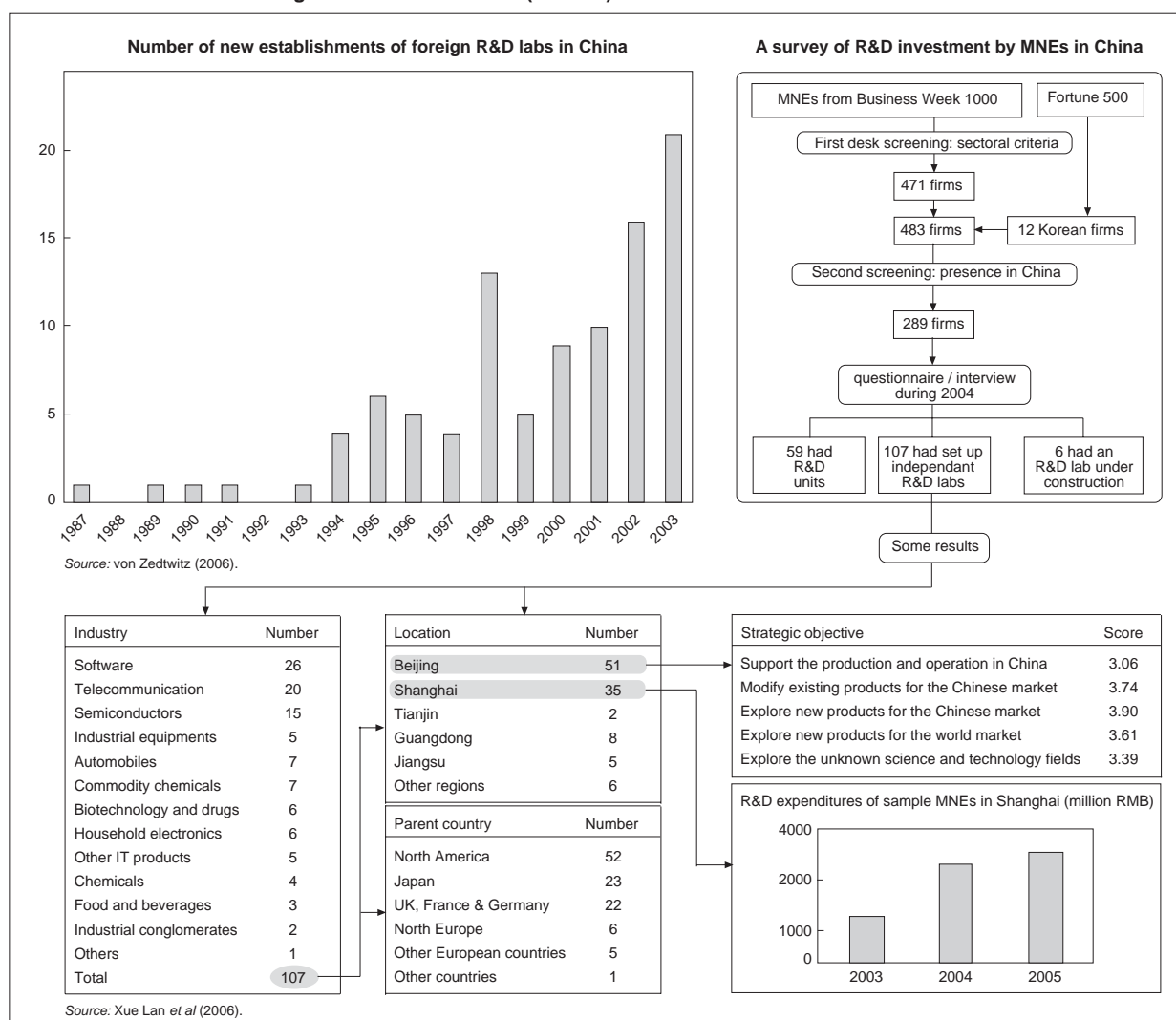
5. Including sino-foreign investment from Hong Kong, China; Macau, China; and Chinese Taipei.

Figure 2.16 The role of foreign-owned firms in industrial R&D: an international comparison
(2004 or latest year available)



1. Including Sino-foreign investment from Hong Kong, Chinese Taipei and Macau.
Source: OECD based on the OECD AFA database and Chinese official statistics.

Figure 2.17 The first wave (till 2004) of FDI R&D investment in China



- Second, small FDI firms are making more autonomous efforts to enter the Chinese market and to participate in the current globalisation of R&D. Over 2000-04, the number of small FDI firms in China doubled. Even though the share of small FDI firms with S&T activities is still low (9% in 2004), their R&D expenditure and their patent applications for inventions have more than doubled.
- Third, Chinese FDI outflows are on the rise, and accessing foreign sources of knowledge through mergers and acquisitions or greenfield investment has become one of the motives behind outward investment decisions of a still small, but expanding, number of Chinese firms.
- Finally, the rapid development of industry-science relationships and the growing sophistication of associated public policies are prompting another very recent phenomenon, namely the involvement of public or public-private research organisations of OECD countries in the Chinese market for knowledge.

Table 2.2 Motivations for and barriers to foreign R&D in China

Motivations	Barriers and difficulties
Fast-growing market with specific requirements (ICT sector)	Overcapacity and “unknown” consumers (automotive industry)
Skilled labour and well-trained R&D personnel (ICT sector, biomedical industry)	Lack of experienced/qualified specialists (automotive, biomedical industries)
Tapping formal/informal networks and new knowledge sources	Weakness of institutional infrastructure, <i>e.g.</i> IPR regime Uncertainty regarding the legal system
Competition	Extremely intensive competition High employee turnover
Policy-driven (<i>e.g.</i> official requirement for setting up of R&D centres and/or fiscal incentives)	“Window dressing” no longer works Some preferential policies have been abolished

Source: OECD summary of relevant literature.

The more important of those trends, for its implications for both China and OECD countries, is of course the multiplication of R&D centres established by major MNEs with an increasing focus on the “R”. Although up-to-date and reliable information is lacking to gauge precisely the size and pace of this development, anecdotal evidence, firms’ surveys and experts’ judgement suggest that it is gaining momentum and is likely to amplify as long as the motivation to do so continues to increase and outweighs the remaining barriers (Table 2.2). The main uncertainty concerns the policy outcome of the current debate in China and in MNEs’ home countries regarding the costs and benefits of this trend.

The Chinese government has so far actively encouraged and promoted foreign corporate R&D in China, viewing it as a way to upgrade domestic technology and skills by importing, and ideally internalising, foreign know-how. However, scepticism regarding the positive impact of foreign corporate R&D on China’s innovation system has recently been increasing. Some academics and policymakers criticise foreign firms’ presence and their behaviour in China, claiming that they charge unduly high licence fees for their patents, “crowd out” domestic firms in the market for highly skilled labour, monopolise technology standards and thwart technology transfer and knowledge spillovers. Foreign firms are seen as dominating standards and technology platforms and reducing Chinese companies to the role of producers with low profit margins.

On the other hand, governments and public opinion in developed countries worry that, after manufacturing production, R&D will now move to China as well. In particular, there are growing concerns in many developed countries that multinationals will increasingly set up R&D in China at the expense of Europe and the United States. Some MNEs warn that China may be tempted to exert unwarranted pressure to artificially accelerate the contribution of foreign R&D investment to the reinforcement of endogenous innovation capabilities.

In addressing these issues, the Chinese government should carefully consider the lessons to be drawn from OECD countries' experience regarding the best way to encourage mutually beneficial interaction between FDI and the domestic economy, as well as the role of proprietary knowledge in efficient innovation systems.

- Spillovers from advanced to less advanced enterprises take time and the main barrier is always the insufficient absorptive capabilities of the recipients rather than any form of restrictive business practices. With time, these capabilities increase as different channels (labour mobility, informal contacts, user-producers relationships, inter-firm research co-operation) become more and more effective, as long as the primary sources remains active. This requires framework conditions (*e.g.* IPR protection) that make foreign companies feel comfortable with operating and diffusing technology in China.
- In this context, forcing the diffusion of proprietary knowledge can only discourage its production and interrupt the development of a spillover process that, over time, will spread knowledge and know-how that are likely to be much richer than a single technological formula or object.

For their part, OECD country governments should themselves resist the temptation to try to “manage” outward foreign R&D to China in the hope of increasing private R&D at home:

- First, there is no evidence so far that R&D investments in China substitute for investments in home countries. They are merely additional and would not take place where expected private returns would be lower. They help to increase the global stock of knowledge by engaging more brains in more efficient cross-borders innovation processes.
- Second, benefits flowing back to home countries from foreign R&D investment should not be underestimated, even if some are indirect, realised through trade (*e.g.* lower inflation and therefore more accommodating macroeconomic policy), or hard to measure, such as cross-border knowledge spillovers within or outside the companies concerned. Foreign affiliates can play an important role in acquiring and transmitting foreign knowledge that can be sent back to the parent enterprise and other affiliates in the group. By appropriating results of R&D conducted by others abroad, foreign affiliates may contribute more to national or regional performance than if they were located in their home country.
- Third, foreign enterprises can contribute to – and should not be discouraged from – strengthening China's ability to provide innovative solutions to problems of a global nature in areas such as safety, health, environment and energy.

Public research organisations

The public research system has been downsized, rebalanced in favour of universities and modernised to a considerable extent by a series of reforms that started in the mid-1980s.

Today, government research institutes still play a key role in supporting basic and strategic research, as well as mission-oriented research, mainly in the natural sciences and high-technology-related disciplines. The last wave of reforms (the industrial conversion started in 1999 and the re-classification reform in 2000) has considerably reduced the number of institutes while improving the average quality of staff. It has refocused the institutes' work on research and provided them with larger and more stable resources to allow them to raise their ambitions and upgrade their research equipment.

The Chinese Academy of Sciences (CAS), the country's most prestigious research institution, illustrates the reform process, its achievements and the unresolved issues. When the reform of the CAS was launched in 1998, it was overstaffed and inefficient, with about 60 000 staff and a network of some 120 institutes with partly overlapping missions and activities.

The main objective of the Knowledge Innovation Programme was to renew and reinvent the CAS as a research organisation, following a centre of excellence approach: this involved the creation of 30 internationally recognised research institutes by the year 2010, five of which were to be world leaders. So far the number of research institutes under the CAS umbrella has been reduced to 89. Their disciplinary focus and missions have been redefined and the vitality of the CAS system has been reinforced through an ambitious effort to renew the human resource base. In addition, new funding and management mechanisms have ensured a better balance between responsiveness to dispersed research end users and coherence in addressing national research priorities, including missions of public interest.

However, while some reforms planned under the Knowledge Innovation Programme have not yet been completed, the CAS constantly faces new challenges as the other components of the NIS evolve and new demands are made on the science system. For example, demand for multidisciplinary research is growing at a time when the CAS still has difficulty bridging disciplines and institutes.

The higher education system

As a research performer, the higher education system has expanded considerably over the last decade. Although almost 700 higher education institutions are recorded as active in R&D because they receive some relevant public support, the number of significant players is much smaller, and only a few of these enjoy international visibility and reputation as major research universities. Compared to their OECD counterparts, they have two main distinctive features: a greater relative number of enrolments in science and, mostly, engineering disciplines, which provide a larger basis for related research activities; and a strong orientation towards applied research.

For university research, government policy has aimed at concentrating increased funding on the universities that were considered to have the greatest potential for developing a world-class research environment and performance. As a result, the R&D expenditure of the top 50 universities accounts for about two-thirds of total R&D expenditure on natural sciences and engineering in the higher education sector.

