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Globalization of R&D and China

- Empirical observations and policy implications

Nannan Lundin*
Sylvia Schwaag Serger$^{\Psi}$

SWEDISH INSTITUTE
FOR GROWTH POLICY
STUDIES

* Research Institute for Industrial Economics and Örebro University, Sweden,
nannan.lundin@esi.oru.se. Financial support from the Jan Wallansers Research Foundation is gratefully acknowledged.
$^{\Psi}$ Swedish Institute for Growth Policy Studies and Lund University, Sweden,
Sylvia.schwaagserger@itps.se

ITPS, Swedish Institute For Growth Policy Studies
Studentplan 3, SE-831 40 Östersund, Sweden
Telephone: +46 (0)63 16 66 00
Fax: +46 (0)63 16 66 01
E-mail info@itps.se
www.itps.se
ISSN 1652-0483

For further information, please contact Sylvia Schwaag Serger
Telephone +86 1391 017 5038, +46 8 4566712
E-mail sylvia.schwaagserger@itps.se

Foreword

China is emerging as a key global player in Research and Development (R&D). This rapid increase in R&D investment is mainly attributed to the effort of strengthening the indigenous innovation capacity of domestic actors and, to an increasing extent, to the process of globalization of R&D with multinational enterprises.

This paper provides a detailed overview of the relative importance of foreign R&D in China based on quantitative mapping in terms of R&D inputs, outputs and local linkages in R&D-related activities, combined with an in-depth description of the nature of foreign R&D activities.

The paper discusses how China competes for knowledge and human resources through structural adjustments and new policy initiatives. At the same time, multinational enterprises from OECD countries are intensifying as well as diversifying their activities in a larger number of R&D intensive sectors in China. In such a rapid and dynamic development, China seems to emerge not only as an important source of R&D but also a key magnet of global R&D operations.

The paper has been written by PhD Sylvia Schwaag Serger, ITPS and PhD Nannan Lundin, the Research Institute of Industrial Economics.

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Suzanne Håkansson
Director, Policy Intelligence, ITPS

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Summary

As one of the world's largest recipients of Foreign Direct Investment (FDI), China is emerging as a key global player in Research and Development (R&D). This rapid increase in R&D investment is mainly attributed to the effort of strengthening the indigenous innovation capacity of domestic actors and, to an increasing extent, to the process of globalization of R&D with multinational enterprises as key driving force.

This paper provides a detailed overview of the relative importance of foreign R&D in China based on quantitative mapping in terms of R&D inputs, outputs and local linkages in R&D-related activities, combined with an in-depth description of the nature of foreign R&D activities. Our empirical observation suggests that the growing importance of China in the globalization of R&D is more than a 'flash-in-the-pan'. On one hand, China is facing new challenges, but at the same time is attempting to seize the "window of opportunity" to compete for knowledge and human resources through structural adjustments and new policy initiatives. On the other hand, multinational enterprises from OECD countries are not only intensifying, but also diversifying their activities in a larger number of R&D intensive sectors in China. In such a rapid and dynamic development, China seems to emerge not only as an important source of R&D but also a key magnet of global R&D operations.

JEL classification: O31, O32, F23.

Keywords: China, R&D, globalization, multinationals

1 Introduction and background

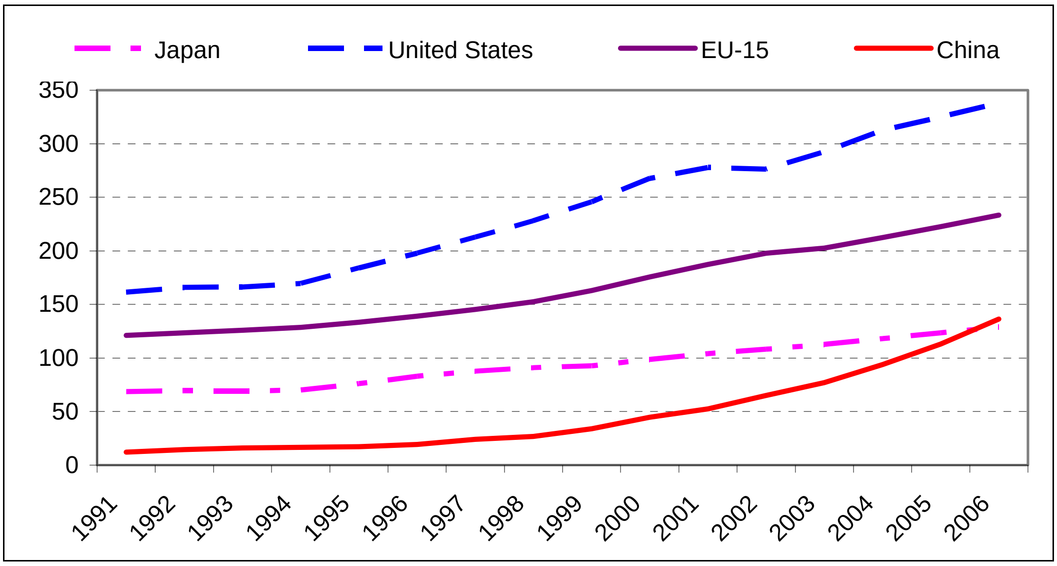
It is a well-known fact that, since its opening up in the late 1970s and as a result of its gradual integration into the world economy, China has accumulated a large stock of Foreign Direct Investment (FDI) and has become one of the top recipients in the recent year. With the new record high level of inflow of $72 billion, China ranked among the world's top three FDI recipients, just behind the UK. and the US in 2005 (UNCTAD, 2006).[1]

In addition to becoming one of the world's largest recipients of FDI, China is also emerging as a key global player in Research and Development (R&D). Gross domestic expenditure on R&D (GERD) in China has increased at an accelerating rate since 1995 (see *Figure 1*). Among the non-OECD countries, China makes the largest contribution to total global R&D investments and accounts for half of the non-OECD share of R&D expenditure (OECD, 2005). In 2005, China's R&D expenditure hit a new record, reaching $US 30.6 billion. R&D expenditure as a percentage of gross domestic products (GDP) has also increased remarkably, growing from 0.6 percent in 1995 to around 1.3 in 2005 (MOST, 2006). The OECD (2007) has ranked China as the second largest R&D spender in terms of purchasing power parity (PPP), just behind the US, although this figure has been questioned, both inside and outside China.[2] The fact remains, however, that the increase in R&D expenditure, both in absolute terms and as a share of GDP, has been spectacular, and China is rapidly becoming an important player in the global R&D landscape. Making a slightly more cautious assessment than the OECD, the European Commission recently predicted that if current trends continue, China will catch up with the EU in terms of R&D expenditure as a percentage of GDP by 2009 (EU Commission, 2007).

[1] China's FDI figures are likely to be overstated due to a practice known as 'roundtripping,' whereby significant funds are taken out of China and then brought in again as 'foreign investment.' Investors thereby benefit from China's preferential policies for FDI. According to some estimates, roundtripping accounts for around 20–30 percent of total FDI to China (see, for example,US-China Business Council 2007). However, even when accounting for this, the FDI flowing into China is still larger than for most other countries. Furthermore, roundtripping does not disprove the fact that both multinational companies and experts recently ranked China the most attractive investment location in the world (UNCTAD 2005).

[2] See, for example the article in Business Week *entitled "Is OECD hyping China's R&D spending?", December 7, 2007, by Bruce Einhorn and an article published on SciDev.Net entitled "China's R&D budget overrated", December 6, 2006, by Hawk Jia, www.scidev.net/news/index.cfm?fuseaction=readnews&itemid=3268&language=1*

Figure 1-1 Gross domestic expenditure on R&D (billion current PPP $), 1991–2006.



Note: (1) Figures for 2005 and 2006 are projected on the assumption that growth of R&D expenditure in 2005 and 2006 will be same as average growth over 2000–2004.

Source: OECD, Main Science and Technology Indicators, 2006-I

Underneath the large increase of R&D expenditure, we have observed an important development in the innovation system of China during the last 15 years. Currently around two thirds of the total R&D is conducted by enterprises in the business sector, compared to less than 30percent in the beginning of 1990s (see *Table 1*). It demonstrates an impressive structural shift from an innovation system dominated by research institutes to an enterprise-centered innovation system during the past two decades. This change is driven by a combination of the restructuring of research institutes, the expansion of the higher education sector and the strengthening of the innovation capacity of enterprises. The ambition underlying this systematic change is to establish an innovation system, in which market mechanisms encourage applied R&D activities and stimulate rapid commercialisation of R&D results in the business sector, while the basic and strategic R&D capacity building will be conducted in the research institutes and the higher education sector, with long-term government support.[3]

Table 1-1 Relative importance of key actors in terms of R&D expenditure, %.

