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Path-following or Leapfrogging in Catching-up: theCase of Chinese Telecommunication Equipment Industry

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Keywords: innovation, catching-up and telecommunication equipment industry.

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1. Introduction

Catching-up is a very important phenomenon in the world economy. Gershenkron argues that targeting rapidly growing and advanced technologies is the advantage of catching-up countries (Gershenkron, 1962). From national innovation system approach, technology and innovation are central to the catching-up process, and a country (or firm, for that matter) must be able to use a specific "window of opportunity" that may arise in the evolution of a technology system to catch-up if they implement appropriate social, industrial and technology policies; otherwise, it will continue to lag behind (Perez and Soete,1988; Freeman, 2002). Many countries and economies have successfully exploited their window of opportunity, such as the USA in the 19th century, Japan from the 1960s, later Korea, Taiwan and Singapore, and most recently China.

Lots of researchers noted that 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 the stage of imitation to the stage of innovation. Bell and Pavitt (1993) pointed out that just installing large plants with foreign technology and foreign assistance will not help in the building of technological capability. In many developing countries, such as Brazil, the primary method of technology transfer has been through subsidiaries of multinationals or the import of "turn-key" plants designed and built by foreign contractors. The former Soviet Union used reverse engineering like Japan, but in the Soviet Union, much of the responsibility for diffusion and development rested in central research institutes rather in large industrial firms in the case of Japan (Freeman, 1988:336-337). In such cases, the recipient enterprises and countries gained little in terms of innovation capabilities which, we argue, differentiate between those who catch up and those who continue to lag behind.

Economically, China has been in a fast track to catch up the developed countries. It had more than 9% growth rate for two decades and increased its GDP per capita from 100 US dollar in 1985 to $ 1700 in 2005. But in doing so, in the Western literature, Chinese companies are still the copy cats rather than innovators. China is a country with huge manufacturing capability but poor in science and innovation. Our paper tries to illustrate how one dynamic industry, that is telecommunication equipment industry, has made a fast transition from an imitative stage to an innovative stage in twenty years in China; More specifically, we try to answer the following questions: how does Chinese company grasp the windows of opportunity? What is the role of government in this process of catching-up? Where does the needed knowledge come from? What is the role of FDI or multinationals in Chinese companies' capability building? What is the policy implication for other industry and countries if we assume that telecommunication equipment industry has already finished the catching-up process in China?

Telecommunication industry is one of the most dynamic industries in China. Before 1980s, this industry was dominated by a large number of SOEs and mainly focused on fixed phone set and some component manufacturing. Due to China's

market liberalization reform and open door policy, foreign companies entered in China with advanced technology, such as digital phone switches and wireless communication. Facing the large demand, China began its large scale of technology import from the world. In the same time, the transition of SOEs, the rising of private company, the coming of joint venture and whole owned companies by multinationals had broken the traditional SOE's dominated position. Since 1980s, the industry has become the fastest growing one in China and in the world. Even in the dismal period after the bubble of .com collapsed in USA, telecommunication industry in China keeps its high growing pace (Table 1), makes itself being the target market for the global telecommunication equipment makers, such as Motorola, Nokia and Ericsson, etc.

Table 1 is here

Catching-up in the macro level means the ability of a single country to narrow the gap in productivity and income vis-à-vis a leader country (Fagerberg and Godinho, 2005).In this paper, we mainly focus on innovation catching-up, includes technology as well as market catching-up. We argued that for the case of China or other developing country with big market size and open economy, which is different from the cases of Japan and Korea, the conditions for Japan or Korea's catching-up may not work in China. Here, we have to take into account the factors of market knowledge, the specific nature of technological opportunity and the strategy of alliance in accessing the latest knowledge for innovation. We also propose two main approaches for catching-up in China: path-following and leapfrogging. They need different factors and conditions.

The rest of the paper is organized as follows. Models of catching-up are reviewed in Section 2. Section 3 describes our framework for understanding catching-up in China. Ssection 4 presents a detailed analysis of telecommunication catching-up in China. In last section, we will discuss the implication for theory of catching-up and for innovation policy.

2. Models of Catching-up

In the earlier study of the catching-up, Gerschenkron (1962) regarded both the new technology and new institutions as very important factors to the final catching-up. New technology has the high potential reward from successful entry while new institutional instruments is very powerful to finish the catch up process. But Gerschenkron also pointed out that Denmark's catching-up did not targete progressive industries, but used the opportunity of the rapidly growing British market for agricultural products.

For the case of Japan, it is said that the role of government is very important by intervention through activist economic, industrial and trade policy. The government, especially the Ministry of International Trade and Industry (MITI), was able to set the direction of technological change and mobilize technological and capital resources to pursue national strategic goals in line with that change. The government helped industry to forecast the new technology trends and facilitated coordination among companies and with universities (Odagiri and Goto, 1993). Japan targeted the

progressive industries as their base for catching-up with a strategy of combing economies of scale, product differentiation with continuous improvement of product and process. Besides, Japan has many unique social innovations such as life-employment and job rotation that support their innovation activity in the firm level (Freeman, 1987).

In the newly emerging economy, such as Taiwan and Singapore, researchers found that their catch up fit well with the Gerschenkronian scheme by targeting new industry. Besides, the government and the export oriented strategy also played key role in their catching-up (Fagerberg, 2005).

In those years, some researchers take a technological regime approach to study the catching-up (Breschi, Malerba and Orsenigo, 2000). The technological regime consists of technological opportunity, appropriability of innovations and cumulativeness of technical advance and the property of knowledge base. For Korea case, Lee and Lim (2001), for example, emphasize that the technological regime plays an important role in explaining why some industries such as DRAM and automobile in Korea have caught up and others not, such as PC and house electrical appliance. The key for success or failure of catching-up in the industry is whether the innovation is predictable or not.

In Taiwan's case, researcher found that OEM and the role of government in providing infrastructure are very important institutions for its catching-up (Fageberg and Godinho,2005).

China is a big, open and transition economy. Its catching-up process is different from what we can see in Japan, Korea or other Asian counties. There are few papers on Chinese catching-up. One exception is Mu and Lee (2005) on Chinese telecommunication industry, they found that the important factors in the catching-up are the strategy of "trading market for technology", the knowledge diffusion from Shanghai Bell to R&D consortium and Huawei, and the industrial promotion by government. And also the technological regime of telephones switches is featured by a more predictable technological trajectory and a lower cumulativeness. But why Chinese automobile and other industries with very similar strategy, industrial promotion and technological regime, do not show a strong trend to catching-up?

We propose that, in China, as other countries that caught-up in earlier periods, the diffusion of new technology and the government played very important roles in China's catching-up process. We agreed with Mu and Lee that technological regime is very important here, but we have to go beyond the accumulation of knowledge, we have to ask how can Chinese companies enter the industry to compete with foreign companies in an open economy; how can Chinese companies to learn and access the latest technology, what is the role of government and FDI or multinationals in helping the knowledge creation and diffusion?

3. Framework for Chinese Innovation Catching-up

3.1 Path-following or leapfrogging

In analyzing the Korean case, Kim (1997) used Utterback and Abernathy's innovation model to identify how the innovation process in a developing (latecomer)

country is different from that in a developed country. Rather than product innovation first and process later, Kim proposed a 3-stage model for latecomer countries like Korea. The first stage is acquisition of mature technology from developed countries; firms learn production technology in this way. Second, the firms acquire process development and product design capabilities. Finally, in the third stage, companies do more significant R&D and thereby develop their product innovation capability. He argues that process innovation precedes product innovation, and uses the term "reversed innovation process" to highlight this feature (Kim, 1997).

