Impact of the Foreign Sector on Innovation in China's Domestic Firms

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Abstract

This paper examines the implications of China's large and growing foreign sector for its ability to innovate. While some observers contend that China's domestic firms and research institutes neither sustain the innovation effort nor achieve the innovation outcomes expected of an emerging industrial economy and that the foreign sector is the principal performer of innovative activity, this paper supports a different perspective. That perspective is that China's domestic industry and research institutes account for the large majority of R&D and patenting activity and that in terms of the volume and extent of innovative effort, the foreign sector plays a decidedly secondary role. However, the foreign sector plays a critical role as a motivator and facilitator of domestic innovation in China. Foreign direct investment plays a dual role of supporting foreign-funded R&D, although the R&D intensity of foreign-funded R&D in the industrial sector lags behind that of China's domestic firms. A critical role of FDI is that by expanding technological opportunity and competition, it motivates domestic firms to intensify their R&D operations. FDI is also a key driver of domestic patenting activity. Furthermore, the foreign sector plays a critical role in transferring important overseas technologies through China's technology markets. These imported technologies in turn raise the returns to domestic firm-level R&D. The paper concludes that China's foreign sector activities – FDI, foreign-funded R&D, and market-mediated imported technology – are all critical drivers of China's rapidly growing innovation capabilities.

1. Introduction

Over the past decade, China has experienced a striking acceleration of innovative activity, both inputs to innovation, such as R&D effort, and the results of innovative activity, such as patents. Over the same period, China has also experienced a dramatic increase in the role of the foreign sector, including foreign funded R&D and foreign direct investment.

Discussions of implications for China of FDI and of foreign-funded R&D are generally viewed separately. That is, FDI, such as that provided by Nike or GM, is generally seen as a vehicle for outsourcing manufacturing, whereas foreign-funded R&D is viewed as the vehicle for creating research centers, such as those established by Intel and Microsoft. However, foreign-funded R&D and FDI are highly integrated, as many multi-national firms sponsoring FDI in China also have established R&D operations. Moreover, the nexus between foreign-funded manufacturing firms and their R&D operations and the R&D operations of domestic firms is more proximate and multi-faceted than most might imagine. The questions that are addressed in this paper are:

- What are the respective direct contributions of the domestic and foreign sectors to China's R&D intensification?
- In what ways does the foreign sector – FDI, foreign-funded R&D, and market mediated technology flows –contribute indirectly to China's technology development?
- To what extent do these foreign sources of technology transfer and motivators of domestic technology development erode the technological advantage of the U.S.?

2. China rising R&D intensity?

Much of the literature on China's S&T system divides over the issue of the respective roles of the domestic and foreign sectors in driving China's technological advance. Analyses that have focused on the question of the role of the foreign sector in China's S&T system include Kathleen Walsh (2003), "Foreign High-Tech R&D in China," and George Gilboy (2004) "The Myth Behind China's Miracle." Gilboy (2004) takes a decidedly skeptical view of the capabilities of China's domestic S&T system, characterizing China's domestically owned firms as hampered by:

> …an "industrial strategic culture" that encourages them to seek short-term profits…(and) forego investment in long-term technology development and diffusion….Most Chinese industrial firms…have not increased their commitment to developing new technologies….R&D expenditure as a percentage of value added at China's industrial firms is only about one percent, seven times less than the average in countries of the OECD. (p. 43).

Gilboy's observation raises several issues. First, to what extent is R&D effort in China less than that of its OECD country counterparts? Figure 1 shows as we might expect, that R&D intensity as measured by the ratio R&D expenditure/GDP is highly associated with GDP per capita. The figure suggested that a low-middle income country like China would exhibit a level of R&D intensity that lies in the range of 0-1 percent, whereas the richer OECD economies would exhibit R&D intensities above two percent and as high as four percent. Thus, as Gilboy suggests, a ratio of 1:7 is plausible for the manufacturing sector, where manufacturing represents a somewhat larger share of GDP for China than it does for say the U.S.

The second issue is whether Chinese firms have increased their commitment to development new technologies, say by intensifying their R&D efforts? Table 1 shows the increasing distribution of R&D effort across China's approximately 22,000 large and medium size industries enterprises (LMEs). Since most of the LMEs do not maintain formal R&D operations, it is arguable, as Gilboy claims, that "most industrial firms…have not increased their commitment to developing new technologies," if we accept R&D intensity as a measure of such a commitment. However, from a time series perspective, the more interesting observation is that an increasing proportion of China's industrial LMEs are establishing formal R&D operations and those that have established such operations are clearly increasing their R&D effort.

