Chapter

1

# Technological Development Challenges in Chinese Industry

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Since the late 1970s, especially in the 1990s, massive foreign direct investment (FDI), accompanied by the importation of foreign technology, have to a large extent recast China's industrial base and upgraded its industrial technology.[1] In 2001, China became the world's leader in terms of its mobile phone subscriber base with 461 million users by the end of 2006. Its 368 million fixed phone lines represented the largest number in the world.[2] Overtaking Japan in 2002, China is expected to surpass the United States as the world's largest PC market by 2010, if not earlier.[3] Barely known in China until the mid-1990s, the Internet now attracts almost 172 million Chinese

[1] Yasheng Huang argues that the inflow of FDI into China has in fact denied growth opportunities for China's most efficient firms, namely, non-government enterprises (*minying qiye*). See his *Selling China: Foreign Direct Investment during the Reform Era* (Cambridge: Cambridge University Press, 2003).

[2] See http://mii.gov.cn/art/2007/02/09/art_169_28756.html (October 19, 2007).

[3] See http://msn-cnet.com.com/2100-1006_3-5091384.html (March 4, 2004).

users.[4] Merchandise labelled "Made in China" has gone beyond toys, garments and sneakers to consumer electronics products and high-tech gadgets. China was the 10th largest high-tech exporting country in the world in 1998–1999.[5] In 2006, China's high-tech exports hit US$281 billion, representing a more than 100-fold increase over those in 1991.[6] Most recently, China has started to use technology standards — notably the third-generation wireless standard TD-SCDMA (Time Division-Synchronous Code Division Multiple Access) and wireless encryption standard WAPI (Wired Authentication and Privacy Infrastructure) — as a technology policy instrument.[7] In some 20 years, China has gradually evolved from a closed and planned economy dominated by agriculture and heavy industry, to an economy dynamised by information, knowledge, skills and competence.

Yet, whether the Chinese industrial and high-tech sector can actually sustain growth remains an empirical question. Domestic politics and the macroeconomic situation aside, the ability to maintain the momentum will ostensibly be determined by endogenous and indigenous technology. In fact, the technological reality behind the economic growth has not been fully revealed, and may consequently have been somewhat distorted and misunderstood. With its further integration into the world economic system in the post-WTO era, China has been facing fiercer international competition. How well might China survive in this global technological competition? Is China capable of developing an indigenous technological capability to support its global economic competition in the short and medium

[4] See http://tech.sina.com.cn/i/2007-10-13/08281790659.shtml (October 19, 2007).

[5] United Nations Development Programme, *Human Development Reports 2001: Making New Technologies Work for Human Development* (New York: Oxford University Press, 2001), 42.

[6] See http://www.sts.org.cn/tjbg/gjscy/documents/2007/070618.htm (October 19, 2007).

[7] For a discussion of this see Richard P. Suttmeier and Yao Xianggui, "China's Post-WTO Technology Policy: Standards, Software, and the Changing Nature of Techno-Nationalism," *NBR Special Report*, No. 7 (Seattle, WA: National Bureau of Asian Research, May 2004).

term? This chapter addresses these issues by examining the technological challenges that China's industrial development has been encountering. The author tries to pinpoint the reasons why the challenges will become more serious, and how the Chinese Government is responding to them.

## GOVERNMENT'S TECHNOLOGY POLICY

China's technology policy in recent years has aimed to stimulate growth in indigenous industrial technological capability. The 1997 National Conference on Technological Innovation promoted the role of enterprises in the nation's R&D activities. Immediately following the Conference, the then State Economic and Trade Commission selected Baoshan Iron and Steel, Changhong, Jiangnan Shipbuilding, Northern China Pharmaceutical (all SOEs), Haier (a collective), and Founder (a university spin-off) to experiment on technological innovation.[8] At the 1999 National Conference on Technological Innovation, the Government further demanded that high-tech enterprises spend at least five percent of their annual sales on R&D.[9] The most recent policy measures include allowing R&D expenditure to be counted as cost, implementing a technology-standard and patent-focused strategy in enterprise innovation endeavours, and supporting software products "Made in China" in government procurements.[10]

In the information and communications technology (ICT) area, emphasis has been placed on developing China's semiconductor industry. Firms have been encouraged to develop central processing units (CPUs) used in certain consumer electronics products and

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[8] Yang Shenghua, *Zhongguo: Chuangxin shengchun (China: Survival Through Innovation)* (Guangzhou: Huacheng Press, 2000), 50.

[9] Ministry of Science and Technology (comp.), *Zhongguo jishu chuangxin zhengce (Policies on Technological Innovation in China)* (Beijing: Kexue jishu wenxian chubanshe, 2000), 1–9.

[10] *Kexue shibao (Science Times)*, March 13, 2002; *Zhongguo jingji shibao (China Economic Times)* May 27, 2002; http://tech.sina.com.cn/it (May 28, 2002); *Keji ribao (Science and Technology Daily)*, July 4, 2002.

mobile phone handsets. Attention has also been paid to design application-specific integrated circuits (ASICs) used in ICT, an area with advanced technological sophistication, wider usability as well as higher added value. China's computer industry has campaigned for the introduction and use of the open-source Linux operating system and related application software packages. Due to the government mandate, the Linux-based operating system and office applications developed by Chinese software companies have eroded Microsoft's dominance in software procurement, which signals not only the sensitivity given the size of the procurement and strategic importance, but also the viability for these companies.[11] Under these circumstances, the normally aggressive Microsoft had to be defensive by agreeing to invest RMB6.2 billion to help develop China's software industry and win over China's e-government initiative.[12]

One of the high-profile technology policy measures is the so-called "technology-standard" strategy by which China intends to formulate its own standards to leverage its large market in international competition.[13] China's participation in the worldwide third-generation (3G) wireless communications standard setting is one such example.

China's telecom equipment manufacturing sector was among the first to open to global competition. It is also a sector in which domestic players have attained critical mass. When China started its massive telecom equipment manufacturing in the early 1980s, technology transfer through direct imports and Sino-foreign joint ventures played an important role. Through absorbing and assimilating foreign technology and most importantly indigenous R&D efforts, some of the Chinese firms, represented by Great Dragon, Datang,

[11] There is suspicion that these Linux software users would eventually switch back to the Microsoft products given their familiarity with, or addiction to them, the greater number of Microsoft applications, and possible incompatibility between Linux-based packages and Microsoft products which are much more widely used. See *Beijing qingnian bao (Beijing Youth Daily)*, March 12, 2002, 36.

[12] *Ershiyi shiji jingji daobao (21st Century Economic News)*, July 12, 2002; *Zhongguo jingji shibao (China Economic Times)*, August 4, 2002.

[13] Suttmeier and Yao, "China's Post-WTO Technology Policy".