Lee and Lim (2001) gave three patterns of catching-up based on Korean experience. They are path-following catching-up, stage-skipping catching-up and path-creating catching-up. Path-following means that the companies in developing countries will follow what the innovative companies did before in the successive stages but in a more efficient way. In stage-skipping way, the companies in the developing countries can skip some stages to the next stage in a parallel way with innovative companies in the developed countries. Path creating will break the way the innovative companies did before and developed their own technology to narrow the gap with the leading companies in the industries. But both stage-skipping and path creating are the way of leapfrogging.

In this paper, we think there are mainly two ways of catching-up. One is path-following, the other is leapfrogging. The path-following catching-up is a more market driven approach in an existing technology trajectory. This kind of catching-up started can be from a mismatch of existing technology with Chinese market or from an innovation ladder of low end market to high end market in a given technology trajectory. The second way is more technology driven approach. They will try to leapfrog some stages and target the next generation technology as a way of catching-up so as to narrow the gap in a quick way.

We proposed that the key factors for the successful catching-up innovation are market knowledge, technological opportunity, governmental role, learning activity and innovation strategy of the company. These key factors play a very important but different role in the catching-up process. They explained why in some stage or industry, the catching-up is succeeded or failed.

3.2Market knowledge and opportunity

In understanding the catching-up process, most of researchers paid more attention to the technology dimension than the market dimension. This is right since catching-up means that the technology gap between developed countries and developing countries has been narrowed (Perez and Soete,1988).

But we think market is an important dimension for catching-up process in a globalized world. Innovation is a new combination of technology with the market. Interactions of producer and users are extremely important for innovation(Lundvall, 2006)For the case of China, market is extremely important. When facing touch competition from multinationals with technology advantage in China, using local market knowledge became their first surviving strategy for local companies. The capability of Chinese companies is how to use the existing technology in a new

market. Just good technology does not mean you will win the market. The key is how to meet the market needs. The weakness part of multinationals in China is their poor knowledge of local market. For example, Nokia in China, never win the design war for handset with local and other multinationals. The Chinese customer pursues the latest fashion of the handset. But Nokia usually puts design as second to the function. This is why sometimes, Nokia lost market share to local or other multinationals in China in handset market at the beginning of the decade.

Following the above arguments, in this paper, we propose that for a company in developing countries, the key opportunity to enter the innovation competition lies in the gap or mismatch between the existing foreign products with real market needs in China. It is the market opportunity that provides Chinese company the incentive to innovate in a competitive background with foreign and local companies. If there is a large gap between the imported products with local demands, the domestic companies will get a strong incentive to innovate. Mismatching can take the following forms: the product is good for China, but the price is too high; then, it will open a large space for Chinese companies to follow in. Or, the design of the product is not suitable for local market. Then, redesign will be required to adapt to Chinese market. This kind of mismatching usually lies everywhere as products developed by multinationals are designed for home country market. They will use their advantage to produce that in developing countries. But market needs in China can be totally different from multinational's home countries. Chinese market needs are more low cost oriented, more diversity, dynamic and complexity than other developed countries.

So, in China, market opportunity for path following catching-up will be extremely important. This is the starting point and the base for companies in China to compete with multinationals in China with advanced technology. The core competency of Huawei, ZTE and others are their capability to innovate in low-end market. But for leapfrogging catching-up, market opportunity is not as important as the one for path-following. Leapfrogging cares about how to narrow the technological gap with the leading companies in the world.

3.2 Technology opportunity

In the earlier literature, new and dynamic industries will open more technology opportunity than traditional industry. This is why in earlier literature, from Gerschenkron (1962) on, emphasized that targeting new industry can give late-comer country a good opportunity to catching-up. In Perez and Soete(1988), university and research organization can help create opportunities for catching-up in new technology area.

For understanding the catching-up process in Korea and Japan, reverse engineering is the first lesson for catching-up in the late comer countries. Japan, Korea and China from 1950 to 1980s are the typical example (Kim, 1997).

In recent years, technological regime became a popular dimension to understand catching-up. Among its factors, technological opportunity is the most important one. Malerba(2005) explaned that technological opportunity reflects the likelihood of innovations for any given amount of money invested in search. But the key point with

technological regime for understanding catching-up is what the determinants of the change for catching-up are. In Lee and Lim(2001), they think cumulativeness of technical advance, the predictability of technological trajectory as the important dimensions of the technological regimes. Regimes in which innovation is more predictable and frequent will give latecomers more opportunity to catch up; such as the case of DRAM and automobile industries in Korea. On the opposite, latecomers will have less opportunity to catch up; the PC and consumer electronics industries in Korea illustrate this situation. But this kind of technological regime has some bit of technology determinism. There are many factors related to nation-specific that are very important for catching-up process. For example, automobile and IC are regarded by Lee and Lim as suitable regime for catching-up, while PC and consumer electronics are not (Lee and Lim, 2001).

But in Chinese case, the catching-up experience is just the opposite of Korea. The automobile and IC industries which have succeeded in Korea have lagged behind more that of PC and consumer electronics industries in terms of catching-up in China. So, to explain catching-up, technological regime just in terms of knowledge cumulative is not enough to understand the catching-up in China. So, it is necessary to improve the approach of technological regime to understand technology opportunity of the catching-up.

In our understanding, the technological opportunity of catching-up can be opened in other ways. For example, government support in university and public institution has been proved to be a good way in Korea and other developing countries (Kim, 1997). Usually, in China, government's target is to find an opportunity to skip some stage of innovation and lay down the foundation for new generation technology so as to narrow the gap between China and the world as soon as possible. Their main tools to achieve the target is government's science and technology program and five year's plan. The most important factors behind the plan are not market performance, but the breaking up the monopoly of multinationals and strengthening national security. Sometimes there is a technological breakthrough that will pay the way for catching-up and next generation technology for some industry.

For path-following catching-up, technological opportunity is not as important as that of leapfrogging catching-up. Without new technology, there will be no leapfrogging. Path-following can be reached by applying existing technology to a new market or new technology to an existing market.

In China, the most important opportunity for path-following catching-up comes from the possibility of redesigning the product in a new way and entering the product system, not the invention of total new technology. The openness of the product system design can give late comer more opportunity to make innovation based on the existing product system. Closeness means not easy for latecomers to learn and enter its future development. The openness can be a technical problem, for example, some processing knowledge is by nature of tacit one, some are more artificial, for example, software code or standards. The owner of technology has the power to open it or not. This is related to apropriobility of the technology. If the product system is easy to be learned by reverse engineering, there will be lot of copy and other similar activity. Innovation

will be second for companies in developing countries.

When redesigning of the existing product is possible, there can be an incremental or stage-skipping catching-up pattern. When redesigning is not possible, it means a totally new technology is needed, this is a leapfrogging pattern of catching-up.

3.3 The 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 catching-up. Targeting progressive industry is a government's strategy to catching-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 2 gives a brief overview of the main programs controlled by Ministry of Science and Technology (MOST).

Table 2 is here

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

In the case of path-following, government will play a limited role. Most of innovative companies in China are good at the innovation in the low end market. They will steer their own way of how to innovate. In the case of leapfrogging, government will play a very important role. They would mobilize their own resources to catch up, such as R&D subsidy, standard setting, industrial strategic alliance and public technology procurement. So, in this kind of catching-up, GRIs and SIE will be the main actors in the first stage. Though later on, nobody will be sure who will get the cake for the technology. This is a technology-driven catching-up process. We think the 3G catching-up process is one of the kinds. TD-SCDMA in China is in the process between R&D and final implementation. It is not clear that whether this kind of model can lead to success.