Finally, to gauge China's growing R&D intensity, we compare its R&D trajectory with those of the large OECD economies. As shown in Figure 2, among the seven large OECD economies with populations over 40 million, six – the U.S., Japan, the U.K., Germany, France, and South Korea , but not Italy – exhibit current R&D ratios in the range of two to three percent. The figure also shows that Singapore has recently made the transition from that of a low-intensity R&D country (< 1%) to a high-intensity R&D country (>2%). On average the six OECD economies required ten years to make the transition. Each of these countries exhibited a kind of "S&T takeoff" – when their R&D ratios rose to one percent, their R&D intensities continued to climb until they leveled off in the two-three percent range.

In Figure 2, China's R&D trajectory is shown in the southeast corner, having penetrated the one percent threshold in 2000 and then rising to 1.4 percent in 2004.[1] Based on the mere fact that China's R&D intensity has risen well above one percent and continues on a steep trajectory we cannot infer that like the OECD economies before it China is in the midst of an S&T takeoff that will soon elevate its level of R&D intensity to be consistent with those of the other large OECD economies. We can, however, contrary to Gilboy's contention, conclude that China's R&D intensity has been rising rapidly, having more than doubled from 0.6 percent in 1995 to the range of 1.3 percent in 2004. Moreover, we can conclude that this level of R&D intensity substantially exceeds the norm for a low or low-middle income country.

Figures 2 and 3, drawn from Hu and Jefferson (2005) also show a surge in patenting activity in China since the late 1990s. What is most interesting is that this surge has occurred for both domestic and foreign enterprises. It has also occurred for both general patenting and for invention patents, which need to meet a higher standard of novelty than utility model and design patents. While it is reasonable to expect the acceleration in R&D spending and patenting to closely correspond, Hu and Jefferson (2005) demonstrate that there are a number of factors that explain the surge in China's patenting activity independent of R&D spending.

What is driving China's the abrupt increase that we observe over the past decade in R&D intensification and patent growth? In particular, what has been the respective roles of the domestic and foreign sectors?

[1] In fact, as a result of the upward revision of China GDP resulting from the 2004 census, staff at the National Bureau of Statistics have revised their estimate of the R&D/GDP ratio for 2004 from 1.44 percent to 1.27 percent.

3. Foreign-funded R&D

Has this growth in R&D intensity resulted from spending by foreign entities in China on R&D? To test the proposition that firms with FDI participation dominate R&D operations in China, we turn to our data set for China's industrial LMEs. As shown in Table 2, which summarizes R&D activity in 1995 and 2001, total R&D expenditure within China's domestic industrial LME sector was more than five times that of the foreign funded enterprise (FFE) sector, which we define as including both foreign firms and overseas investment from Hong Kong, Macao, and Taiwan (HMT). That is, in 2001 domestic firms accounted for 84 cents of every R&D dollar spent by the large and medium size industrial enterprise sector.[2] Moreover, as shown in Table 2, in 2001, while the ratio of R&D to value added in China's domestic LMEs had reached 3.3 percent, for the foreign firms it stood at just 2.6 percent. While these findings are broadly consistent with a recent OECD report that states, "…foreign firms that invest in China appear to have engaged in only limited levels of R&D activity and their role in the innovation process seems even more limited." (OECD, 2002, p. 267). Nonetheless, the rapid growth of the FFE industrial sector is causing its share of total LME industrial R&D to grow faster than the domestic sector, causing the R&D share of the domestic sector to fall from 91 percent in 1995 to 84 percent in 2001 and then to 77 percent in 2003. Still, because FFEs are not as R&D intensive as their domestic counterparts, contrary to the assertions of Gilboy, the rapid growth of the FFE industrial sector is depressing the overall rate of

[2] Accounting for the fact that in 2001, 61 percent of China's foreign funded enterprises were domestically owned, we can reapportion a proportional share of the FFE research and development spending to the domestic side of the ledger. The domestic share of China's LME industrial R&D spending in 2001 then rises to 91 cents on the dollar.

China's industrial R&D intensity. Later, in section 6, we investigate the contribution of foreign funded research centers to R&D intensification and innovation in China.