Zhongxing and Huawei (JuDaZhongHua according to the first characters of the firms' Chinese names), gradually acquired advanced technology and accumulated technology capability to develop their own products. These firms employ a higher percentage of scientists and engineers with master's and doctorate degrees, and invest 10 percent or more of their sales revenue on R&D.[14] They may still lack some critical technology such as ASICs, and could acquire them through participating in the international division of labour — outsourcing those to foreign firms.[15] They are not in the same league as the world's big players either in size, technology, quality or performance of the equipment because most of the manufacturers are technology followers rather than innovators, and by the time they reverse-engineer the imported products and develop the manufacturing capability to imitate them, their international competitors would have introduced a successive generation. Nevertheless, because of their presence, foreign firms have to give up the low-end product market or reduce price for similar products sold in China. Domestic suppliers accounted for 43 percent of the stored programme-controlled central office switches in 2000 from none in 1982 (from another angle, the statistics show why China's international competitiveness in communication exports increased).[16]

Therefore, as China, along with other countries is moving towards 3G mobile communications, it offers a domestically-proposed and International Telecommunications Union approved

[14] Xiongjian Liang and Kaisheng Ding, "Manufacturing Industry," in *Telecommunications in China: Development and Prospects,* ed. Jintong Lin, Xiongjian Liang and Yan Wan (Huntington, NY: Nova Science Publishers, 2001), 75–98; Xiaobai Shen, *The Chinese Road to High Technology: A Study of Telecommunications Switching Technology in the Economic Transition* (New York: St Martin, 1999); Zixiang Alex Tan, "Product Cycle Theory and Telecommunications Industry: Foreign Direct Investment, Government Policy, and Indigenous Manufacturing in China," *Telecommunications Policy* 26, no. 1 (2002): 17–30.

[15] Zixiang Alex Tan, "Product Cycle, Wintelism, and Cross-National Production Network (CPN) for Developing Countries: China's Telecom Manufacturing Industry as a Case," *INFO: The Journal of Policy, Regulation and Strategy for Telecommunications* 4, no. 3 (2002): 57–65.

[16] Tan, "Product Cycle Theory and Telecommunications Industry."

standard — TD-SCDMA, jointly developed by China's Datang and Germany's Siemens — to compete with the cdma2000 standard by the US mobile network developer Qualcomm, the owner of key patents behind the code division multiple access (CDMA) standard, and the wideband CDMA (WCDMA) standard, also known as universal mobile telecommunications service (UMTS), from Europe. The Chinese Government has also allocated more radio spectrum to the home-grown TD-SCDMA standard than to its competitors — WCDMA and cdma2000, which gives greater likelihood that China will request that one of its telecom operators adopt this 3G mobile telecommunications standard and in turn boost the R&D activities among China's leading high-tech firms. Although the Chinese standard may not be as advanced as the other two standards, and it is premature to suggest that one of China's mobile operators would adopt the standard, the case itself — some may label it techno-nationalist — at least suggests that China's technical community has realised the importance of independent intellectual property rights and devoted its innovative capability to developing the most advanced technology. It remains to be seen whether the government initiative will lead to indigenous innovation at the firm level.

## RECENT MOVES IN CHINA'S INDUSTRIAL TECHNOLOGICAL DEVELOPMENT

Facing more challenges and fiercer competition in the post-WTO environment, Chinese firms are feeling fearful because without access to updated technology and managerial know-how, they may lose their battle with their foreign competitors. For example, FDI agreements may not mandate the technology transfer requirement; the phasing out of many tariffs means a gradually eroded price advantage for domestic products; the domination of technology, quality and cost, rather than price in competition; and restrictions on subsidising industrial R&D.

In the meantime, multinational corporations (MNCs) have expanded their R&D presence in China through opening independent R&D centres and collaborating with Chinese researchers. This is part of the global development strategy of the parent companies, i.e., being close to their Chinese operations and localising technology developed in the "home base," so that their contribution to China's R&D should not be exaggerated. But it is possible for MNCs to tap the high-quality researchers, even from domestic enterprises, so as to go beyond the use of cheap labour in their creation of systems of production in China.[17] Under these circumstances, it is a matter of ultimate responsibility and survival, not choice, for China's domestic enterprises to upgrade their technologies and products on their own. In this regard, the Chinese Government has also tried its best to stimulate innovation and provide policy guidance.

## INCREASED R&D ACTIVITIES IN ENTERPRISES

In 2000, China's R&D spending by Chinese enterprises exceeded 60 percent for the first time, implying that enterprises had become a more important player in research and innovation. A study of all high-tech firms in the Haidian District of Beijing where the Zhongguancun Science Park is located finds that current sales revenue of the firm provides an important driving force for private R&D expenditure.[18] Between 2000 and 2003, the top 100 domestic electronics and information enterprises spent on average about 3 percent of annual sales revenue on R&D, with telecom equipment manufacturers Huawei Technologies, Datang Telecommunications and Zhongxing Telecommunications leading the way, each devoting about 10 percent of the sales revenue to R&D.[19] Nationwide, of the more than 10 million medium- and small-sized firms, 150,000 allocate more than 5 percent of sales to technological development.[20]

[17] For a discussion about the creation of productive systems in China, see Rigas Arvanitis, Pierre Miège and Wei Zhao, "A Fresh Look at the Development of a Market Economy in China," *China Perspectives*, No. 48 (2003): 51–62.

[18] Albert Guangzhou Hu, "Ownership, Government R&D, Private R&D and Productivity in Chinese Industry," *Journal of Comparative Economics* 29, no. 1 (2001): 136–157.

[19] See http://www.mii.gov.cn (June 10, 2003).

[20] *Kexue shibao (Science Times)*, March 11, 2002.

Some of the most technology-intensive companies have taken the R&D issue seriously by establishing or reinforcing their R&D institutes.[21] For example, in Shenzhen, China's Open-door Policy "window", 477 (91.7 percent) of the 521 R&D institutes are associated with enterprises, and 90 percent of the R&D personnel work in enterprises.[22] Legend, Founder, Chunlan, among others, have central research academies oriented towards developing process and product technologies, and long-term technology strategies. Several Chinese corporations have also set up R&D centres abroad as they expand internationally.[23]

Huawei, a non-state-owned telecom equipment maker, is a particular case in point. Founded in 1988, its charter specified that it would devote 10 percent of its sales revenue to R&D, and increase the expenditure if necessary. Forty percent of the company's employees are engaged in R&D, and the company is also involved in exploratory and pre-competitive research.[24] In 2006, Huawei earned sales revenues of RMB65.9 billion, of which RMB5.9 billion (8.9 percent) were spent on R&D. The company now owns 3,335 patented technologies with a significant percentage being invention patents, and its intelligence network won the first-class prize of China's Scientific and Technological Progress Award in 2002, a rare but impressive achievement for an enterprise.[25]

## HIGH-TECH EXPORTS: COMPARATIVE OR COMPETITIVE ADVANTAGES?

A high-tech industry is, loosely speaking, one whose success depends largely on the ability to keep up with rapid innovations in

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[21] *Beijing qingnian bao (Beijing Youth Daily)*, March 22, 1999, 6.

[22] Yang Shenghua, *Zhongguo: Chuangxin shengchun,* 60.

[23] Research Group, *Zhongguo keji fazhan yanjiu baogao 2000: Kexue jishu de quanqiuhua yu zhongguo mianling de tiaozhan (A Research Report on China's S&T Development (2000): The Globalization of Science and Technology and Its Challenges for China)* (Beijing: Social Science Literature Press, 2000), 298.

[24] Yang, *Zhongguo: Chuangxin shengchun*, 253, 262.