3.4 Learning activity and alliance strategy

Learning is one of the most important ways for companies to master the necessary technology for catching-up. The learning activity can be in forms of the following: formal alliance with foreign companies, own R&D activity, outsourcing to local university and research institutes, from the existence of foreign companies in China.

Different from a time that companies relied on imported technology to operate,

companies have to emphasize their own R&D lab to improve their innovation capability. In 1995, total R&D expenditure from enterprise was 15 billion RMB. In 2005, it was 167 billion RMB, with an annual growth of 27.85%, which is higher than that of national R&D expenditure, 21.7%. Its share in GDP increased from 0.26% (1995) to 0.92%(2005) of GDP (Figure 2).

Fig 2 is here

Chinese companies have been using outsourcing strategy with local university and public institutions to improve their innovation process. During the last five years, they have been spending more money to do that. In 2004, about one third of their R&D expenditure outsourced to university and research institute(Table 3).

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Table 3 is here

Besides local R&D collaboration, international strategic alliances and global outsourcing are also very important forms for Chinese companies to learn and innovate. International technology alliances and mergers have became more important for Chinese firms to become international competitive once they have grown to a certain scale based on their market-oriented innovation and low cost strategies. At this stage, limited technological capabilities and lack of branding are common bottlenecks. International technology alliances and mergers with other multinationals' relevant business can strengthen the areas in which they are weakest.

One typical example is Huawei. Huawei has setup joint laboratories with TI, Motorola, Intel, AGERE, ALTERA, SUN, Microsoft and NEC, as well as a joint venture with 3COM. More recently, the acquisition of IBM's PC division by Lenovo for US$ 1.75 billion is another example of Chinese companies to access latest technology.

Currently, several Chinese firms are expanding their R&D activities globally to access global knowledge. For example, Huawei has set up five research institutes abroad, in Silicon Valley and Dallas, USA, Bangalore in India, and in Russia. In Bangalore they now employ 800 software engineers, most of them locals.

Immigrants of overseas Chinese become the new Argonauts to mobilize the latest knowledge to China (Saxenian, 2006). This is especially true in TD-SCDMA case.

For both of path-following and leapfrogging cases, learning activity and alliance strategy are important. The catching-up companies in China almost started from zero in their catching-up process, they have to find an efficient way to learn and alliance so that they can access the leading technology as far as possible. For leapfrogging catching-up, alliance with leading foreign companies, collaboration with local university and research institutes will be most important. For path-following, companies' R&D activity will be the key for their innovation.

3.5 C**ompany's innovation strategy**

There are several strategies for Chinese company to adapt to compete with

foreign companies.

For path-following catching-up, cost advantage that based on Chinese low priced resource is the most important one in the current stage. Since Chinese market is huge, market segmentation is very important to win the market competition. The most success strategy is to innovate in the low end market which has been missed by existing multinationals in China by applying existing technology or new technology into new market.

For leapfrogging catching-up, the companies must have access to the latest technology and the ability to introduce their new technology to the market and to compete the existing foreign technology system usually.

The above five elements will be the key factors to understand the catching-up process in China and by this, we reached a new framework (Figure 3).

Fig 3 is here

The role of five elements in path-following and leapfrogging catching-up can be seen in Table 4.

Table 4 is here.

4. Catching-up in Telecommunication Equipment Industry of China

Telecommunication equipment industry in China has its special features. It is a most progressive and open industry. Besides multinationals, local companiese are catching quickly in the last twenty years. We can divide the catching-up process in three stages, that is, phone digital switches, GSM and 3G. In the following, we will see how Chinese companies narrow their technological gap in these different stages.

4.1 Path-following catching-up: fixed phone digital switches

4.1.1 Market knowledge and opportunity

The high growth rate in telecommunication industry can be seen from the following facts: from 2000 to 2004, the amount of investment was never below 200 billion a year. The rate of fixed phone holder in 1995 was 3.35 per 100 capita; 11.45 in 2000;24.9 in 2004.The real holder in 1995 was 0.4 billion, in 2004, the number is 3.12 billion, making China the largest fix phone holder in the world (Table 5).

The market for wireless phone has a more accelerating growth. In 1995, the number of mobile hand holder were 3.62 million, in 2004, it was 0.33 billion.

Table 5 is here

The diversity of telecommunication is also astonishing. In rural area, the main product needed is fixed phone, while in metropolitan city, the market for data business, VPN, multimedia telecommunication was expanding quickly.

Facing the huge and fast growing market, domestic companies had very limited capability to respond because they could only make common fixed telephone sets and some parts. So, technology import became urgent and necessary.

In the end of 1982, the first digital program switch controller was imported from Japan. It was called F-150 and established in Fujian Province.

In 1984, the first joint venture was Shanghai Bell as the result of long negotiation of Chinese government with Beligen's government. Its main product was S-1240. Bell Telephone Manufacturing in that time was a son company of the ITT at that time and later was acquired by Alcatel. Shanghai Bell became a very important company in Chinese IT industry. In 1990s, it was the largest IT equipment company in China.

In 1988, Beijing International switching company(BISC) was established. It is a joint venture with three Chinese partners and German Siemens. Its main product was digital program controlled switches—EWSD, developed by Siemens. In 2000, Shanghai Bell, Huawei and BISC were the top three switches suppliers in China ,

In 1993, Lucent established its joint venture in Qingdao and began to produce its product—5ESS—2000. It was said that localization was about 50%.

The main joint venture in digital phone switches market can be seen in Table 6:

Table 6 is here

In early 1990s, most of main multinational's products with different brands came to China in the switches market. In 1995, it is said that all main models of digital program controlled switches in the world were used in China.

In 1996, the market was dominated by foreign related joint venture(JV), for example, in Beijing area, local companies only got a market share of 4.4% (Table 7).

Table 7 is here

But the rapid expansion of imported digital switches did not mean there was no mismatch between the existing products and potential market needs. Firstly, most of imported or JV's production were used in the large city area and their design were based on market needs in their own main market instead of the Chinese market. For example, there was once a time a big problem in China: fixed phone users often accessed internet via fixed line, this made the phone line very busy. Huawei found that problem and introduced a solution for that. Secondly, the price of their products were usually high, the users in the small city or rural area did not have the capability to pay for it.

4.1.2 Learning and knowledge accumulation

In the earlier stage, both domestic companies and university and GRIs lacked relevant knowledge of digital switches. The market was dominated by foreign companies. Knowledge flow from those multinationals was critical for later on emerging of domestic companies. In some sense, the window of opportunity was opened by FDI.

In the paper of Mu and Lee(2005), they pointed out that Chinese government has used their power to influence the knowledge flow from multinationals to domestic companies. One is bargaining power, that is, to use market size as a source to push multinationals to transfer technology. This is coined as the strategy of "trading 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, to demand 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. Firstly, quite often, foreign part would have a dominant role in the board and would not transfer the key technology for reason of competition and others. Secondly, SOE itself did not have a strong incentive to acquire the technology. In the automobile industry, researchers found that joint venture is not a good institutional arrangement for technology transfer (Lu and Feng, 2004).

Spillover of FDI is very important for Chinese companies to learn the latest technology. 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 center in China, these centers will not have much direct contacts with their company in China. The main function of R&D center are to localize their products and service for the global needs(Gao, 2004).