Performers	1990	1995	2000	2005
Research institutes	50	42	29	21
Universities	12	12	9	10
Enterprises	27	44	60	68

Source: China Statistical Yearbook on Science and Technology, 2001, 2004, 2006

Part of the rapid increase of the R&D effort in China can also be attributed to the increasing globalization of R&D activities, in general, and to China's success in attracting foreign firms' R&D operations, in particular. Several studies confirm firstly, that the globalization of R&D is increasing, and, secondly, that multinational enterprises are key drivers in this process (Narula and Zanfei 2005). Thus, between 1994 and 2002, US firms'

[3] *See Liu and Lundin (2007b) for a more detailed description of the historical transition process of the Chinese innovation system.*

R&D expenditures increased more rapidly abroad than at home (National Science Foundation 2006). Simultaneously, R&D expenditure by foreign companies in the US, as a percentage of total industrial R&D expenditure, increased (ibid.). Sweden, the UK, Finland, Japan and Germany are other examples of countries where the share of R&D investments funded by foreign firms has been increasing. In the case of Sweden, R&D by foreign firms accounted for as much as 46 percent of total business R&D expenditure in 2005 (ITPS 2007).

In the case of China, the increase of foreign R&D activities reveals a fundamental shift in the international economic geography, in which both knowledge generation and exploitation are becoming increasingly internationalized, and even mobile, and with developing countries actively competing for knowledge resources such as corporate R&D activities and highly skilled labor (see, for example, UNCTAD 2005). In a recent study of the R&D activities of large Swedish firms abroad, the Swedish Institute for Growth Policy Studies (ITPS) finds that Swedish firms' R&D activities have increased much more rapidly in low-income, or developing, countries than in high-income, or developed, countries (ITPS 2007). Thus, between 1995 and 2005, R&D expenditure by Swedish firms in developing countries increased by 25 percent per year on average, compared with less than 11 percent in developed countries. China was one of the countries where Swedish firms' R&D activities increased most rapidly. Confirming this trend, in recent surveys, multinational enterprises ranked China one of the most attractive locations for future R&D investments followed by the US and India (A.T. Kearney 2006 and UNCTAD 2005).

As a consequence of the rapid increase of R&D effort in China, combined with the intensified competition in the global market and in innovative activities, we are entering a new phase of globalization, in which R&D production and knowledge flows are no longer limited to a handful of OECD countries. Rather, globalization of R&D now extends to include a number of selected developing countries. In this new era, China has emerged not only as an important source of R&D but also a key magnet of international firms' R&D operations.

In the above context, it is of great empirical interest and policy relevance to understand and properly assess the implications of the globalization of R&D in China. This paper therefore aims to provide a detailed overview of the relative importance of foreign R&D in China based on available statistical indicators, combined with an in-depth description of the nature of foreign R&D activities, which are more difficult to quantify but are of great importance for understanding the foreign R&D investments in China. Based on empirical observations and analytical discussion, we will also shed some light on the policy implications, from the perspectives of both host-country and home-country, in particular from the perspective of more advanced OECD countries. Our contribution to the existing empirical literature and policy discussion is twofold. Firstly, based on the up-to-date statistical information processed by the National Bureau of Statistics of China (NBS), we assess the presence of foreign actors in the Chinese innovation system, not only from the input, but also from the output side, as well as through observed linkages with local actors. Secondly, if focusing on manufacturing alone, there is a large risk of underestimating the presence of foreign R&D in China. To overcome this risk, we present also detailed information on foreign R&D labs, which are often established outside the manufacturing sector, and whose R&D activities are missing from official industrial and Science and Technology (S&T) statistics. In contrast to previous studies, we combine available official statistical data on foreign R&D activities with our own data on foreign R&D centers. As a result, we are able to observe both intensification and diversification of the process of globalization of R&D in China, which are essential observations underlying our discussion on policy implications.

The remainder of this paper is organized as follows. In Section 2, we provide a brief theoretical overview regarding the phenomenon of globalization of R&D. Based on available statistical indicators, a quantitative mapping of globalization of R&D in China is presented in Section 3. As a complementary part, we present the rapid development of establishment of foreign R&D labs in China. In Section 4 we look at linkages of foreign firms' R&D activities with local firms, research institutes and universities and examine outputs of foreign firms' R&D activities. Finally, we conclude with a detailed discussion on policy implications in Section 5.

2 Conceptual framework of globalization of R&D

2.1 Why R&D abroad: an investor perspective

Compared with the globalization of production, purchasing and sales activities, the globalization of R&D is a relatively recent phenomenon. Until the 1990s, R&D was concentrated in a few highly developed OECD countries. Multinational enterprises (MNEs) are among the most important drivers of the globalization of R&D and innovation (Narula and Zanfei 2005). As explained in Kumar (2001) and Grassmann and Han (2004), MNEs make their decisions with respect to the location of R&D by balancing various factors, which reflect, on one hand, the need for centralizing R&D activities, and on the other hand, the driving force for decentralizing such activities.

Firstly, concerning the centralizing force, which underlies the motives for home-country-based R&D activities is associated with various scale-related advantages. For instance, the concentration of R&D activities in the same location, may give rise to economies of scale in innovation activities and also reduce the cost for coordinating R&D units in different locations. More importantly, due to the strategic and long-term nature of R&D, the need for protecting firm-specific technology and know-how as well as the roots embedded in the local innovation environment or the economies of agglomerations also make R&D activities less mobile and more likely to be located close to headquarters.

By contrast, closely related to the ongoing globalization of production activities and in the face of intensified competition and increased pressure on innovation cost consideration, decentralizing forces lead not only to more globalised R&D, but also to a broadening of the geographic scope to include selected developing countries such as China.

Globalized R&D activities, in particular in developing counties, initially often aim to support existing foreign production by adaptations, e.g. to account for different market conditions in the host-country market, such as consumer tastes and production processes. R&D activities may also facilitate the establishment of export platforms, through strengthened technological capacities in the foreign affiliates. In addition to market-related factors, access to cheaper R&D human resources is become an increasingly important driving force for allocating R&D to developing countries where trained R&D personnel is available. Furthermore, to keep track of the activities of competitors and to achieve additional competitive edges by benefiting from localized knowledge networks and spillovers have also become important strategic actions of many MNEs. They try to compress the speed to market through reduced product development and product life cycle and shifting market penetration strategies, from established to new and unknown markets (Archibugi and Iammarino, 1999).

Based on previous experiences and observations from some OECD countries, such as the US, Japan, the UK and some Scandinavian countries, four different types of R&D globalization strategies by MNEs have been identified (see e.g. Le Bas and Patel, 2005 and Le Bas and Sirerra, 2002)[4]:

[4] Most evidences achieved by applying data on US patents (Patel and Vega, 1999). There are also evidences obtained by questionnaire surveys on Japanese and Swedish MNEs. (Granstrand, 1999).

- Strategy 1: Technology-seeking FDI in R&D.

This is host-country-exploiting FDI in R&D, where a firm is simply exploiting host country technological advantages in areas of domestic weakness in the home country.

- Strategy 2: Home-based-exploiting FDI in R&D.

This is the opposite of the strategy 1. The firm explores existing firm-specific capability in a foreign environment.

- Strategy 3: Home-based-augmenting FDI in R&D.

A firm targets technology in which the investing firm has a relative advantage at home and the host country is also relatively strong.

- Strategy 4: Market seeking FDI in R&D.

A firm invests abroad in technological activities in which it is relatively weak in its home country and the host country is also relatively weak. This type of investment is less technology-oriented.

Depending on the motives behind and the strategies of globalization of R&D, which are not static, but evolving and dynamic, the role played by MNEs in the globalization of R&D is also undergoing a rapid transformation process. The above highly stylized facts, to some extent reveal the fundamental qualitative driving forces behind the increasing globalization of R&D. This has taken place mainly in some OECD countries but has recently been extended to include developing countries, particularly in China and India, with a growing intensity and complexity of competition. The strategies of MNEs' R&D activities in these developing countries may represent a mixture of tactical short-term adaptation of operations and more strategic medium-term product development and long-term knowledge creation. However, the choice of a certain type of strategy, or the combination of different types of strategies, is closely related to the conditions from the supply side (e.g. host country technology competence and capacity, and human resource availability) as well as to the relationship, between the foreign R&D subsidies and their home-country R&D base and global R&D network, which is in many cases increasingly interdependence rather than dependant.

2.2 Why attract R&D-oriented FDI: A host-country perspective

Not only the volume, but also the *nature* of R&D activities carried out by MNEs outside their home countries may have important implications for the host country (and the home country). From the viewpoint of host countries, particularly developing countries, the key questions are, to which extent, developing countries are participating in knowledge creation, accumulation and diffusion embodied in the new R&D-oriented FDI and how their indigenous technology capacities are affected by the rapid increase in the globalization of R&D. From a policy point of view, the questions is what policy measures, in terms of S&T- and FDI policies, can be undertaken to bridge the technology gap and to integrate their innovation systems into the more advanced global R&D network.

The knowledge generation and diffusion from more advanced to developing countries can take various forms. (see e.g. Görg and Greenaway (2004) and Lipsey (2004) for more detailed surveys). First, the technology embodied in imports of both final products and intermediate goods from more advanced economies may help domestic firms to acquire foreign technologies, which are not available in the home market. This trade-related technology/R&D spill-over is important for developing countries, which conduct relatively little R&D to improve the technological standard of domestic firms and to enhance their competitiveness in export markets. The interpretation of a high dependence on technology import, nevertheless, can be twofold; it may imply a high capacity of assimilating foreign technology, but also a low degree of indigenous innovation capacity.