[25] See http://www.huawei.com.cn (October 19, 2007).

products, production processes, or both.[26] Microelectronics, biotechnology, new materials, telecommunications, civilian aviation, robotics plus machine tools and computer hardware and software are considered to be crucial in the global competition.[27] Statistical classifications of high-tech industry typically rely on such indicators as the ratio of R&D expenditures to sales, share of scientists and engineers in the labour force, etc. The US Bureau of Census has adopted a separate classification code, "advanced technology", in reporting merchandise trade. Products within the classification are supposed to meet the following criteria: (a) the underlined technology is from a recognised high technology field (e.g., biotechnology, information technology); (b) products represent leading-edge technology in that field and (c) such products constitute a significant part of all items covered in the "advanced technology" classification.[28]

In China, a firm can register and be certified as "high-tech" only if it falls into the above-mentioned categories and meets the following requirements: at least 30 percent of its employees have college or above education, more than 5 percent of its sales are spent on R&D and more than 60 percent of its sales are related to technology

[26] For a survey and discussion on the analysis of high-tech trade statistics, see J. A. D. Holbrook, "High-Tech Trade Pattern Analysis: Its Use and Application for Industry Competitiveness Response and Government Policy Development," *CPROST Report # 95-11* (Ottawa: The Canadian Advanced Technology Association/Industry Canada Workshop on High-Tech Trade Statistics, 1995).

[27] Lester C. Thurow, *Head to Head: The Coming Economic Battle among Japan, Europe, and America* (New York: William Morrow, 1992).

[28] Robert H. McGuckin, Thomas A. Abbott, III, Paul E. Herrick and Leroy Norfolk, "Measuring the Trade Balance in Advanced Technology," *Center for Economic Studies Report, no. 89-11* (Washington: US Bureau of Census, 1989); US Bureau of Census, "US International Trade in Goods and Services: Information on Goods and Services," at http://www.census.gov/foreign-trade/Press-elease/current_press_release/explain.txt (November 15, 2001); John Sullivan Wilson, "The US 1982–1993 Performance in Advanced Technology Trade," *Challenge*, no. 1 (1994): 11–16.

services and high-tech products.[29] "High-tech," in China's trade statistical reporting system until 1998, referred to computers and telecommunications, life sciences, aerospace and aeronautics, electronics, weapons, opto-electronics, computer integrated manufacturing, nuclear technology, biotechnology and materials. Since 1998, China has reported high-tech trade statistics under a new scheme, which omits weapons and nuclear technology, but introduces a new "other" technology category, presumably a combination of the weapons and nuclear technology categories.

Each high-tech category can be further divided into different levels according to technological intensity and the resulting profit and added value. For example, in the PC category, the first level is CPUs and core software, which has been dominated by the Wintel model (microprocessors from Intel and operating systems and major applications packages from Microsoft). The second, which includes such critical elements as integrated circuits, memory chips and displayers, has both a higher level of risk as well as profit. The third and lowest level is the assembling and manufacturing of terminal products, which have lower levels of technological intensity but higher logistic costs and whose advantages are reflected through economies of scale and localised sales and services.[30] Apparently, China has been stuck mainly in the lowest level of the high-tech value chain.

One measure of the high-tech industry is trade statistics. However, comparable high-tech trade data are difficult to locate not only because the "high-tech" definition is dynamic but also because it varies across countries. Here, two sets of data are used, one from official Chinese sources and the other from the United States. Although there are discrepancies between these, which may come

[29] Ministry of Science and Technology, "Guojia gaoxin jishu chanye kaifaqu gaoxin jishu qiye rending diaojian he banfa" (Conditions and Methods of Certifying High- and New-Technology Enterprises in National High- and New-Tech Industrial Development Zones), in Ministry of Science and Technology (comp.), *Zhongguo jishu chuangxin zhengce (Policies on Technological Innovation in China)* (Beijing: Kexue jishu wenxian chubanshe, 2000), 78–79.

[30] Yuko Arayama and Panos Mourdoukoutas, *China against Herself: Innovation or Imitation in Global Business?* (Westport, CT: Quorum Books, 1999), 107.

from different statistical specifications, different currency exchange rates during different periods, etc., both illustrate the positions, trends and changes of China's high-tech trade. The data from the American source provides further comparable high technology trade statistics of, and specific categories for, economies in the world between 1980 and 1998[31] so that it is possible to calculate Trade Competitiveness (TC)[32] and Revealed Comparative Advantage (RCA).[33]

Having experienced a steady increase, high-tech exports seem to be an important growth engine in the Chinese economy (see Figure 1.1). As measured by TC, China's high-tech competitiveness in trade has improved from –0.53 in 1991 to –0.04 in 2003 according to the Chinese data. If the data from the American source is used, however, China's TC in high-tech declined slightly from –0.11 in 1980 to –0.14 in 1998 (see Figure 1.2). Among the nine high-tech

[31] The data are compiled by the US National Science Foundation from the WEFA/ICF World Industry Service database. See National Science Board, *Science and Engineering Indicators* (Arlington, VA: National Science Foundation, 2002), Appendix Table 6-1: World Industry and Trade Data for Selected Countries or Economies and Industries: 1980–1998.

[32] Trade competitiveness (TC) measures the share of a nation's difference in exports and imports in the nation's trade:

$$TC = (X - M)/(X + M),$$

where $X$ is nation's exports and $M$ is nation's imports. A positive $TC$ displays a competitiveness of a nation's good, with a greater than 0.5 reading meaning comparative advantage and a less than –0.5 reading indicating comparative disadvantage.

[33] Revealed comparative advantage (RCA) measures a nation's share in world exports of a good in the nation's share of total world exports:

$$RCA_j = (X_j / X_{wj})/(X_t / X_{wt}),$$

where $X_j$ is a nation's exports of good $j$, $X_{wj}$ is world's total exports of good $j$, $X_t$ is a nation's total exports and $X_{wt}$ is world's total exports. A greater than 2.5 RCA measure demonstrates that a nation has a very strong competitive edge in producing and trading a good, a reading between 1.25 and 2.5 means a strong competitiveness of a nation in a good and a lower than 0.8 RCA index signifies that the nation is less competitive in its particular product. See Bela Balassa, "Trade Liberalization and 'Revealed' Comparative Advantage," *The Manchester School of Economics and Social Studies* 33, no. 2 (1965): 99–123.

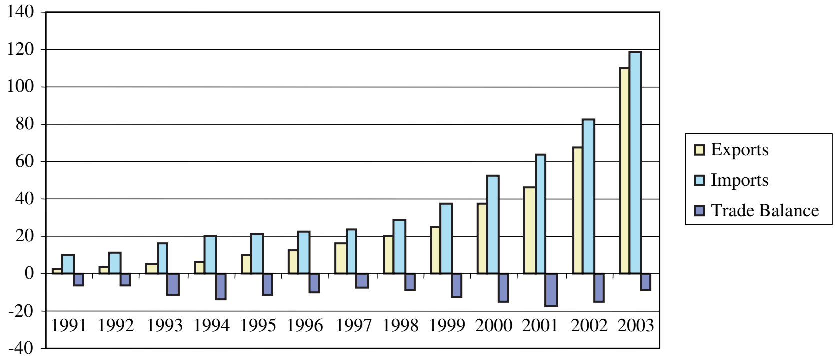


**Figure 1.1:** China's High-Tech Trade (US$ billion, 1991–2003)

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), *China Statistical Yearbook of Science and Technology* (Beijing: China Statistics Press, 2003).