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),

Another 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)

Role of government and innovation of HJD-04

Since the first joint venture in digital program controlled switches, China has gone into a huge market growth. The market needs drove both government and companies to make domestic and cheap machine for the market.

The first is that Chinese engineers used new technology to redesign the old product. Following absorbing knowledge from different design of digital switches in different areas, Chinese engineers mastered the advantage and disadvantage of them. In the same time, the technological progress in computer gave them a hand to make

the architecture innovation possible.

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.

Technology opportunity and the openness of product system

The opportunity of the catching-up is depending on how wide the window for catching-up? IT industry is a network industry with a wide window for catch up than other industry like automobile.

The first technological opportunity came from the technological progress in computer design in 1980s 1990s. The chief designers of the forthcoming innovation in digital switches is a former computer engineer. They are familiar with computer design. When assigned the task to design a new kind of digital phone switches, they thought the new machine should borrow some concepts of design from computers. This good idea laid the foundation for the future successes.

Secondly, they should thank the open structure of the existing digital network. Before the program controlled switches are popular in China, there are six levels of the public network: level one(C1) for international transit, level two(C2)for provincial transit, level three(C3) for city transit, level four(C4) for county transit, level five(C5) for town and level six(C6) for village. In the digital program controlled switches, China used the open No.7 Signaling system so that different switches can access the same phone system and different scale of transit can enter in each level. So, the development of digital network is an incremental process. This ensures that late comer can enter the market in anytime, rather than being kept out of the system. Chinese network system is based on a open No.7 signal system, it opened a time for lots of foreign products to enter Chinese market widely, in the same time, it paved the way for the later entrance of domestic companies with new technology.

Companies' innovation strategy after HJD-04

The Chinese new product HJD-04 is a small scale and low price system and can be used in C4 or lower level. At that time, MNCs or JVs did not pay much attention to the rural market. They targeted the high end city market. Even they tried to do so, their high price product may not suit to the needs of county users' needs.

The first company to sell the HJD-04 is called Great Dragon. It was established in 1995 as a son company of Luyang Telephone Equipment Factory with other SOEs under MPT. The emergence of Great Dragon became the symbol of national hero to break the dominance of foreign companies. In 1998, Great Dragon had a 14% of market share (Mi and Yi, 2005). But the innovator may not be the final winner of the market. Today, ,as a SOE that lacked good mechanism to make sustainable innovation, Great dragon lost its market leader position to late Huawei and ZTE. Great Dragon also had involved IPR debate with Zhengzhou Institute of Information Engineering of the People's Liberation Army.

The next important innovation based on HJD-04 was done by Xian Datang, a GRI under MPT. They also got the idea that it is good to incorporate knowledge of computer design into digital switches. Datang was setup as a spin-off companies specialized in product development in 1995. They introduced their new product of SP30, which has more high speed and volume than HJD-04.

But in digital switches market, coming late means getting more. Huawei and ZTE, both late comers with an ownership structure of private companies, aimed the low end market with their own technology. In 1993, ZTE launched out digital product ZXJ2000 for rural market while in 1995, Huawei developed its own digital product C&C08. Both ZTE and Huawei aimed at rural market (small town and county) which was neglected by multinationals. Both of them started earlier to develop product of accessing equipment which can make exchange among different system of digital switches possible. This is a unique problem for China, but these two companies have a much more quick response to the market needs. So, since these two companies entered the market, they emerged from the innovation capability in low end market and left the high end market to multinationals and JV first. It is the rich market knowledge that lay down their success in the competitive industry.

Besides that, they also accumulated their production knowledge in a fast way. From 1997, Huawei invited international consulting companies(Towers Perrin, The Hay Group, Pricewaterhouse Coppers(PWC) and Fraunhofer-Gesellschaft (FhG) to get advice of how to establish IT-based managerial system, human resource management, quality control, etc.. They had a long term collaboration with IBM to introduce IBM's system of integrated product development(IPD) and integrated supply chain(ISC) into Huawei so as to reduce the lead time of new product and more fast to respond to the market needs(Mi and Yi, 2005).

Since then, Huawei entered a period of boom: in 1996, with gateway of 1.8 million; in 2000, 12 million; in 2001, 16.59 million, a level just second to the Shanghai Bell (Table 8). Now, Huawei is number one in traditional program control switches in the world with about 16% of market share(Economic daily, April 20, 2006).

Table 8 is here

In 1998, ZTE began to apply the AT&T's management system of R&D so as to increase its efficiency in R&D department. Following that, it introduced two new departments: system and testing departments. It also reengineered its R&D process(Mi and Yi, 2005).

The local manufacture in program controlled switches now played more and more important role in Chinese market. In 1992, the market share of local manufacture is about 10.6% while in 2000, it became 43%（Mu and Lee, 2005,p.764）.

4.2. Path-following Catching-up in GSM and CDMA

The market knowledge and opportunity

In 1987, China began to deploy wireless phone system. The system is a simulative 900 MHz TACS. The main equipment providers were Motorola and Ericsson. The former network was called Network A adopted by 21 provinces and large cities. The latter called Network B was adopted by 15 provinces and large cities. These two networks were interlinked each other. In the end of 1995, there were 3.47 million users in China(Mobile Telecommunication Research Team, 1997).

In 1994, GSM, a digital wireless system was introduced by Chinese government and it gradually replaced the former TACS system. At the end of 1995, it had 0.15 million users, but in the end of 1996, it reached about 1 million(Mobile Telecommunication Research Team, 1997). Since that year, GSM entered its fast growing period until now.

In the mobile phone market, there was no big mismatch between what multinational offered and the real market needs in China. Since the earlier time, mobile phone had experienced an explosive growth. The market from 1994 to 2005 has been continuously growing with a speed of each year adding new users as existing users. It is a kind of exponential growth. This had accelerated the infrastructure building (Table 9)

Table 9 is here

The market in the earlier time was opened by multinationals and also controlled by multinationals.

Motorola entered China very early. In 1987, it set up an office in Beijing. In 1992, it set up a wholly owned company in Tianjing. Till 2000, it had already invested 28.5 billion RMB in China. It was the largest investment in IT industry in China. Its investment got its rewarding: China is the largest market outside of USA for Motorola. In 2000, its sale in China was 37.5 billion RMB.

In 1985, Ericsson opened its first office in Beijing. In 1992, a joint venture with China Putien was set up. Till 2000, Ericsson had invested about 0.6 billion USA dollar in China. Its products cover from system to end products for mobile telecommunication.

In the same year with Ericsson, Nokia opened its office in Beijing. Now Nokia is

the leading company in mobile market. Before 2000, it had already invested in China more than 1.7 billion USA dollar. In 2000, it had a sale volume of 2.8 billion USA dollar in China.

The market share is illustrated in the Table 10. Motorola, Siemens, Nokia, Ericsson, Lucent and North Telecom were the main winners of the market. Domestic companies only had a share of 3%.

Table 10 is here

Since Huawei and ZTE have already accumulated experience in equipment manufacturing and service, it seems that they can enter the GSM market easily and to copy their successes in mobile switches. Since 1995, the market has undergone a sharp change: mobile telecommunication became the hot products and experienced a fast growing stage. Motorola, Nokia and Ericsson became the main players in the new market.

Technology opportunity

But the GSM market is more closed compared to digital switches. In GSM system, there is Abic interface between base station controller (BSC) to base transceiver station (BTS) that is not open. Then if in a region one system of mobile telecommunication is deployed, all mobile switches, BSC and bases have to be compatible. This makes locked-in become possible. As all of the telecommunication infrastructures were built by foreign companies, it left no space for domestic companies as Huawei and ZTE. Besides, Motorola, Nokia and Ericsson have longer experience in GSM than Chinese new comers.