Second, R&D activities conducted by foreign MNEs in the domestic market are expected to generate training, learning and positive externalities that benefit domestic industrial development. MNEs and their investments, particularly in technology- and knowledge intensive sectors are thus regarded as important conduits for transferring advanced technology from industrialized to developing countries, since it links foreign technology access and acquisition to the catch-up process and economic development.

Finally, in the face of intensified competition imposed by foreign firms, domestic firms are forced to conduct their own R&D- and other innovation activities to enhance their competitiveness. The presence and the activities of MNEs thus affect the market structure in the product market (and labour market) and in turn spur innovation in domestic industries through this pro-competitive effect (see e.g. Vickers, 1997; Boone, 2000; and Aghion and Schankerman, 1999). On the other hand, the domestically-owned /local firms might suffer from congestion or crowding-out effects because of the limited stock of resources (scientists and engineers, etc) and financial resources for conducting R&D activities. The loss of market share and the contraction of the production of domestic firms are often a part of short- and medium run adjustment costs.

Motivated by the potential benefits generated from R&D activities of MNEs, but at the same time being aware of costs and risks, some policy makers in developing countries have been selectively encouraging FDI investments in certain industries, while simultaneously protecting indigenous industries from competitive pressure. As a result of increased economic integration, the openness towards MNEs has increased in many developing countries, which can be observed in forms of a paradigm shift in the "foreign investment regime" (see e.g. Athukorala, 2007). Departing from an old paradigm of passive, reactive and at best selective approaches, the FDI regimes in some developing countries, such as in China have, in different time periods, moved toward gradual liberalisation, and in some cases even towards full-fledged liberalisation. The paradigm shifts imply not only relaxed micromanagement of MNEs' participation in the national economy and a removal of performance requirements for MNEs such as local contents, exports and technology transfer. They also mean a holistic approach to facilitating MNEs' activities, through improving the institutional framework conditions and creating a favourable investment environment. The latter is of particular importance when attracting R&D-oriented FDI, since this type of FDI cannot be driven solely by fiscal incentives and /or by a simple trade-off between technology and market share. Instead, based on the requirement for a sound institutional framework, in which intellectual property protection and competitive environment prevail, the driving forces from the supply side in terms of human resources and knowledge base as well as the demand for innovation products are all essential determinants for the choice of location for R&D-oriented FDI.

To summarize, drawing on the observations from a few OECD countries, the motives and determinants of MNEs' R&D activities have been explored extensively in a recent stream of theoretical papers. However, the existing framework still calls for further refinement to take the development dimension of globalization of R&D into account. It is important to keep in mind that that the globalization of R&D may indeed offer new opportunities for developing countries, but the benefits from these opportunities depend largely on the nature of the mechanisms, through which a local and collaborative process of knowledge creation and diffusion can be generated.

3 A mapping of globalization of R&D in China

The economic growth of China is to a great extent related to its openness in terms of international trade and FDI. China has benefited from the globalization in many aspects, such as accelerated structural change, strengthened market mechanisms, improved output and export performance and job creation. Science and technology and R&D related fields are no exception. However, because of the short-run adjustment cost associated with increased competition and the apparent lack or shortage of spillovers from more advanced foreign firms to domestic firms, this new development of FDI in China remains an issue of debate. In this section, based on available statistical indicators, we attempt a mapping of R&D activities conducted by FDI firms in China with particular attention to:[5]

- The relative importance of R&D activities in Large- and Medium- sized Enterprises (LMEs) with foreign ownerships in the Chinese manufacturing.
- The rapid increase of establishment of foreign R&D labs.

The statistical information presented in this paper is compiled by the NBS. It is based on a large microeconomic database of all LMEs in the Chinese manufacturing sector for the period 1998-2004, which covers around 16000- 24000 enterprises annually, depending on the year of calculation. A similar database for earlier periods (1995-2001) has been applied in several previous empirical studies (see e.g. Jefferson et. al. 2002 and 2006 and Jefferson and Hu, 2004 and Motohashi, 2006). In contrast with previous studies and based on more updated statistical information, we aim to provide an *overall* description of the presence of MNEs. More specifically, as we have discussed in Section 1, the innovation system, with the business sector as a key player, is an open system and the influence of globalization can be observed in various indicators, such as R&D inputs, interaction and linkages established for collaborative R&D and outputs generated from R&D. The classification of ownerships applied in this paper, follows the classification given in Jefferson et. al. (2002) and the details can be found in Appendix 1. FDI firms in our analysis refer to the following three types of foreign ownerships:

1. Overseas joint venture (with Hong Kong, Taiwan and Macau, JV-HTM)
2. Foreign joint venture (JV- foreign)
3. Foreign wholly owned firms (Foreign)

Domestic firms include the following three types of ownerships:

1. Stated-owned enterprises (SOEs) and collective-owned firms
2. Private-owned enterprises (Private)
3. Share holding and other domestic ownerships

[5] *Another important aspect of globalization of technology-related activities, which is indirectly related to R&D is the international trade of high-tech products. However, we choose to limit the scope of this paper on R&D activities of FDI firms. More detailed information, regarding the recent development of international trade of high-tech products can be found in Gao et. al. (2006).*

3.1 The relative importance of LMEs with foreign ownerships in manufacturing sector

During the period of 1998–2004, the number of large- and medium-sized FDI firms has been steadily increasing in the manufacturing sector in China and more than doubled, from 3579 in 1998 to 8748 in 2004. We assess their relative importance in Chinese manufacturing by looking at both some general economic indicators as well as key indicators of R&D-related financial and human resource inputs in *Table 1*. As shown in Column (1)- (3), the shares of value-added and employment of FDI firms in the Chinese manufacturing sector, have increased from 26 percent and 14 percent in 1998, to 40 percent to 34 percent in 2004, respectively. Put differently, as of 2004, the majority of value-added (60 %) and employment (66 %) is still attributed to domestic firms. However, the ownership distribution of export shows the opposite, i.e., the share of FDI firms was nearly 60 percent already in 1998 and it has reached 76 percent in 2004. Turning to R&D-related financial and human resources, shown in Column (4)-(5), although the shares of FDI firms, as expected, are lower compared to the general economic indicators, we observe a steady increase over time. The share of R&D expenditure has increased, from 21 percent to 29 percent, and the share of R&D personnel from 7 percent to 20 percent. There are two important facts that we need to bear in mind when interpreting such increases. Firstly, taking account of the rapid increase of total R&D expenditure in the business sector during this period, (i.e. from 15.1 billion RMB to 88.7 billion RMB among LMEs included in the dataset), the moderate increase in the share of R&D expenditure by FDI firms (8 %), actually implies a considerably increase of R&D expenditure in absolute terms (about 24 billion RMB). Secondly, R&D expenditure in *Table 2*, captures only foreign R&D activities *within* the manufacturing sector. In recent years, we also observe that foreign firms are to a larger extent carrying out R&D-related activities *outside* the manufacturing sector, in the form of independent R&D organizations, or in cooperation with domestic R&D institutes and universities. This will be discussed in more detail later in this section. R&D activities carried out by foreign firms in stand-alone R&D labs and research centers are not systematically captured in the official statistics. As a result, we may underestimate the participation of foreign firms in the R&D and innovation system of China.

In addition to in-house R&D activities, technology import is another important resource for S&T activities in the manufacturing sector.[6] As shown in Column (6), while domestic firms are still highly dependent on technology imports, the share by FDI firms has increased in recent years. One of the potential explanation, suggested in Jefferson et. al. (2004) is that there is a complementary, instead of substitute effect between FDI firms' R&D expenditure and technology import, i.e. when FDI firms conducing R&D activities in China, they are also relying on technology sources from the global market.

[6] *In the Chinese S&T indicator system, the technology import is defined as purchases of patents, models, designs and know-how as well as key equipment and instruments from abroad. This indicator is collected as part of S&T expenditure at the enterprise-level. This measurement is different from import of high-tech goods in the Technology Balance of Payment (TBP), which is commonly applied in OECD countries. At the current stage, China has not set up the TBP statistical system, which makes it difficult to achieve similar indicators for an international comparison in this field.*

Table 3-1 Importance of FDI firms in the manufacturing sector, 1998-2004

(Share in the manufacturing sector, %).

	General economic indicators			**R&D-related financial & human resource inputs**		
	(1) Value-added	**(2) Export**	**(3) Employment**	**(4) R&D expenditure**	**(5) R&D personnel***	**(6) Technology import**
1998	26	58	14	21	7	20
1999	28	61	16	23	8	16
2000	30	63	18	20	9	18
2001	31	66	20	23	11	28
2002	33	68	23	23	12	24
2003	36	71	27	25	16	27
2004	40	76	34	29	20	48

Note: Following the Frascati Manual recommendation, R&D personnel is measured by Full-Time-Equivalence (FTE), instead of head count.

Source: Compiled by NBS and based on authors' own calculation

In *Table 3*, we give a similar presentation of the importance of FDI firms with a focus on high-tech industries. The internationalization in the high-tech industries is of significant importance in China, but it also has some controversial characteristics.[7] On one hand, the increased trade volume shows the international competitiveness of high-tech industries of China. On the other hand, the dominance of FDI firms and the large share of processing of imported materials as well as the reliance on foreign technology raise the questions: Are China's high-tech industries really high-tech? And are the high-tech industries in China really Chinese?

