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China's Development Model:

An Alternative Strategy for Technological Catch-Up

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An Alternative Strategy for Technological Catch-Up☆

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Abstract

The context in which Chinese firms and, as a nation, China is attempting to catch-up is fundamentally different that that facing earlier latecomers such as Japan and Korea. This paper contrasts these contexts and describes an alternative model of catch-up that can be discerned through an examination of the industries in which Chinese firms are competing successfully. The basic elements of Chinese catching up strategy are: market size, market-oriented innovation, global alliance and open innovation, spillover of FDI and role of government. The core capability of Chinese company is an integration capability of market knowledge, outsourcing and learning. The paper explained the new model of catch-up in ICT industry in China.

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1. INTRODUCTION

In the decades that the topic of catching up has received attention, two approaches and explanations have emerged to explain the catch up process in the world. One approach is in growth accounting level. By using patent as the index for innovation capability, people try to answer a question: what are the key factors for their catching up in developing countries or newly developed countries. Furman and Hayes(2004) tries to do that in a qualitative way. Based on growth model of Romer (1990), theory of national competitive advantage (Porter,1990) and national innovation system(Nelson,1993), they build a new framework and found that the factors behind the catching up or standing still are: the development of innovation enhancing policies and infrastructure, ever-increasing financial and human capital investment in innovation. They then did some cluster analysis. But this approach cannot give a specific answer to this: what is the country-specific factor to account for a country's catch-up? How can those factors work together to reach the fast catch-up?

The second approach is more historical and dynamic. In Freeman's book(Freeman,1987), government's regulation, shop floor innovation and social institutions such as life employment, Keiretsu, are the key factors for Japan to catch up. In Kim's Imitation to Innovation(Kim, 1997), learning is the key activity for Korean company to master the advanced technology. Lee and Lim(2001) tried to explain the Korea's catch-up in terms of technological regimes. Hobday used the ladder of catching up--OEM---OBM---ODM to explain the Taiwan and other economies' emerging (Hobday, 1995). But some researchers do not agree with this. For example, in World Bank's report, market rather than government, is more important in Asian catch up (World Bank,1993).

Not all countries have the opportunity or ability to capitalize on the chance to catch up(Fagerberg, 1988). For a developing country, it is not easy to proceed from stage of imitation to stage of innovation. Bell and Pavitt (1993) pointed out, just installing large plants with foreign technology and foreign assistance will not help in the building of technological capability. In the time of planned economy, China was a typical country that failed to catch up. China, heavily imported technology from the developed country, but did not realize the transition from imitation to innovation in 1950-1970s. China, the former Soviet Union used reverse engineering like Japan, but in China and Soviet Union, much of the responsibility for diffusion and development rested in central research institutes rather in large industrial firms as in the case of Japan (Freeman, 1988:336-337).

But after China's opening up and adapted the system of market economy, China becomes a fast catching up country. Now, China is a very controversial country for economist to understand its emerging in the world stage. Firstly China has finished a two-digit growth for thirty years and transformed a poor country to a No. 7 country on GDP level in the world. It is expected to reach a level of Japan by 2020 and USA by 2035. In the same time, China keeps investing in R&D in a fast way, to reach a level of R&D per GDP in 2020. This kind of speeding threats the world. So, there is a voice of the threat of China, such as China will be next S&T superpower (Sigurdson, 2005). But in the same time, China is still relying heavily on purchasing technology from the world. No radical innovations to account this fast growth. There is a big imbalance between Chinese GDP level and its innovation level. A country with a level of Germany in terms of GDP but only has an US registered patent of 500 a year, very low in the world. A country with lots of industry volume top in the world, such as steel, cement, chemicals, coal, etc, but they has to rely heavily on exported technology, such as digital machine tools, IC, for its operation. So, how can give China a relevant explanation is a challenge for the researchers.

The purpose of this paper is to identify the key features of the Chinese catch-up process and propose an alternative model of catch-up that takes into account key features of the current environment in an industry level. In China, as other countries that caught-up in earlier periods, the diffusion of new technology and the government have played very important roles. However, other factors—using of global outsourcing and knowledge, big market size, market-oriented innovation, FDI —have resulted in China's catch-up process differing significantly from that of Japan and Korea.

The remainder of the paper is organized as follows. First we review the catch-up processes of Japan and Korea during the 1960s-1980s to highlight key features of their model. Next, we introduce our framework that is grounded in China's experience, and describe China's on-going catch-up process in those terms. We then, based on lots of cases, illustrate the catch-up process in ICT industry in China. Finally, we discuss the general implications of our framework for both research and policymaking.

2. NEW ENVIROMENT FOR CATCH-UP

2.1 Experience of Japan and Korea

During the era in which Japan and Korea caught-up, manufacturing technology was considered to be the core of an industrial society. Japanese business management system such as lifetime employment, the seniority system, lean production, the main bank system, and Keiretsu not only emerged from and matched the country's institutions, but also created highly efficient closed networks among related firms (Kondo and Watanabe, 2003:327). This system works especially well in complex manufacturing industries with high interdependencies, such as the automobile and machine tool industries. Under this system, Japanese manufactures develop new products based on their own in-house technology and in-house procurement of manufacturing parts. Engineering skill is accumulated by rotation and life-time employment, and keiretsu linkages increased stability.

In terms of the nature and degree of foreign compared to domestic action and participation, Japan and Korea's catch-up model is relatively closed. They imported foreign technology but did not innovate together with foreign companies. They focused on in-house R&D to be able to improve imported and "mature" foreign technology gradually; and did not simply rely on foreign technology for their new products.