Therefore, all Chinese companies thought in that time that CDMA is one of the new opportunity for Chinese companies to enter the industry. At the same time, they began to try to enter the new CDMA market. CDMA is one of the technologies to break the GSM monopoly in China. So, Huawei and ZTE both spend huge money on the development of CDMA. During this time, government also tried to deploy CDMA system so that it can break the monopoly of GSM in China. In 1999, China Unicom(Liantong) was established as the unique CDMA operator in China. In 2001, both Huawei and ZTE joint the bidding process for the Unicom project. The result is that Motorola got the biggest piece of cake and ZTE got small one. This forced Huawei to go to abroad. Based on their efforts on CDMA, they later on became a membership of WCDMA club in 3G standards.

In the same time, they never stop to enter the GSM market. They learned and won some marginal and value added markets. For example, both Huawei and ZTE made themselves as the dominant providers for text message and intelligent markets.

Besides, both companies have targeted future technology, for example, NGN, as their own leapfrogging strategy.

Role of government

The size of Chinese market had given Chinese companies a leverage to access the

leading technology in the world. Via government's market for technology strategy and attracted by Chinese market size, Qualcomm in 2000, licensed its technologies to Huawei, ZTE, Datang and other companies of base station, switches and handset.

Knowledge accumulation and alliance strategy

Motorola has a wide horizontal and vertical linkage with more than 700 local Chinese companies. In the same time, knowledge spillover was observed by companies involved those transactions, especially knowledge of logistics, quality control and standardization.

Labor turnover is also one of the important ways of knowledge transfer. This does not happen in foreign companies, as they can give their employee very good salary. So, they usually recruited a lot of talent experts from Chinese companies. From our interview with the CTO for Beijing Capital Telecommunication, a son company of China Putien(the General Group of MPT) but also parent company of joint venture with Nokia in Beijing, we learned that Capital Telecommunication is the earliest companies in mobile phone industry in China as they formed joint venture with Nokia. So they leaned a lot of knowledge from the joint venture. But as a SOE, it did not have a strong technology incentive to innovate. The result is that a lot of engineers went to Huawei, ZTE and other Chinese companies. It meant that most of the earlier SOEs with advanced knowledge would be the large training schools for private companies[1].

How can they enter the wireless market so quickly with their own capability? Firstly, both of them continuously upgrade its technology by heavy investment on R&D and human resources. Huawei is the highest in technology intensity in ICT industry in China. Since its establishment, Huawei has spent about 10-15% of its sales to R&D. In 2005, its R&D/sales is about 10%. It aimed earlier on 3G technology than other domestic companies. Huawei and ZTE's R&D and sales is shown in Table 11.

Table 11 is here

Secondly, both Huawei and ZTE used the alliance strategy with foreign companies to get the latest technology.

Huawei adapted alliance strategy to learn the technology. It has set a joint digital signal processing lab with TI to jointly develop DSP products, a communication system lab with Motorola, a joint lab with Lucent and Sun (2000). It has established partnership with 3Com and Nortel (ultra- broadband access solutions).Besides that, Huawei established its R&D centers globally in USA, Sweden, Russia, India and others. The biggest one is in India focusing on software with more than 800 engineers[2].

ZTE entered PHS with an alliance with Japan's Kyocera. Only later, they spend money on their own station development.

Innovation strategy of local companies

Facing the tough competition from multinationals and technological locked-out effect, local companies have to find other way to catch up.

[1] This is from an interview with Mr. Lai, the former CTO of Beijing Capital Telecommunication in 2006.

[2] This is based on our interview on April 16 of 2006 in Huawei.

Again, they had to find missing or low end market that neglected by multinationals. ZTE decided to be the main system provider for PHS, a technology invented by Japanese company. The advantages of PHS are its low cost and wider coverage. Huawei did think PHS a good product for its low technology and possible limited market. All multinationals were busy to expand their GSM network in China. But ZTE look PHS differently. First, China Telecommunication was willing to build another network to get a share in wireless market. Second, PHS had a big advantage in cost. For example, it allows no charge for receiving call while both GSM and CDMA charge users when receiving call. Third, there is a mass market in Japan. It means that the technology is mature. Fourth, 3G is a future market and PHS can give ZTE some experiences of how to deal with 3G.. Following this kind of logic, ZTE entered the system network market in 1999. The market gave ZTE a big reward. In 2002, ZTE had a sale of PHS in 3 billion Yuen. In Sept. of 2004, the users of PHS was 57 million, CDMA only got 22 billion in April of 2004(Mi and Yi, 2005, 33-35).

They established themselves in new market needs, such as text messengers, ring sound. Huawei constructed mobile intelligent network for China mobile for users to make prepay phone call possible. When text message became big market for value added service, Huawei quickly established its capability here and get two third of Chinese market for the equipment(interview).

The last strategy is going global to access international low market. When China delayed its 3G time to time, Huawei had to enter international market for making balance. In 2005, about 60% of its sales comes from international market. Now, Huawei owns 69 WCDMA basic patents, about 5% of WCDMA total basic patents, constructed WCDMA for more than 15 countries. In ICT industry, Huawei is the number one in invention patents. It has more than 4000 patents in wireless area. In 3G, it has more than 200 patents (Qiu, 2006). It turned out that Chinese companies are good at innovation for low end market (Table 12).

Table 12 is here

ZTE also had make great progress in international market. Just in 2003, they had 1.5 billion dollars of orders from international market. The regions include Pakistan in south east, Russia, Nigeria Zambia and Ethiopia in Africa, Spain, Portuguese of Europe and Peru and Chili of South America (Mi and Yi, 2005).

But their strategy is not just stick to low end market. They aim to climb the high end market as far as possible. For example, they both now prepare the next generation network such as NGN so that they can enter a leapfrogging track in future.

The performance of the catch up can be seen from Table 13.

Table 13 is here

4.3 Leapfrogging catching-up in TD-SCDMA

Market knowledge and opportunity

TD-SCDMA is not the result of mismatch between the existing technology and Chinese market needs. The key problem is that as Chinese companies have been locked out of existing 2G GSM network, the government agency and researchers have

got a strong pressure to leapfrog the next generation technology so that Chinese companies can have more competence in the future.

Role of government and technology opportunity

Since in 2G market, GSM and CDMA have a network effect, hence, whether China can play or how China play a role in 3G is critical for the government and business.

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.

The latest knowledge from overseas Chinese are critical for the ongoing leapfrogging innovation in TD-SCDMA. In the innovation process of 3G, the most important actor is Datang, a former government research institute, Research Academy of Post and Telecommunication, MPT. In 1998, this GRI was transformed into a technology based SOE, but research was still one of its main functions. As a research institute, it had some industrial experience in digital switches for fixed line communication. Also by the government support, it had knowledge of 1G and 2G-GSM. But there is no commercial products followed their research.

After many years of research on CDMA, Chinese engineers found that they can not bypass Qualcomm's IPR to development new technology.

In 1994, two overseas Chinese, one worked for Motorola called Chen Wei, the other from University of Texas, Austin, called Xu Guanhan, met together to develop a new wireless network technology to bypass Qualcomm's technology.

In 1995, they went to Beijing and had a nice talk with Mr. Li Xuhe, the vice director of Research Academy of Post and Telecommunication, MPT. They had same ambition and idea. They set up a company called CWILL in the USA and in the same time, they set a Chinese joint venture called Xingwei between CWILL and Research Academy of Post and Telecommunication of MPT.