4. Role of FDI

China has emerged as the leading recipient of FDI, although on a per capita basis, FDI flows to China are comparable to those of certain S.E. Asian countries and substantially less than the U.S, Canada, and most western European countries. FDI is likely to motivate R&D effort through two channels. First, concentrations of FDI create technological opportunities for domestic firms as they can use research funds to imitate products and processes that enter their geographic and technological space. Furthermore, infusions of FDI create competition, so that in order to simply survive, domestic firms are obliged to upgrade technologically, so that their product quality and production efficiency enable them to remain competitive.

To test this hypothesis that industry FDI concentration motivates R&D intensity, we use the LME data to estimate the impact of the growth of FDI concentration across 4-digit industries on the growth of individual firm-level R&D intensity within each of these industries. The result, shown in Table 3, indicates a statistically significant association between the growth of FDI industry concentration and firm R&D intensity. That the relationship is not more robust may reflect the finding of Aghion et al (2006) who show that firms in technologically advanced industries react positively to a foreign firm entry, but to laggard industries.[3] To allow for heterogeneity across industries, the regression in

[3] We will also estimate this relationship separately for the subset of domestic firms and foreign-funded firms.

Table 3 should be tested separately for technologically advanced industries and laggard industries. Nevertheless, we find across all industries evidence of a significant impact of FDI growth on firm R&D effort.

Hu and Jefferson (2005) have also conducted research on the causes of the surge in patent applications and grants in China since the late 1990s. Their Table 3, reprinted here, shows several interesting results that compare the impact of FDI on the patenting behavior of domestic and foreign firms. While concentrations of industry FDI have no impact on the propensity of foreign firms to patent, the impact on the propensity to patent of domestic firms to is substantial. A 10 percent increase in the concentration of industry FDI motivates on average a 6.4 percent increase in patenting by domestic firms. This result suggests two interpretations. The first is that concentrations of FDI substantially expand technological opportunity and the incentive to innovate for domestic firms leading to a higher incidence of patenting; the second interpretation is that the presence of foreign firms with patent protected products and production technologies may also be spurring China's domestic companies to file patents for strategic competitive purposes that enable them to infringe on the intellectual property of foreign firms while claims are being settled. The large patent-FDI elasticity suggests that both these effects may ensue in the domestic sector as a result of high concentrations of FDI. Because neither R&D expenditure nor FDI has any appreciable impact on patenting on the foreign sector, while the autonomous time dummies "explain" most of the foreign patenting, especially during 1999 and 2000, when China extensively amended its patent law in preparation for its accession to the WTO, it is likely that during this period, 1995-2001, much of the patenting of foreign firms involved filings to extend coverage to existing intellectual

property by utilizing China's reforming patent system.

5. Role of imported technology markets

Again according to Gilboy, "Chinese firms are taking few effective steps to absorb the technology they import and diffuse it throughout the local economy, making it unlikely they will rapidly emerge as global industrial competitors." (p. 38) To put these claims in perspective, Table 4 shows the importance of technology purchases in relation to in-house innovation spending within China's industrial LME sector. Purchases of imported technology in 2000 amounted to 30 percent of total internal S&T expenditure, a measure of innovative activity that is somewhat broader than R&D but closely tracks R&D expenditure. While the proportion declined to 27.6 percent in 2003, purchases of imported technology nevertheless grew at an annual rate of 18 percent during 2000 to 2003. Compared with imported technology, at just 3.7 percent of total internal S&T expenditure in 2003, the purchase of domestic technology played a much smaller role. With purchases having doubled over the period 2000-2003, however, LME activity in the internal technology market is outpacing the growth of internal S&T spending and imported technology purchases.

Research by Hu and Jefferson (2005) documents important complementarities that exist among internal R&D and technology purchases, both imported and domestic. In particular, in-house R&D shares strong complementarities with technology imports, which enable domestic firms to capture higher returns to their own R&D spending.[4]

[4] Hu, Jefferson, and Qian (2004a) show this result within the context of a production function. Fisher Vanden and Jefferson find this result using a cost function approach.

Fisher-Vanden and Jefferson also find that domestic firms that combine in-house R&D with imported technology are more likely to be active exporters.[5]

What is the distribution of technology purchases over domestic and foreign firms? In 2001, 1,460 LMEs, over 80 percent ow which were domestically owned, recorded purchases of imported technology. Furthermore, the foreign funded enterprises (FFEs) purchased virtually nothing in China's domestic technology markets. In conclusion, in contrast to Gilboy's assertion that Chinese firms are "taking few effective steps to absorb the technology they import and diffuse it throughout the local economy," among the LMEs, the domestic firms are far more active participants in both the imported and domestic technology markets than their foreign counterparts. While these MNCs may transfer technology from their parent companies, they are substantially less connected with technology markets than their domestic counterparts. By creating incentives for domestic firms to perform R&D while also enhancing the impact of R&D by combining it with foreign technology transfer, China's fast growing foreign sector is supporting the growing capabilities of China's domestic companies to compete on world markets.