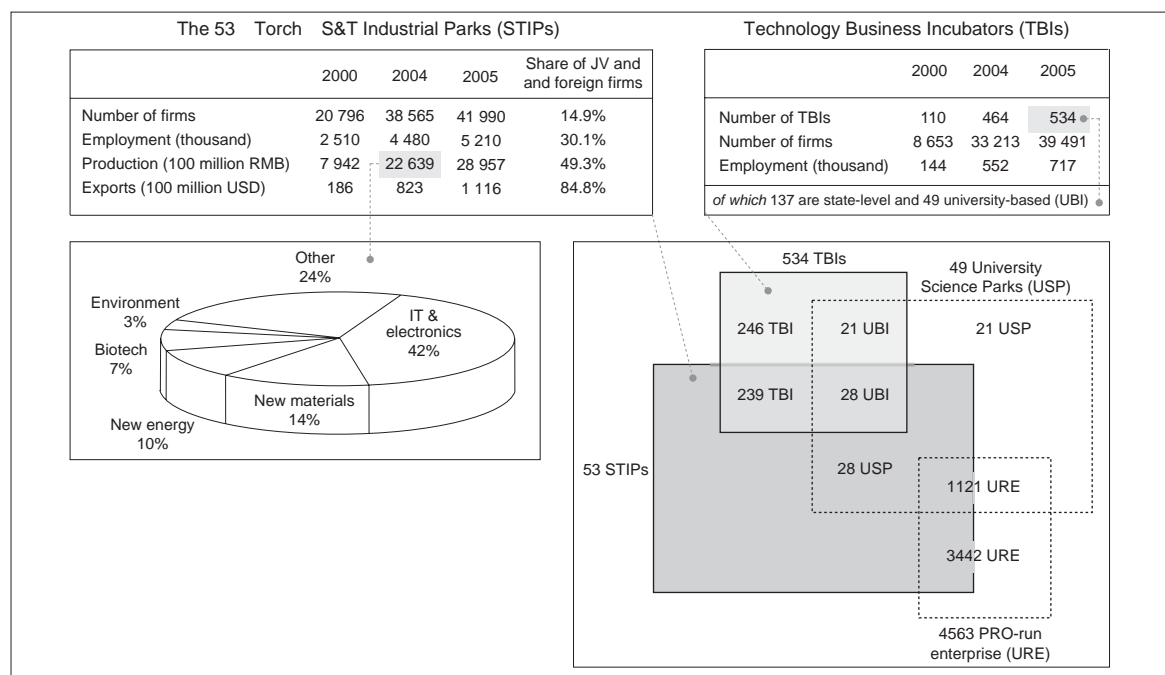
Universities are key knowledge infrastructures (Box 2.2) and the central pillar of Chinese industry-science relationships (see also the next section). In addition they still run a number of their own S&T companies (URE in Figure 2.18 in Box 2.2). They are very active in all areas of technology diffusion and commercialisation:

- University S&T parks and incubators (Figure 2.18).
- Direct participation in the technology market. The higher education sector had a share of more than 10% of the total contract value in the technology market in 2004 (Figure 2.19 in Box 2.2).
- Active patenting. Universities account for about 20% of patents granted by the Chinese Office of Intellectual Property (SIPO).
- Co-operation with the business sector. In 2003, business-funded R&D expenditure accounted for 36% of total R&D expenditure in the higher education sector, 1.4 times more than in 2000. At the same time, higher education institutions and industrial enterprises jointly participated in a broad range of national S&T programmes supported by the government, such as the 863 Programme, the Torch Programme, the Spark Programme and the S&T Achievement Spreading Programme.
- Provision of venture capital (Figure 2.20). University-backed VC firms (UVCF) emerged in 2000 in the major scientific universities such as Tsinghua, Shanghai Jiaotong, Fudan, etc.

Whereas many OECD countries have struggled for many years to make their universities more interested in research with a practical use, the problem for the Chinese government has been the reverse. Its objective is clearly to build a number of world-class universities that would be less involved in what should be now primarily be the task of the business sector and would complement the CAS by providing the innovation system deeper scientific roots. The evolution of China's scientific production gives some indication of the progress made in this direction (Figures 2.21 to 2.23 and Table 2.4).

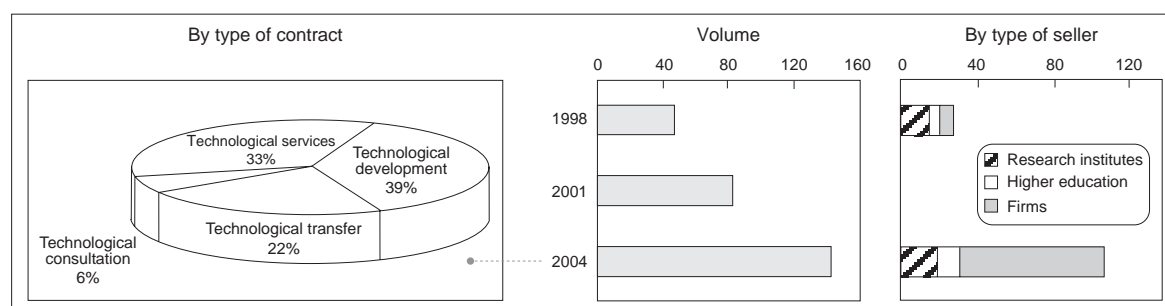
Box 2.2 Knowledge infrastructures and markets

Figure 2.18 S&T Industrial Parks and Technology Business Incubators



Source: OECD based on data from China high-tech industry data book.

Figure 2.19 Market of technology (billion RMB, %)



Source: OECD based on data from China Statistical Yearbook on Science and Technology.

Table 2.3 ICT infrastructure related indicators: the BRICS and selected OECD countries, 2004

	PCs per 100 inhabitants ¹	Internet subscribers per 100 inhabitants ¹	BB subscribers per 100 inhabitants ¹	International Internet bandwidth (Mbps) ²	Secure Internet servers ²	Telephone mainlines (millions) ²
CHINA	4.0	5.5	2.0	74 429	293	312.4
Russia	13.2	1.3	0.5	14 365	297	37.0
India	1.2	0.5	0.0	12 300	462	44.0
Brazil	10.7	4.4	1.2	27 449	2001	42.4
South Africa	8.3	2.2	0.1	882	909	4.8
Poland	19.1	6.5	2.1	21 380	565	12.3
Czech Republic	24.0	22.3	0.7	25 000	316	3.5
Hungary	15.0	7.6	3.8	10 000	210	3.6
France	48.7	19.8	11.2	200 000	3855	33.9
Germany	56.1	27.9	8.4	566 056	13 847	54.6
Japan	54.2	26.5	14.9	132 608	20 465	58.8
United Kingdom	60.4	26.6	10.5	781 554	21 034	33.7
United States	74.1	21.5	12.8	970 594	198 098	177.9

Source: 1. ITU (2005), numbers for 2004, numbers in italics are estimates or refer to years other than 2004; 2. World Development Indicators, World Bank, Online Database.

Box 2.3 Scientific development and Chinese culture

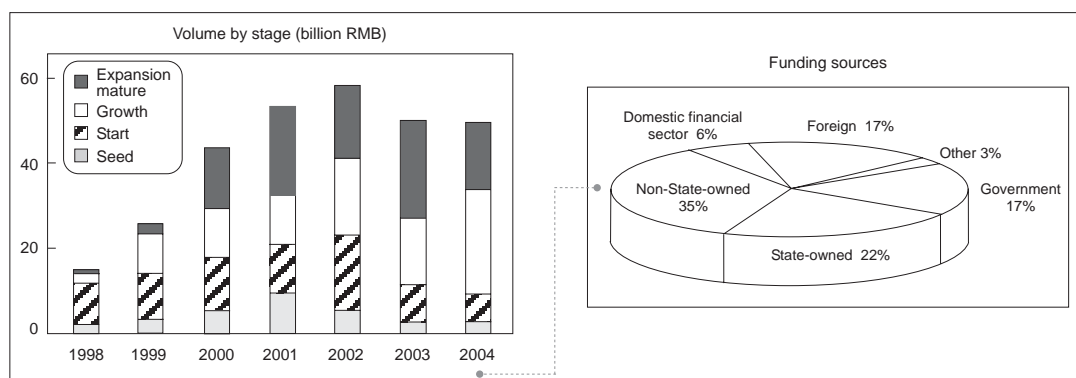
The scientific and technological revolution, which transformed Europe from about 1600, did not take place in China, despite the fact that many inventions were actually made in China before they appeared in Europe. It has therefore usually been concluded that there is something in Chinese culture and tradition that impedes the development of original science and technology. This view is more and more challenged by researchers who point to a long tradition of scientific reasoning in China and argue that science should not be identified with the European version of scientific development.¹ The implication is that China can draw on its own culture to build an indigenous capacity for scientific development.

At least two different approaches were taken in early China to explain the causes of rainfall and the need, or not, to perform the rain sacrifice. One approach held that it was possible, by the performance of certain rituals, to affect various natural phenomena. The other looked for natural phenomena related to rainfall, such as the presence of wind, heat or clouds, and attempted to find causal relationships. Debates concerning science as rational investigation occurred on many occasions. The famous astronomer and statesman Zhang Heng (78-139 AD) improved the armillary sphere, or celestial astrolabe, invented by his predecessors in China one or two centuries after Eratosthenes. The sphere has the structure of a celestial globe with circles divided into degrees for angular measurement while inner moveable rings demonstrate the order and motion of the planets. The aim of his work was to support the theory that heaven is shaped like a complete sphere (*hüntian*) and not like a cupola (*gaitian*), and that this permits correct measurement of the length of a day. Exactness in such evaluations was recognised as more important than the favour of the court.

After 1279 science and technology in China went into gradual decline and stagnated, in sharp contrast with the rise of science in Europe. It was also at that time that the Jesuits travelled to China, taking with them Western ideas and thus interrupting the hitherto largely separate evolution of Chinese scientific thought.

1. See for instance: C. C. Gillespie, *Essays and Reviews in History and History of Science*, ed. American Society, 2007; Agnès Chaliér, *Des idées critiques en Chine ancienne*, L'Harmattan, Paris, 2000; Liyan and Du Shiran, *Chinese Mathematics, A Concise History*, Oxford U.P. 1987; J. Needham, *Science and Civilisation in China*, Cambridge U.P., 1954.

Figure 2.20 Venture capital in China (billion RMB, %)



Source: Venture capital development in China (NRCSTD, 2005); China Science & Technology Indicators (Chinese version).

The increased funding for R&D seems to have been quite efficient in terms of scientific publications, allowing China to end an old debate about its cultural aptitude for scientific work (Box 2.3) by becoming a scientific power that ranked fifth in 2005 in the SCI (Science Citation Index), after the United States, the United Kingdom, Germany and Japan, with a share of 6.5% of the world's publications, compared to only 2% less than a decade before. In some disciplines, such as nanotechnology, China is already quite close to the United States in terms of number of publications (Figure 2.23).

Figure 2.21 The growth of Chinese scientific publications is spectacular despite a still comparatively modest productivity of the Chinese research community

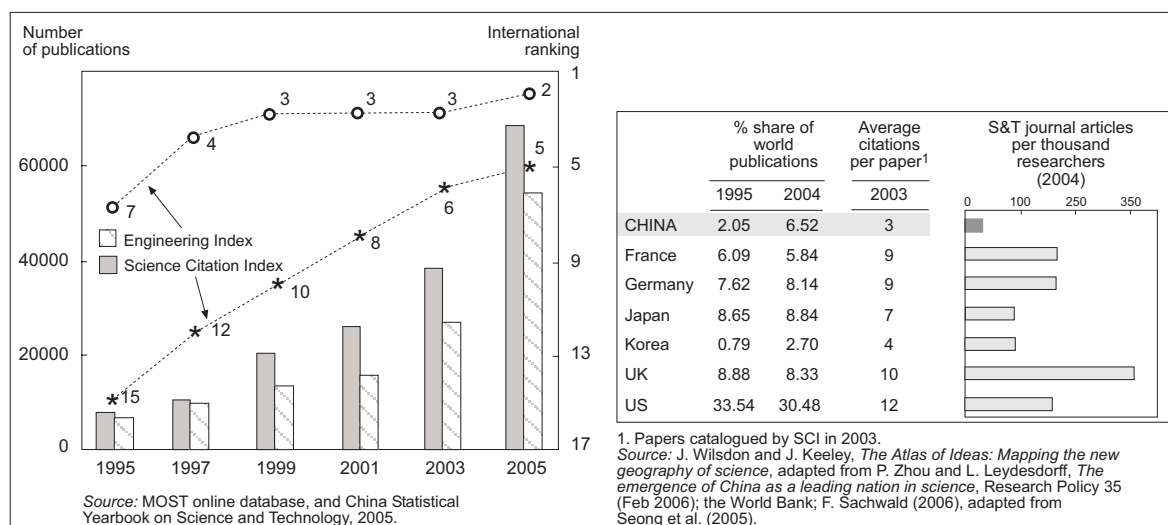


Table 2.4 Most prolific sources of scientific publications in China

	Papers in all fields				Nanotechnology papers	
	Number		Impact		Number	Rank ²
	1995	2005	1995	2005	2005	2005
Chinese Academy of Sciences	1524	14051	1.163	1.849	2916	1
Tsinghua Univ.	345	3650	1.470	0.873	749	4
Zhejiang Univ.	188	3268	n.a.	0.741	528	11
Peking Univ.	488	2710	0.916	2.626	400	22
Shanghai Jiao Tong Univ.	161	2435	n.a.	0.667	367	26
Nanjing Univ.	617	2031	1.673	1.668	534	10
Univ. of S&T of China	358	1992	2.092	3.601	482	16
Fudan Univ.	353	1770	1.586	1.856	n.a.	>30
Shandong Univ.	158	1344	n.a.	n.a.	n.a.	>30
Jilin Univ.	259	1330	n.a.	n.a.	378	25

1. Excluding Hong Kong's universities.

2. International rank in terms of the number of publications according to Kostoff *et al.*, *Structure of the Global Nanoscience and Nanotechnology Research Literature*, DTIC Technical Report Number ADA461930
Source: R.N. Kostoff *et al.* (2007), *Chinese science and technology -- Structure and infrastructure*, *Technological Forecasting & Social Change*, doi:10.1016/j.techfore.2007.02.008.