In 1995, a new technology was invented by those mixed research group: a TDD model other than FDD model of WCDMA and CDMA2000. The main inventor is the overseas Chinese engineer, Mr. Chen Wei. The new technology system is called TD-SCDMA (Time Division - Synchronous Code Division Multiple Access), with characteristic of synchronization, smart antenna and software defined radio, joint detection, high-speed transmission technology for downlink packet data (Jiang Xiaoxin, 2006). Compared with other mobile systems, it is said that TD-SCDMA boasts outstanding technological benefits:

High Spectrum Efficiency: better supports dense services in populated areas. It is capable of making full use of fragmented spectrum, and effectively alleviates spectrum resource shortage and limitations at carriers' side.

High Capacity: adoption of high-edged technologies dramatically lowers interference and increases system capacities.

Highly Suitable for Operators Asymmetrical Data Services: As TD-SCDMA is competent for dynamically adjusting data transmission rates with uplink and downlink, it specially suits to handing asymmetrical IP data services.

Low Costs: Adoption of Smart Antenna technology decreases transmission Power

in TD-SCDMA system and dramatically lowers the cost of the system products.

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.

Role of government and the alliance of TD-SCDMA

But the next step is also critical for TD-SCDMA. When applied for a third standard for 3G communication, ITU only needs some simulation results without any testing. But to make the new standard a commercial system, more steps are needed. In the earlier time, the government did not provide lots of help. So, Datang, had to find real partner who has both the money and technology. Datang seeked TI and Philips for help in the first round. Only very late they found that Siemens showed its interests and both signed the cooperation contract soon. The development project consisted of two parts, base station and end product. Siemens almost finished the joint development in base station. Since for a long time the market is not clear, Siemens stopped the further development of end products. Later on, some other companies such as ZTE, also joint the technology development of TD-SCDMA. Because this complex joint process, there is a wide distribution of patents in this technology. A report done by Norson Telecom Consulting company, based on patent databank, found that there were 148 patents related with TDD, Siemens had 21.6%; 66 patents related with SCDMA, Siemens had a share of 21.2%, but here, Datang and ZTE have almost similar share(Norson, 2006)(Table 14).

Table 14 is here

But standard plus patents are not enough for innovation. Most operators still think 3G is not mature for China. Even ready to implement 3G in China, the existing 2G companies would think WCDMA be a more mature technology than TD-SCDMA. There is also a problem that WCDMA can be thought as expanding of GSM network, TD-SCDMA is not compatible with that of WCDMA and other networks. Huawei and ZTE used their WCDMA and CDMA2000 to get market in other countries, though they spent some money on TD-SCDMA. This kind of situation made Datang have a very hard time before 2002.

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. The members in the alliance includes Huawei, ZTE, China Putien, Lenove and others. Besides that, the government invested 0.7 billion Yuen for further testing and other purposes. Partners of TD-SCDMA are as follows:

- System equipment: Datang, Siemens, UT Starcom.
- Network equipment: Siemens, Huawei, ZTE.
- End product chip: TI, Philips, STmicroelectronics;
- End product: Samsung, LG, Hauli, Lenovo,etc.

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.

Challenge of leapfrogging catching-up

Firstly, the technology is still undergoing small scale of testing for further improvement. Datang has already spent about two billions yuen for R&D of TD-SCDMA. Most of the money came from state-owned bank loan. Who will spend more money to finish the testing and improving before the final use is still unclear. The operators and government can not fully decide before all the tests are finished.

Secondly, even if the result of the test is good, there is still a risk of how Datang as a SOE can push that further to the actual uses. Former experience of digital fixed phone switches is a good example. Though the SOE Great Dragon is the main innovator, but the poor management capability could not guarantee them to spend more money on R&D for further innovation. They just watched how Huawei, ZTE and others took over the market as a late innovator. Datang may not be the final winner of the TD-SCDMA, even if the government will issue the certification as one of the 3G networks for that.

The role of government is very critical for the leapfrogging catching-up in TD-SCDMA. But this will lead to strong government interference and possible negative effect for their decision making far away from market decision making. For example, after TD-SCDMA became the international standard, Datang needs other stakeholders to enter the industrial chain to invest and share the intellectual property rights. But how much they can get from their open the standard codes for other relevant manufacture? The government influenced the price setting. Finally, they only got 50 million Yune for their uncovering more 1000 texts and 2.8 million Chinese standards codes(interview). This amount is very small compared to its billions of R&D investment. It may be a good strategy for others to use and diffuse the standards. But in the time, as a small company in the industry, this gave Datang a fatal blow of how can they get money to do next important job.

Third is the efficiency of industry alliance. On one hand, though there are many

local and foreign companies joining the alliance, this makes future transaction costs be very high. It is not easy to coordinate all players and push the technology forward. On the other hand, lot of so called alliance partner are watching and standing by to see the government's further action. TD-SCDMA is just one of their technology options.

Fourth, how big 3G market will be is also critical for its future. Some optimistic said that the market value of TD-SCDMA will be about 400 billion yune (Zhou Huang, 2005). But some researchers pointed out that 3G made no money in other countries. Can Chinese be an exception?

Fifth, it is said that TD-SCDMA is not compatible with other 3G standard network. This can be a fatal drawback for the technology.

Lastly, should government or operators decide use of 3G technology for the market. To adapt strategy for indigenous innovation, it seems that it is rational to purchase TD-SCDMA as a main 3G technology provider. But as a member of WTO, China is also cautious as to favors TD-SCDMA against WCDMA and CDMA2000. So, MII just announced that in order to match the WTO, it is the operators (market), not the Chinese government, has the power to decide what kind of technology and standards should be used in Chinese market. This gives future 3G market a blur for the role of TD-SCDMA.

5. Conclusion and discussion

Telecommunication industry is of the most dynamic industry in China. Most of FDI clusters in this industry and most innovative domestic companies also came out from this industry. Thus, we take the industry as our research object to study how catching-up and innovation happen in a Chinese industry.

Based on this industry case study, we found that the size of market, the new industrial context and open economy made Chinese catching-up different from that of Japan and Korea. More specifically, we take the mismatch between existing product and Chinese market needs as the starting point of catching-up, new technology as the opportunity of catching-up, the role of government, the innovation strategy that the companies take, alliance strategy for knowledge with local and international university, research institutes and companies. We think this framework is better than just considering the technological regime in Chinese catching-up case.

We also found that in telecommunication industry, there are two different technical approaches to catching-up. One is path-following approach driven by using new technology in low end market. The other is leapfrogging approach which tried to leapfrog some stages to the next generation technology. It seems that leapfrogging strategy will meet more tough problems of technology compatibility with existing (foreign) technology, the high risk of financial costs compared to the leading multinationals, the strong interference from the government and etc.

But in the catching-up process, the industrial structure also matters. Usually, the earlier birds for catching-up were the SOEs which are strongly supported by government, but they would lag behind as they do not have a clear ownership structure and get more interference from the government. This is why Huawei and ZTE have better performances than Great Dragon or Capital Telecommunication.

The first policy implication from this study is that government can play a very important role in the catching-up process in the earlier stage of the process and is more important in leapfrogging than in path-following catching-up.

The second policy implication is that open to the world and encouraging the collaboration and alliance activity can give companies in the developing countries more opportunity to access the latest knowledge. Without that, catching-up is almost impossible. In doing so, the Chinese government did little to protect the local companies since 1990s. So, the open, collaboration and alliance strategy can give late comers more opportunity to catching-up than protection of local company.