Summarizing, in trying to single out the domestic or foreign sector as the key driver of China's technological advance, some of the literature takes a static view in which the foreign sector and the domestic sector are viewed as disjoint. We find that while foreign-funded firms are not leading the intensification of China's innovation activity, the foreign secto, broadly interpreted, os playing a key role in motivating rising R&D intensity. The foreign sector is motivating domestic innovation effort and outcomes through one direct channel, foreign-funded R&D, and at least two indirect channels – FDI and technology markets.

[5] Fisher-Vanden and Jefferson (2004).

6. The MNC research centers[6]

China's Ministry of Commerce recently reported that as of September 2005 foreign companies had established approximately 750 R&D centers in China. MNCs that have established separate R&D centers include Dupont, Ford, G.E., General Motors, IBM, Intel, Lucent Technologies, Microsoft, and Motorola. These generally lay outside the industrial R&D survey data. They also lay outside the annual survey of domestic research institutes administered by the Ministry of Science and Technology.

MNC established R&D centers generally reflect one or a combination of three motivations. These are:

- Applied research intended to adapt established products to the local Chinese market. The localized innovations include design innovations that are intended to appeal to Chinese consumers and process innovations that are intended to enhance efficiency, often by capitalizing on the abundance of low-cost labor.
- Access to skilled talent. Bell Lab under Lucent Technologies is the largest MNC research institution in China. It has more than 500 scientific researchers in Shanghai and Beijing, 96 percent of whom possess PhDs or master's degrees (Wei Cai, 2006).
- Strategic motives focused on establishing an MNC as a first mover or leading player in a Chinese market. This positioning may be intended to establish branding advantages in the Chinese market as well as to influence Chinese policy toward the MNC in question.

Examples of R&D focused on localization include IBM's China Research Lab, established in 1995, which is mainly focused on the local market with its work largely conforming to the Chinese market. Patent applications – more than 90 percent of IBM technology patents were from its R&D Center based in the US while that from China

[6] This section is formative; a further draft will compare China's research institute sector with the foreign-funded research centers.

Research Lab accounted for less than one percent. Matsushita Electric Industrial Co. has two R&D centers in China, both of which are focused on applied R&D. According to Iwazaki Morio, general manager of the 2 centers, "Infrastructure research institutions are mainly set in mainland Japan. For Panasonic and many other transnational corporations, the core significance of establishing applied R&D institutions is to enable products to further meet market demands." (Wei Cai, 2006).

A fourth incentive for establish MNC according to China's Ministry of Commerce is to facilitate control over relevant technologies. According to the Ministry, 46 percent of transnational corporations tend to set up foreign-owned R&D centers mainly for technology control. According to the Ministry's report, the MNCs use research centers t to control the diffusion of critical technologies by acquiring competing R&D operations, blocking the diffusion of competing technologies. Out of security concerns China's government has set up a series of policy barriers for MNCs seeking to merge with related domestic R&D institutes. But, in fact, the more significant spillovers are likely to flow in the other direction – from foreign institutes to domestic R&D operations.

These research centers are unlikely to be producing leading innovations that would otherwise be made in the U.S. or other advance scientific centers in the OECD countries. For instance, the lead R&D manager from Sun Microsystems reported in May 2005 that China's research centers have yet to achieve the scale or quality needed to deploy the leading Sun scientists to a Chinese research setting. However, the presence of these centers is likely to be conveying more advanced technologies than those developed in the industrial sector while at the same time demonstrating to Chinese counterparts how to organize successful R&D labs with a high-end commercial orientation.