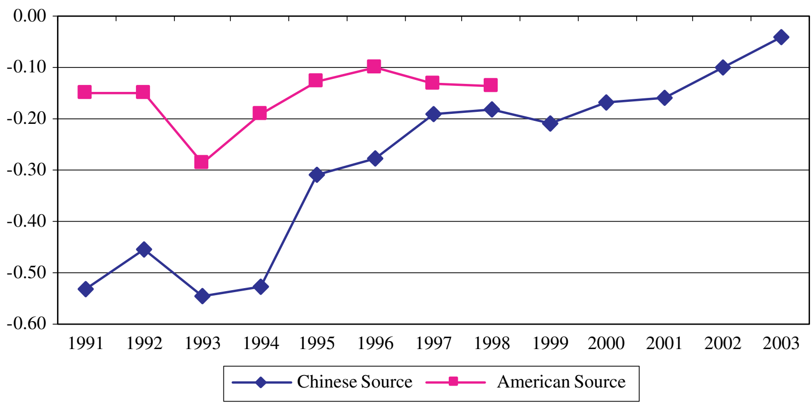


**Figure 1.2:** Trade Competitiveness (TC) of China's High-Tech Trade (1991–2003)

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), *China Statistical Yearbook of Science and Technology* (Beijing: China Statistics Press, 2003); National Science Board, *Science and Engineering Indicators* (Arlington, VA: National Science Foundation, 2002).

categories defined by the Chinese statistics, computers and telecommunications, aerospace and advanced materials have gained international competitiveness; opto-electronics and the 'other' technology category have lost competitive advantages, while electronics, computer-integrated manufacturing, life sciences and biotechnology have not seen much change in the trade pattern. As a whole, computer-integrated manufacturing, 'other' technology, aerospace and electronics are the least competitive.

China's high-tech trade deficits have been fluctuating but increasing, reflecting the high demand for, and dependence upon, advanced foreign technology. Although China has enjoyed a trade surplus in computer and telecommunications technology for several years, TC (0.39 for 2003) is less than the critical 0.5 threshold, suggesting that China is still left behind in this largest trading area which accounted for 83.3 percent of the high-tech exports in 2003. Trade deficits have been growing gradually in almost all other high-tech areas, especially in electronics and computer-integrated manufacturing, except in biotechnology whose trade surplus has been too small to form a critical mass. Similar results can be obtained by using American data as well, with "office and computing machinery" and "communications equipment" gaining ground but still being far from the 0.5 reading. "Drugs and medicines" suffered a dramatic loss while there was not much change in "aerospace".

Next, RCA is used to further measure how competitive China's particular high-tech fields are in the world (see Figure 1.3). The "office and computing machinery" category had been the only high-tech area in which China made strong international gains, as indicated by the remarkable increase of RCA from 0.076 (a very low competitiveness reading) in 1980, to the level of 1.30 in 1998 (strong TC). RCA for "communications equipment" increased between 1980 and 1990 and declined thereafter, and the competitiveness of the "aerospace" industry had improved but not that well. However, the RCA for "drugs and medicines" eroded significantly over the period in which comparable data are available, from a very competitive industry to not competitive.

Over the 1990s, China made progress in international high-tech exports and commanded competitiveness in some high-tech areas. But what are behind these impressive trade statistics? First, obviously, while the export-oriented strategy has shown results, processing and assembling using materials from abroad for export purposes

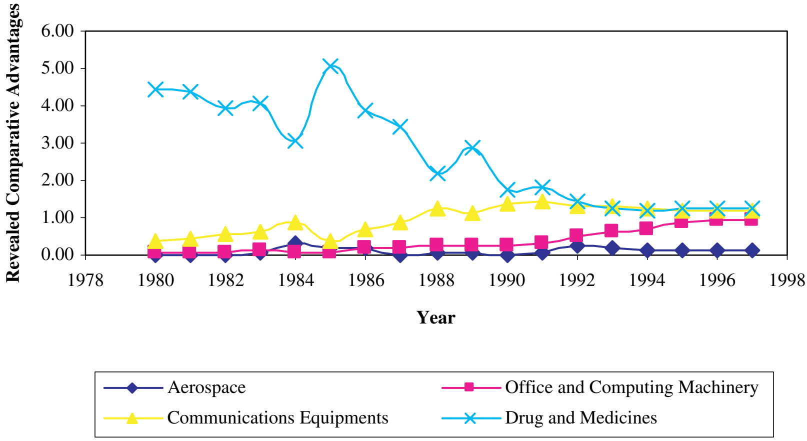


**Figure 1.3:** Revealed Comparative Advantages (RCA) of China's High-Tech Trade (1980–1998)

Source: National Science Board, *Science and Engineering Indicators* (Arlington, VA: National Science Foundation, 2002).

accounted for about 90 percent of China's high-tech exports in 2006.[34] It is doubtful that China has acquired much advanced technology through assembling activity, although in terms of technology content, FDI in China in the early 21st century was much different from that in 1985 or even the early 1990s.[35]

Second, the export-led high-tech industry has been based on low labour costs and imported foreign technologies or even components. China has become a big assembly line for products made of critical high-tech parts from abroad plus some low-tech domestic components. Most of the Chinese exports are lower-end products involving basic processing and manufacturing techniques, while imports in general are much more sophisticated.[36] There has

[34] See http://www.sts.org.cn/tjbg/gjscy/documents/2007/070618.htm (October 19, 2007).

[35] For a similar finding through the use of a different set of international trade statistics, see Francoise Lemoine and Deniz Unal-Kesenci, "Assembly Trade and Technology Transfer: The Case of China," *World Development* 32, no. 5 (2004): 829–850.

[36] Denis Fred Simon, "The Microelectronics Industry Crosses a Critical Threshold," *China Business Review* 28, no. 6 (2001): 8–20.

been a tendency for the world's leading MNCs, especially those in the ICT area, to move their manufacturing facilities (to outsource production) to China, which, unfortunately, is not due to the nation's competitiveness in technology, but largely because of its comparative advantage in labour.[37] China has moved, and will steadily upmarket anything, either high- or low-tech, that requires many pieces to be assembled in an efficient manner at low cost. Investors can find attractive production bases in China, and this is globalisation at work in the purest sense.[38] Being labour- rather than technology-intensive, those so-called "high-tech" gadgets have a profit margin sometimes as low as 2–3 percent. For example, Wanda, a wireless mouse manufactured by Logitech International SA, a Swiss-American company, sells in the United States for around US$40. Of this, China takes a meagre US$3 for wages, power, transport and other overhead costs.[39] In a word, located at the lower end of the international division of labour, the nation has yet to achieve much in added value and raise its competitive advantage significantly. This may also explain the discrepancy of trade statistics between the Chinese and American sources: products considered as "high-tech" in China may not be considered so elsewhere.