Figure 2.22 The impact of Chinese scientific articles is still low

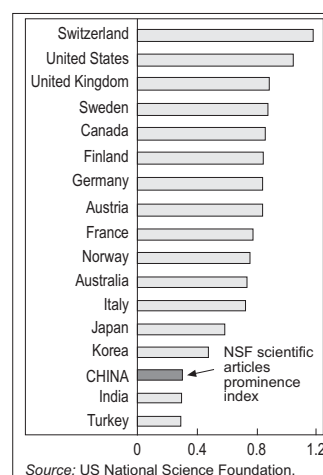
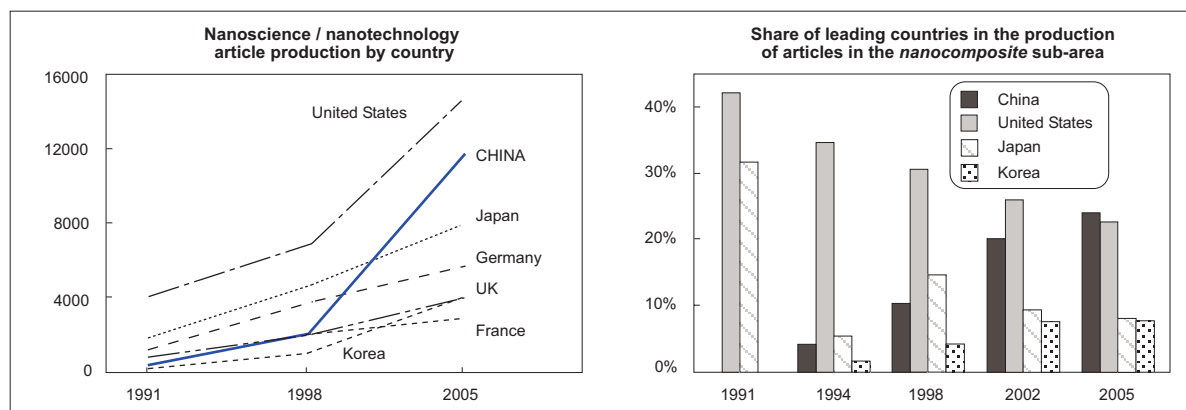


Figure 2.23 The Chinese scientific system emphasises increasingly nanoscience / nanotechnology



However, this picture should be qualified. First, this skyrocketing trend is partly due to increased incentives to publish. PhD students are now expected to publish at least one article in a journal listed in Thomson's Science Citation Index; for more experienced academics, publication records are more and more used to determine funding. Second, quality does not seem to keep pace with quantity. Citation rates and other indicators of quality remain relatively low (Figure 2.22); scientific fraud has even become a serious concern. At the same time, the national figures conceal strong performance by some individual universities. One study found that Peking University was among the top 1% of world institutions in citations for physics, chemistry, engineering, materials, mathematics and clinical medicine. Five other Chinese universities were in the top 1% for at least one of these fields.

The Chinese science system is already well connected internationally, as demonstrated by the number of Chinese publications with foreign co-authors, especially from the United States and Japan. International scientific collaboration is important in all disciplines, with the exception of chemistry (Table 2.5), and seems to expand more rapidly with other Asian and Anglo-Saxon countries than with most European countries (Table 2.6).

Table 2.5 International co-authorship by discipline, 2003

	Number of internationally co-authored articles	% of the total number of articles in the discipline
Mathematics	1 035	32.1
Physics	2 105	27.5
Chemistry	1 351	14.0
Geology	1 201	40.5
Biology	714	31.9
Clinical medicine	743	36.5
Engineering	2 800	24.2
<i>All disciplines</i>	<i>11 739</i>	<i>23.6</i>

Source: Chinese Institute for Scientific Information.

Table 2.6 International co-authorship: top ten partner countries/territories

1995		2000		2005	
Country/territory	Number of papers	Country/territory	Number of papers	Country/territory	Number of papers
United States	914	United States	2 411	United States	5 995
Japan	377	Japan	1 082	Japan	2 411
Germany	309	Germany	694	Germany	1 422
United Kingdom	227	United Kingdom	596	United Kingdom	1 401
Hong Kong, China	221	Canada	418	Canada	1 175
Canada	198	Australia	382	Australia	1 024
France	174	France	325	France	866
Italy	141	Singapore	299	Singapore	799
Australia	109	Chinese Taipei	229	Korea	712
Sweden	96	Italy	227	Chinese Taipei	474
Total number of Chinese articles	6 991	Total number of Chinese articles	29 294	Total number of Chinese articles	72 362

Source: R.N. Kostoff *et al.* (2007).

Overall over the last decades, public research organisations have played a positive role in advancing China's S&T capabilities. Their role is likely to evolve but remain important in the more enterprise-centred NIS of the future. The challenge is to redefine their missions in the new system, taking into account the need for a large innovation-oriented economy to be rooted in a strong, internationally open and responsive science system.

Interaction within the innovation system

The efficiency of a national innovation system depends much on its “knowledge distribution power”, that is, its capacity to stimulate and optimise the diffusion, sharing and creative use of ideas in any form, whether in a scientific publication, expressed orally at a meeting, embodied in equipment, software or a business practice, etc. Intellectual property rights certainly play a crucial dual role (ensuring that exchange of knowledge does not discourage its productive use but also providing information about trends in such use) and competition stimulates the demand for new economically relevant knowledge. However, firms' networking and clustering and science-industry relationships constitute the main modes of interaction, and their efficiency determines this distribution power. From this perspective China's innovation system has improved a lot over the last decade but still presents serious weaknesses.

Inter-firm innovation-oriented collaboration, within networks or clusters, remains rare outside S&T industrial parks (STIPs) and university science parks (Figure 2.18) and, as noted above, foreign firms have so far developed few linkages with domestic firms. Moreover, STIPs present an example of “mission creep”, in that they were initially created and supported under the Torch Programme to provide a supportive environment for the development of indigenous innovation capabilities but have often become mere platforms for export-oriented manufacturing by affiliates of international corporations. Generous support policies, especially tax exemptions, have in fact encouraged production and exports rather than innovation.

Industry-science relationships (ISRs) are at the heart of the most innovative networks and clusters. They are pervasive in the most advanced economies and take many forms: casual contacts between academic scientists and engineers, spin-offs from public research, licensing and patenting by universities, contract research, mobility of researchers, public-private partnerships for research, co-operation in training and education, etc. They allow a two-way exchange between curiosity-driven research and market-led innovation to the benefit of both. They are therefore not simply channels of knowledge transfer but stimulate creativity throughout the innovation system.

The role of the science sector in China's economic development has changed quite dramatically, especially since the late 1990s. ISRs have been restructured and intensified. Market-based channels, such as patenting and contract research, play an increasing role but some institutional features specific to China, notably the importance of business affiliates of universities and to a lesser extent research institutes and the role and nature of intermediaries in the “technology market”,⁶ continue to strongly influence ISRs' patterns. The following trends are noteworthy:

- The technology market has expanded considerably (Figure 2.19). In 2004, the business sector spent on this market the equivalent of 85% of its own R&D expenditures. A study found that the impact of the “technology market” on productivity growth has been significant but is decreasing over time, suggesting that the relative importance of in-house R&D has increased, but also that the purchase of technology has allowed enterprises to set up technological capability on which they can rely for further development.

6. “Technology market” refers to physical entities set up to facilitate technology transactions between sellers and buyers of technology and technological services. The first of these was created in 1984 in Wuhan and was composed of about 60 technology offices in research institutes, universities and firms in the area.

- The share of business funds in the budget of public research organisations is increasing for universities but stable for research institutes.
- The number of firms in technology business incubators (TBIs) has more than quadrupled since 2000 to almost 40 000 in 2005, many of which are spin-offs from publicly funded research (Figure 2.18).
- About one-quarter of the 750 R&D centres established in China by foreign firms are estimated to be joint units with universities or research institutes.
- Leading universities have been very active in developing linkages with industry in order to improve the quality and relevance of their teaching programmes.⁷

ISRs in China suffer from the same generic factors as in other countries, such as insufficient demand from firms, an academic research culture that does not emphasise economic relevance, low mobility of researchers, and competition between public research and industry for public support. However some of these impediments are more severe in China than in most OECD countries, notably:

- The demand for scientific inputs to innovation is very limited as the vast majority of domestic firms have not put innovation at the core of their business strategy.
- The concept of pre-competitive research, as opposed to near-market applied research or mere technological development, as well as that of public-private partnership, are not yet well understood by many actors in the innovation system.
- Researchers in the public sector, especially in the restructured research institutes, have weak incentives to collaborate with industry.
- China's venture capital system has developed rapidly over the past ten years but suffers from important weaknesses.⁸ As a result investment in seed and start-up stages seems insufficient and rather volatile.
- More generally, defective framework conditions that hinder entrepreneurship and innovation in the business sector (see Part I) also impede the development of fruitful ISRs.

7. For example, Shanghai Jiao Tong University continuously modifies its curriculum in automotive engineering, creating new specialities in response to new developments in automotive design. The Suzhou Industrial Park Institute of Vocational Technology (SIPIVT) has introduced an "order-driven" training model, under which it selects students together with enterprises and co-operates with them to design labs, set specialities and courses and create teaching programmes. Foreign firms established near the universities frequently provide equipment on which students can experiment and use modern research techniques and methods. Some universities have established committees involving enterprises and opened special offices in charge of co-operation with industry in education.

8. Between 1995 and 2004 the number of venture capital firms (VCF) in China increased from 21 to 217. There exist four types of VCF. The government VC firms (GVCF) were the first to appear. They are controlled by and get their funds from local governments. Recently GVCF have diversified their funding sources and depend increasingly on listed and cash-rich companies. However, they may suffer from interference by local government in their investment decisions and they have insufficient skills to evaluate and monitor new ventures because they do not attract the most qualified managers. University VC firms (UVCF) which primarily fund high-technology companies in the early stages also suffer from relatively weak managerial expertise. Corporate VC firms (CVCF) are primarily funded by listed companies but also by unlisted ones with large cash flows, individual investors and foreign firms. CVCFs mainly invest in expansion stages. Foreign VC firms (FVCF) have now become the major actors in new venture funding. Among the top 20 VCF in China a large majority are FCVF.

Part III

Promoting Innovation: The Role of Policy and Governance

Introduction

This part of the report builds on previous parts and analyses China's policy instruments dedicated to fostering science and technology (S&T) and innovation and the governance of its innovation system. Following the discussion of the framework conditions for innovation in Part I, and the analysis of the performance of the Chinese national innovation system (NIS) in Part II, it explores the implications of current policies and governance on innovative performance by looking at the policies the government has used to promote R&D and to encourage the transition to a market-based NIS and their main limitations.

Major policy implications of the previous discussion include:

- Improvement of a wide range of framework conditions to support market-based innovation should be made a priority in the implementation of the long and medium-term innovation strategic plan.
- Co-ordination of government policies needs to be improved.
- Diagnosis of inefficiencies in the Chinese NIS indicates deficiencies in policy and/or governance.
- The overarching challenge for policy is to make the policy and governance better suited for promoting an enterprise-centred technology innovation system.