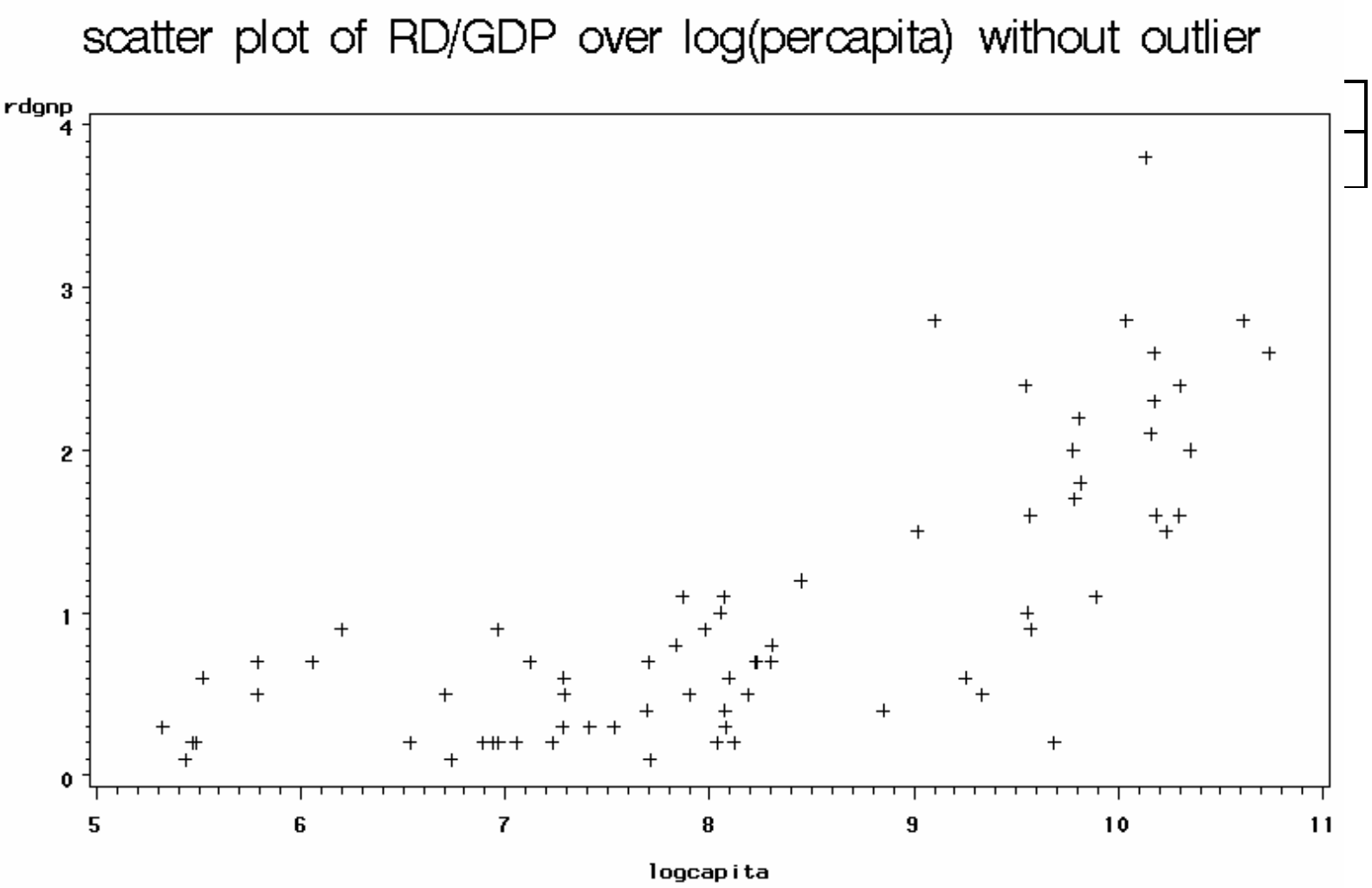
7. Conclusions and next steps

This paper examines the implications of China's large and growing foreign sector for its ability to innovate. Specifically it critically examines the proposition that China's domestic firms and research institutes neither sustain the innovation effort nor achieve the innovation outcomes expected of an emerging industrial economy and that the foreign sector is the principal performer of innovative activity. This paper argues that China's domestic industry and research institutes account for the large majority of R&D and patenting activity and that in terms of the volume and extent of innovative effort, the foreign sector plays a decidedly secondary role. However, the foreign sector plays a critical role as a motivator and facilitator of domestic innovation in China. Foreign direct investment plays a dual role of supporting foreign-funded R&D, although the R&D intensity of foreign-funded R&D in the industrial sector lags behind that of China's domestic firms. A critical role of FDI is that by expanding technological opportunity and competition, it motivates domestic firms to intensify their R&D operations. FDI is also a key driver of domestic patenting activity. Furthermore, the foreign sector plays a critical role in transferring important overseas technologies through China's technology markets. These imported technologies in turn raise the returns to domestic firm-level R&D. The paper concludes that China's foreign sector activities – FDI, foreign-funded R&D, and market-mediated imported technology – are all critical drivers of China's rapidly growing innovation capabilities.