Recent developments, manifest in the rise of the Chinese economies and firms (in stark contrast to the stagnation of Japan's), suggest that a new framework is necessary to understand catch-up today. Indeed, the features of Japan and Korea's catch-up process seem outdated and in some critical ways inappropriate given recent economic, technological and social changes in the global environment. One fundamental shift has been in the dominant economic paradigm, from industrial dynamics to information-based dynamics. Japanese firms seem to have tried to change, but results suggest that they are more locked-into the earlier paradigm than perhaps they even realized. Indeed, more than ten years of economic stagnation have led many researchers to reevaluate the Japanese model. One conclusion is that the original "Japanese model" was effective in a manufacturing-based industrial system, but that its institutional system does not have the elasticity to adapt to the information-based economic system that emerged in the 1990s (Kondo and Watanabe, 2003).

In contrast, companies in developing countries today are able to access the relatively latest technology from multiple sources to undertake product innovation at a speed much faster than Japan and Korea's companies ever could; they basically had to wait for technologies to be mature before they could efficiently import and incrementally innovate on them. Similarly, findings from recent studies of FDI flows are in contrast to what the product life cycle theory proposes (Cantwell, 1997). Many new technologies have been moved immediately to developing country locations for exploitation, and many new technologies are being developed by multinational corporations' R&D labs located in developing countries.

2.2 China's experience

Starting with a low level of technological capability, Chinese firms (led by the government) placed heavy emphasis on reverse engineering and technology imports in their strategic development. The source of that technology was the Soviet Union in the 1950s, shifting to Japan, the USA and Europe from the 1970s. For example, in 1980s, there were about more than 100 imported color TV production lines in China, most of them from Japan. It was the same story in chemical, steel and many other heavy industries. Such imports also had unexpected consequences. In the switch industry (communication equipment for landline telephone systems), for example, there were 8 different equipment standards from 7 countries in use in China in the 1980s because of the diverse sources of technology.

In each of these industries that China was using technology imports to develop, the government's efforts were frustrated by a recurring pattern of "lag, import, lag again, import again." Three factors seem to lead to this outcome. First, there was a gap between technology user and technology creator. Up to the 1980s, the large state-owned enterprises (SOEs) were the main technology users, but they had no incentive to master the manufacturing technology in order to innovate. The research institutes were supposed to be the technology creators, but they were far away from production sites and were administered by a different part of the government than the SOEs. Furthermore, as economic and enterprise reforms progressed starting in the 1980s, there was even less coordination among them; the disintegrated national innovation system described by Liu and White (2001).

Second, Chinese enterprises spent little money on assimilating the imported technology (Table 1). They did not have a system similar to the "shop floor as laboratory" system of Japanese firms. Corporate R&D labs were actually undertaking primarily maintenance work and perhaps quality control activities, not activities that would improve or create new processes. Furthermore, general managers of these SOEs and government officials cared more about "hardware" element of technology, such as equipment, rather than "soft" part, such as software, processes or people. They would boast of having the world's best technology (i.e., hardware, plants and other equipment), but not truly master it in the sense of being able modify and improve it. Their allocation of resources (Table 1) indicates their emphasis; enterprises typically spent US$ 5 for assimilation for every US$100 on equipment purchase.

Table 1 is here

Third, although some Chinese enterprises did try to invest in internal R&D activities following technology imports in order to learn and master the imported technology, their efforts were too little, especially compared to Japan. Even in 2005, the ratio of R&D to sales in large and midsize enterprises remains below 1%, much lower than in developed countries, even though it has been increasing steadily since 1994 but a bit declined since 2002 (Table 2).

Table 2 is here

2.3. Factors characterizing China's development

Although China has failed to make the transition from imitation to innovation in the way that Japan, Korea and a few other countries and their firms have, China has been catching up economically since the 1980s. The GDP has grown at more than 9% for more than 20 years, and is now second (in purchasing power parity terms) only to the USA (IMD, 2004).

To explain this, we propose that China's catching up has followed a different model than that of Japan and Korea.

Firstly, globalization makes China one of the most important parts of the world and gives Chinese companies vast opportunity to access lots of technology for local innovation purpose. After China opened to outside, especially after China entered WTO, China becomes the play-field for global companies. China now is the number one in the developing country to attract FDI, which bring lot of latest technology to Chinese market and give Chinese companies more directly learning opportunity of managerial, organizational as well as operation knowledge. In the same times, more and more Chinese companies operated their companies with global perspective. They can make R&D globally such as in Silicon Valley; purchase frontier technology from top companies in the world as their material and technology suppliers, market their product worldwide. Finally, globalization also means Chinese companies can use more non-equity technology alliance as an important form of co-innovation. A necessary condition for firms attempting to catch up and compete based on this industry structure is that they have access to the needed technologies and modular packages in their domestic context. Thanks to the IT revolution, globalization of processing technology has occurred in parallel (Archibugi and Pietrobelli, 2003). Also, owning to China's open policy (when compared to Japan and Korea's at a similar stage), companies in many industries can obtain technology from multiple sources, and China's large market has itself led to its becoming a market for international technology sourcing. The source of technology may be previously integrated manufactures; for example, some watch manufactures in Japan now not only sell the final products, they also sell core components (movements) to Chinese assemblers to make extra money. Or, the source of technologies may be intermediate specialized technology providers. In mobile phone handsets industry (discussed further below), there are many intermediate technology providers from European, Japan and Korea. Many universities and high-tech SMEs have also become important technology providers. Finally, in industries in which tacit knowledge is critical, the mobility of engineers is important.

Secondly, dynamics of technology play an important part in Chinese catch-up. Gerschenkron argue that targeting rapidly growing and advanced technologies is the advantage of catch-up countries (Gerschenkron, 1962). We think, information technology is this kind of technology. It has made the world smaller and changed the rules of the game for catch-up. When analyzing windows of opportunity for developing country firms to catch up, Perez and Soete (1988) argue that the life cycle of a technology system is more relevant than single product cycles because the knowledge, skills, experience and externalities of the various products within a system are interrelated and support each other (p.475). They assume that external university research may introduce a new technology system and thereby open a new window of opportunity. Information technology is such an example a new system of technology that is totally different from that dominating manufacturing. It has given rise to new business models, products and services. Traditionally, production process begins with R&D, procurement of parts and components, manufacturing and assembling, logistics, marketing and customer service. Japanese companies are good at effectively integrating the entire process through a combination of hardware, software and "humanware". The new IT-enabled business models, however, have given rise to many firms that specialize in only one activity within the whole process. Global procurement and mobile human resources are both possible and support the new structure and process, and takes advantage of network externalities that seem to supersede the closed networking system of the Japanese keiretsu and Korean chaebol.