This part focuses on the following policy and governance aspects of the Chinese NIS:

- The evolution of post-reform S&T policy development, highlighting the significant changes brought about by the progressive shift towards a market-oriented national innovation system that has been in the making for more than two decades.
- The current focus of China's S&T policy: the policy initiatives announced by the government for the implementation of the S&T Strategic Plan (2006-2020).
- Main characteristics of the governance of S&T and innovation, both at the central government level and at the central-local government interface.
- A brief overview of S&T policy instruments from a policy mix perspective.
- A particular focus on the government R&D programmes, the most important policy instruments for promoting S&T and innovation in the post-reform period.
- An assessment of the main issues and shortcomings of the policies and governance mechanisms, and areas for improvement.

The evolution of post-reform S&T policy

S&T policy reform and development evolved in four main phases marked by the strategic National S&T Conferences (1978, 1985, 1995 and 2006), at which strategy decisions were taken. The reform of S&T policy has taken an incremental approach, characterised by a progressively deeper understanding of policies, systemic transformation and institutional innovation.

The 1978 conference started the process of S&T reform. It clarified the productive roles of science and technology and of intellectuals in economic growth by discarding the earlier doctrine that viewed science and technology and intellectuals as “non-productive” and “non-proletariat” forces. The years to 1984 were marked by bottom-up experiments aimed at freeing the energy and potential of the research community. An unanticipated institutional innovation of the period was the creation of spin-offs from the public research organisations (PROs) to commercialise research results and bridge the gap between research and industry by taking advantage of the economic freedom created by the reform. Some of these spin-offs, such as Lenovo (formerly Legend) and Founder of Peking University became recognised successes of China’s information technology industry. University reform initially focused on the promotion of basic research and the establishment of graduate programmes. However, the R&D institutions and the direct institutional funding mechanisms of the pre-reform period changed little. Policy learning was predominantly based on analysis, “self-criticism” and “learning by doing” through the implementation of reform experiments.

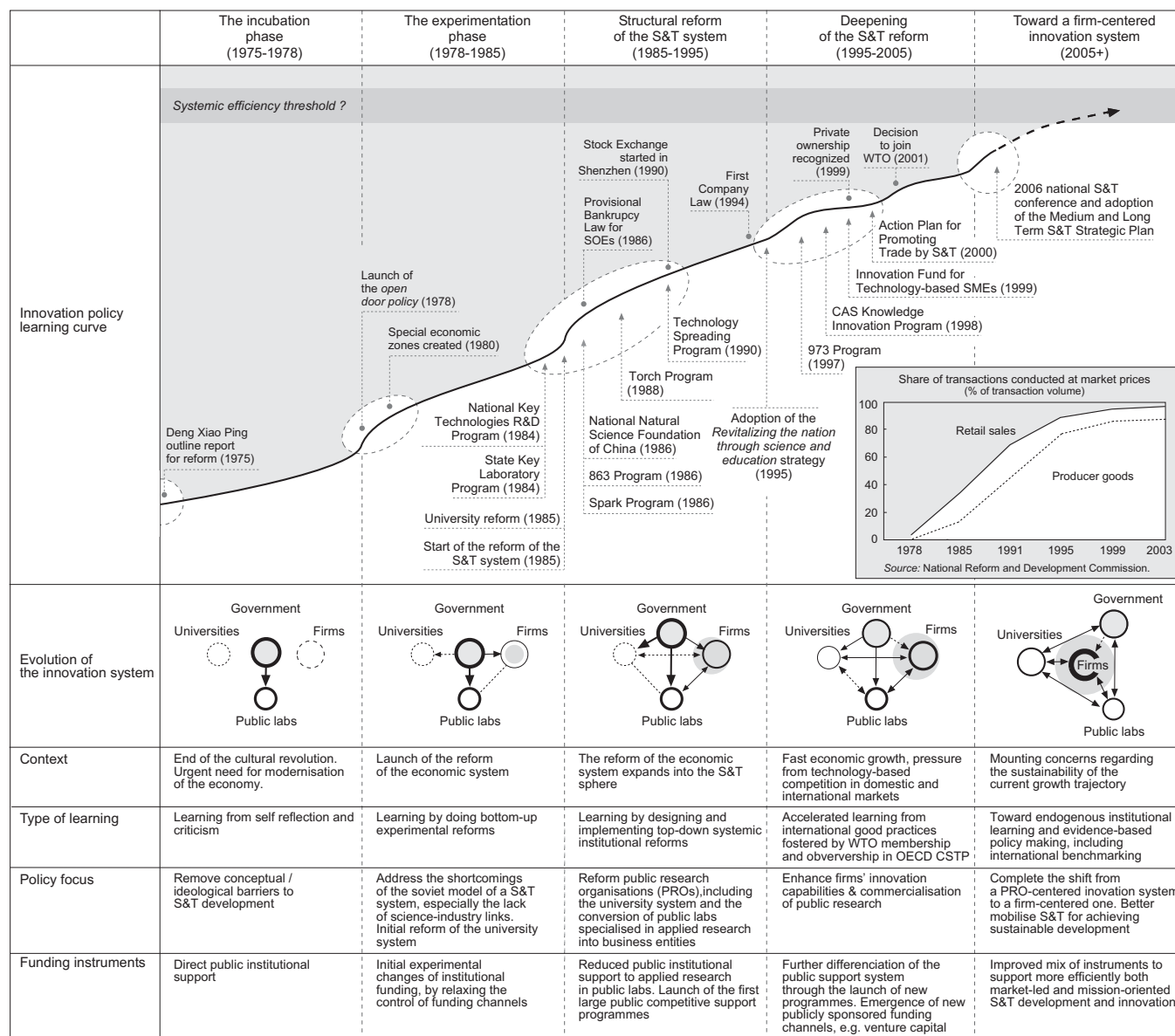
Following the government’s decision to reform the economic system, institutional reform of the S&T system was launched in 1985. The primary goal was to overcome the separation of R&D from industrial activity, the key shortcoming of the pre-reform S&T system. The reforms focused on:

- The allocation mechanisms for public R&D funding.
- Transformation of R&D institutions in applied research into business entities and/or technical service organisations, and the incorporation of large R&D institutions into large enterprises.
- Creation of markets for technology.
- Reform of the management of human resources in public research institutions.

These reforms gradually enhanced the economic orientation of the S&T system by introducing elements of competition and market discipline. Major institutional innovations have included the establishment of a variety of government R&D programmes, the emergence of markets for technology and of non-governmental technology enterprises. The increased reliance of public research organisations on non-government funding, and a growing share of R&D funded and performed by the enterprise sector were also among the main achievements of the period. Policy learning resulted from implementation of the reforms of the S&T system.

Against the background of the emerging global knowledge economy, and in the face of global technology-based competition, the Chinese leadership adopted in 1995 the “revitalising the nation through science and education strategy”, which initiated a new phase of S&T reform and policy. The strategy was inspired by concerns over China’s future competitiveness in the global knowledge economy following the decision to join the World Trade Organization (WTO). In the following decade, S&T policies focused on engineering and implementing a systemic shift from the PRO-centred R&D system to an enterprise-centred innovation system, while fostering firms’ innovation capabilities and commercialisation of technology. The institutional innovations included further R&D funding programmes, on the one hand, and intensified reform of PROs, on the other, as in the Knowledge Innovation Programme of the Chinese Academy of Science (CAS). During this phase, China paid increasing attention to learning from advanced OECD countries, as senior policy makers and analysts became familiar with the leading innovation policy concepts. The official adoption of an enterprise-centred technology innovation system is a result of this phase of policy learning.

Figure 3.1 China's innovation policy: institutional reform and learning curve



Source: OECD.

However, experience to date has proved that to improve the innovation capability of Chinese firms and to make firms the centre of technology innovation is much more challenging a task than the adoption of a new conceptual framework. The government still faces the challenge of appropriately balancing the new market-based approaches to innovation and direct government support through national R&D programmes. These remain the two most important challenges today.

The 2006 National Science and Innovation Conference and the adoption of the Medium- to Long- Term Strategic Plan for the Development of Science and Technology are the most recent phase in the construction of the national innovation system. It will be supported by new and enhanced S&T policies and measures. The S&T Strategic Plan (2006-2020), which is part of the government's effort to shift China's current growth model to a more sustainable one, seeks to make innovation the driver of future economic growth, and emphasises the building up of an indigenous innovation capability. To accomplish this task will require some fundamental reorientation and increasingly sophisticated policy and governance. The main challenges involve a change from an uncoordinated, piecemeal style of S&T policy making to a co-ordinated whole-of-government policy approach; from policies targeted at promoting R&D activities to policies for creating an innovation-friendly framework; and from one-size-fits-all policy measures to fine-tuned and differentiated policy measures tailored to delivering more sophisticated support for policy needs.

These changes imply that the government will embark on a steep learning curve and that in some areas drastic institutional innovations will be called for. The formation in 2007 of four industrial-research alliances (see Box 3.1) sent an early signal that new market-based initiatives, following international good practice, are under way. In this context, as policy makers' tasks have become increasingly sophisticated, requiring the use of more market-based instruments, learning from international experience and best practice has become more important than ever (Box 3.2). This may have been one of the reasons behind the government's decision to appoint an overseas returnee as the new Minister for Science and Technology.

Box 3.1 Industrial research alliances for technology innovation

In June 2007, four industry-research strategic alliances, concerning steel, coal, chemistry and agricultural equipment, were set up with government support. They aim to address long-standing problems related to the low level and dispersal of innovation capabilities, the inadequate supply of generic technologies and the lack of core technological competencies in these sectors. They seek to enhance these sectors' technological innovation capability by creating a stable, institutionalised industry-university-research partnership based on market principles. The formation of these alliances was inspired by successful industry-science partnerships in OECD countries.

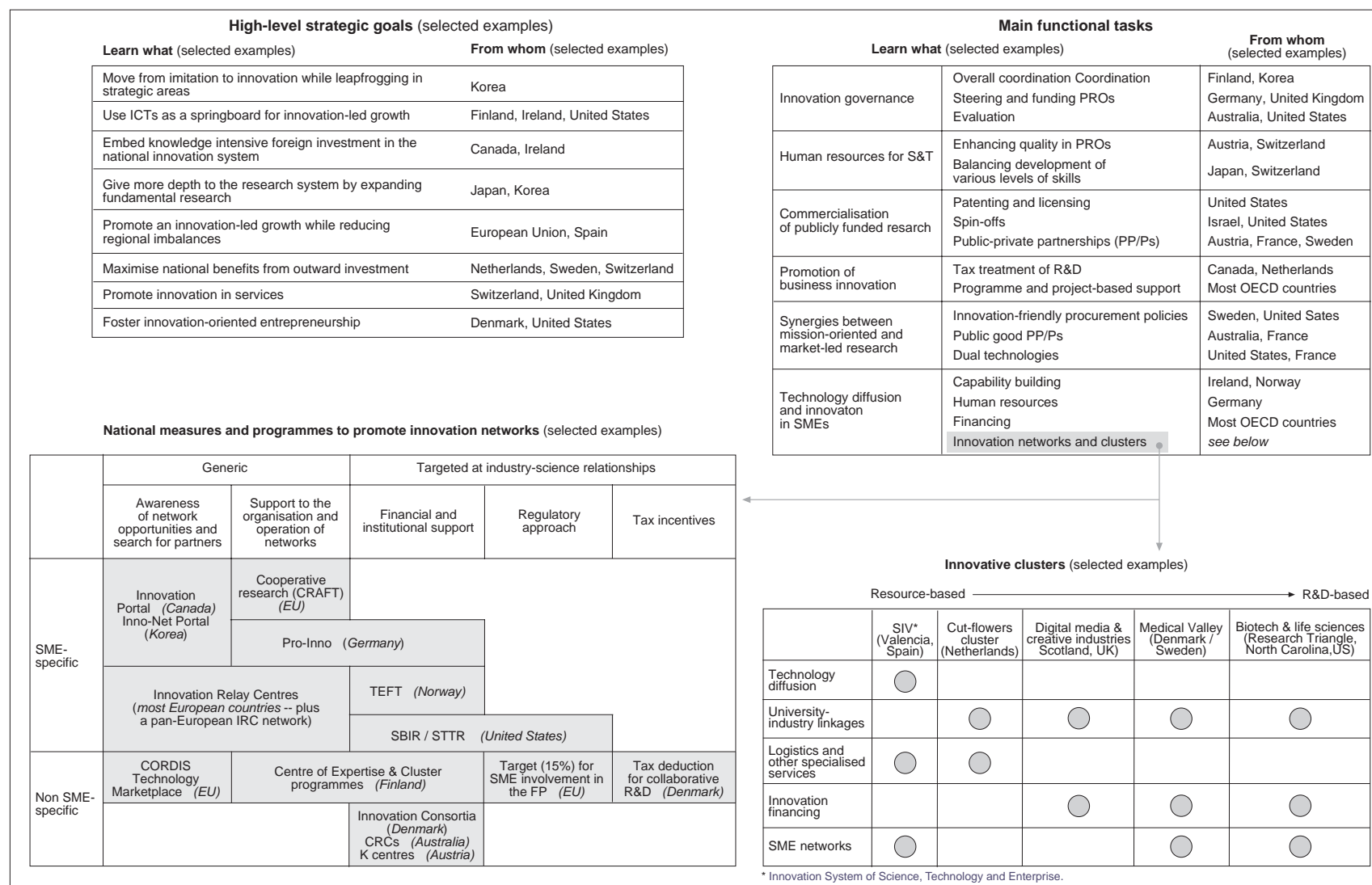
Important features of these strategic alliances include:

- *Key industries:* The four industries are considered backbone industries that are an important foundation of China's economy.
- *High potential:* The alliances encompass 26 leading enterprises (with total sales revenue of RMB 900 billion in 2006), 18 leading universities and nine key research institutions, with important upstream and downstream implications for industry as a whole. They are expected to play a positive role in accelerating technological progress and structural upgrading throughout Chinese industry.
- *Flexible formations:* Each alliance has its own form, adapted to the specific industrial structure and technological problems of the industrial sector.

The Ministry of Science and Technology and the relevant departments will work together to ensure that there is a good policy environment for the alliances. The alliances will take priority in terms of funding in national R&D programmes and in obtaining government support for innovation during the implementation of China's Medium- to Long- Term Strategic Plan for the Development of Science and Technology.

Source: Ministry of Science and Technology, at www.most.gov.cn/sjzjt/200706/t20070619_50548.htm.

Box 3.2 Learning from international good practices



Source: OECD.

The current focus of China's S&T policy

The implementation of China's Medium- to Long- Term Strategic Plan for the Development of Science and Technology is the central priority of current S&T policy, which focuses primarily on achieving three strategic objectives:

- Building an innovation-based economy by fostering indigenous innovation capability.
- Fostering an enterprise-centred technology innovation system and enhancing the innovation capabilities of Chinese firms.
- Achieving major breakthroughs in targeted strategic areas of technological development and basic research.

To this end, the State Council announced late in 2006 a new policy package covering four broad categories:

- Enhancing R&D financing not only through enhanced public funding, but also through extended tax incentives for S&T⁹, government support for the development of financial market funding channels, public funding to support the absorption of imported technology, etc.
- Promoting innovation through improved framework conditions: active use of intellectual property rights (IPR) protection, active participation in setting international technology standards, public procurement, and R&D infrastructure construction, including key labs, science parks and incubators, etc.
- Enriching human resource in S&T by nurturing scientific leaders and talent and tapping into the global pool of HRST, including overseas Chinese, reforming higher education, and improving public awareness of innovation.
- Improving the management of public R&D by introducing a new evaluation system and increasing policy co-ordination.

These policy measures indicate a convergence of Chinese government policies with those adopted in OECD countries. For example, the use of tax incentives for R&D and tax breaks for incubators and university science parks are common in OECD countries. The policy that encourages accelerated depreciation of machinery and equipment for R&D seems to be inspired by firms' practices, if not by government policies, in industrialised countries. The policy that encourages Chinese firms actively to use IPR protection to build their competitiveness and improve their market position is inspired by the IP strategies employed by multinational enterprises. As pointed out in Part I, this policy will raise Chinese IP owners' stake in IPR protection, and should improve the environment for innovation among Chinese and foreign companies alike. In general, the move towards more innovation will tend to align policies and framework conditions for innovation.

The technology procurement policy as a tool for fostering technology and product innovation by domestic firms and the policy that encourages Chinese firms to take an active part in formulating international technology standards have raised some concerns internationally. Since China has not yet signed the WTO government procurement agreement (GPA), foreign companies are concerned about the procurement policy's potential for discrimination. Moreover, implementation of this policy will require overcoming certain technical issues, such as how to identify innovative products that could benefit from the public procurement policy and how to ensure the consistency of the new policy with the Chinese law on public procurement. The policy that actively encourages Chinese companies' participation in the formulation of international technology standards is also raising considerable concerns. As China has a long-term interest in being perceived as a fair and

9. More details on tax incentives will be included in the full report.

responsible actor in the global innovation system, the implementation of these policies needs to follow established international norms while taking China's long-term interests into account.

Governance of the S&T and innovation system

Governance at the central level

Governance of the S&T system, in which the Ministry of Science and Technology (MOST) plays a prominent role, has the following important features:

- The State Council Steering Group for Science, Technology and Education is a top-level co-ordination mechanism, which meets two to four times a year to deal with strategic issues.
- A number of ministerial level agencies – the National Development and Reform Commission (NDRC), the Chinese Academy of Sciences (CAS), the Chinese Academy of Engineering (CAE), sectoral line ministries such as the Ministry of Information Industry (MII) and the Ministry of Agriculture (MOA), and the National Natural Science Foundation of China (NSFC) – play a direct role in designing and implementing S&T and innovation policies.
- A number of other ministerial agencies, notably the Ministry of Finance (MOF), and the Ministry of Commerce (MOC) have significant influence on S&T and innovation policies and implementation, while others, such as Ministry of Personnel (MOP) and the State IP Office (SIPO), also exert an important, albeit somewhat indirect, influence.

The current governance structure has resulted from the institutional changes and innovations implemented during the post-reform period, including:

- The creation of the Natural Science Foundation of China (NSFC) in 1986 and of other major funding programmes throughout the 1980s and 1990s, as new funding mechanisms for public research.
- The creation in 1998 of the State Council Steering Group for S&T and Education as a top-level co-ordination mechanism for S&T and education policies and strategic decision making.
- The transfer in 1998 of the National S&T Commission to MOST, owing partly to the downsizing of central government and partly to the creation of the more powerful State Council Steering Group in the same year.
- Several government restructuring and downsizing efforts in the 1990s that reduced the number of ministerial agencies from 40 to 29 (this mostly affected sectoral ministries that were part of the pre-reform government structure) and the number of government employees by 47% on average.

To allow MOST to fulfil all its main missions (see Figure 3.2) requires close co-ordination, joint decisions and shared responsibilities with other ministries:

- To formulate strategies; identify priorities, design policies, laws and regulations: all agencies concerned.
- To promote the building of the national innovation system and reform the S&T system: all agencies concerned.
- To promote technological R&D and innovation: NDRC and sectoral ministries.

- To promote basic research: CAS, CAE, MOE (Ministry of Education), and NSFC.
- To develop measures to encourage S&T investment and support innovative SMEs: NDRC and MOF.
- To develop HRST policies: MOE, MOP, CAS and CAE.
- To promote international S&T cooperation and exchanges: all relevant agencies.

Given the strong need for co-ordination between MOST and other agencies in the design and implementation of S&T and innovation policies, the existing governance structure suffers from an obvious shortcoming: the lack of a co-ordinating body with the status to co-ordinate all key policy issues.

In particular the current governance system may not be well suited to carry out the missions set out by the S&T Strategic Plan (2006-2020) owing to the lack of interagency co-ordination to ensure the consistency and coherence of various policies, to improve systemic efficiency and to optimise resource allocation.¹⁰ As pointed out earlier, the implementation of the strategic goal of building an “innovation nation” calls for a whole-of-government approach. This in turn makes it all the more important to enhance the co-ordination of S&T policies and initiatives by different government agencies at the central and sub-national levels to avoid departmental competition and duplicative and wasteful investment in light of rising public R&D expenditure. More concretely, to create better framework conditions for innovation, as a major requirement for fostering an innovation economy as pointed out in Part I, MOST would need to improve co-ordination with a wide range of government agencies, in areas such as taxation, competition and financial market supervision. Better co-ordination between MOST, CAS and NSFC, aside from others, is essential in order to make more efficient use of government resources for R&D. All this would suggest the need for an interagency co-ordination mechanism, and given its current missions, MOST would seem a natural choice; this could be combined with measures to reduce MOST’s direct involvement in the management of R&D funding programmes.

The central-local government dimensions of the innovation governance system

At the sub-national level, the S&T governance structure displays the following features:

- Comparable regulatory powers at all levels: no official guidance or limitation in terms of the types of policy tools a sub-national government can use.
- Sub-national actors participate in the implementation of national programmes and make an important contribution, currently nearly 40%, to total government appropriation for S&T.
- The primacy of horizontal over vertical links: sub-national governments play a more important role in defining the role and activities of their own agencies than the higher governmental level.

There are generally parallel governance structures at the national, provincial and even sub-provincial levels, with a high degree of ambiguity in the division of labour across levels. Overall, sub-national governments enjoy a substantial degree of autonomy, and government at all levels may fund S&T projects at national, provincial, municipal and even county levels. In fact, S&T funding by sub-provincial actors may even exceed that of the provincial level, a situation that is highly unusual in OECD countries. While it is important to mobilise resources at all levels, it is necessary to have a clear division of labour in terms of the roles and responsibilities of the central and sub-national governments to avoid uncoordinated actions, competing priorities and

10. For more reasons for and OECD experience with policy coherence and co-ordination, see the OECD’s Monitoring and Implementing National Innovation Policies (MONIT) project report (OECD, 2004).

duplication of investments. Cross-sectoral co-ordination problems also exist at the sub-national levels and are exacerbated by the different sectoral policy streams from the national level.

Chinese S&T policies – a policy mix perspective

The elaboration of Chinese S&T and innovation policies throughout the post-reform period has focused on achieving the following objectives: *i)* promoting basic research in selected scientific fields with perceived significant potential impact on social progress and economic development; *ii)* research and development on new technologies in selected high-technology areas of national priority, such as biotechnology, information technology (IT), space technology, energy technology, new materials, etc.; *iii)* technology innovation and commercialisation; *iv)* support for the construction of infrastructure for scientific research; and *v)* development of human resource in S&T and rewards for S&T excellence. In each policy area, the government uses a set of instruments to support the policy objective.

- Support for *basic research* consists of various programmes, such as the Natural Science Foundation programmes and 973 programmes, the reform of public research institutions and the various programmes for HRST, such as the Yangtze River Scholars Programme, the CAS Hundred Talents Programme, the NSFC National Distinguished Young Scholars Programme, etc.
- Support for *high technology R&D* consists mainly of the High Technology R&D Programme (863 Programme), and the National Key Technology R&D Programme.¹¹
- Support for *technology innovation and commercialisation* includes programmes for the development of new products, such as the National New Product Programme, and those for the construction of infrastructure for technology transfer and commercialisation, such as the Torch Programme, the Spark programme, the S&T Achievement Dissemination Programme, the Action Plan for Thriving Trade through S&T, etc. Related support measures include the Technical Innovation Fund for Small and Medium-sized S&T Firms, and provisions for tax incentives, venture capital, etc.
- Support for the *construction of infrastructure* for scientific research consists of the National Key Laboratories Programme, and the MOST programmes for the construction of platforms for sharing research facilities such as large research equipment, biological resources, S&T literature and R&D databases, and a network for scientific research.
- Development of *human resources in S&T* (HRST) and rewards for S&T excellence: in addition to those mentioned above in relation to support for scientific research, a host of programmes and rewards initiated by the MOE are aimed at nurturing HRST, such as the New Century Talents Training Programme, the University Young Scholar Awards; others are also made available by CAS.