Several issues have not been explored as thoroughly as they might be. These include the respective roles of overseas R&D and FDI originating from Hong Kong,

Taiwan, and Macao versus that from other origins, mostly OECD economies. We surmise that the OECD foreign funded activities in China may be substantially more R&D and technology intensive than that embodied in and motivated by the overseas presence. Tables A1 and A2 suggest that this is the case. Also, it would also be instructive to prepare several case studies examining the actual research scope and capabilities of leading MNC R&D facilities, both in the industrial sector and the research institute sector. The encounters of this author with MNC-sponsored R&D work in China have suggested that it is overwhelmingly oriented toward the localization of MNC products and manufacturing processes. For example, the R&D operation at Beijing Jeep, some years ago, was tasked with the job of redesigning parts of the Jeep's chassis, so that it could better contend with local road conditions. Such R&D agendas strongly suggest that these MNC China-based R&D operations steer clear of the core competencies of the parent companies. A more extensive basic research sector,, however is being developed, in part through joint ventures with Chinese research outfits. The work of these organizations requires more extensive on-site investigation.

Figure 1



All LMEs								
1995	79.81	7.21	3.24	3.38	1.44	1.67	3.24	19,117

2003	72.32	6.41	3.40	4.59	2.63	3.78	6.86	23,358
%increase (95-03)	-9.4	-11.1	4.9	35.8	82.6	126.4	111.7	-
Balanced LMEs								
1995	73.63	10.78	4.21	4.21	1.76	1.99	3.41	3,515
2003	54.18	10.70	5.94	7.58	4.28	6.43	10.90	3,485
%increase (95-03)	-26.4	-0.8	41.1	80.1	143.2	223.1	219.7	-

Figure 2

S&T Takeoff in 10 Countries (vertical axis: R&D/GDP)