We observe similar increases of the importance of FDI firms in terms of both general economic performance and R&D-related activities between 1998 and 2004. Interestingly, we also see substantial cross-industry variations. The ICT sectors, which include electronics, telecommunications, and computer and office equipments, are the most internationalized high-tech industries. Already in 1998, FDI firms had very high shares of value-added (64 % and 63 %) and export (86 % and 94 %). By 2004, the exports of these two sectors had almost been totally taken over by FDI firms (93 % and 99 %). In terms of employment, there was also a large increase in these two sectors. Having entered China much later than ICT firms, FDI firms in medical equipments and instruments have also achieved a considerable expansion, their shares of value-added, export and employment all having more or less doubled between 1998 and 2004.

[7] The classification of high-tech industries applied in the paper follows the OECD classification. One has to keep in mind that not all products in a "high-technology industry" necessarily have high technology content. Likewise, some products in industries with less technology intensities may well incorporate a high degree of technological sophistication. This is particularly true for non-OECD countries such as China, because of differences in the technological standard and in the industrial structure, compared to OECD countries.

Table 3-2 Importance of FDI firms in the high-technology sector, 1998-2004

(Share in the high-technology sector, %).

	(1) Value-added	(2) Export	(3) Employment	(4) R&D expenditure	(5) R&D personnel	(6) Technology import
Year 1998						
Pharmaceutical products	19	19	11	20	8	4
Electronics and telecom	64	86	42	41	18	77
Computer and office equipment	63	94	51	37	21	94
Medical equipment and instrument	28	40	14	11	3	41
Year 2004						
Pharmaceutical products	23	21	16	22	14	20
Electronics and telecom	81	93	73	42	38	93
Computer and office equipment	95	99	91	82	64	99
Medical equipment and instrument	55	88	36	27	19	33

Source: Compiled by NBS and based on authors' own calculation

With regard to R&D-related activities, in contrast to the common suspicion that FDI firms do not conduct R&D, we observe relatively large increases, in the share of R&D expenditure and R&D personnel of FDI firms, in all high-tech industrial sectors, except in the pharmaceutical industries. In particular, the largest increase took place in the computer and office equipment industries, in which these shares have more than doubled, starting from already large shares in 1998 (37 % in R&D expenditure and 21 % in R&D personnel).

This finding is confirmed when examining the recent development of large Swedish firms' R&D activities in China. Between 2003 and 2005, Swedish firms' intensity of human resources for R&D in China, measured as R&D man-hours in relation to total number of employees by the firm in China, has increased dramatically. As a result, the intensity of human resources for R&D of Swedish firms in China is today higher than in the US or the European Union, or, for that matter, anywhere else in the world, with the exception of Sweden (ITPS 2007).

Another interesting finding is that the share of technology import in these two most FDI-dominated high-tech industries is also extremely high (93 % and 99 % in 2004). The dominance of FDI firms in technology import stands in stark contrast to the situation in the manufacturing sector as a whole. In addition to the complementary relationship between R&D and technology import, it may also suggest that the knowledge and the access to international technology markets in the high-tech fields give also competitive edges for these FDI firms, in which intra-firm technology trade can play an important role.[8]

[8] Unfortunately, the information of multinationals activities in China has not been systematically collected for this type of questions.

In addition to the relative importance of FDI firms at the industry level, another important, but also somewhat controversial question is whether FDI firms are more R&D-intensive than domestic firms in China. In *Table4*, we compare the average R&D intensity, defined as the R&D expenditure to sales ratio, both over time and across different ownerships. While the R&D intensities across different ownerships all have increased during the period 1998-2004, so far domestic firms, both stated-owned and private have higher R&D intensity than FDI firms. This is true both in the manufacturing sector as a whole, as well as in the individual high-tech industrial sectors. What are the implications behind these observations? Firstly, domestic firms in China are strengthening their innovation capacity through increased R&D investments. This is achieved not only by the increased R&D investments by the SOEs, which are often closely related to various government supports, but is also driven by innovation efforts by an increasing number of entrepreneurial and S&T-based private firms.

Table 3-3 R&D investment as percentage of sales across ownerships 1998 and 2004, %.

	SOE	**JV-HTM**	**JV-foreign**	**Foreign**	**Private**
Average R&D intensity in 1998	0.6	0.1	0.4	-	0.4
Average R&D intensity in 2004	1.3	0.4	0.6	0.3	0.9
R&D intensity 1998	**SOE**	**JV-HTM**	**JV-foreign**	**Foreign**	**Private**
Pharmaceutical products	1.0	0.4	0.5	-	0.5
Electronics and telecommunication	1.1	0.5	0.7	-	0.8
Computer and office equipment	2.2	-	0.9	-	1.3
Medical equipment and instrument	1.9	0.4	0.4	-	0.3
R&D intensity, 2004	**SOE**	**JV-HTM**	**JV-foreign**	**Foreign**	**Private**
Pharmaceutical products	2.0	1.9	1.3	0.8	1.3
Electronics and telecommunication	3.2	0.6	1.0	0.4	3.7
Computer and office equipment	2.0	0.7	0.9	0.3	4.7
Medical equipment and instrument	4.1	1.0	2.2	0.1	3.0

Source: Compiled by NBS and based on authors' own calculation

The lower R&D intensities in FDI firms may be explained by two types of FDI activities in China. Firstly, some FDI firms' activities still consist of capital- or labor intensive manufacturing in the high-tech industries. Secondly, while the number of FDI firms with R&D activities has increased, which is reflected in the increased R&D shares of FDI firms at the aggregate industry level in *Table 2* and *Table 3,* the scale of R&D activities in each individual FDI firm is still quite small. In other words, in the manufacturing sector, FDI firms are making very cautious R&D efforts, and many R&D activities are still home-based.

Finally, it is important to recall that even though the R&D intensity, defined as R&D investment as percentage of sales in the high-tech industries have increased over time, they are still at a much lower level compared to the high-tech industries in the OECD countries. For instance, the average R&D investment to sales ratio in the high-tech industries of China was around five percent since 2000, while the corresponding numbers for those advanced OECD countries such as the US, Japan and the EU were between 25–30 percent in the same period (OECD, 2005). From a long-term perspective, the R&D intensities need to, and will, be further boosted, driven by continued indigenous R&D efforts and intensified competition between domestic and FDI firms when the technology gaps between them are being narrowed. Furthermore, the narrowed technology gap can also facilitate strategic alliances among firms with various ownerships and thereby boost R&D investments in both domestic and FDI firms.

3.2 Foreign R&D Labs in China: from product adaptation to innovative R&D

The establishment of stand-alone R&D centers by foreign firms in China, as opposed to having R&D divisions within or attached to a production facility, is a relatively recent but rapidly growing phenomenon. In the 1980s and 1990s there were relatively few R&D activities by foreign enterprises in China and they consisted primarily of product development and adaptation to the Chinese market. In the past five years, the establishment of foreign corporate R&D centers in China has increased dramatically (see, for example, von Zedtwitz 2004 and Schwaag Serger 2006 and 2007). Furthermore, while adaptive R&D continues to dominate foreign firms' R&D activities in China, in recent years, large MNEs, many of whom are technology leaders in their fields, are increasingly locating innovative R&D in China. We use the term 'innovative' to differentiate between R&D activities devoted merely to adapting products to the Chinese market (adaptive R&D), and operations with a scope and nature that exceeds the domestic Chinese market. Centers with innovative R&D functions are also sometimes referred to as 'global R&D centers'.

In this section we examine the development of foreign R&D centers in China. Furthermore, we examine motivations and barriers that explain the increasing tendency towards establishing R&D labs in China. Finally, we analyze the trend for foreign multinationals to establish innovative, or strategic, R&D activities in China, as opposed to merely using R&D facilities to adapt products to the Chinese market. The establishment of stand-alone foreign R&D centers or labs, and the activities carried out in these labs, is an important phenomenon in China which, for several reasons, is not fully captured measured in the available official or enterprise-level statistics.[9]

The findings of this section are based on a combination of reviews of existing studies on foreign R&D in China, analyses of press clippings and annual company reports, and interviews and surveys. Between June 2005 and March 2007, we interviewed approximately 70 senior executives and other experts on foreign R&D in China, such as representatives of chambers of commerce, employers' organizations, trade associations, universities and colleges, government authorities, international organizations, academics, and journalists.[10] The role of foreign R&D labs in China is illustrated in the following aspects:

- The rapid increase of foreign R&D organizations in China.
- The motivations and barriers for foreign R&D and their mandates in China.

[9] *In contrast to R&D activities which are part of manufacturing operations, foreign firms are not obliged to submit statistical information by foreign firms to the Chinese authorities about these centers. Furthermore, very few firms provide detailed statistics regarding R&D expenditure, personnel, type of activities in China in their annual reports or on their websites.*

[10] *The findings are analyzed in greater detail in Schwaag Serger (2006) and Schwaag Serger (2007).*

The rapid increase in number of foreign R&D labs

The trend towards establishing R&D labs in China is a relatively recent phenomenon, which was led by a few pioneering companies in the ICT sectors, such as Microsoft, Nortel, Ericsson and Nokia in the mid of 1990s. Since 2000, the number of foreign R&D labs has increased dramatically with newcomers including firms in not only ICT but also in biomedical and automobile industries (see *Table 5*).