A general assessment of the policy mix

- The policy mix is quite well developed and covers all policy areas relevant to innovation, ranging from scientific research, to technology research, to innovation (development research), to commercialisation. In addition, special policy attention has rightly been given to HRST and infrastructure building.
- Policies in inherently interrelated areas, such as science policy and HRST policies, and those for the construction of research infrastructure, seem to be designed with a view to synergy and mutual

11. This programme was renamed the National S&T Support Programme (*Guo Jia Ke Ji Zhi Cheng Ji Hua* in Chinese) in 2006. However, the English translation on the programme's website was not changed.

reinforcement. However, it is not yet clear whether sufficient attention is being given to achieving synergy and interrelation of policies across different domains.

- China has already introduced many of the policy instruments used in OECD countries. However, all of these policy instruments, and therefore their mix, are characterised by a top-down approach in their design and implementation, with little influence from other stakeholders, especially the private sector. The government's top-down approach tends to have implications for the mode of implementation and the effectiveness of policy instruments.
- All policy mixes are characterised by the strong legacy of the planned economy, as the programmes – literally “plans” in Chinese – are the main instruments for addressing policy priorities. This approach has some shortcomings, which are discussed below.
- There is a bias in favour of large state-owned enterprises in the design of policy instruments for innovation. This bias appears to influence the choice of policy instruments. For instance, programmes for private-public partnerships for innovation, which have emerged in OECD countries as instruments to foster long-term industry-science linkages (see Box 3.3), have not yet found their place.
- The dynamic evolution of China's economic environment and the fast pace of advances in S&T worldwide suggest a strong need to re-assess the relevance and effectiveness of individual instruments over time and to adjust the overall policy mix. However, since China lacks the necessary policy evaluation mechanism and culture, the effectiveness and rationale of some large programmes, some of which were introduced 20 or more years ago, have not been evaluated. This is likely to reduce the effectiveness and efficiency of the overall policy mix.

More specific observations on the mix of policies and instruments

- Programmes to support innovation, such as Spark and Torch, account for the lion's share of public funding, arguably indicating an imbalance in public support.
- Compared to the strong focus on building the physical infrastructure for S&T, policies designed to foster an innovation culture and establish framework conditions conducive to innovation do not figure prominently in the current key policy package. While individual policy efforts to improve framework conditions are indeed often made for other primary objectives, their impact on innovation performance needs to be explicitly taken into account.
- Priorities and divisions of labour could be better articulated between the 863 Programme and the National Key Technology R&D Programme, the two main programmes for promoting technological R&D. Similarly, more synergy and mutual reinforcement could be achieved between the key programmes supporting basic research, such as those funded by the NSFC and MOST's 973 programme, in spite of the differences in their focus.
- The programmes and awards related to fostering human resources are characterised by three biases: science is favoured over technological competence; talent is favoured over improving the quality and mobility of HRST at large (for example through on-the-job training); and S&T competencies are favoured over management competencies. These biases need to be overcome in order to address structural imbalances in human resource for S&T.

Box 3.3 Public-private partnerships for R&D and innovation in OECD countries

Since the 1990s, more and more public/private partnerships (P/PP) have been implemented in R&D and innovation policy in OECD countries.¹ They typically last for seven to ten years, have their own management, include five to 20 long-term industry partners and have an overall annual budget of USD 2-7 million. They are usually characterised by:

- A multi-annual research programme, drawn up and co-funded by one or a few universities or research institutes and a number of firms.
- A public funding authority that provides the structure, a competitive selection procedure and a considerable share of the funding.
- Most of the programmes do not pre-select fields or topics, but make priority setting a bottom-up process.

Successful practices in P/PPs include several important features:

- *Careful selection of projects and participants:* A rigorous competitive process, international openness, participation of small firms and the prior agreement on IPRs are of vital importance.
- *Optimal financing:* High-leverage, long-term commitment, a subsidy ceiling of less than 50% and flexibility are highly valued.
- *Efficient organisation and management:* A successful model should give the partners sufficient autonomy, while maximising their interaction through an institutional form that ensures continuous pressure to improve and facilitates further co-operation.
- *Complete evaluation system.* A good evaluation system consists of *ex ante*, interim and *ex post* evaluation, and assesses the potential long-term impact, such as the changes in the attitudes of both the public and private research communities.

Compared with most existing Chinese industry-research partnership, P/PPs in OECD countries focus more on the leverage of public support for private business R&D. This is evident in their focus on promoting long-lasting collaboration and nurturing the innovation capacity of the partners involved and in the technological areas concerned.

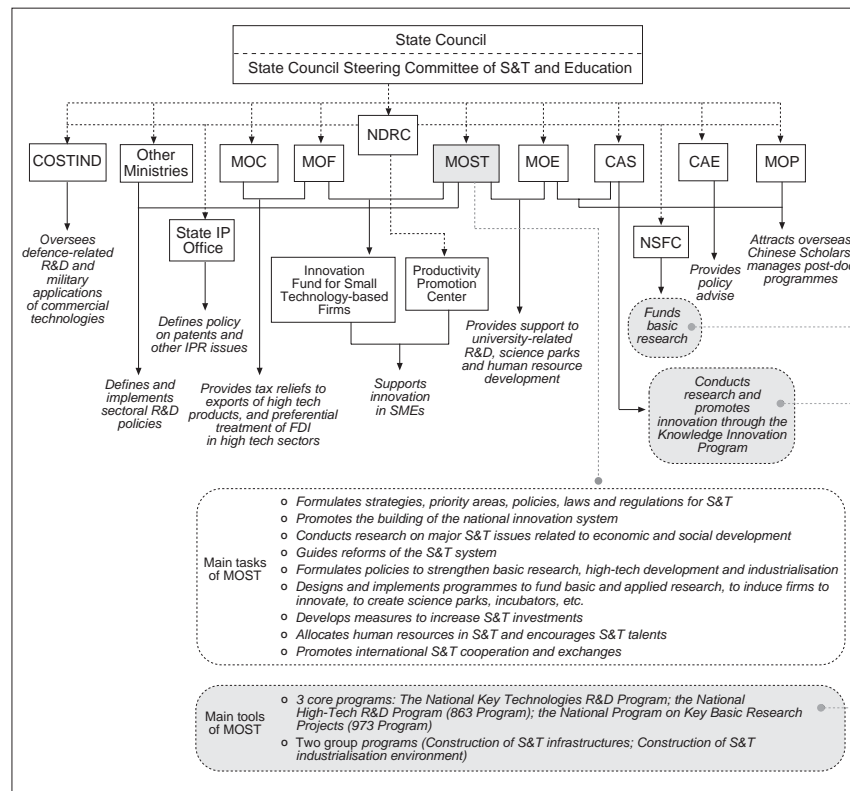
1. See the detailed case studies in the forthcoming OECD report, *Public/Private Partnerships for Innovation*.
Source: OECD.

R&D programmes - the single most important policy instrument

Strengths and achievements

Since the introduction of the first programmes in the early years of economic reform, S&T programmes have mushroomed in China, initially as an attempt to reform the old S&T system by injecting competitive funding mechanisms, and later as a response to the central leadership's call to enhance S&T and innovation. Further programmes were added to address the priorities in each five-year plan period. The funds allocated from the central government to the main programmes represented as much as 17% of total public S&T expenditure in the first half of this decade, an indication of their significance as the single most important policy tool for innovation. The most important programmes for which MOST is directly responsible are configured in the so-called 3+2 structure (see Figure 3.2).

Figure 3.2 Public governance of S&T and innovation in China: The institutional profile



NDRC: National Development and Reform Commission
 MOC: Ministry of Commerce
 MOST: Ministry of Science and Technology
 MOF: Ministry of Finance
 CAS: Chinese Academy of Sciences
 COSTIND: Commission of Science, Technology and Industry for National Defence
 MOE: Ministry of Education
 CAE: Chinese Academy of Engineering
 MOP: Ministry of Personnel
 NSFC: National Natural Science Foundation of China

Source: OECD based on data from MOST and other sources.

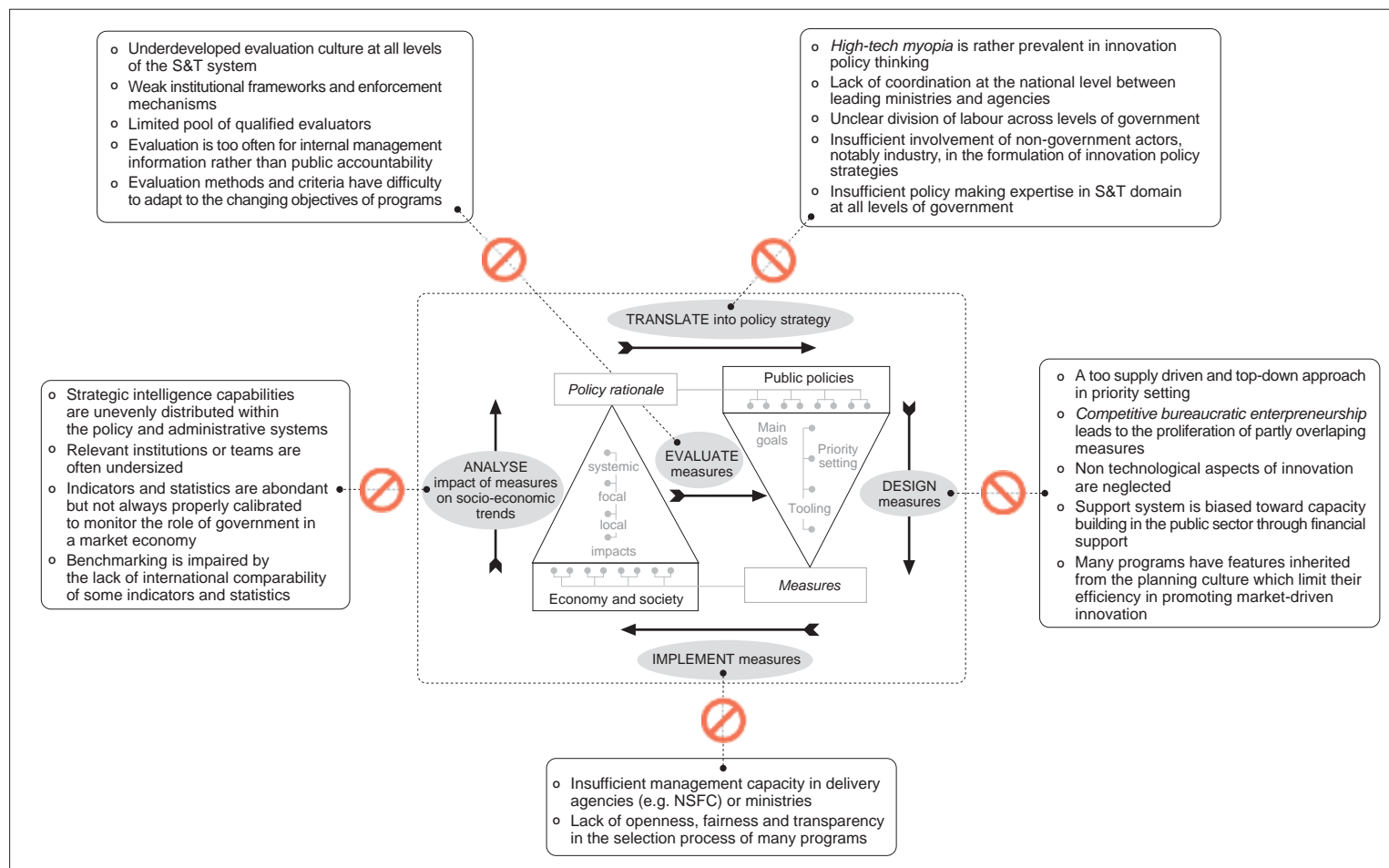
Table 3.1 Funds allocated by central government to the main S&T Programs (100 million RMB)

Program	Year of start	Implemented by	1981-85	1986-90	1991-95	1996-00	2001-2005
Key Technologies	1983		15	35	45.2	50	50
973	1997	MOST	-	-	-	12	21
863	1986		-	59			150
NNSFC	1986	NNSFC	-	5.7	15.9	44.7	100
Knowledge Innovation	1998	CAS	-	-	-	54	200
TOTAL			15	-	-	-	521
Total as a share of total public S&T expenditures							17%

Table 3.2 Main MOST Programs

Core Programs				Two Group Programs	
Key Technologies	863	973		Construction of S&T infrastructures	Construction of S&T Industrialisation Environment
Promote the development of key technologies needed for industrial and social development	Promote R&D capabilities in high tech	Support basic research in selected areas		Support the development of infrastructures and capabilities	Support environmental projects, regional economic development, tech-based SMEs, and S&T intermediaries
million RMB (2004)	Key Technologies Program	863 Program	973 Program	Funds allocated by central government to selected Two Group Programs (million RMB)	
Total funds raised	14985	9293	1031		
Government funds	3003	4231	903		
Gov. as % of total	20%	46%	88%		
Origins of funds for the Torch and Spark Programs (2004)					
	Total	Torch	Spark		
Funds raised (million RMB)	91886	71313	20573		
% government	3%	2%	5%		
% enterprise	70%	72%	60%		
% bank loans	23%	21%	30%		
% overseas	0,3%	0,3%	0,8%		
% others	4%	4%	4%		
				State Key Laboratory Construction Program	125 130
				National Engineering Research Centre	40 85.5
				Spark Program	39 105
				Torch Program	51 50
				Science and Technology Achievements Spreading Program	20 23
				National New Products Program	135 140
				Innovation Fund for Small Technology based firms	- 500
				Agriculture Science and Technology Transfer Fund	- 250
				Action Plan for Promoting Trade by Science and Technology	- 20
				Special Technology Development Project for Research Institutions	- 182

Figure 3.3 Public governance of the innovation system as an institutionalised policy learning process: Main hindrances in China



Source: OECD.