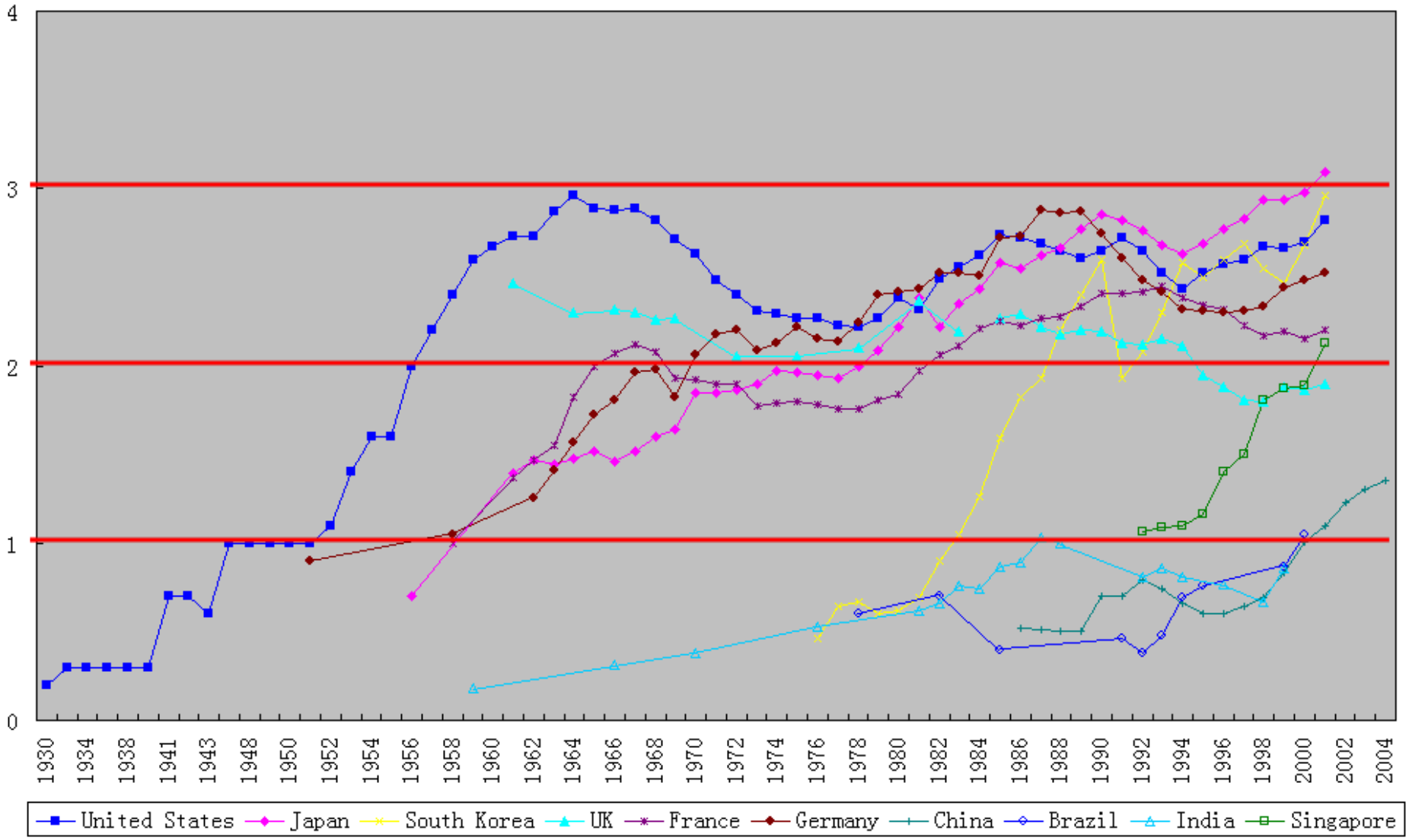
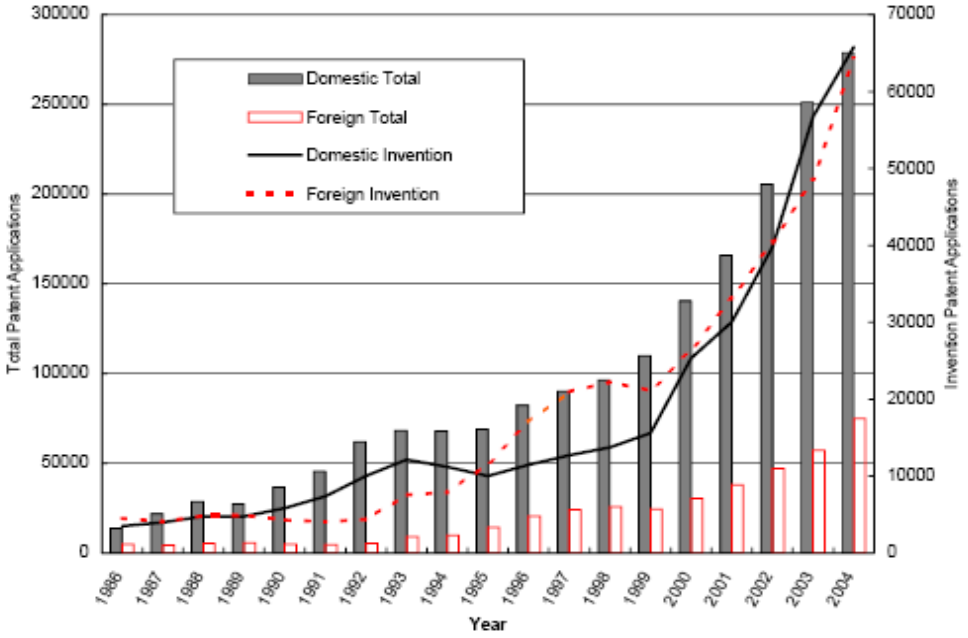
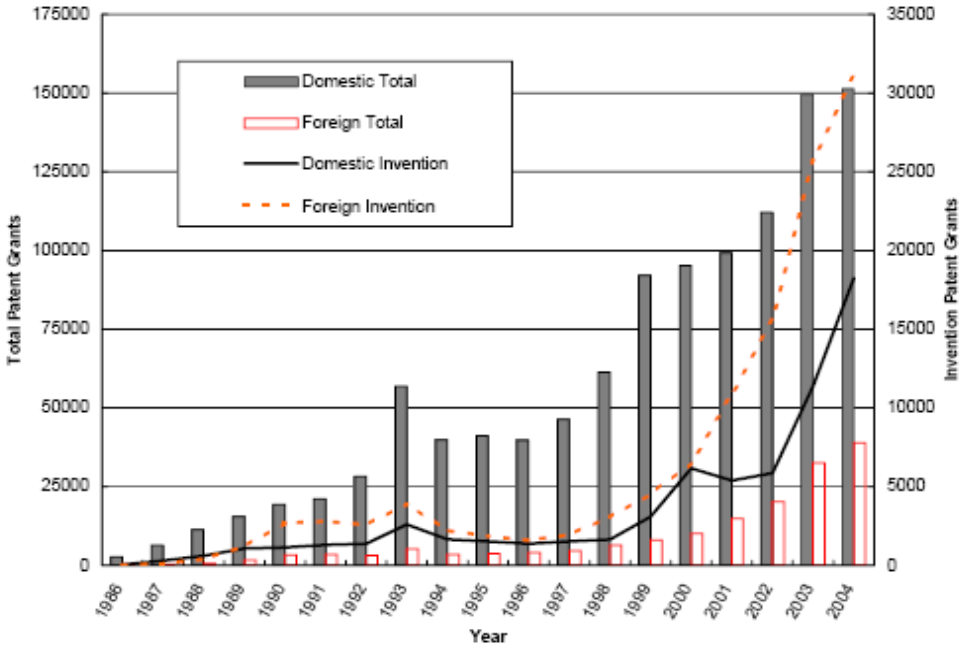