Third, in areas where China is enjoying a certain level of competitiveness, much of it has come from foreign-invested enterprises (*Sanzi qiye*). In 2000, for example, 92.5 percent of computer systems and 96.4 percent of mobile communications equipment were exported by

[37] There are conflicting views about China's comparative advantage in labour. Some believe that such a situation is expected to exist for at least 10 years, given China's large pool of cheap labour in the central regions. See *Asian Wall Street Journal*, March 15–17, 2001, 1, 8. Others think that China may lose such a comparative advantage because in some Chinese cities, labour costs are as high as those in some Southeast Asian countries. See *Asian Wall Street Journal*, December 30, 2002, A1, A2.

[38] Joe Studwell, *The China Dream: The Elusive Quest for the Great Untapped Market on Earth* (London: Profile Books, 2002), 225.

[39] Andrew Higgins, "Symbiotic Ties to China Are a Boon and a Burden for American Economy," *Asian Wall Street Journal*, February 2, 2004, A1, A5B.

foreign-invested enterprises.[40] In 2006, foreign-invested enterprises contributed 88.1 percent of China's high-tech exports, while state-owned enterprises (SOEs) have seen its portion continuously declining.[41] FDI to China is supposed to diffuse advanced technology to Chinese enterprises and make them technologically competitive. Unfortunately, the high-tech export statistics show a different picture.

The above analysis seems to indicate another reality about China's high-tech sector and industry: they have developed rapidly, but they are structurally risky, e.g., processing- and assembling-focused, low-end product-oriented and low value-added, and foreign-invested enterprises-led. Because of this, China may make and export "high-tech" products in large quantities, but may not enjoy higher added value as high-tech products are supposed to do, as a larger share of its companies' hard-earned profits go to owners of core-high technologies. The situation has not been improved, and therefore the growth is probably unsustainable. To become a high-tech power, China has to move beyond comparative advantage in labour to gain competitive edge in a "cluster" of technologies so as to climb the technology value chain.

## CHALLENGES

Although technological development seems a priority, Chinese firms have many difficulties in attaining sophistication in technology, mainly because they lack the technological capability. This has lead to price wars, patent infringements and generally speaking, difficulties in upgrading its technologies.

### Continuous Price Wars: The TV Sector

China's TV sector has recently received enormous attention. In November 2003, TCL, a consumer electronics producer in China,

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[40] Jiang Xiaojuan, "Zhongguo de waizi jingji dui zhengzhang, jiegou shengji he jingzhengli de gongxian" (Contributions of Foreign Invested Enterprises in China to Local Economic Growth, Structural Upgrading and Competitiveness), *Zhongguo shehui kexue (Social Sciences in China)*, no. 6 (2002): 4–14.

[41] See http://www.sts.org.cn/tjbg/gjscy/documents/2007/070618.htm (October 19, 2007).

merged its TV manufacturing facilities with those of its French counterpart, Thomson. The combined company, in which TCL holds a 67 percent share, is expected to export 18 million TVs in 2004, thus becoming the world's number one, with 10 percent of the market. But in the meantime, TCL, along with fellow Chinese TV makers Changhong, Konka and Xoceco, lost in the US Department of Commerce anti-dumping case.

Using price as a weapon, i.e., anti-dumping being a countermeasure, in the TV sector is nothing new in China. Since 1996, the Chinese market has witnessed a series of TV price wars. In the name of defending the indigenous industry, price wars do help domestic firms gain market shares over their foreign competitors. But the rising market shares of some of the Chinese firms are often at the expense of their domestic peers or even themselves.[42] As price wars ate up their profit margins, many TV makers could not even maintain a price that is higher than the cost. In fact, in 2001, TV manufacturers saw the average profit level fall from 2.26 percent in 1999 to 2.05 percent and suffered losses of nearly RMB3 billion.[43]

The intense price wars must have something to do with supply and demand. When demand for TV sets exceeded supply in China, local governments piled into this sector which had an artificially low market entry barrier, but actually a high technology entry barrier, and then used a high degree of protection to ensure captive markets for local products and prevent unprofitable firms under their jurisdictions from being acquired. Then, overcapacity occurred as a result of duplicate economic activity at many Chinese firms that had been set up just for the sake of creating employment for the excessive labour.[44] However, it is argued here that such interpretations miss a vital point, or at least an important factor: China's TV makers do not possess core technologies in very large-scale integrated circuits, tubes, displays and others.

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[42] At one point, Changhong TV sets were sold according to their weight: a 29-inch (52.5 kg) sold at RMB1,575 or RMB30 per kilogram. See *Zhongguao jingji shibao (China Economic Times)*, June 12, 2002.

[43] *Hong Kong iMail*, April 26, 2002, 2.

[44] *Financial Times*, October 19, 2001, 13.

## Infringement of Foreign Patents: The Case of DVD Players

In early 2002, China-made DVD players were impounded by customs in several European countries with the charge that their makers had not paid for the patents used. Later, Philips, Sony and Pioneer (or so-called 3C) waged a legal battle in the European Union court, pressuring Chinese DVD player makers to pay royalties for the technologies. Initially, payment was requested at US$20 per DVD machine, which the Chinese side claimed to be too high given that the sales price of a player was only US$90.[45] Through negotiation, these firms settled the case by agreeing to pay US$5 per machine to 3C. Later, they also reached agreements with other foreign companies on royalty payments: 4 percent of the sales price, or US$4, whichever is higher, for each player to the 6C alliance of NEC, Panasonic, Toshiba, JVC, Mitsubishi and Time Warner, US$10 to DTS, US$4.95 to Dolby Laboratories and US$2.5 to MPEG LA. Most recently, Thomson, the partner of TCL, requested a payment of US$1 or US$1.50, depending upon where the player is sold, i.e., in China or abroad. With the number of DVD players made in China in 2003 being at least 50 million, the total payment was huge.[46]

Such incidents have been typical of Chinese industry in the past decade. From the product life cycle perspective, MNCs have gradually moved the production of consumer electronics products from the United States and Japan to Singapore, South Korea, Taiwan and Hong Kong, and then to China and other countries with low labour costs. However, they use critical technology patents as leverages and also focus on developing next-generation products or technology embodied in the existing products. China is supposed to absorb and assimilate such technology and gradually develop indigenous products and climb the ladder of technological learning. Unfortunately, this has not happened. Thus, located at the downstream of the global value chain, China has no

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[45] *Beijing qingnianbao (Beijing Youth Daily)*, March 11, 2002.
[46] See http://tech.sina.com.cn/it/2004-03-11/0712303633.shtml (March 11, 2004).

choice but to continue paying for the use of foreign technology. In the meantime, the homogenisation and commoditisation of these products have inevitably dragged Chinese firms into price competition. As such, their earning power has been diminished significantly. The profits that TV producer Changhong made from sales of 6.94 million sets was about equal to what Sony earned selling half a million sets.[47]

Moreover, the phenomenon is not limited to the consumer electronics industry. Take Legend, China's largest PC maker, as an example.[48] In 1998, it took over IBM to become the leader in China's PC market (it acquired the PC business from IBM in 2004). But as Liu Chuanzhi, Legend's chairman, acknowledged, the company has merely played the role of a "mover" (*banyungong*) for foreign technology.[49] Similarly, having spent several billion dollars importing first-generation analog technology and second-generation global mobile communications (GSM) technology, China's mobile communications industry is still under the shadow of foreign technology. Although home-made mobile handsets held a market share of more than 50 percent in 2003, a dramatic increase from 5 percent in 2000, Motorola and Nokia have sold more phones to Chinese customers while many of those shipped by Bird, China's top handset maker, are still sitting in warehouses or on store shelves.[50] Moreover, as few firms have devoted themselves to technological development, each and every mobile phone made in China has critical components imported from abroad.[51]

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[47] *Financial Times*, October 19, 2001, 13.