Thirdly, FDI can be a positive factor for catching-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 catching-up.

But our research is a single industrial case study. Our framework and conclusion have to be tested by other industrial study. We will try to find pair industry such as biological industry or automobile industry to explore their catching-up experience so that we can contribute more to the catching-up theory.

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Table 1 Outline of Chinese ICT industry

	2000	Oct.2006	Average annual growth	Position in 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 phe users	85.0 million	449 million	40%	
Sales of ICT industry	607 billion	3800 billion(2005)	31%,	Number 3 in the world

Source: The Speech of Wu Bangguo in World Telecommunication Exhibition in Hong Kong, Dec.3, 2006. www.xinhua.net

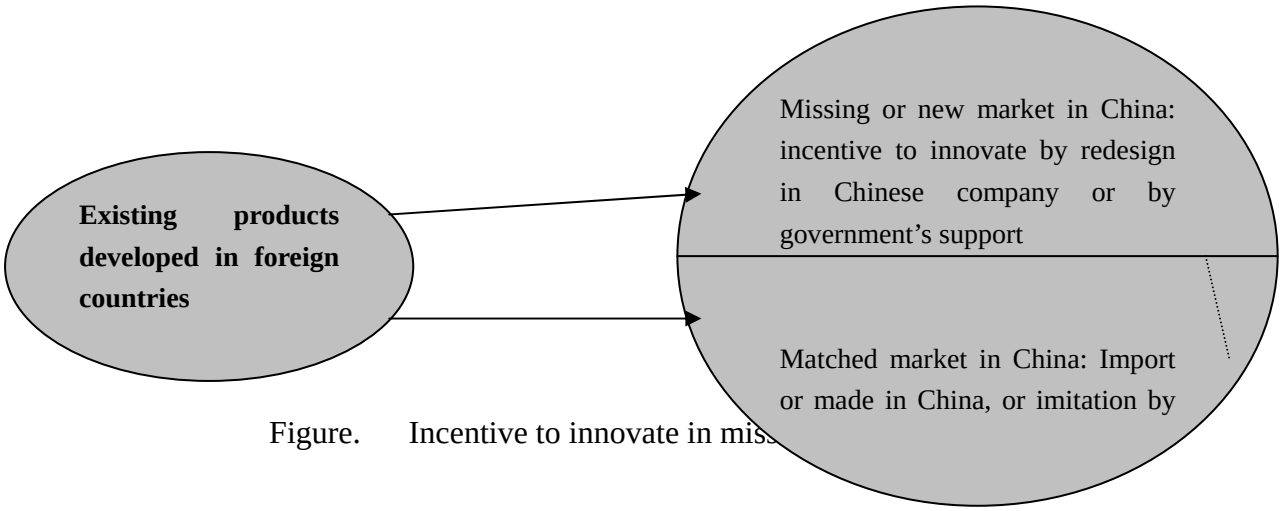


Figure. Incentive to innovate in miss

Table 2 Current national R&D Programs（in 0.1 billion RMB）

	1996	1997	1998	1999	2000	2001	2002	2003	2004
973 basic research			3	4	5	6	7	8	9
863National High Tech R&D program(from 1986)	4.5	5.054				25	35	45	55
Key Technologies R&D program(from 1983)	5.2	5.372	10.37	11.66	10.32	10.63	10.634	12.464	16.144
Torch program(1988, for high technology)	0.51	0.51	0.51	0.51	0.5	0.5	0.5	0．5	
Spark program(1988 for rural SME)	0.39	0.39	0.39	0.4	0.4	1	1	1	
Key S&T Diffusion program	0.19	0.19	0.2	0.2	0.2	0.2	0.2	0.2	

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

. Table 3 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	35.4	44.2	56.0	72.1	95.4
Funds for university	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	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: China Science and Technology Statistical Yearbook, 2005. Beijing: Chinese Press of Statistics.

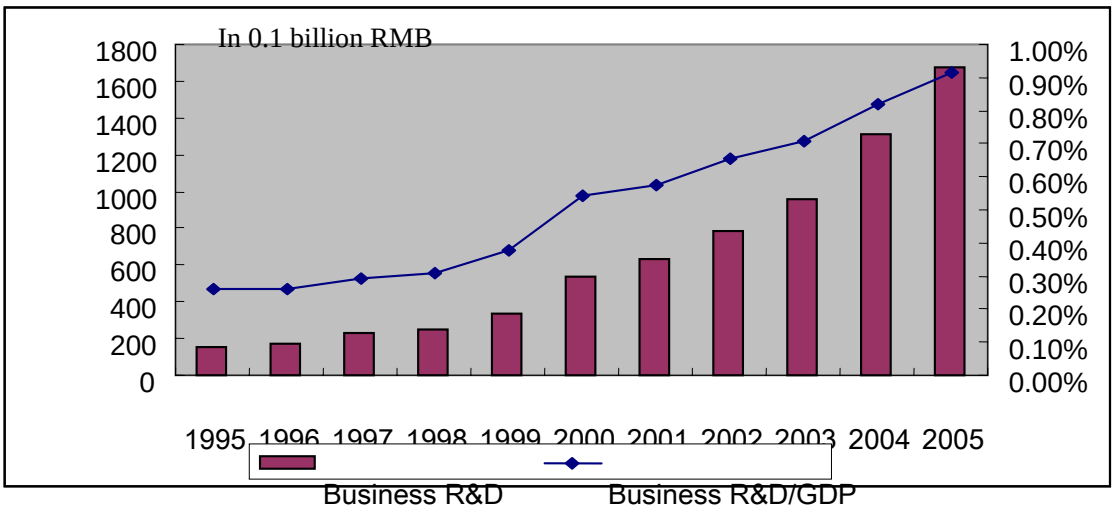
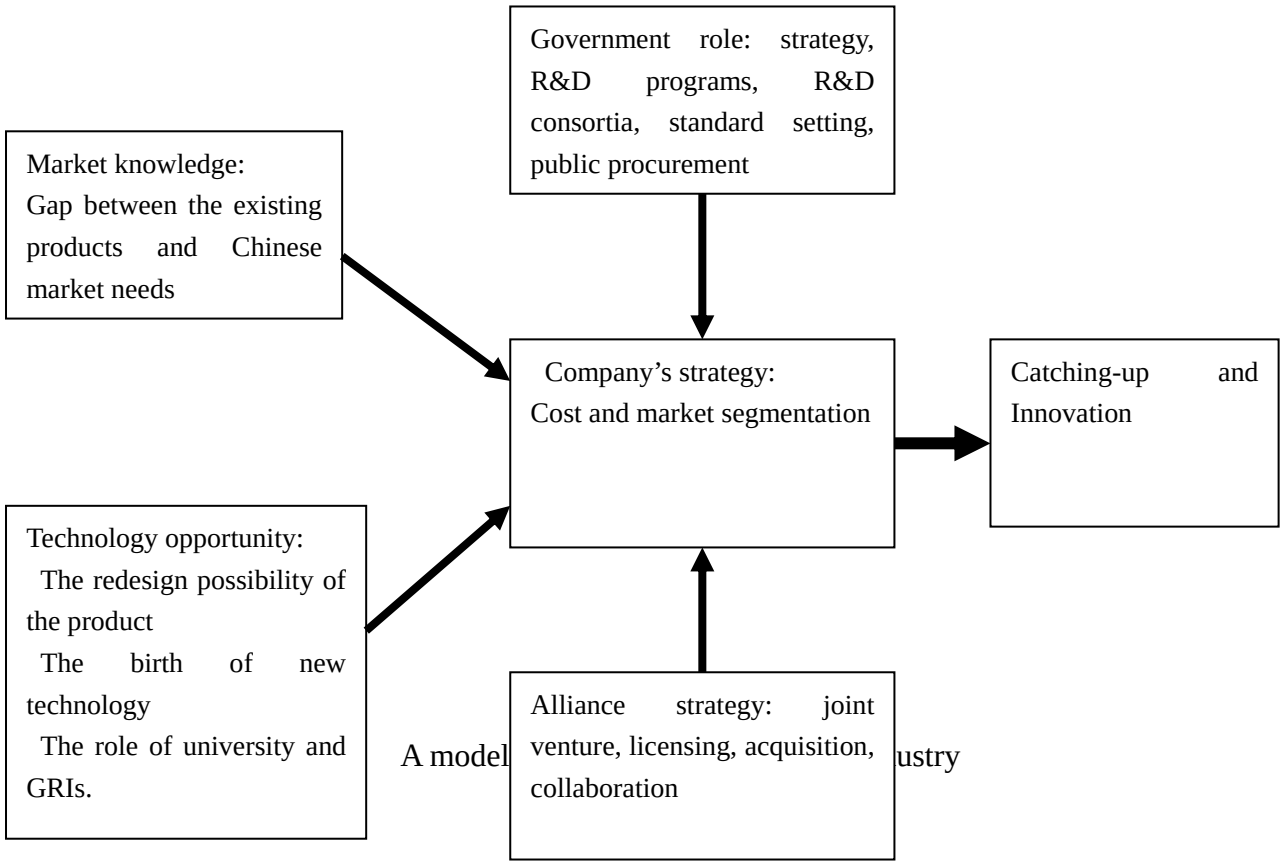