Thirdly, the local big market size and tough competition has driven Chinese company an incentive to make product innovation as quick as they can. The Chinese economy is among the world's fastest growing with an average annual growth rate 10 percent for about 20 years. China has a relatively big market size. From Chinese statistics, GDP per capital in 2005 is about 1703 US dollar and 2042 US dollar in 2006. higher than India(723 US dollar) , but lower than Rusia (5129US dollar) and Brasil (3300 US Dollar). But the big population makes China one of large size of markets in the world. Now, in terms of total GDP, China is about No.7 in the world, just behind the Germany.

Comparing Chinese market with the rest of the world, there are several characteristics that make innovation in China unique from a way what multinational is familiar. Firstly, the market changes very quickly, both out of rapid industrial restructuring, income increasing. This kind of market change does not match multinational familiar rhythm. Fiber industry is one of the examples. Secondly, graphical vastness makes lots of technology developed in advanced countries are not directly usable in China. For example, road condition usually is poor than that of developed world, this makes necessary to redesign lot of trucks imported or licensed from developed countries. Thirdly, consumer conditioned by culture and other factors. For example, Chinese customers pay more attention on design, sound of ring than other customers in using mobile phone..

Whether firms in developing countries can take advantage of international technology outsourcing or not is a problem mentioned in literature on the "make-or buy dilemma" at the enterprise level (Pisano, 1990; Veugelers and Cassiman, 1999). Here, transaction costs are the key issue. When a technology market emerges, transaction costs will decline and technology outsourcing can become a more important strategy (Cesaroni, 2004). As most dynamic Chinese enterprises are quite young and do not have significant internal technology capabilities, they have adapted the "buy" or technology outsourcing strategy widely to compensate. Nor do they suffer from a "not invented here" syndrome vis-à-vis technology developed elsewhere. When technology is available from international market, their main task is to find the most appropriate technology for specific market needs.

Fourth, the learning capability of Chinese in an open economy is also one of important factor for Chinese companies to catch-up. Openness gives Chinese the sources to learn from importation, technology alliance and existence of multinationals in China. Openness also gives Chinese companies to learn from local university and research institutes. Chinese companies spend about 26% of their R&D expenditure to local universities and research institutes for them to do contact research (LIU, 2006). But the most important capability is that Chinese companies can integrate market knowledge, technology opportunity and alliance capability in a fast way. So, knowledge integration is the core capability that Chinese companies have.

The fifth factor is the strategy of the large companies. The strategy can be a market-oriented innovation, or cost-advantage strategy or technology-oriented innovation. As Chinese companies lack of necessary key technology, so, cost-advantage is a very common one in China. But some of Chinese companies adapted a market-oriented innovation to build up their capability. Few of them, mostly supported by government, take a technology-oriented innovation strategy.

Lastly, the role of government is critical for some industry. The strong government support can not make the industry or the companies to be innovative. The direct intervention in China is also impossible following China's entry of WTO. So, there is a question of how smartly for Chinese government to help the industry or company to be innovative. Some of Chinese researchers argued that the policy is good for developed countries may not good for developing countries. They strongly suggest government to select strategic industry as way of leverage for innovation (Lu and Feng, 2006).

3. Catching up experience in IT industries

In order to answer the Chinese way of catching up, I select ICT industry to see how the key factors shape the catch-up process in China. ICT, leading by Huawei, Lenovo and ZTE, is regarded the most innovative industry in China.

3.1 Role of market size and market-oriented product innovation

Innovation is new combination of technology and market. So, market plays very important role no less than technology. But its importance relates to market size and complexity and dynamics. In China, market related knowledge is one the key comparative advantage to multinationals. Market -oriented innovation is one of the key features of Chinese industrial catch up. This is against a feature that Japan and Korea had: incremental process innovation based on American company's radical product innovation.

This market-oriented strategy is composed by three related elements: innovation for low end market, innovation for market niche, innovation in a fasting changing market or industry.

The market size of telecommunication industry can be seen from the Table 3.

Table 3 is here

Innovation for low end and local market:

The low-end market is also the biggest market in absolute size in China. The low-end market, however, requires a low-price technology. Bird, fore example, grew based on its pagers business that thrived in the rural regions of western China, which the multinationals neglected. Bird saw this type of region as niche market in which it could enter the market more easily (Xie and White, 2005a:16). This was also the case for Huawei, whose initial approach was to capture rural markets first and city markets later so that they can get rid of tough competition from multinationals in city. Compared to multinationals with technology advantages, local companies in developing countries have the advantage of local market knowledge. For example, multinationals did not timely offer the clam shell design with the Asian customers prefer, and Chinese makers quickly captured that market; now, this design accounts for 80% of the Chinese domestic market.

The fast growing and leading firms in China are usually very young, like Huawei, ZTE and Lenovo. Since their birth, they have been able to survive only by understanding and responding to market needs; technology development has not been the critical factor. A market-oriented innovation strategy is their natural mode.

Huawei, ZTE, Lenovo, etc, all take the unexploited rural market as their first customer for innovative products. ZTE introduced PHS，a low price and local mobile phone invented in Japan, in China.