The three core programmes shown in Figure 3.2 are designed to concentrate resources and improve the focus on basic research and the key and high technologies of significance to China's economic development, social progress and industrial upgrading; and the two groups shown in the figure refer to the programmes for strengthening the infrastructure for S&T and commercialisation of science. The government's share of programme funding varies considerably from nearly 90% for basic research to around 50% for applied research, and considerably less, around 20%, for technology innovation. For programmes to support the commercialisation of research, such as Torch and Spark, the government accounts for no more than 2 to 5% of total funding, while local governments and enterprises typically provide large shares of funding for programmes related to innovation and dissemination of technologies.

The programmes' main strengths lie in their power to allocate public resources to the national priorities identified by the government. It is widely recognised that these programmes have played a significant role in advancing S&T in post-reform China by introducing the new funding mechanisms needed to move from the old S&T system to the new market-based one, directing funding and human resources to national priorities, feeding economic development with S&T inputs, and closing the technological gap between China and world leaders.

Shortcomings of the current programmes

Despite the strength of the R&D programmes as a tool to mobilise public resources to achieve national priorities, their design, management and evaluation reveal some shortcomings:

- Programme design is characterised by a top-down, “picking-the-winner” approach: the government decides on programmes and sets priorities with little involvement of other stakeholders.
- There is a lack of differentiation in programme design. There is some duplication of priorities, and programmes are often too general to take into account sector-/subject-specific needs in terms of the duration and amount of funding.
- Despite improvements made to date, the management of programmes needs to become more open and transparent. More openness, fairness and transparency in the selection process and in programme management are necessary to improve the efficiency of the programmes.
- Programme evaluation also needs improvement (see below). The *de facto* subordinate relation of the National Centre for S&T Evaluation (NCSTE) to MOST undermines its independence and reduces the credibility of NCSTE evaluations.

Main issues and challenges in the governance of the innovation system – hindrances in the learning process

China has made impressive strides in reforming its S&T system and in building a national innovation system based on its model for a “socialist market economy”. In this process, the government's function, its relation to the market, its attitude and its conduct have changed profoundly. Yet, the transformation of the public governance of the innovation system is far from complete. This section looks at the main areas in which reforms or improvements will be needed.

Using the policy learning framework set out in Figure 3.3, the basic functions of government in terms of policy making can be broken down into: *i*) identifying the main issues in social and economic development through evidence-based policy analysis; *ii*) defining the policy rationale and strategic objectives and priorities; *iii*) designing policy measures (tooling); *iv*) implementing policy measures; and *v*) policy evaluation to provide feedback to the policy learning circle, which continues over time as a dynamic and progressive process. These various stages are discussed below.

Evidence-based policy analysis

To base policy making on evidence-based analysis is relatively new in China. “Policy intelligence” is therefore underdeveloped. In the area of S&T and innovation policy, existing policy research capabilities are quite limited. There are very few institutions and experts with sufficient experience and in-depth expertise in S&T and innovation policy. Institutions are understaffed, so that staff is overstretched, and leading experts are overwhelmed by competing demands. There are difficulties with indicators and statistics. While these are abundant in China, there are problems of quality and international comparability. The scarce availability of indicators to monitor the role of government and the effectiveness of policies in a market economy is a further challenge that is faced by China and OECD countries alike.

Defining policy strategy and priorities

- A high-technology myopia pervades current policy objectives and policy thinking on innovation. In designing policy objectives, priority has mostly been given to high-technology-based innovation. As a result, innovations of other types and in other sectors of the economy are neglected. One of these areas is innovation in services, which is gaining in importance on government agendas in OECD countries. The policy attention recently given to research on public goods and S&T subjects related to social welfare may help correct this myopia, but it cannot substitute for a conscious effort to move to an agenda for a more broadly conceived innovation policy.
- Policy making in S&T and innovation typically requires co-ordination among a number of relevant government agencies and bodies, but the present government structure lacks a suitable co-ordination mechanism. The lack of interagency co-ordination poses a major challenge for moving from a piecemeal to a comprehensive innovation policy and strategy, which is required if China is to achieve its goal of becoming an “innovative nation” by 2020.
- The division of labour in policy making between the central and sub-national governments requires clarification. Decentralisation and the reform of the tax regime have contributed to shifting decision making and tax revenue from the central to sub-national governments. This implies that sub-national governments can, and do, play an important role in influencing S&T policy in their localities. S&T policy is mainly the responsibility of central government owing to the nature of R&D activities. However, since the sub-national governments in China control a great deal of tax revenue, it is important to establish some principles to guide the division of labour between the central and sub-national governments regarding their respective responsibilities for S&T. This will not only help ensure the overall efficiency of the national innovation system, but is also necessary in order to address regional disparities. This is clearly the role of government, because markets are not well suited to addressing social and economic disparities.
- As mentioned, policy making is traditionally a government monopoly in China. With reform, this has started to change, notably with the involvement of top scientists in the S&T policy-making process. However, the involvement of the non-government sector, especially the private business sector, is still insufficient. To make policy more relevant and effective, involvement of other stakeholders is important.
- China is developing rapidly from an agricultural economy to a dual economy in which a modern, high-technology industrial sector co-exists with a still relatively large agricultural sector. The short history of industrialisation implies relatively short experience with S&T policy making at all levels of the Chinese government. The lack of government capacity to make and implement such policy creates a bottleneck, as policy makers have had little experience in promoting innovation.

Designing policy instruments

- There is a strong path dependency in the design of policy instruments. A typical example is the proliferation of programmes with features inherited from the planning culture which limit their effectiveness in promoting market-driven innovation.
- A specific problem that stems from following the planned economy path is the top-down approach in priority setting. However, MOST has recently indicated that it would create communication channels with the business sector in the planning process. Such mechanisms should be institutionalised and should involve all relevant stakeholders.
- Owing to the lack of co-ordination between government agencies and levels, competitive bureaucratic entrepreneurship (*i.e.* departmental competition for resource and influence) tends to result in the proliferation of partly overlapping measures, funding programmes, duplicate investments and wasteful use of resources.

Implementing instruments

- The implementation of policy instruments increasingly faces the challenge presented by the limited capacity of government agencies. Compared to agencies that carry out similar responsibilities in many OECD countries, MOST has a slim structure and a small number of staff. The situation is the same in other implementing agencies, such as NSFC. Funds managed by NSFC increased by 60% between 2002 and 2006, but the number of staff changed little.
- Despite various efforts recently made – online submissions of applications, expert panel evaluation of project applications, random selection of panel members from a pool of experts, etc. – lack of openness, fairness and transparency in programme management remains a serious concern.

Evaluation

- There was no evaluation of S&T programmes before the creation in 1997 of the National Centre for S&T Evaluation. In addition to an underdeveloped evaluation culture and practice, there are few qualified evaluators. NCSTE has only 20 professional staff for managing evaluations.
- Evaluation can play an important role in the policy learning process, in addition to its function in ensuring the accountability, efficiency and transparency of programme management. Owing to the weakness of existing evaluation mechanisms, the function of evaluation in providing feedback to the policy making process is very limited. Furthermore, since NCSTE is *de facto* affiliated to MOST, it is difficult for NCSTE to perform independent, critical evaluations of MOST policies and instruments.

Conclusions and Recommendations

Achievements and challenges

China's re-emergence as a major power in the world economy is one of the most significant developments in modern history. Economic reforms and the "open door" policy have prepared the ground for the Chinese economy's nearly three decades of impressive performance and have yielded outstanding results in a number of areas:

- Economic growth has led to a significant increase in income per capita and a noteworthy reduction in poverty levels.
- The Chinese economy is now the world's fourth largest and macroeconomic performance is strong.
- China has become a major destination for foreign direct investment (FDI) and a trading nation of global rank.

In spite of these remarkable achievements, there are some downsides to China's development which raise concerns about the sustainability of the current pattern of growth:

- The benefits of economic development are unevenly distributed across regions and between urban and rural populations. Large migration flows to urban areas exert pressure on the social fabric and the environment.
- China's rapid economic growth requires the consumption of large amounts of energy and raw materials. The surge in industrial activity is also putting heavy pressure on the environment. Ecological challenges may eventually become an obstacle to China's further economic development.
- To a significant extent, the growth of exports has been driven by the expansion of cost-based manufacturing. While China has become a major export platform for multinational enterprises, including for high-technology products, and while this has brought new technologies and managerial know-how to China, the technological capabilities of a large majority of domestic firms continue to be weak.

A major challenge for China is to make its future development economically, socially and ecologically sustainable. Developing the country's innovation capacity is a prerequisite for escaping from a pattern of specialisation characterised by intensive use of low-skilled labour and natural resources and a low level of technological capabilities.

China has embarked on the implementation of a strategy to promote more innovation-driven growth and an "innovative society". A major element of its strategy is the building of an enterprise-based innovation system.

This report finds that there has been considerable progress in raising China's innovative capacities. China has mobilised resources for science and technology exceptionally rapidly and on an unprecedented scale and is now a major R&D player.

In spite of its significant achievements, the efficiency of China's innovation system still needs to be improved. China has a long way to go to build a modern, high-performance national innovation system. To achieve its goals it will have to maintain a high level of investment in R&D, innovation and education and to overcome the remaining institutional and structural weaknesses of its current innovation system. In these areas, it can benefit from international best practice.

China's integration in the global innovation system: towards a positive sum game

From an international perspective the main goal is the smooth integration of China into an increasingly global knowledge and innovation system. If managed properly, this integration can give rise to a positive sum game in which the development of China's capabilities in science, technology and innovation will be beneficial not only to China but to the world at large. Large potential gains can be realised by integrating China into the wider global innovation system:

- China can make a significant contribution to the world's knowledge pool and help to solve global problems. Among these are those relating to the strong demand for energy and natural resources and the environmental pressures associated with the rapid economic growth both of China and other emerging economies. China and OECD member countries have a shared interest in solving these problems.
- China's emergence as a more innovation-based economy will lead to more vigorous competition in the production and application of new knowledge. This can be expected to have a positive impact on long-term global innovation performance.
- An increase in domestic innovation capabilities will facilitate the integration of foreign-invested enterprises in the Chinese innovation system and the entire economy.
- The maturation of an enterprise-based innovation system will contribute to a better alignment of interests in areas in which friction has occurred in the past, such as the protection of intellectual property rights.
- More generally, China will need to improve the framework conditions for innovation, including good corporate governance and a modern and pro-competitive regulatory regime, in order to strengthen the basis for long-term growth. This can also be expected to reduce the risk of international friction.

A failure to manage the process of integrating China smoothly into the global innovation system carries the risk of costly tensions. There is the risk that discontent arising in both China and OECD member countries may complicate this process. In China, there is some dissatisfaction owing to the perceived deterioration of the cost/benefit ratio of providing a low-cost manufacturing platform for much of the world. This is mirrored by concerns voiced in OECD countries over the perceived negative impact of offshoring, excessive competitive pressure from Chinese exports, infringement of intellectual property rights and what is sometimes referred to as "forced technology transfer". Perceptions of this kind on either side may lead to policy measures that would be detrimental to efforts to maximise long-term mutual benefit.