Table 3-4 Selected list of Multinationals with R&D organisation in China, (2006).

ICT industry	Biomedical Industry	Automobile industry
IBM	AstraZeneca	Shanghai GM
Sun	Novo Nordisk	Shanghai Volkswagen
Nokia	Eli Lilly	Nissan Motor
Ericsson	Roche	DaimlerChrysler
Microsoft	DSM	Honda motor
Fujitsu	Lonza	Toyota Motor
Motorola	GE medical system	Hyundai Motor
HP	Siemens	

Source: Various press reports

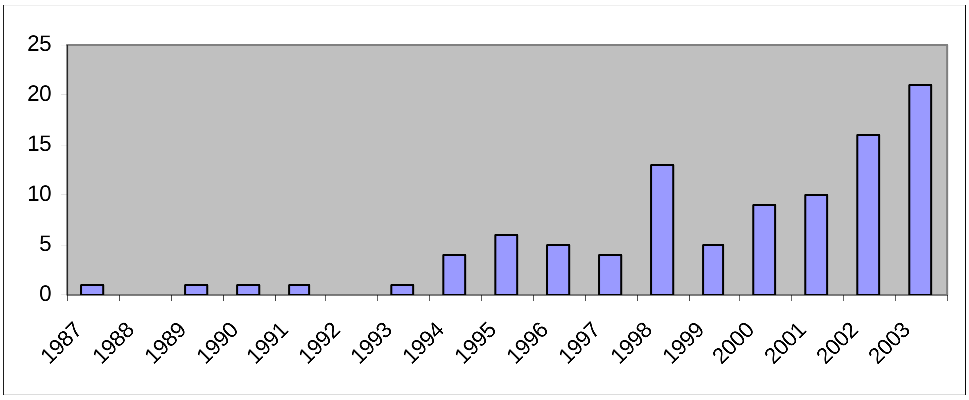
There are three ways for foreign firms to establish their R&D operations in China (von Zedtwitz, 2004):

- Wholly independent R&D labs.
- R&D unit (department) within a branch of Chinese operation.
- Co-operative R&D with Chinese universities or research institutes.

Despite the rapid increase, the exact number of foreign R&D organizations varies largely depending on the sources of information. The Chinese Ministry of Commerce stated that by late 2006 there were close to 1000 foreign-established or foreign-invested R&D organizations in China (Science and Technology Daily 2006). According to von Zedtwitz (2006) there were 199 foreign R&D facilities in China in the beginning of 2004 (see Figure 2). The number has increased rapidly since then, possibly amounting to around 350–450 operational foreign R&D centers currently (Schwaag Serger 2007).[11]

[11] *We arrive at this number by using von Zedtwitz's figure from 2004 as a point of departure and then conducting a search of Chinese and foreign media articles, press releases and company reports to get an estimate of how many foreign companies have established R&D centers since 2004. We focus particularly on companies with existing production facilities, or other relevant presence, in China, since it is very unlikely for firms without manufacturing or other operations in China to set up R&D there.*

Figure 3-1 Number of new establishments of foreign R&D labs in China, (1987–2004).



Source: von Zedtwitz (2006)

The motivations, barriers and mandates

Based on interviews as well as existing studies and surveys, we have identified three principal drivers for why foreign firms locate R&D in China. The first driver is proximity to market and production. Many foreign centers are set up to adapt products and services to the strategically important Chinese market and/or to be near production facilities which are already in China. The second reason for companies to locate R&D to China is political or institutional conditions. Examples of this driving force include “local content” rules, or national standards (see, for example, von Zedtwitz 2004). There are also national regulations that may require foreign companies interested in setting up production facilities to also set up R&D facilities, as well as fiscal incentives. The third factor attracting R&D to China is the supply of knowledge resources in China. Furthermore, behind various stated motives for setting up R&D centers in China, we observe a clear competitive pressure among the multinationals, i.e. ‘you cannot afford not to do it when your competitors have done it’. This is not only about competition for (future) market shares, but also competition for the best talent and networks and the R&D activities are therefore a long-term strategic preparation for future market expansion.

While all three factors play a role in explaining foreign companies’ R&D activities in China, the relative weight of each factor has been changing over time. Furthermore, the motivations and types of R&D activities that are conducted in R&D labs tend to differ according to sector-specific characteristics (see *Table 6*). For instance, as the technology frontier is being moved towards the Asian market and because of the huge demand with specific local characteristics, the R&D investment in the ICT sector is both technology- and demand driven. Different from the ICT sector, the innovation capacity and demand for innovative drugs so far have not been strong and large enough to make China a magnet for foreign R&D investments and innovative activities (see, for example, Nilsson et. al. 2006 and Liu and Lundin 2007a). Furthermore, the Intellectual Property Right (IPR) issue is still perceived as a key concern for foreign firms in the Chinese biomedical industry (ibid). But on the other hand, human resources and special research competences make China interesting for both big pharmaceutical companies and small biotech firms. Finally, in the case of the automobile industry, while the huge potential demand for both passenger cars and commercial vehicles in the Chinese market attract rapidly increasing R&D investments in the automobile industry from abroad, the complexity in both industrial structure and government regulations, imposes significant influence on R&D investments of both domestic and foreign firms.

Table 3-5 Motivations and barriers for foreign R&D in China.

Motivations	**Barriers and difficulties**
Fast-growing market with specific requirement (ICT sector)	Overcapacity and ”unknown” consumers. (Automotive sector)
Skilled labour and well-trained R&D personnel. (ICT sector, Biomedical)	Lack of experienced /qualified specialists (Automotive, Biomedical)
Tapping formal/informal networks and Knowledge sources	Weakness in institutional infrastructure, e.g. IPR regimes. Uncertainty in legal systems.
Competition driven	Extremely intensive competition and High employee turnover
Policy driven (e.g. official requirement for set-up of R&D centre and/or fiscal incentives)	”Window-dressing” no longer works and Some preferential policies disappear

Source: Liu and Lundin (2007b)

In addition, the mandates and activities of foreign R&D labs may also be limited by various (sector-specific) problems:

- The volume of innovative or new products that are developed locally is still inadequate to achieve sufficient economies of scale, due to either the overcapacity (e.g. in automobile industry) or competition (e.g. in telecom industries) in the local market.
- The lack of experienced/qualified specialists in certain sectors (e.g. automobile industry) is still a serious drawback.
- The technology- and R&D-gap between foreign and domestic firms may give foreign firms the opportunities to capture some “high-end” markets (in the short run). But at the same time, the possibility for long-term strategic partnership with domestic firms is still limited.

The mandates of the majority of the foreign labs are development focused (rather than research focused) to support local business and customers. Examples of such activities are translations of product manuals and software into Chinese. This is sometimes also referred to as ‘localization’ of foreign products. The development carried out in China is to a large extent targeted at the Chinese market, with a few exceptions of worldwide mandates for certain products and technologies.

While adaptive R&D continues to dominate foreign firms’ R&D activities in China, however, in recent years, large MNEs have begun to locate innovative R&D in China. It is difficult to assess how many foreign companies are carrying out *innovative* or *global* R&D. The distinction is obviously somewhat arbitrary, since it is difficult to draw a clear line between innovative and adaptive R&D. Nonetheless, it is useful to attempt to make such a distinction. While adaptive R&D can be argued to be location-specific, determined by the need for proximity to market or production, innovative or global R&D, on the other hand, refers to activities which, in theory, could be carried out elsewhere in the world. We see a number of companies that are choosing China as one of a select few number of countries for setting up a global R&D center. A recent study by Schwaag Serger (2007) found around 40 large multinational companies that currently have up to 70 facilities performing innovative R&D activities in China.

The extent to which foreign companies locate innovative or global R&D functions in China differs significantly according to industry. So far, telecommunications and IT or personal computer companies are at the forefront, whereas life-science companies have been less likely to locate such functions in China. A number of pharmaceutical companies have established, or make use of, clinical trial capabilities in China, but few have located innovative R&D there. Starting in 2006, a number of chemical and pharmaceutical companies have announced plans to set up global R&D in China (Tremblay 2006).

Whereas, initially, R&D investments were concentrated within high-technology industries and activities, lately, a number of foreign-owned or foreign-invested global product design centers have sprung up in the Shanghai area. A growing number of companies with design operations are attracted to China because it offers good and inexpensive designers (Business Week 2005b). Some are also starting to view the Chinese market as strategically important, not only because of its size, but because it is a dynamic and rapidly changing country that is assuming an increasingly significant role as global trendsetter. Thus, for example, Coca Cola recently developed a new soft drink at its facility in Shanghai, which is targeted at consumers in developing countries (*The Economist*, “Orange Gold”, March 1, 2007).

At the current stage, taking advantage of human resources of high-quality and low cost, multinationals are to an increasing extent trying to integrate their R&D organizations in China into their global research networks. This is typically done in an experimental mode and very cautiously. However, for those who have managed to integrate their Chinese operations it has indeed given them a competitive edge compared to their competitors both in China and in the global market.