Huawei, a leading telecommunication company in China that is challenging Cisco, also grew based on a market-oriented innovation strategy. During the 1980s, the switching equipment market was divided among suppliers from 7 countries with 8 different standards, and included NEC and Fujitsu of Japan, Lucent, Siemens, Erickson, Alcatel and BTM of Europe. Huawei, established in 1987, first started as a distributor of the HAX switch produced by a Hong Kong company. Huawei's first product of its own was the C&C08 switcher with 2,000 lines, and the customer was a small city in Zhejiang, a market neglected by the multinationals. In September of 1993, they lunched their C&C08 switchers with 10,000 lines, and these sold very well in rural areas. So, Huawei's strategy is to get rural market first, urban market later. Ren Zhengfei has said that the user and customer are the source of innovation for Huawei (Chen and Liu, 2003:59). The movement from the underserved rural markets into progressively more developed and larger cities has also been a basis for their growth strategy.

ZTE, its first market product is small program control switcher for rural area use. This company has a very strong strategy called ”low-cost test and second best ”. In order to control the risk, they would enter the new market areas by shallow test and put more money when it becomes clearer. All their new products development will be jointly decided by both departments of R&D and marketing. Customer is their starting and ending point for their innovation. Following their strategy, they lead the market in PHS technology, network accessing equipment and etc. all those products are not technological intensive products, but with good market size. Network accessing equipment is a new product for Chinese market for those using different brands of switcher equipment to be compatible for communication in a region. This was their first innovation for ZTE(1994) and Huawei to be late-innovators. PHS is technology invented by Japanese company. But it is ZTE that made this kind of networking to be low-end product for those living in a small city to use wireless communication.

In developed country, for CDMA networking, it is a usually way to integrate the SIM card in the handset. In China, customers prefer the separation of SIM card with the handset. It is ZTE in 2000 to launch out the first mobile phone handset with this function.

Innovation for market niche

In order to make the remote area possible for wireless communication, ZTE developed a special CDMA net called C++net, just for remote area.

Lenovo, the leader in computer industry, adapted its unique strategy: trade first, manufacture second, and lastly technology. So, Lenovo’s key capability is its deep understanding of Chinese market needs, to design its PCs to appeal specifically to Chinese customers (Gold, Leibowitz & Perkins, 2001). As Xie and White(2005b) observed, “The PCs being sold by multinationals were not differentiated to match local customers in markets such as China, which were considered relatively minor at that time. Lenovo, in contrast, was designing products for different market segments, from banks and other large organizations to SMEs in the corporate market, and similarly diverse individual customer groups. Lenovo incorporated feedback and experience in user needs from its distribution channels and marketing department into design and innovation efforts in its business-level R&D centers”. It is just because of this incremental and market-oriented product innovation that makes Lenovo to replace IBM as the top computer in the Asia market.

A verification of market-oriented innovation in China can be seen from the increasing number of patents for utility models and external design. Both of them have increased dramatically over the last ten years. The number of invention, utility model and external design patents in 2001 are 4, 3 and 14 times of the number in 1991. While foreigners are accounting for a larger and larger share of invention patents, it is the opposite trend for design patents. This reflects the nature of product innovation in China: foreign technology coupled with Chinese design (Table 4).

Table 4 is here

The market-oriented innovation strategy gives Chinese firms several advantages over their competitors: more targeted new product development plan, more scheduled production, and lower risk. Furthermore, with Chinese companies' low cost production, they have beaten their competitors in some industries, such as consumer electronics.

Innovation in a fasting growing market and industry

IT industry is one of the typical fast growing and changing industries in China and the world. Penetration rate of mobile phone in China is astonishing (Table 2). There is a strong market competition here. To survive in Chinese market requires the company to be highly flexible. From our interview, we know that in China, a company needs to develop 40-60 new products of mobile handsets in one year. This never happens in other countries. This made lots of foreign mobile handset manufactures quit from the Chinese market, such as NEC, Siemens, Philip, etc.

In fiber industry, a company called YOFC(Yangtze Optical Fiber and Cable Company) originally is a SOE and joint venture with Philips on fiber making. Now, YOFC is the only company who masters the core technology-pre-form making and has their own innovation capability. YOFC is the number one in term of sales, size and technology in China in its field. The big size of Chinese geography matters in demand size: China, from North to South, is more than 3000 kilometers; this is a distance across Europe. European did not have such large demand of fiber and cable. Furthermore, as the IT was in a boom, China Mobile, China

Unicom and other are very sensitive to quality and technology. In 1997, both of telecommunication service providers required new fiber-single mode. But Darak in Europe still preferred multiple mode fiber. When YOFC try to manufacture G652 single mode fiber, Darak did not have this kind of technology, these pushed YOFC to set their own R&D facility and do innovation themselves.

As market for optical fiber is expanding and the existing technology is not enough to match the market needs, so YOFC thought it is necessary to set its own R&D center. YOFC finally did that in 2000 with a staff of 30 engineers. R&D center in YOFC has contributed YOFC greatly. They developed lots of new products to win the market competition.

So, compare with Japanese model which focused on shop floor innovation, Chinese companies are better at market oriented innovation.

3.2 Open innovation and global alliance

It is not easy for late-comer companies to spend huge money on R&D as Microsoft and IBM do. So, companies in the developing country have to use open innovation strategy Chesbrough (2003) in a fast and efficient way than that in developed country.

The traditional way for company in developing countries to get new technology is via technology import. This usually took long time and only got the mature technology. From Chinese experience, company in developing countries can adapt open innovation in a new way to get the latest technology and to pave the way for innovation. Because Chinese companies have limited capabilities in in-house technology development, their R&D inputs are still limited compared with companies in developed countries, so domestic as well as international outsourcing and alliance are the key for exploration of new market opportunities, also in line with a market-oriented innovation model.

Globalization of technology can be either a window of opportunity or a further burden, depending whether the firm playing catch-up has made the technological effort supporting the absorption, adaptation, mastery and improvement of technology or not (Archibuchi, 2003:864). But there is a further option: in order to grasp the windows of opportunity in a much faster way, relying less on absorption and adaptation, and driven more by market-oriented innovation supported by technology outsourcing and alliances. Indeed, this option has emerged as the basis for Chinese firms to catch up and distinguishes their model from that of Japan, Korean and other latecomers.