To integrate China into the global innovation system successfully, both China and OECD countries need to maintain a spirit of dialogue and co-operation and an open attitude so as to avoid reverting to protectionist measures that impede trade and capital and knowledge flows. Maintaining realistic expectations will also help to minimise the risk of friction. For China, more can be gained by following a long-term, coherent strategy to build its own capabilities than by attempts to accelerate technology transfer artificially. For their part, OECD members are well advised to base their policies on a broad understanding of the benefits of China's presence as an actor in the global innovation system.

Guiding principles and strategic tasks

China's transition to more innovation-driven growth should be guided by the following principles:

- *Retaining openness.* Even the most advanced large economies depend to a significant degree on scientific and technological knowledge generated outside their borders, on international migration of highly skilled personnel and foreign direct investment, including in R&D. Today, technological “autarky” is not a feasible option under a scenario of sustainable high growth.
- *Learning from international good practice.* Chinese innovation policy can be strengthened by drawing on international good practices of OECD member countries to promote the optimal generation, distribution and use of new knowledge. Member and non-member countries that have succeeded in raising their innovative capabilities to advanced levels provide useful examples.

The overriding policy objectives should be to:

- *Strengthen China's own capabilities in science, technology and innovation.* Given its size and dynamism, China has the potential to develop capabilities in a wide range of areas of science and technology. The Chinese government's current efforts to strengthen basic capabilities in science and technology relevant for both market-led and public interest innovation, and to create an enterprise-centred innovation system, are well-founded and should continue.
- *Reinforce correlatively the country's “absorptive capacities”* in order to make good use of knowledge and technology generated elsewhere in the world but also to increase spillovers from the foreign-invested sector to the rest of the Chinese economy.

This will require improving the framework conditions for innovation as well as appropriate policies targeted at building a well-functioning national innovation system:

- *Improving framework conditions for innovation.* This includes, among others, a modern system of corporate governance and finance, anti-trust law and effective intellectual property rights protection, and a modern, pro-competitive regulatory regime. Their improvement can help create the necessary conditions for an open innovation model in which indigenous innovation capabilities and R&D-intensive foreign direct investment can reinforce each other. There are large potential gains to be made from appropriate framework conditions for innovation in view of the current stage of economic development and the transitional state of the Chinese economy and innovation system. The importance of framework conditions for innovation needs to be better acknowledged.
- *Dedicated policies* aimed at building a well-performing innovation system involve, among others:
 - Enhancing the innovation capability and performance of the Chinese business sector and increasing its absorptive capacities through the use of best practice instruments, as found in OECD countries.
 - Developing a modern set of institutions and related mechanisms for steering and funding public research organisations (PROs).
 - Improving synergies between and spillovers from hotspots of innovation activity, spreading innovation beyond the fences of S&T parks and incubators and promoting more market-based innovative clusters and networks.

- Strengthening the interaction between the actors in the innovation system, notably between public research organisations and industry. The use of instruments successfully tested in OECD member countries can make a major contribution and provide an opportunity to engage foreign enterprises more deeply in the emerging innovation system.

Specific recommendations

ADJUSTING THE ROLE OF THE GOVERNMENT

- *Overcome the legacy of the planned economy.* Government officials should be encouraged to change their attitudes and methods of work with a view to giving a greater role to market forces, competition and the private sector, and to encouraging actors throughout the national innovation system to adopt a more market-/demand-oriented attitude and behaviour.
- *Enhance the role of government in the provision of public goods.* The role of government should be enhanced in areas characterised by a prevalence of market and systemic failures. The Ministry of Science and Technology (MOST), together with other relevant government authorities, should pay more attention to developing policy measures that deal with regional disparities and the delivery of public goods through science and innovation, including to address social and ecological issues.
- *Balance the role of government.* Government innovation policy should put more emphasis on the creation of framework conditions conducive to innovation, while maintaining and developing dedicated policies aimed at supporting R&D and innovation in both the public research and the business sector.

IMPROVING THE FRAMEWORK CONDITIONS FOR INNOVATION

- *Improve the enforcement of intellectual property rights protection.* This is necessary both to maintain the country's attractiveness for knowledge-intensive foreign direct investment and to increase the propensity of domestic firms to innovate.
- *Foster competition.* Modern and effective anti-trust legislation should be introduced at the earliest possible stage. This should contribute to more vigorous market competition and encourage more firms to put innovation at the centre of their business strategy.
- *Continue improving corporate governance.* Further improving corporate governance will increase incentives for business to invest in R&D and innovation.
- *Foster open and efficient capital markets.* Open and efficient capital markets enable entrepreneurs to take greater risks, such as those related to founding new and innovative ventures, entering new markets and developing innovative products and services.
- *Implement innovation-oriented public procurement policy carefully.* Public procurement can help promote innovation and accelerate the diffusion of innovative products and services. The Chinese government has recognised this potential and attempts to make use of it. The implementation of an innovation-oriented procurement policy requires expertise and the co-ordination of the government agencies involved. The new policies should avoid creating an obstacle to China's joining the WTO Government Procurement Agreement (GPA). Accession to the WTO GPA would not only open up China's public procurement markets to foreign companies, it would – following the principle of reciprocity – also provide new opportunities for Chinese companies to enter such markets abroad.

- *Use technology standards in a pragmatic way.* China is striving to promote its own technology standards and to take part in international standard setting. China's size, the dynamism of its domestic market and its rapidly evolving technological capabilities give it unique opportunities. It seems legitimate for China to use the standards regime to foster innovation. The challenge for China is to develop a standards regime that is in line with WTO regulations and does not lead to distortions of national and international competition which may eventually stifle innovation.

SUSTAINING GROWTH OF HUMAN RESOURCES FOR SCIENCE AND TECHNOLOGY

- *Sustain growth of HRST.* Against the background of a comparatively low share of HRST and the risk that shortages of specialised human resources may become a major obstacle to the development of the Chinese innovation system, the government should ensure the sustained growth of HRST. It should consider taking measures to reverse trends such as the declining share of science and engineering degrees in the tertiary education system and the drop in the number of undergraduate degrees in science.
- *Increase the quality and efficiency of researchers.* The ongoing reform of public research organisations should aim at increasing the qualification and efficiency of the workforce, including by providing incentives for stimulating both quality and quantity of R&D output.
- *Provide incentives for investment in training.* Incentives are needed to help raise the currently insufficient level of business investment in training and to address deficiencies in vocational training.

IMPROVING GOVERNANCE OF SCIENCE AND INNOVATION POLICY

- *Create a better framework for central and sub-national government relations.* The central government should adopt clearer principles regarding the division of labour and responsibility between the central and the provincial governments for promoting science, technology and innovation.
- *Better co-ordinate regional initiatives.* The central government should consider the need to introduce guidelines for co-ordinating initiatives implemented at the level of regional innovation systems with a view to ensuring the efficiency of the national innovation system as a whole.
- *Manage support programmes at arm's length.* MOST's two main functions in terms of policy making and managing R&D programmes should be kept at arm's length in order to avoid conflicts of interest. In line with practices in most OECD countries, further efforts should be made to ensure an adequate separation between policy making and the operational management of funding programmes.¹²
- *Strengthen the evaluation culture.* China's science and innovation policy governance could benefit from a stronger evaluation culture. For this purpose the necessary competencies can be developed by supporting the creation of research teams, of platforms for experts in and users of evaluations, and of links to international networks, including in the framework of the OECD, in order to benefit from international good practice. Evaluation should become a standard feature of the design and implementation of programmes and the allocation of funding to institutions.
- *Ensure the independence of evaluations.* At present, the National Centre for Science and Technology Evaluation (NCSTE) works as an in-house evaluation unit at MOST. The government should give priority to legislation to provide a basis for independent evaluation agencies. Independent external

12. Current arrangements already feature a certain degree of separation of these functions, as various programme centres affiliated with MOST were created for this purpose.

evaluation should be institutionalised to ensure effective programme management aligned with strategy.

- *Create an interagency co-ordination mechanism.* The government should consider the creation at the central government level of a mechanism to improve co-ordination across agencies and levels of government to ensure a better co-ordinated whole-of-government approach to the implementation of the national S&T Strategic Plan (2006-2020).

ADJUSTING THE SET OF POLICY INSTRUMENTS

- *Adjust R&D programmes to changing priorities.* The orientation of R&D support programmes should be adjusted on the basis of the dynamics and evolving needs of the Chinese innovation system.
- *Deepen R&D efforts.* Rebalance the system of public support for R&D to encourage more in-depth R&D across a broader range. There is still a wide gap between a relatively small basic research sector and massive technological development activities in many areas.
- *Avoid high-technology myopia.* The system of public support for R&D and innovation should pay more attention to industries that are not classified as belonging to the high-technology sector, such as traditional industries and the services sector.
- *Overcome “programme activism”.* To combat the proliferation of public funding programmes for R&D and innovation, new programmes should only be introduced when supported by a strong rationale. It is important to be sure that this is the best way to address a specific market or systemic failure by considering the advantages and disadvantages of alternatives.
- *Balancing spending on “hardware” and “software”.* Much policy effort in the past has concentrated on the provision of “hardware”, including the physical infrastructure for R&D and innovation. The government should devote more attention to “soft factors”, such as fostering public awareness of science, technology and innovation, nurturing an entrepreneurship spirit, and improving education and training in the non-S&T skills required for innovation, such as managerial skills.
- *Deepen policy learning.* As China has introduced most – but not all – types of instruments used by OECD countries, policy makers and analysts should pay more attention to gaining an in-depth understanding of how they work and to improving their effectiveness by differentiating them to meet specific purposes and adapting them to the national context.

ENSURING ADEQUATE SUPPORT FOR PUBLIC R&D

- *Build on the strengths of public research.* To maintain the strong science base needed to support an enterprise-centred innovation system, it is necessary to reassess the role of public research organisations and university research. Government policy on public research should seek to strike a better balance between mission-oriented research and research driven by market demand. In this context, the government’s effort to give stronger support to public research organisations in research relating to public goods, such as environment-related research, is well-founded.
- *Strike a balance between competitive funding and institutional funding of PROs.* Competitive funding schemes play a useful role in enhancing the efficiency of public research organisations. As in most OECD countries, however, a degree of institutional funding should be maintained in order to provide stable core funding for public research. This funding needs to be complemented by rigorous performance evaluations in order to ensure efficiency and adequate returns on the investment in public R&D.

STRENGTHENING THE LINKAGES BETWEEN INDUSTRY AND SCIENCE

- *Create competence centres.* The government should consider the establishment of a “competence centres” programme of the type established in a number of OECD countries. Competence centres institutionalise long-term co-operation in R&D and innovation between business firms and PROs or universities. In China, competence centres could provide an effective platform for better integrating foreign-invested enterprises into Chinese R&D networks.
- China can *draw on extensive experience* in designing, establishing and operating competence centres in OECD countries over the past two decades.

Abbreviations

CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CVCF	Corporate Venture Capital Firm
FDI	Foreign Direct Investment
FVCF	Foreign Venture Capital Firm
GDP	Gross Domestic Product
GPA	Government Procurement Agreement
GVCF	Government Venture Capital Firm
GERD	Gross Domestic Expenditure on Research and Development
HRST	Human Resources in Science and Technology
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
ISR	Industry-Science Relationship
IT	Information Technology
MII	Ministry of Information Industry
MNE	Multinational Firms
MOA	Ministry of Agriculture
MOC	Ministry of Commerce
MOE	Ministry of Education
MOF	Ministry of Finance
MOP	Ministry of Personnel
MOST	Ministry of Science and Technology
NCSTE	National Centre for S&T Evaluation
NDRC	National Development and Reform Commission
NIS	National Innovation System
NSFC	National Natural Science Foundation of China
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PPP	Purchasing Power Parity
P/PP	Public/Private Partnership
PRO	Public Research Organisation
R&D	Research and Development
S&T	Science and Technology
SCI	Science Citation Index
SIPO	State Office of Intellectual Property
SIPIVT	Suzhou Industrial Park Institute of Vocational Technology

SME	Small and Medium-sized Enterprise
SOE	State-Owned Enterprise
STIP	Science and Technology Industrial Park
TBI	Technology Business Incubator
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UVCF	University-backed Venture Capital Firm
VC	Venture Capital
VCF	Venture Capital Firm
WTO	World Trade Organization