4 Linkages and outputs

When looking into the involvement of FDI firm in the Chinese innovation system and making assessment of its impact, the existing literature has so far focused on the input side, while the local linkages and R&D outputs of FDI firms are investigated to a much less extent. As a consequence, the strategic nature and network dependence in R&D-related activities of FDI firms have not been sufficiently captured. Furthermore, when FDI firms are intensifying their R&D effort in China, the results in terms of both physical and tacit outputs have also imposed significant influence on the development of innovative capacity of the Chinese innovation system. To bridge this gap, we now look at linkages of foreign firms' activities with domestic firms and research institutions, as well as examine some output indicators of foreign R&D.

4.1 Increased importance of S&T outsourcing of FDI firms

In addition to the increased importance of FDI firms in R&D-related physical and human inputs, more recently, in order to take advantages of the large, and rapidly growing, supply of S&T resources in China and to gain new competitive edges in the Chinese market, FDI firms have started to establish domestic innovation interfaces through co-operating with other firms as well as universities and research institutes. This type of linkages can be both an efficient way of identifying talent pools and potential partners as well as tapping into the local knowledge and innovation networks. While the weak linkage with local actors or the missing spill-over to domestic firms often create sceptics against FDI in China, the increased interaction can create various important potential channels, through which the linkage can be established and spill-over can take place. To capture this new and rapid development, we use the indicator for S&T outsourcing to measure FDI firms' linkages with both other (domestic and foreign) firms and with research institutes and universities. An important methodological issue that needs to be clarified here is the differences in definitions of R&D and S&T respectively in the Chinese statistical indicator system. Both S&T and R&D are two key measures on technology development in China. According to the commonly used international classification from the OECD, these two concepts are defined as follows.

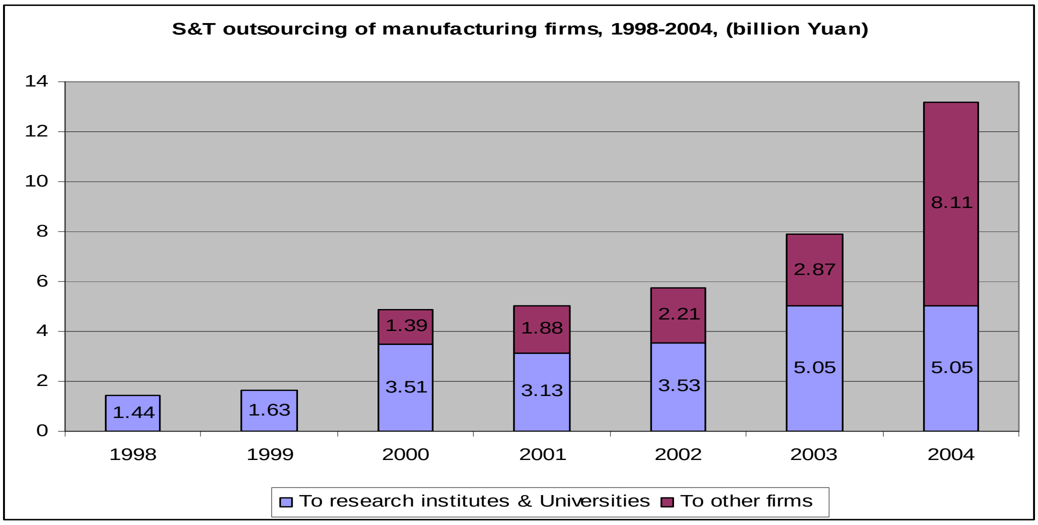
S&T: *Systematic activities, which are closely concerned with the generation, advancement, dissemination and application of science and technology. These include such activities as Research and experimental development (R&D) science and technical education and training (STET) and scientific and technological services (STS). (Frascati Manual, 2002, OECD).*

R&D: *Comprise creative work undertaken on a systematic basis in order to increases the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications. The term R&D covers three activities: basic research, applied research and experimental development. (Frascati Manual, 2002, OECD).*

In the current indicator system in China, the definition of R&D is in line with the Frascati Manual. The definition of S&T followed the UNESCO manual when the Chinese S&T statistics system was first introduced in the mid 1980s. In the last two decades the definition of S&T has changed more towards the Frascati manual recommendation. S&T in the Chinese indicator system includes R&D, technology acquisition (licenses) and re-innovation, and miscellaneous expenditures on preparation for production of new products and applications of R&D results. Hence, S&T includes several activities not included in R&D. In our mapping, we use R&D as the key indicator to keep our measurements and analysis internationally compatible. However, for outsourcing activities, the data were collected using S&T activities, instead of R&D, which we have to follow. S&T outsourcing is defined as acquisition of S&T services, which is purchased from other organisations, such as other firms or research organisations (NBS 2006).

As show in *Figure 3*, S&T outsourcing activities have been increasing rapidly since 2000, from less than 5 billion RMB to more than 13 billion RMB in 2004. The largest increase was outsourcing to other domestic and/or foreign firms, although outsourcing to research institutes and universities has also experienced a notable increase.

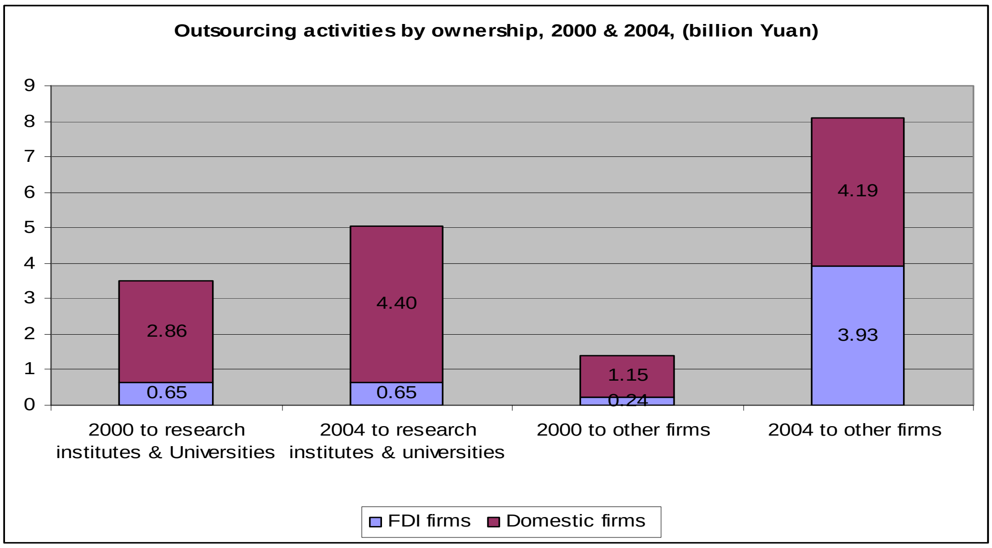
Figure 4-1 Increase of outsourcing activities over time.



Source: Compiled by NBS and based on authors' own calculation

A further breakdown into foreign and domestic ownerships in *Figure 4* gives us some interesting insights. Firstly, outsourcing to other firms has increased substantially in both domestic and FDI firms in the period 2000-2004. Secondly, for domestic firms, their outsourcing to research institutes and universities has increased much more than that of FDI firms. To some extent, it may imply that domestic firms are more dependent, than their foreign counterparts, on domestic science-industry-linkage, as a complementary channel, through which they undertake innovation activities.

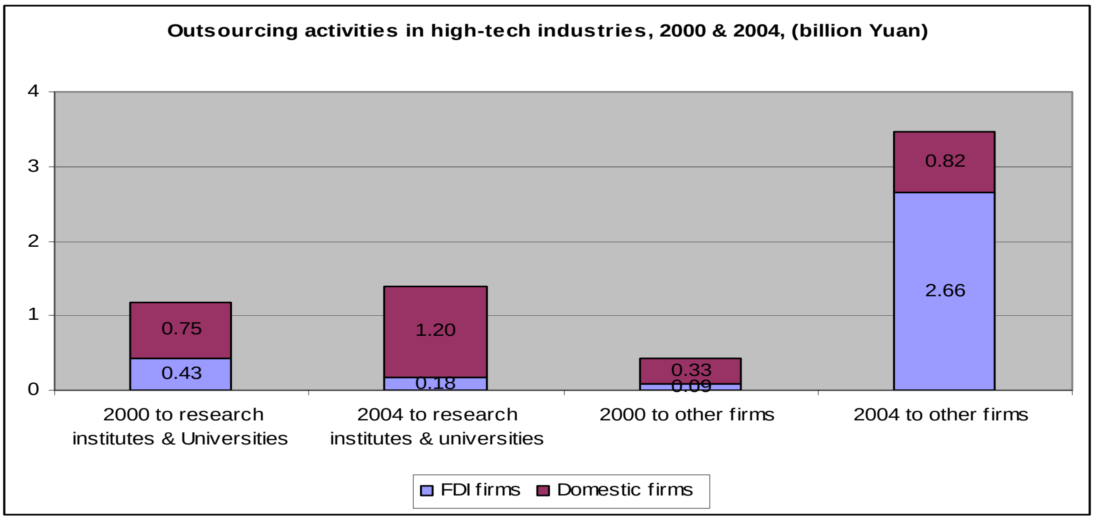
Figure 4-2 S&T outsourcing activities by ownership.