Global technology outsourcing and alliance

The technology outsourcing and alliance strategy can be discerned from the structure of technology expenditures across the many channels companies have to source technology. Technology imports are the traditional source for Chinese firms, and that will continues to play an important role. For a long time before 1999, industrial enterprises spent more money on technology importation than their own R&D. Although R&D activities have received more attention after 1999, technology imports still matter very much for production.

In the same time, Chinese companies become to use both domestic as well as global alliance strategy to develop technology and products. For example, in their GoTa (global open trunking architecture) development, ZTE jointed different alliance. In equipment development, they do that together with North Telecom, China Capital Telecommunication and etc. For end products, they formed alliance with South High-tech and other companies. For value added service, they do that with more than 100 SP companies. Table 5 shows that Chinese companies are spending more and more money on collaboration with university and government research institute.

Table 5 is here.

Huawei has formed joint laboratories with TI, Motorola, Intel, AGERE, ALTERA, SUN, Microsoft and NEC, as well as a joint venture with 3COM. China Mobile has set up a R&D alliance with A&T, Vodafone , Docomo, Softbank, to do research on 4G standard setting.

In mobile handset industry, domestic companies began to enter the handset market based on a strategy of internationally outsourcing their design and technology. The largest local mobile phone handset maker in China, Ningbo Bird, has gone through the following stages in terms of its approach to innovation:

- 2000: Design collaboration with a UK company, but later found that the company was not very good, so it ended the relationship.
- 2001: Cooperation with Korea's Sewon, using Seown's model; although the first

sales of the S1000 were satisfactory, Bird later found that Sewon had sold its design to other Chinese companies, so it ended its relationship.

- 2002: Cooperation with Korea ATEX that is on-going, with a design house in Korea with 20 people.
- 2003: In order to upgrade Bird's product quality, Bird spend US$ 6 million to get 30 experts from Europe to do quality control work, and this has greatly improved product quality.

Concurrently, they began their own new product development efforts. They first collaborated with Sagem in manufacturing the RC838 and RC818 to learn the tacit knowledge of the whole design process for mobile phone handsets. Based on this new technology, it developed independently its own product, the S288.

Following this kind strategy, Chinese companies acquired some market share from multinationals in China, although most of them still do not have the core technology or capabilities, but instead have relied on technology from Korean, European and Japanese firms(Table 6). Here, local Chinese universities and research institutes have contributed very little, except as suppliers of engineers.

Table 6 is here

This approach of international technology outsourcing gives enterprises in developing countries some special advantages compared to in-house R&D development. First, they can focus on and thereby better serve the market needs. For example, Bird has contracted different chip designers such as Sagem, Siemens and TI for the purpose of market differentiation. Second, they can reduce costs. Owing to the dis-integration of the industry, more and more Korea technology suppliers have entered the Chinese market with low prices, so the Chinese firms can shift to them for technology. Third, they can respond and incorporate technological developments faster. Usually, companies in developed countries with strong in-house R&D often fall into the trap of locked-in or dead-end technology. Companies based on a technology outsourcing strategy do not have this problem. They follow the leaders and enter the dominant design quickly with little risk. In the handset industry, technology and design have continuously changed from black screen, blue to color screen, from digital to camera function to intelligent, and so on. Chinese companies have followed very closely the technology leaders in the industry from different countries.

The size of the market helps Chinese companies to use global alliance strategy and mergers with international partners that their technology is in a much higher level than Chinese counterparts. Many of foreign companies, not in the leading positions in market of developed countries, or take China as their strategic market for future, would like to find Chinese partners for cooperation to co-develop or diffuse their technology for Chinese market. Siemens, coming to China to jointly develop 3G TD-SCDMA with Chinese Dadang, is one of the typical cases. 3G technology for China means a big market opportunity. Siemens came to China and try to get 3G market share of China that they cannot in market of developed countries. Now, in 3G TD-SCDMA, Siemens is leading in granted patents in this technology than its Chinese partner.

Global R&D centers

Several Chinese firms have entered this stage and embarked on strategies to address their weaknesses vis-à-vis global competition. Huawei has set up 5 research institutes abroad, in Silicon Valley and Dallas in the USA, Bangalore in India, and Russia. In Bangalore they have 800 software engineers, and most of them are local engineers. Huawei also has formed joint laboratories with TI, Motorola, Intel, AGERE, ALTERA, SUN, Microsoft and NEC, as well as a joint venture with 3COM.

With this global distribution of R&D, Huawei was able to develop lots of technology related with WCDMA and software VRP for IPV6 router.

ZTE has set up their R&D labs in USA, France, India and Pakistan, some for getting latest technology, some for close to the market needs. Their R&D funds from 2002-2005: 1.1 ,1.5, 2.26 and 1.96 billion RMB, they have more than 4000 patent application globally, and 90% of them are invention patents. They have more 120 patents in GoTa technology and licensed the technology to other foreign companies.

Lenova after the acquisition of IBM have three R&D centers in the world, one in USA, one in Japan and one in Beijing.

International acquisition

International acquisition is another way of open innovation in China (Table 7). Though this kind of strategy is far to say successful strategy for Chinese companies or not. We have seen the case of Lenovo's acquisition of IBM to be a successful example but not so good for TCL's case.

Table7 is here

3.4 Role of government

In explanation of Japanese success, former MITI used to be given an important role for Japanese industrial catch up. In Korea, Lin and others also regard the role of government very important, such as provide public knowledge and pick winner strategy.

China is a transition economy. Therefore, in current stage, government will play an important role in industrial catch-up. Targeting progressive industry is a government's strategy to catch-up. Most of developing country will give more resources on new and high technology than traditional industry. IT is the industry that all Asian country tried to have fast development. The history shows that this kind of targeting dynamic industry could make a good return. .

Government science and technology program plus five year plan or long range plan are the key policy tools in China. Table 8 gives a brief overview of the main programs controlled by Ministry of Science and Technology (MOST).