[48] Although its Chinese name is still *liangxiang*, "Legend" recently changed its English name into "Lenova." "Legend" is used here as it will take time for "Lenova" to be known worldwide.

[49] Fang Zhou, Guo Tianxiang and Tian Yishan, *Jinggao weiji: Zhongguo jiaru shijie maoyi zhuzhi qianxi* (*Crisis Warning: Self Examination of Chinese CEO on the Eve of China's WTO Accession*) (Kunming: Yunnan renmin chubanshe, 2001), 45.

[50] See http://www.emtchina.com/eNews/emt_200302a.htm (March 5, 2004); Evan Ramstad, "Amid Tech Boom, Chinese Stalwarts Scrape for Gains," *Asian Wall Street Journal*, February 27–29, 2004, A1, A8.

[51] *Ershiyi shiji jingji daobao (21st Century Economic News)*, December 30, 2002; January 10, 2003.

China's handset market has also been experiencing disastrous price wars and profit erosion.[52] And although the exact amount of money that China Unicom paid for Qualcomm's CDMA technology is unknown, it includes an entry fee, a software license fee and a fee linked to the number of subscribers or revenues. Recently, Cisco Systems, the world's leading networking and communications manufacturer, accused China's switcher/router developer Huawei Technologies of patent infringement.[53] Future areas of contention involving intellectual property rights in China include automobiles and digital TV.

## BROADER AND DEEPER PROBLEMS

Since the early 1980s, in an effort to explore the Chinese way of technology diffusion, new technology enterprises have spun off from China's research institutes, while universities have competed with MNCs. Many have been successful because of their strong connection with the institutions from which they were spun off, for example the Chinese Academy of Sciences' (CAS) "Legend," Beijing University's "Founder," etc. Although they were financially humble at the beginning, they were very successful in getting access to staffing and facilities. Significantly, the roots of these research achievements were formed as a result of state investment during the planned economy period.[54]

It seems that the strategy has been working well thus far. But further development of these young technology enterprises, and the high-tech sector as a whole, which has been viewed as key to China's future, will depend more on an indigenous technological capability. Sadly, such a capability is quite weak for the following reasons.

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[52] See for example, *Shichang bao (Market News)*, September 27, 2003; *Zhongguo gongshang shibao (China Business Times)*, February 11, 2004.

[53] Bruce Einhorn, "China: Too Fast a Learner?," *Business Week*, February 3, 2003.

[54] Qiwen Lu, *China's Leap into the Information Age: Innovation and Organization in the Computer Industry* (New York: Oxford University Press, 2000).

First, many of China's industrial firms have few financial resources to carry out innovative R&D activities. Large- and medium-sized enterprises have spent on average 0.5–0.8 percent of their sales on R&D (see Table 1.1).[55] According to a more comprehensive survey of the nation's R&D resources in 2000, firms within high-tech parks spent an average 1.9 percent of their sales on R&D, far below the 5 percent standard by the Chinese definition of a high-tech firm, noted above, while those outside the parks a mere 0.63 percent.[56] As enterprises have been cautious in R&D spending, a fair guess would be that the industry cannot afford to spend money on technology.[57]

Second is the serious lack of qualified personnel because of a severe "brain drain" of Chinese talent to foreign countries and foreign-invested enterprises in China. In 2002, personnel involved in technological development in large- and medium-sized SOEs accounted for 5 percent of the total employees, and only about a quarter had technological development units, representing a steady decline since the 1990s.[58] As a result, even after acquiring designs from MNCs, SOEs still lack the depth of engineering expertise necessary to fully exploit the technology and become competitive globally.[59]

[55] National Bureau of Statistics and Ministry of Science and Technology (comp.), *China Statistical Yearbook on Science and Technology* (Beijing: China Statistics Press, 2003), 94–95.

[56] See http://www.china.org.cn/chinese (June 8, 2002).

[57] One may argue that given its complex, uncertain, prolonged and even risky nature, R&D does not guarantee an immediate return to the investment or an increase in the firms' competitiveness. See Sanjaya Lall, "Technological Change and Industrialization in the Asian Newly Industrializing Economies: Achievements and Challenges," in *Technology, Learning, and Innovation*, ed. Linsu Kim and Richard R. Nelson (New York: Cambridge University, 2000), 13–68. For a recent news report on the Japanese case, see "Japan Asks Why More Yen Don't Yield More Products," *Science*, 296 (May 17, 2002): 1230–1231. One may also argue that Dell has not relied on technology to achieve its status as the world's largest PC maker. The fact of matter is that in the US there are Intel, Microsoft, Hewlett-Packard and many other technology-intensive firms, while Chinese high-tech firms such as Legend, Founder, Huawei, etc., are mandated to become technologically innovative.

[58] *China Statistical Yearbook of Science and Technology*, 2003, 94–95.

[59] Kathryn Kranhold, "China Makes Power Play to Score Technology from Foreign Partners," *Asian Wall Street Journal*, February 26, 2004, A1, A7.

**Table 1.1:** Enterprise Technology-Related Expenditure (RBM100 million, percent, 1991–2002)

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R&D Expenditure | 58.6 | 76.1 | 95.2 | 122.0 | 141.7 | 160.5 | 191.3 | 197.1 | 249.9 | 353.6 | 442.3 | 560.2 |
| Technology Importation | 90.2 | 116.1 | 159.2 | 266.7 | 360.9 | 322.1 | 236.5 | 214.8 | 207.5 | 245.4 | 285.9 | 372.5 |
| Absorption and Assimilation | n.a. | n.a. | 0.6 | n.a. | n.a. | 1.4 | 1.4 | 1.5 | 1.8 | 18.2 | 19.6 | 25.7 |
| Purchase of Domestic Technology | 3.7 | n.a. | 4.7 | 13.2 | 25.5 | 25.8 | 16.6 | 18.2 | 13.8 | 26.4 | 36.3 | 42.9 |
| Enterprise/National R&D Expenditure (percent) | 38.86 | 36.3 | 37.2 | 39.4 | 40.6 | 39.7 | 37.6 | 35.8 | 36.8 | 60.0 | 60.4 | 61.2 |
| R&D Expenditure/Sales Revenue (percent) | 0.49 | 0.50 | 0.50 | 0.51 | 0.46 | 0.48 | 0.52 | 0.53 | 0.60 | 0.71 | 0.76 | 0.83 |

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), *China Statistical Yearbook of Science and Technology* (Beijing: China Statistics Press, various years).