Figure 1: Chinese Patent Applications, 1986-2004



Source: web site of China's National Bureau of Statistics - www.stats.gov.cn.

Figure 2: Chinese Patent Grants, 1986-2004



Source: web site of China's National Bureau of Statistics - www.stats.gov.cn.

Table 2. Domestic vs. foreign contributions to R&D spending (Industrial LMEs)		
	Domestic	Foreign/ HKT
1995		
Firm count	16,823	1,323
R&D exp ('000s)	67,130	6,480
R&D/value added	1.11	0.99
2001		
Firm count	14,429	4,360
R&D exp ('000s)	281,770	53,380
R&D/value added	3.29	2.63
2001:1995		
R&D exp	4.19	8.23
R&D/value added	2.96	2.66

Table 3. Dependent variable – growth R&D/value added, 2000-2004	
constant	0.049 (3.84)*
gFDI_4	0.061 (1.80)*
R-squared (obs)	0.002 (1,525)
*The figures in parentheses are t-statistics	

Table 4. LMEs spending in technology markets (billion yuan)			
	2000	2003	Annual growth %
Internal S&T expenditure	82.4	146.8	21.2
Purchase of mported technology	24.5 (29.7%)	40.5 (27.6%)	18.2
Purchase of domestic technology	2.6 (3.2%)	5.4 (3.7%)	27.6

Figure in parentheses is proportion of total internal S&T expenditures
CSYST (2004), pp. 142, 149; CSYST (2001),

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Table A1. R&D effort by ownership: R&D expenditure/value added					
	1995	1999	2002	2003	2004
State-owned					
Population	1.97	3.68	10.67	3.23	5.39
Balanced sample	2.03	3.47	3.86	3.72	8.15
Collective_owned					
Population	1.30	1.74	1.84	1.56	1.64
Balanced sample	1.19	2.49	2.12	3.67	1.97
HMT					
Population	1.07	4.59	4.07	1.72	1.67
Balanced sample	0.64	2.09	2.85	4.61	4.54
Foreign					
Population	0.97	3.03	4.63	2.31	2.49
Balanced sample	0.62	2.23	3.34	5.71	3.11
Shareholding					
Population	1.80	5.89	3.76	3.36	4.27
Balanced sample	1.63	3.39	4.36	4.98	6.43
Private					
Population	0.21	1.41	2.13	1.63	1.95
Balanced sample		0.23	1.67	2.72	3.85
Other domestic					
Population	1.37	3.82	8.71	2.44	3.07
Balanced sample	0.33	13.25	5.69	8.02	7.19
Total					
Population	1.75	3.70	5.91	2.55	3.25
Balanced sample	1.72	3.24	3.73	4.24	6.58

Table A2. R&D outcomes: patent applications					
	1995	1999	2002	2003	2004
State-owned					
Population	2,837	3,099	4,253	5,291	4,672
Balanced sample	1,242	1,307	2,048	2,966	2,364
Collective_owned					
Population	506	1,776	1,880	2,114	1,288
Balanced sample	99	444	200	238	102
HMT					
Population	120	469	2,739	3,863	4,929
Balanced sample	54	130	688	564	480
Foreign					
Population	94	465	2,634	5,387	9,091
Balanced sample	43	208	370	762	714
Shareholding					
Population	307	1,650	7,791	10,877	16,044
Balanced sample	99	374	2,885	3,189	5,242
Private					
Population		117	1,374	3,680	6,264
Balanced sample		0	150	303	324
Other domestic					
Population	35	26	214	22	15
Balanced sample	0	12	3	5	0
Total					
Population	3,899	7,602	20,885	31,234	42,303
Balanced sample	1,537	2,475	6,344	8,027	9,226