Table 8 is here

But a key issue is to what extent government should interfere in the catch-up process, especially as market institution becomes more and more important in resources allocation and China became a membership of WTO.

For ICT industry in China, government firstly used the strategy of market for technology. In the first "Law of Sino-Foreign Equity Joint Ventures" adopted in 1979, the article 5 states that foreign company should used advanced technology and equipment in their joint venture.

For example, the government required joint venture of Shanghai Bell to manufacture large scale integrated chips in China. In the same time, as most of Chinese counterparts in the joint venture were SOE in that time, most often, regional telecommunication equipment companies of Ministry of Post and Telecommunication (MPT). So, MPT sometimes would use the advantage of that to ask Shanghai Bell to have R&D consortia with domestic companies. But the direct result of this strategy for knowledge transfer is debatable. But this strategy gave Huawei and ZTE in the earlier time some market space to survive. Later on after China became a member of WTO, this strategy went to end.

In mobile phone handsets, the government used the licensing policy. Foreign companies were limited to get the license to make the handsets in China. This can explain why before 2003, domestic company could hold more than half of the market. After 2003, this policy was cancelled and foreign companies regained the leading position. .

In the telecommunication industry, a government research institutes under MPT had developed a product DS-2000 in 1986, but failed in commercialization of the new product. In the end of 1980s, Post and Telecommunication Industrial Corporation(PTIC) had been established. In 1989, PTIC signed a contract with Zhengzhou Institute of Information Engineering of the People's Liberation Army, to develop large digital switches. As a user, PTIC had rich market knowledge. And as a partner of Shanghai Bell, it had also already acquired the basic technology from Shanghai Bell. Luoyang Telephone Equipment Factory of MPT as producer of crossbar switches also entered the research consortia. In the same time, the key engineer for the project, Mr. Wu had years of experience with Japan F-150 system, he also used to be engineer for computer research. His innovative idea was to apply the principle of computer to the development of digital switches. The previous model done by multinational had developed in a time which computer technology was not as mature as end of 1980s. So, Mr. Wu, with his team, began to develop the new type of digital switches to integrate the advantage of Fujitsu's F-150(centralized control system), Shanghai Bell's S1240(distributed control system) and computer design. In November of 1991, they developed a new product called HJD-04. The new product adapted a multi-processors distributed control system, consists of up to 32 identical, independent modules, it is a radical new design in digital switches (Gao,2004).

The biggest advantage of the innovation is that it can cut the price down substantially. In 1992, when this new product entered the market, its price was 100 $ per line, while for imported or joint venture's product, the price was about 170-200$ per line. Encouraged by government as well as its cost advantage, HJD 04 became a game winner in the market.

TD-SCDMA is product from a former government research lab called Datang Telecommunication Research Academy with strong landmark of government support.

From 1990s on, just in the rising of GSM in China, government agencies have began to support research on CDMA in 1993 and 3G in 1997 in government research institutes (GRIs) and universities by MPT and Ministry of Science and Technology. But the research basically followed the path of Ericsson and Qualcomm, though had made some progress but no breakthrough came out. There is an implication that the research in GRIs provided some basic knowledge for 3G technology.

A milestone event happened to the technology. In May of 2000, TD-SCDMA (Time Division - Synchronous Code Division Multiple Access), proposed by Datang Telecom Technology and Industry Group on behalf of the Chinese government, was approved by the International Telecommunication Union (ITU) as one of the 3G mobile communications standards. Actually, TD-SCDMA was an infant technology compared to WCDMA and CDMA2000. But the potential big market share gave the standard a big support in the competition process.

In 2002, the government was determined to support the new technology. State Development and Reform Committee, MOST and MII jointly made a strong support for the industrialization of TD-SCDMA. They supported a TD-SCDMA Alliance so that more companies can join and share the benefits of new technology.

Lastly and also most important, they give TD-SCDMA a 155m wireless frequency for its future uses. All these measures sent a strong signal that TD-SCDMA technology is now an authorized technology for future 3G markets.

In 2006, in the National Middle and Long Range S&T Plan, indigenous innovation is given a national strategy. The whole society now regards TD-SCDMA as a national hero in the IT industry. It seems that the climate helps TD-SCDMA again to get a favor in future 3G market against the existing multinationals in China. But the technology still faces lot of uncertainties in future.

But from two years ago, the government began to use market power to help the TD-SCDMA. Firstly, slow down the licensing process, so as to give TD-SCDMA more time to be mature. Secondly, let the SOE China mobile to spend money in 8 cities to establish the net and do pre-commercial operation. But the results are not so good as it still has many technical problem to solve.

3.5. Spillover of FDI and learning

IT is the most FDI intensive industry in China. This gives Chinese company good opportunity to learn the latest technology from the world. Firstly, by contract of joint venture, many Chinese counterpart acquired lot of production knowledge, from knowledge of assemble, testing to later on knowledge on manufacturing of circular board, quality control and manufacturing information system. They also learned much knowledge of maintaining, service and training from their parent companies. Mu and Lee stated that in case of Shanghai Bell, Shanghai Bell had established lot of maintenance centers, widely circulated on information about their System-12, trained lot of qualified engineers since its operation in China (Mu and Lee, 2005, p.15). But multinationals usually would not transfer their key technology. Even they set up their R&D centers in China, these centers will not have much direct contacts with their company in China. An important spillover of knowledge is managerial knowledge, including marketing, human resources and incentive plans. In the earlier stage, domestic companies had limited knowledge beyond some production knowledge. The existence of multinationals gave Chinese companies lots of good opportunity to learn.

Shanghai Bell had provided a lot of training and maintenance work for the Chinese customers, that is one the important opportunity for Chinese to learn the technology（Mu and Lee，2005）. In order to make Shanghai Bell's S-1240 better adapted to local market needs and the progress in phone network, Shanghai Bell has let Chinese software engineers to join the country development engineering(CDE) and customer application engineering. Since Chinese engineers had a better knowledge of the local market needs, they finished 80% of CDE work. They also played important role in CAE. By this process, Chinese engineers learned a lot of knowledge (Gao,2004, pp.360-362).