Third, there is always the question of how the limited amount of resources is utilised. In pursuing a quick and short-term pay-off, almost all Chinese enterprises are keen to import foreign technology as a way to upgrade production technology. In the past, the focus has been on obtaining hardware instead of software, i.e., patents, know-how, blueprints, etc. Between 1991 and 2002, 95 percent of the spending on technology imports was devoted to hardware with very little devoted to obtaining technology licenses. At large- and medium-sized enterprises, more money was spent on technology importation than on R&D until 1999 (see Table 1.1). And once the equipment was imported, almost no financial resources were devoted to absorption, assimilation and innovation, thus resulting in a vicious cycle of "importing, lagging behind, importing again, and lagging behind again."[60]

Fourth, enterprises also lack interest in engaging domestic learning institutions with respect to R&D efforts. The reforms in the science and technology system since the mid-1980s have to some extent activated the enthusiasm of researchers in these institutions (the supply side of technology), but enterprises (the demand side) have been reluctant to acquire technology from domestic sources. That is to say, the deeply-rooted problems of separation between innovation and the economy, and of organisational rigidity between enterprises and institutions of learning, have not been solved.[61] Such a problem may be due to the culture conflict between industry and academia. For example, in late 1998 when the CAS set out to make its "Knowledge Innovation Programme" the nation's centre in basic research and

[60] An analysis of the Chinese statistics indicates that imported technologies are more likely to lead to market success in new product sales through their absorption. See Yifei Sun, "Sources of Innovation in China's Manufacturing Sector: Imported or In-house Developed?," *Environment and Planning A* 34, no. 6 (2002): 1059–1072.

[61] For the structural difficulties that China needs to overcome in order to respond to the innovation challenge, especially the *danwei* effect, referring to the fact that the work unit is still very much the unit of reference of the governments (local and national) as well as the companies themselves, see Rigas Arvanitis, Pierre Miège and Wei Zhao, "A Fresh Look at the Development of a Market Economy in China," *China Perspectives*, no. 48 (2003): 51–62.

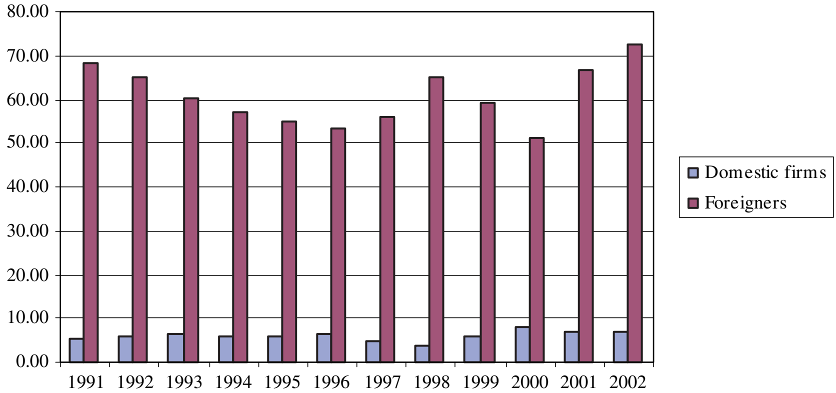


**Figure 1.4:** Invention Patents Granted in China (percent, 1991–2002)

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), *China Statistical Yearbook of Science and Technology* (Beijing: China Statistical Press, 2003), 434.

high-tech development, one of the measures was a reverse takeover by Legend of CAS' Institute of Computing Technology which had spun off the Institute 14 years earlier. But the marriage ended in divorce because both sides had difficulty accommodating each other in research focus and technological development strategy.[62]

Fifth, inevitably and consequently, fewer Chinese enterprises own independent intellectual property rights in core technologies, as the data on patent (an important benchmark for the level of industrial technology) suggest (see Figures 1.4 and 1.5).[63] Chinese firms seem to be more interested in utility model and design patents that link to unsubstantial modification, but lag far behind their foreign counterparts in invention patents. Since the 1990s, out of the more than 273,000 invention patent applications, only 47,452 (17.4 percent) were from Chinese firms, which were granted 5,876

[62] *Jishuanji shijie (China Computer World)*, no. 1 (January 3, 2000): A17–A24.

[63] Although the economy has been struggling worldwide, one would never know it by looking at the booming patent activity, especially in information technology and telecommunications, in the US. See Erika Jonietz, "Economic Bust, Patent Boom," *Technology Review* (May 2002): 71–77.

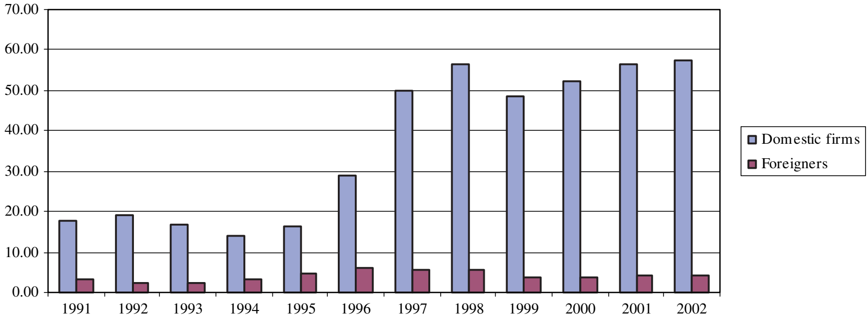


**Figure 1.5:** Utility Model and Design Patents Granted in China (percent, 1991–2002)

Source: National Bureau of Statistics and Ministry of Science and Technology (ed.), *China Statistical Yearbook of Science and Technology* (Beijing: China Statistical Press, 2003), 434.

(6.4 percent) of the total. While Chinese enterprises have been busy importing technology, foreign entities, most likely MNCs, have grabbed 63.2 percent of the total invention patents from China. This may further restrain China's industrial technology. For example, China's pharmaceutical industry is built on modelling generic or off-patent drugs from abroad.[64] Of the more than 1,000 core patents on colour TVs, none belongs to China; 92 percent of the 426 3G mobile communications invention patent applications filed in China were from abroad, while China's Huawei Technologies ranked eighth with 23 applications, about a quarter of Samsung's.[65] In the petro-chemicals industry, patent applications from MNCs accounted for 90 percent of the total; and in the aerospace industry, invention patents filed by foreign firms are 30 times more than those by domestic ones.[66] Of the invention patents received by China's Patent

[64] Recently, China issued a new regulation on new medicine approval, according to which, a new medicine is defined as one appearing in China for the first time. See *Beijing xiandai shangbao (Beijing Business Daily)*, December 26, 2002, 5.

[65] *Renmin ribao and Huanan xinwen (People's Daily — Southern China News)*, June 21, 2002, 1.

[66] *Jingji guanchabao (The Economic Observer)*, April 22, 2002, 1.

Administration between 1987 and 2002 in the areas of optical technology, photography and information storage, 75, 81 and 89 percent, respectively, were from foreigners.[67] The serious question is what the bottom line for the Chinese economy will be if MNCs continue to define the technological agenda and set the tone for the path of economic development.

As a result, a yawning gap remains between the finest corporations in China and the world. The nation has yet to come up with a China-created product as Japan did in the early 1970s, or as South Korea did in the 1990s,[68] and not one of China's largest SOEs, or "national teams" as they are always referred to, have become a globally competitive giant with a global market, global brand or global procurement system.[69] This seems to be a bitter but fair technological assessment of the current situation in the Chinese industry.