Source: Compiled by NBS and based on authors' own calculation

Instead of the manufacturing as a whole, in *Figure 5* we examine the ownership distribution, only in the high-tech industries. Interestingly, in the high-tech industries, FDI firms, have both a much larger increase from 2000 to 2004 and account for a major share S&T outsourcing to other firms in 2004. In other words, FDI firms' outsourcing to other firms take mainly place in the high-tech industries (2.7 billion RMB out of 3.9 billion RMB), while most part of outsourcing by domestic firms are outside high-tech industries (3.3 billion RMB out of 4.2 billion RMB) However, FDI firms' outsourcing to research institutes and universities is still very limited. At same time, it is important to bear in mind that, such co-operation between FDI firms and domestic research organizations takes place more often beyond the scope of manufacturing, which is not captured in the industrial statistics.

Figure 4-3 S&T outsourcing activities in high-tech industry by ownership.



Source: Compiled by NBS and based on authors' own calculation

4.2 Contribution of FDI firms in innovation output

Having investigated the importance of FDI firms in R&D-related inputs and S&T linkages, in the last section of the quantitative mapping, we turn to the contribution of FDI firms to innovation outputs in terms of both physical output, measured by outputs and exports of new products; and tacit output in the form of patent applications.

China has not yet carried out an innovation survey, such as the Community Innovation Survey (CIS) which has become a regular survey for innovation activities of industrial enterprises in the EU countries. However, in the yearly industrial R&D survey carried out in China since the mid of 1990s, several innovation indicators have been collected, following the international practices recommended in the Oslo manual (OECD, 2003). In this paper, we use outputs and exports of new products, which are defined as new to the firm as measurement for the physical outputs of innovation activities.[12] As shown in column (1) and (2) of *Table 7*, the shares of FDI firms in both total output and export of new products in the manufacturing sector have increased over the period 1998–2004. The new products of FDI firms seem also to be more export-market oriented than those of domestic firms. While less than half (42 %) of new products were produced by FDI firms in 2004, the majority (67 %) of exports of new products were from FDI firms. The dominance of FDI firms in innovation outputs and exports is even more apparent in the high-tech industries where the shares of output and export of new products reached 68 percent and 88 percent respectively in 2004.

Table 4-1 importance of FDI firms in S&T physical outputs, 1998–2004

(Share in the manufacturing sector and high-tech industrial sectors, %).

	In manufacturing sector		**In high-tech industries**	
	(1) Output of New product	**(2) Export of New product**	**(3) Output of New product**	**(4) Export of New products**
1998	27	44	43	81
1999	32	44	52	79
2000	35	57	57	83
2001	38	57	63	81
2002	37	53	59	70
2003	41	58	57	78
2004	42	67	68	88

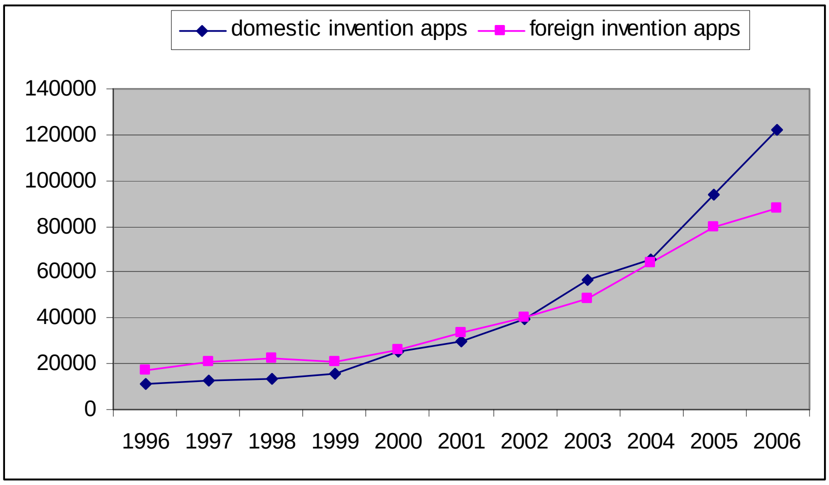
Source: Compiled by NBS and based on authors' own calculation

Turning to the tacit innovation output, patents registered in China are classified into three categories: invention, utility model and (appearance) design. This classification of patents differs to various degrees from the international standard. For instance, design refers to new appearance and utility model refers to functionality modification or improvement, without substantial technological contents. The invention patents are thus presumably more

[12] *The degree of novelty of a new product, according to the Oslo manual (2003), can be defined as new to the firm, new to the market and new to the world. However, in practice, it is difficult for individual firms to give precise definition of the degree of novelty of their product. In the Chinese S&T indicator system at the current stage, new to firm is applied when collecting innovation indicators.*

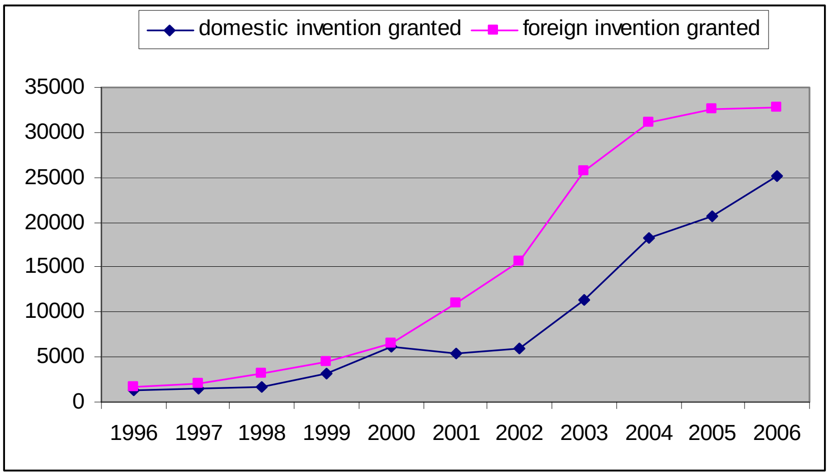
R&D intensive than the other two types of patents. One of the largest differences between domestic and foreign applications is the structure of the application. For domestic firms, the majority of their patent applications belong to the first two categories, although the number of invention applications has been increasing as well. For foreign applications, the invention application is the main category. As shown in *Figure 6 and Figure 7*, the number of invention applications by domestic firms exceeded their foreign counterparts for the first time in 2003. However, the foreign firms still outperformed their Chinese counterparts significantly in terms of the numbers of granted invention patents in the past years.[13] Thus, in 2006, foreign invention patents accounted for 58 percent of total invention patents granted in China, underlining the importance of FDI firms in total patenting activity in China.

Figure 4-4 Domestic and foreign applications for invention patents, (Pieces).



Source: State Intellectual Property Organization of the People's Republic of China (SIPO)

Figure 4-5 Domestic and foreign invention patents granted, (Pieces).



Source: State Intellectual Property Organization of the People's Republic of China (SIPO)

[13] *Note that the number of applications and the number of inventions granted for the same year are not comparable, due to the time lag created by the application procedure. The whole process, from application to approval can take three-four years for an invention patent.*

Among foreign patent applicants, the MNEs from Japan and the US are the most active applicants, while German, Korean and French enterprises are also applying for an increasing number of patents in China. The distribution by field of technology illustrates the competitive strengths of these MNEs in the Chinese market and, at the same time, reflects intensified competition among these MNEs within a few narrow defined niches in the Chinese market (see *Table 8*). More recently, the large number of patent applications by a small group of MNEs caused considerable attention in China, regarding their role in the innovation capacity building. On the one hand, the question is if these patents are really developed by utilizing R&D resources located in China; and on the other hand, if these patents function as strategic blocking against domestic competitors, rather than contribution in the innovation capacity building.

Table 4-2 Top ten foreign enterprises in applications for invention patens (2003).

Ranking	Country	Enterprise	Number of applications
1	Japan	Matsushita Electric Industrial Co., Ltd.	1817
2	South Korea	Samsung Electronics Co., Ltd.	1560
3	Japan	Canon Co., Ltd.	820
4	Japan	Seiko Epson Corp.	781
5	South Korea	LG Electronics Corp.	624
6	Japan	Toshiba, Inc.	583
7	United States	IBM Corporation	581
8	Japan	Sony Corp.	560
9	Japan	Mitsubishi Electric Co., Ltd.	556
10	Japan	Sanyo Electrical Motors Co., Ltd.	541

Source: MOST (2005)

5 Concluding remarks and policy implications

In the face of the rapid development we witness in China today, the question is whether the surge of R&D investment, both domestic and foreign, is a short-lived fad, a 'gold-rush' type phenomenon, with little long-term consequence or whether we are witnessing the beginning of a structural shift, both in terms of the large-scale upgrading of China's innovative capacity and in terms of global knowledge stocks and flows. There is no clear-cut and straightforward answer to this question. Nevertheless, from the mapping of the relative importance of MNEs in the Chinese manufacturing sector and the detailed description of foreign R&D labs beyond the scope of manufacturing, we observe not only the remarkably increased importance of foreign actors in the Chinese innovation system, but also the increased complexity and sophistication of their R&D-related activities in China. This indicates that the growing importance of China in the globalization of R&D is more than a 'flash-in-the-pan'.