A survey on source of knowledge from domestic companies in the end of 1990s showed that there was a strong demonstrating effect of FDI. Chinese regards information of multinational products, product exhibition, specialized journals as their most important sources of technology. They will also learn knowledge of which products are profit making ones so that Chinese companies can import, reverse engineering later on(Gao,2004), In the stage of mobile telecommunication period, Beijing Capital Telecommunication and lots of other companies have set joint venture with Nokia, Motorola and others. Chinese companies learned lots of knowledge from this. Via human resources mobility, Huawei, ZTE learned the GSM as well as CDMA technology(Jiang, 2004; LIU, 2008).

Performance of catch-up

IT is the largest industry in China now. It has a wide spread impact to Chinese economy and society. It gave birth of new and giant companies such as Huawei, Lenovo and ZTE. Huawei has is its sale of 70% from international market and become the third hardware company in European market in 2007. Chinese companies quickly narrowed the gap with that of companies in developed countries (Table 9). In a sense, the industry has written a lovely story of catching up and shed us new lessons for how to catch up in an open, dynamic and global world.

Table 9 is here

4. Conclusion and discussion

China has narrowed the technology gap with developed countries since China opened to the world and adapted the system of market economy. But not all countries can have this kind of speed in catching up and also it is not easy for such a large country to do that. So, Chinese experience can give other developing countries, especially other BRICS countries some lessons to learn and share.

Firstly, huge home market size can be powerful leverage for companies in the open economy to compete with multinationals from the world. Market-oriented innovation strategy is the most common and effective strategy to win the catch-up war. This is just as what Japanese company's shop-floor innovation did thirties years ago to catching up with USA. Multinationals will care about high-end market, high quality market. This gives Chinese companies the windows of opportunity to catch up. So, innovation aiming rural market and low end market is the passport for Chinese companies to win the market in the world. Huawei now is the third hardware provider in EU market and it can provide 3.5G technology. 70% of its revenue in 2007 came from international market. ZTE has a relative similar market performance.

Secondly, opening-up and globalization can give companies in developing country opportunity to use global knowledge and alliance. But the learning capability and appropriate innovation strategy are the keys to the goal of catching up. Traditional infant industry protection theory will not work anymore in a open economy.

We found that government market protection can not promote innovation capabilities. Lenovo, Huawei and ZTE, all are not SOEs with lots of government protections. But the some national technology program, promoting linkages of industry with university and GRI can greatly help Chinese company to step in the dynamic industry. In the TD-SCDMA case, government help the industry from R&D, bank loan, market access, standard setting, public purchase, but this kind of protection only made Datang to rely government further support, little progress in innovation and service.

We also found that, FDI can be a positive factor for catch-up in developing country for providing frontier technology and diffusion of knowledge. We have observed positive spillover from FDI in the three stages: Shanghai Bell and others in fixed phone switches, Nokia, Ericsson, Motorola and Qualcomm in GSM and CDMA, Siemens in TD-SCDMA. So, in the dynamic and advanced industry, FDI can be a very important factor for the technology transfer and catch-up.

The final important lesson is that the companies have to learn and spend on R&D in this Catching-up process. Both Huawei and ZTE never regards themselves just a low price product makers. They continue their spending R&D and even go to overseas to set up their R&D centers. They also used alliance strategy to fast their innovation process.

But the existing trajectory of market-oriented innovation strategy has its own challenge.

Firstly, there are few radical innovations in Chinese industry. Most of innovations in China are incremental innovation, innovation of new business model, innovation of flexibility. Lots of technologies have been outsourced to companies in the developed world. This makes Chinese companies hollowing out of their core technology.

Secondly, government still relies on university and GRI as main technology providers. This makes companies to be a marginal role in frontier technology development.

Thirdly, innovation culture is lacking in Chinese education system. Chinese government spends more and more money on education, so do the Chinese family, but the whole innovation system of China still lacks of culture for innovation. No pluralism in education, too much care about testing, bureaucratic system, all kill the curiosity in their young age. This happens in elementary school, high school as well as university.

In order to have a high growth of GDP, regional government controls the price of land, resources, labor as well as pollution cost to a low level. This drives Chinese company to take advantage of this, rather then to spend more money on R&D and innovation. Now, the cheap price of labor, land, resource and pollution will go away in those years. This will give Chinese a new turning point to enter another developing road. Some will die out of cost rising wave. Some will survive with more innovative capability.

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Table 1 Expenditure of In-house R&D and technology importation and assimilation

unit: 100 million RMB

	Expenditure on R&D	Expenditure on technology import	Expenditure on technology assimilation	Ratio
1991	58.6	90.2	4.1	1:1.54:0.07
1993	95.2	159.2	6.2	1:1.67:0.07
1995	141.7	360.9	13.1	1:2.55:0.09
1998	197.1	214.8	14.6	1:1.09:0.07
1999	249.9	207.5	18.1	1:0.83:0.07
2000	353.6	245.4	18.2	1:0.69:0.05
2001	442.3	285.9	19.6	1:0.65:0.04
2002	560.2	372.5	25.7	1:0.66:0.05
2003	720.8	405.4	27.1	1:0.56:0.04
2004	954.4	367.9	54.0	1:0.39:0.06
2005	1250.3	296.8	69.4	1:0.24:0.06

Source: MOST. China Science and Technology Statistics Yearbook, 1991-2006, Beijing.

Table 2 Ratio of R&D/sales in Large and medium sized companies

Year	1991	1995	1998	1999	2000	2001	2002	2003	2004	2005
R&D/sales	0.49	0.46	0.53	0.60	0.71	0.76	0.83	0.75	0.71	0.76

Source: MOST. China Science and Technology Statistics Yearbook, 1991-2006, Beijing.