## CONCLUSION AND DISCUSSION

China's high-tech sector and industry have gained vitality in the past two decades, but much of the development has been built on a massive infusion of foreign capital and FDI-embodied technology. It is quite understandable for a developing country like China to follow the technology importation path in its economic and technological development. However, to what extent should China be dependent on foreign sources for technology and for how long should China adopt such a development strategy?

Historically, Japan, Taiwan and South Korea all experienced the lag between technology importation and indigenous innovation. For example, when South Korea started its heavy-and-chemical-industry-led industrialisation in the 1960s, it chose the importation of foreign

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[67] See http://www.blogchina.com/new/display/24128.html (February 26, 2004).

[68] See http://peopledaily.com.cn/GB/jinji (March 23, 2002); Arayama and Mourdoukoutas, *China Against Herself*, 8.

[69] Peter Nolan, "China and the Global Business Revolution," *Cambridge Journal of Economics* 26, no. 1 (2002): 119–137; Evaluation Association for China's Enterprises (comp.), *Shiji zhijiao de Zhongguo daxing gongye qiye (China's Large Industrial Enterprises at the Turn of the Century)* (Beijing: Jingji ribao chubanshe, 2000).

technology. Later on, through establishing enterprises as the important player in the national innovation system and providing policy guidance, the country has seen endogenous innovation-driven development.[70] Korean firms have gradually moved from original equipment manufacturing (OEM) to own-design manufacturing (ODM) and own-brand manufacturing (OBM) so as to garner much added value.[71] One would expect China to develop along the same trajectory.

In the meantime, the experiences of Asia's newly industrialised economies also suggest that it is not technology importation, but rather the lack of local absorptive capacity to assimilate, adapt and improve imported technology, that leads to dependency on foreign technology. Heavy reliance on FDI as a means of technology transfer may to some extent reinforce such dependency.[72] China's economic development seems to be at a critical juncture in that it is facing the danger of dependency.

Notwithstanding the many advantages that would push China to overcome its current technological slump and nurture a knowledge-based economy in the 21st century, the creation of new products and services resulting from innovations will be easily accommodated by a large domestic market that has started to be affluent, thus paving the way for even more innovations. However, the market advantage as well as comparative advantage in labour in many years to come could also discourage Chinese firms from being innovative. For one thing, by combining its strengths in low cost manufacturing and marketing channels with after-sales service capabilities, China has successfully overcome its weaknesses in quality, which probably gives firms less incentive to do well in the first place. With its

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[70] See for example, Linsu Kim, *Imitation to Innovation: The Dynamics of Korea's Technological Learning* (Boston, MA: Harvard Business School Press, 1997).

[71] Jin W. Cyhn, *Technology Transfer and International Production: The Development of the Electronics Industry in Korea* (Cheltenham, UK: Edward Elgar, 2002).

[72] Linsu Kim, "Pros and Cons of International Technology Transfer: A Developing Country's View," in *Technology Transfer in International Business*, ed. Tamir Agmon and Mary Ann Von Glinow (New York: Oxford University Press, 1991), 223–239.

market leverage, China will likely continue having access to foreign technology. But only through its enhanced technological capacity can China assume a leading position in the world market and enhance the position of indigenous firms vis-à-vis those from the advanced industrialised nations.[73]

Moreover, the ability to attain sustainable development can only be achieved through absorbing and assimilating imported technology and then turning out new products bearing such technology in the near term. China's technological capability in industry is still weak, which, plus the lack of urgency to pay attention to innovation among Chinese firms, makes the outlook not that optimistic. The current technology policy, namely, playing the standards game, is in fact a sign of its weakness rather than strength, as China in the globalisation process has gained little in its indigenous capability.

Of course, while it may be tempting to attribute the lack of technological innovation in Chinese enterprises to the bottleneck that inhibits or impedes China's industrial development, technology is one of the determining factors. If some of China's high-tech enterprises at the very beginning were successful in exploiting and commercialising research results, they now run the risk of becoming so large and bureaucratic that they are unable to continue as they previously did or even lose entrepreneurial spirits, as has happened to large corporations elsewhere.[74] In the name of diversification and joining the "Fortune 500 Club", for example, Legend had expanded its business into system integration and services as well as areas in which the company does not have enough expertise to compete with established firms, such as mobile phone handsets, digital cameras, management consulting and even real estate.[75] It turned out to

[73] Alberto Gabriele, "S&T Policies and Technical Progress in China's Industry," *Review of International Political Economy* 9, no. 2 (2002): 333–373.

[74] Jay B. Barnet and Barry Baysinger, "The Organization of Schumpeterian Innovations," in *Strategic Management in High Technology Firms (Monographs in Organization Behavior and Industrial Relations*, vol. 12*),* ed. Michael W. Lawless and Luis R. Comez-Mejia (Greenwish, CT: JAI Press, 1990), 3–14.

[75] *Lianhe zhaobao* (Singapore), March 11, 2002, 17; *Nanfang zhoumo (Nanfang Weekend)*, March 28, 2002; *Beijing Chengbao (Beijing Morning Post)*, April 22, 2002.

be a painful move and the firm recently had to re-focus on its PC business.

Emphasising innovation and indigenous technological capability build-up does not mean that institutional arrangements (including industrial policy, venture capital, stock market, etc.), ownership and enterprise culture are secondary. But it remains to be seen whether China's recently initiated standards-centred technology policy will stimulate innovation or protect less advanced domestic technology and hinder technological development in China.

Since the whole issue of technological development in industry boils down to development of an indigenous technological capability, the ultimate question is whether or not this capacity can be created by enterprises alone. The creation of this technological capability is country-, region-, or history-specific: many Silicon Valley firms have close relations with Stanford University; Japanese capability began in the pre-Meiji era; and South Korea has emphasised the importance of the educational system and construction of a structure that massively supports technology and engineering.[76] Of course, firm-specific characteristics also explain some push toward technological development. Though what has proved successful in other countries may not be necessarily applicable to China, many of its high-tech enterprises did spin off from institutions of learning in the 1980s. In the meantime, the Chinese Government has granted institutions of learning more leeway in transferring research results achieved through government funding. With large increases in investment in R&D and minimal increases in personnel, Chinese enterprises can develop an indigenous technological capability

[76] See for example, James F. Gibbons, "The Role of Stanford University: A Dean's Reflections," in *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship*, ed. Chong-Moon Lee, William F. Miller, Marguerite Gong Hancock and Henry S. Rowen (Stanford, CA: Stanford University Press, 2000), 200–217; Hiroyuki Odagiri and Akira Goto, "The Japanese System of Innovation: Past, Present and Future," in *National Innovation Systems: A Comparative Analysis*, ed. Richard R. Nelson (New York: Oxford University Press, 1993), 76–114; Linsu Kim, "National System of Industrial Innovation: Dynamics of Capability Building in Korea," in *National Innovation Systems*, ed. Richard R. Nelson, 357–382.

through collaborating with universities and research institutes. It should also organise firms and institutions of learning to tackle common technology.[77]

## ACKNOWLEDGEMENTS

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[77] For a recent case in which the US Semiconductor Industry Association sought federal assistance to help create and fund a Nanoelectronics Research Institute, see Don Clark, "US Chip Makers Want to Create Research Institute," *Asian Wall Street Journal,* June 11–13, 2004, M8.