Although domestic firms are rapidly strengthening their R&D inputs, FDI firms in China are still outperforming their Chinese competitors, in many qualitative aspects, in terms of both economic performance in general, as well as R&D output in particular. Nevertheless, the competitive pressure has increased, as a result of the continuing "gold rush" to the Chinese market of a large number of foreign actors who are not only market-seeking, but also resource- and knowledge seeking. This competitive pressure has on one hand, forced FDI firms to increase their R&D efforts in China, and on the other hand, opened up potential channels of knowledge transfers and spillover, such as outsourcing, which are mainly to domestic firms for the time being, but with great potentials for establishment of industry-science linkages in the near future. The other apparent source of competitive pressure is from the domestic sector. Associated with stronger awareness of the importance of indigenous innovation capacity, and as a result of structural reforms aiming at improving market mechanisms and encouraging entrepreneurship, there is indeed a gradual catch-up process taking place. As multinationals' operations in China mature, and as the absorptive capacity of domestic Chinese firms increases, the potential for innovative R&D activities and serious collaboration is likely to grow continuously.

Having these recent trends and key facts of globalization of R&D in China in mind, in this concluding section, we attempt to shed some light on the implications of this new and fast-growing phenomenon for both China and OECD countries, of which multinationals are to a larger extent, and more actively involved in the process of globalization of R&D.

The impact of globalization of R&D on China, in general is positively perceived by both the business sector and policy makers in China. Beyond the benefits generated by FDI in China in terms of development of the Chinese industrial sector, export competitiveness and job creation, R&D investments by FDI firms are considered an important step to further improve the "quality" of foreign investment in China as well as to promote the S&T development in the Chinese business sector. An increasing number of MNEs have established full scale R&D centres, which will engage in partnerships with local research organisations and establish brain circulation of human resources of R&D. The emerging global R&D network and improved environment, in forms of advanced physical infrastructure and research network will attract expatriate scientists back to China. These newly established R&D centers will bring new knowledge and new projects which will result in training for Chinese workers at the forefront of international industry. They will become the centre of clusters in their industry, and may attract more foreign players. In the long run it is possible that MNEs will move their R&D headquarters there. Furthermore, the pro-competitive effect is regarded as an important (indirect) positive effect. The R&D intensity of domestic firms is rising most quickly in industries with high R&D-intensive FDI participation, which is associated with intensified competition and proliferation of product variety. The high concentration of FDI at the industry-level imposes also a pro-competitive effect on domestic firms' propensity to innovate.

However, there are also some less optimistic views regarding the impact of foreign R&D on China. Firstly, the R&D activities of most foreign firms/labs are still predominantly development focused (rather than research focused) to support local business and customers. The development carried out in China is to a large extent targeted at the Chinese market, with a few exceptions of worldwide mandates for certain products and technologies. Secondly, the links between foreign-invested R&D firms and domestic firms and local R&D institutes are still weak. The increase in outsourcing and diversification of foreign R&D-related activities have created new channels of knowledge diffusion and spillovers, however, such positive externalities are limited by a few factors, such as limited absorptive capacity and weakness of human resources in domestic firms, as well as the limited labor mobility between foreign and domestic firms. Thirdly, in some technology-intensive sectors, e.g. telecommunications and automobiles, the market entries of multinationals and increased concentration among a few large foreign firms have caused concerns of monopolistic power and decreased market competition.

Furthermore, there are some risks in involving foreign firms in China's R&D. The largest risk that is often mentioned is the crowding-out effect: if foreign firms perform research, and particularly development work, it may result in less demand for those functions from local firms and organizations. Also, crowding-out can take place due to the competition for talents between domestic and foreign firms. Some Chinese academics and policymakers criticize foreign firms' presence and their behavior in China, claiming that they charge unduly high licenses for their patents, that they 'crowd out' domestic firms in the market for highly skilled labor, and that they thwart technology transfer and knowledge spillovers (see, for example, Lin 2006). Furthermore, foreign firms are seen as dominating standards and technology platforms, and reducing Chinese companies to the role of producers with low profit margins.

From an S&T policy viewpoint, the identification of potential barriers in the diffusion- and technology transfer process, which can be related to market-, technology- and institutional factors, is essential for the policy design and implementation. Furthermore, due to WTO-related deregulations, foreign firms are no longer required to have Chinese venture partners to invest in most high-tech industries. As a result, more and more R&D facilities in China are wholly foreign owned. The shift of entry mode (from previous joint venture) seems to impose an additional challenge to S&T strategy formation in terms of technology co-operation and partnership. Despite these new challenges and potential risks, Chinese policy makers seem to have the ambition to seize this "window of opportunity" anyway. This ambition can be observed from several current policy initiatives and actions. Firstly, in terms of S&T policy, in the recently released National Guideline for Medium- and Long-term Plans for S&T Development (MOST, 2006), S&T is considered the key driving force for sustainable economic growth in the future and China is going to undertake the transformation to an innovation-oriented nation with strong emphasis on domestic S&T

capacity building in the form of indigenous innovation capacity.[14] Secondly, in the field of FDI policy, on one hand, some preferential treatments on FDI enterprises, such as tax incentives are in the process of being phased out and the investment approval procedure in certain natural resource intensive and environmental impact heavy sectors is being tightened. On the other hand, new policy instruments in particular targeted at attracting foreign R&D investments and promoting linkage with domestic sectors are being discussed.

With regards to the implications for OECD countries, from the viewpoint of MNEs, R&D activities in China is becoming an important strategy for moving their R&D closer to their production activities and customers as well as for facilitating their market expansion in the Chinese market, where the demand for high value- added and innovative goods and services is growing rapidly. Furthermore, the access to human resources and low wages even for skilled and well-educated segments of the labour force is one of the most import attractions in China. This is in contrast to an ongoing decline of the supply of human resources in science and engineering, in terms of enrolments and graduates in most OECD countries.

However, taking the specific market- and institutional conditions in the Chinese market into account and from a global perspective, entry into the Chinese market is becoming more difficult. First of all, the Chinese market has become highly competitive where all large global players have been trying to enter and establish themselves with large-scale investments. Also, it is no longer obvious that China is a “low cost country”, in particular in R&D- and knowledge intensive sectors. In other words, the cost structure will be different, but the total amount will not necessarily be less than elsewhere. The reduced personnel cost will probably be offset by increased operational costs, in terms of travel, management, training and, not the least, start-up expense and time. More importantly, the lack of protection for intellectual property rights (IPRs) remains a key concern for foreign R&D investors. The Patent Law in China was revised extensively to meet the minimum protection standard set by the *Agreement on Trade-Related Aspects of Intellectual Property Rights* (TRIPs), just before China’s accession to the WTO. However, the implementation is still in great need of improvement, despite the improvement in the legislations and critique from foreign countries and foreign firms. This is an ongoing, and time-consuming process, through which a genuine domestic interest and the involvement of domestic firms become integral elements in the enforcement of IPR in China.

Based on previous observations from the production activities in ICT and other labour-intensive sectors, the fear of globalisation associated with job losses and wage competition from developing countries such as China and India can easily prevent us from seeing the new possibilities offered by the development in knowledge-based and R&D-intensive sectors in these developing countries. Furthermore, the allocation of R&D activities of multinationals in China causes further concerns of “hollowing out” of the innovation capacity in the OECD countries and losses of core technology and skills. From a policy perspective, to maximize benefits and mitigate potential risks of this new development, on one hand, OECD countries need to target the strengthening of the domestic innovation system, and on the other hand enlarge the platform for co-operation in R&D related fields with China and to identify new fields and forms of long-term and strategic co-operation.

[14] *For a discussion and assessment of China’s 15-year plan, see Schwaag Serger and Breidne (2007).*

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Appendix 1

Classification FDI- versus domestic firms

Code	**Ownership**
Domestic ownership: SOE	
110	State-owned enterprises
141	Stated-owned, jointly operated enterprises
151	Wholly stated-owned enterprises
	Domestic ownership: Collective
120	Collective-owned enterprises
130	Shareholding cooperatives
142	Collective-owned, jointly operated enterprises
	Domestic ownership: Shareholding
159	Other limited liability enterprises
160	Shareholding limited enterprises
	Domestic ownership: Private
171	Private wholly owned enterprises
172	Private-cooperative enterprises
173	Private limited liability enterprises
174	Private shareholding enterprises
	Domestic ownership: Other
143	State-collective jointly operated enterprises
149	Other jointly operated enterprises
190	Other enterprises
Foreign ownership: Hong Kong, Taiwan and Macau invested	
210	Overseas joint ventures
220	Overseas cooperatives
230	Overseas wholly owned enterprises
240	Overseas shareholding limited companies
Foreign ownership: foreign invested joint ventures	
310	Foreign joint ventures
320	Foreign cooperatives
340	Foreign shareholding limited companies
Foreign ownership: foreign invested	
330	Foreign wholly owned enterprises

Source: National Bureau of Statistics of China.