Table 3 Outline of Chinese ICT industry

	2000	2006	Average annual growth Share of the world
Fixed phone users	145 million	371 million	21%, 1/4 of the world
Internet users	33.70 million	131 million	31% , 1/10 of the world

Wireless phone users	85.0 million	449 million	40%
Sales of ICT industry	607 billion	3800 billion (2005)	31%, Number 3 in the world

Source: calculated from Chinese Yearbook of Statistics of Information Industry.

Table 4 The granted three patents in China Domestic vs. Foreign owners

	1991	1995	2000	**2003**	**2004**	**2005**
Sum of three patents granted in China	24616	45064	105345	182226	190238	214003
Invention patent	4122	3393	12683	37154	49360	53305
From Domestic owners	1311	1530	6177	11404	18241	20705
Share of domestic owners	31.8	45.1	48.7	30.7	37.0	38.8
From foreign owners	2811	1863	6506	25750	31119	32600
Share of foreign owners	68.2	54.9	51.3	69.3	63.0	61.2
Utility model patent	17327	30471	54743	68906	70623	79349
From domestic owners	17200	30195	54407	68291	70019	78137
Share of domestic owners	99.3	99.1	99.4	99.1	99.1	98.5
From foreign owner	127	276	336	615	604	1212
Share of foreign owners	0.7	0.9	0.6	0.9	0.9	1.5
External design patent	3167	11200	37919	76166	70255	81439
From domestic owners	2667	9523	34652	69893	63068	72777
Share of domestic owners	84.2	85.0	91.4	91.8	89.8	89.4
From foreign owners	500	1677	3267	6273	7187	8572
Share of foreign owners	15.8	15.0	8.6	8.2	10.2	10.5

Source: MOST. China Science and Technology Statistics Yearbook, 2000-2006, Beijing

Table 5 R&D outsourcing for university and R&D institutes from large and medium-sized industrial enterprises

	2000	2001	2002	2003	2004
Total R&D expenditure(Billion RMB)	35.4	44.2	56.0	72.1	95.4
Funds for university (Billion RMB)	5.5	7.2	9.0	11.2	24.9
Share of total business' R&D (%)	15.5	16.2	16.1	15.5	26.1
Funds for R&D institutes(Billion RMB)	3.8	2.5	3.6	4.7	5.0
Share of total business' R&D(%)	10.7	5.6	6.4	6.5	5.2
Total outsourcing for domestic Univ.and R&D inst.(%)	26.2	21.8	22.5	22.0	31.3

Source: MOST, 2006, China Science and Technology Statistical Yearbook, 2005. Beijing: Chinese Press of Statistics.

Table 6 The source of technology for local handset makers

Company	Source of main technology	Products
Ningbo Bird	Sagem Philips Sewon, LG, Pantech, Telson Electronis(Korea)	GSM, CDMA
TCL	Sagem Pantech, Standard Telecom(Korea)	GSM, CDMA
Haier	Sewon, Standard Telecom(Korea) Sendo	GSM, CDMA
ZTE	Maxon LG, E-Ron Tech,Giga Telecom(Korea)	GSM, CDMA
Konka	Acer Telson Electronics, Pantech&Curitel(Korea)	GSM, CDMA
Eastcom	Sewon, LG, E-Ron Tech, Giga Telecom(Korea)	GSM, CDMA
Xoceco(Xiahua)	Panasonic Sewon	GSM,CDMA
Kejian	Maxon Samsung(Korea)	GSM, CDMA
CEC	Philips E-Ron, Standard Telecom(Korea)	GSM, CDMA
Capital	Kenwood LG, Pantech&Curitel(Korea)	GSM, CDMA
Soutec	Motorola Pantech, Sewon Telecom,Standard Telecom(Korea)	GSM, CDMA
Daxin group	Motorola	GSM, CDMA
Amoisonic	Samsung, Bellwave(Korea)	GSM, CDMA
Chabridge	Context systems VK(Korea)	GSM, CDMA
Datang	LG, Standard Telecom(Korea)	GSM,CDMA
Panda	Sewon Telecom	GSM

Sources: edited by authors based on Keun Lee and Mihnsoo Kim (2004), and other sources in journal and daily.

Table 7 **Selected M&A deals in IT industry by Chinese firms (2001-2005)**

Chinese bidder	**Target foreign firm / Unit**	**Industry**
Holly group	Philips Semiconductors, CDM hand-set reference design (US),2001	Telecommunication
TCL International	Schneider Electronics AG (Germany), 2002	Electronics
TCL international	Thomson SA, Television manufacturing unit (France), 2003	Electronics
BOE Technology Group	Hyundai display technology,(South Korea), 2003	Electronics
Lenovo group	IBM ,PC Division (US), 2004	IT

Source: from different sources of news.

Table 8 National S&T programs

	1996	2000	2001	2002	2003	2004
973 Basic Research		5	6	7	8	9
863National High Tech R&D program(from 1986)	4.5		25	35	45	55
Key Technologies R&D program(from 1983)	5.2	10.3	10.6	10.6	12.5	16.1
Torch Program(1988, for high technology)	0.51	0.5	0.5	0.5	0．5	
Spark Program(1988 for rural SME)	0.39	0.4	1	1	1	
Key S&T Diffusion program	0.19	0.2	0.2	0.2	0.2	

Source: MOST, China Science and Technology Development Report, 2006.China S&T Literature Press.

Table 9 Some indicators of catching up in telecommunication industry

Key products	International Commercial time	Commercial time in China	Time gap
Analog program switcher	1965, Bell	1986, Great Dragon	21 years
Digital switcher	1970, France	1989, ZTE	19 years
GSM base station	1991, Ericsson	Huawei, ZTE, Datang, 1997-99	7 years
CDMA base station	1995, Qualcomm	2001,ZTE	6 years
WCDMA base station	2001, Ericsson	2003, Huawei	2 years

Source: Zhang Yutai and LIU Shijing (editors): Promoting Innovation(Jili chuangxin)(in Chinese), Beijing: Intellectual Property Rights Press, 2008.pp. 353.