Figure 2 The trend of business's R&D in China（1995 - 2005）,

Source: MOST, Main S&T Indicators Database, 2006.



A model ustry

Table 4 key factors in path-following and path creating catching-up

	Path-following catching-up	Leapfrogging catching-up
Market knowledge	Current dynamic and complex market needs	Future market needs and vision, government target.
Technological opportunity	Technology from other industry, redesign the existing product	New technology, system technology
Role of government	Policy of market for technology	R&D subsidy, R&D consortia, public procurement policy
Learning activity	R&D activity, alliance with leading foreign companies, spill-over of FDI.	Alliance with leading foreign companies, role of university and research institutes
Innovation strategy	Innovation in low-end market.	Very important

Table 5 Main indicator of telecommunication industry in China

Indicator	Unit	1995	2000	2001	2002	2003	2004
Investment	Billion	199.5	231.4	264.2	210.6	224.6	217.3
Local fixed phone switches	Million gate	72.04	178.26	255.66	286.57	350.83	423.47
Long distance fiber	1000 kilometer	110	290	400	490	590	700
User of fixed phone	Million	40.71	144.83	180.37	214.42	263.31	312.44
Fixed phone popularity	set/100 people	3.35	11.45	13.9	16.8	21.2	24.9
User of mobile phone user	Million	3.62	85.27	144.81	206.62	268.69	334.82
Mobile phone popularity	set/100 people	0.3	6.77	11.2	16.19	20.9	25.9

Sources: calculated on China Yearbook of Electronics（1990～2005）, www.mii.gov.cn.

Table 6 Outline of joint venture's production in digital switches

Product type	Company	multinationals	Equity share by Chinese partner	Start year of production	Sales volume (10000 lines)1997
S-1240	Shanghai Bell	Alcatel Belgian	60%	1986	500
EWSD	Beijing International communication	Siemens Germany	60%	1992	300
AXE10	Nangjing Ericsson	Ericsson Sweden	43%	1993	80
NEAX-61E/61	Tienjing NEC	NEC Japan	60%	1994	70
5ESS	Qingdao Lucent	Lucent USA	49%	1995	150
DMS-100	Guangdong Nortel	Nortel Canada	60%	1995	100
F-150	Jiangsu Fujitsu	Fujitsu Japan	35%	1995	100
Total					1300

Source: "Key Industry Innovation" Project Team Report of Ministry of Science and Technology，1997。

Table 7 The share of different models in Beijing in the end of 1996

Model	Local phone switches	Share in the Beijing Market
AXE-10	4.63	1.3
E-10B	43.56	12.6
S-1240	84.20	24.4
DMS10	81.32	23.6
EWSD	116.50	33.7
Domestic products	15.18	4.4
总计	345.39	100.0

Source: "Key Industry Innovation" Project Team Report of Ministry of Science and Technology，1997。

Table 8 The sales of telecommunication manufactures in China in billion yuen

	1994	1995	1996	1997
Shanghai Bell	5.12	4.54	4.57	5.00
Beijing International Switches	1.57	1.02	1.72	1.99
Eastern telecommunication of POST	1.55	2.84	3.90	4.63
Shanghai Telecommunication of POST	0.47	0.57	0.61	0.65
Beijing telecommunication of POST				4.89
Huawei		1.28	Na	4.19

Sources: Top100 Chinese IT companies.

Table 9 The infrastructure of wireless communication has been expanding in China（1995 - 2001）

Year	Volume of Wireless switches （10,000 gateway）	New volume to the last year（10,000 gateway）	Wireless Switches station	New station to the last year	Total channels	New channels to the last year	Total users （10,000）	New users (10,000)
1995	797	425	5038	2569	186385	112054	362	323
1996	1536	739	10826	5788	403547	291493	685	638
1997	2586	1049	20796	9970	767442	363895	1323	1063
1998	4707	2121	34451	13655	1458178	690736	2386	1943
1999	7795	3088	54381	19930	2256063	797885	4329	4198
2001							14481	

Sources: Gao Shiqi, 2004.p.366.

Table 10 The market share of wireless telecommunication in China in 1999

	Motorola	Siemens	Nokia	Ericsson	Lucent	North Telecom	Domestic brands
Share of net increase in the year of wireless communication station (%)	36	15	14	13	10	9	3
Share of net increase of wireless switches (%)		44	12	12	10	19	3

Sources: Gao Shiqi, 2004.p.366.

Table 11 Huawei and ZTE's performance in international market in million US

Year	Huawei		ZTE
	Country market	Sales for international	
1997	Russia		Bengal
1998	India		PTCL, Pakistan
1999		50	
2000	Africa, Middle East	128	Russia
2001	Europe,eg.UK, France, Portuguese	330	Africa
2002	USA	550	India
2003		1,050	Nigeria, et. al., Europe
2004		2,000	
2005		About 3,400	

Source: www.cww.net.cn, www.huawei.com, author's calculation.

Table 12 Sale and R&D expenditure of Huawei and ZTE 2001-2005

		2001	2002	2003	2004	2005
ZTE	Sale	10.92		17.45	22.70	21.58
	R&D	0.79		1.33	2.25	1.96
	R&D/sale	7.2%		7.6%	9.9%	9.1%
Huawei	Sale	16.23	17.21	21.67	31.52	46.97
	R&D	3.05	3.06	3.18	3.97	4.75
	R&D/sale	18.8%	17.8%	14.7%	12.6%	9.6%

Source: China top 100 ICT companies.

Table 13 Technological catching-up in telecommunication equipment

Product	The first time of use in the world	The first time of introducing in China	Made in China first time by JV	Made in China first time by local companies	Technological gap with foreign products	Local R&D
Digital switches	1970	1982	1986	1992	No gap	Large
GSM	1980's	1994		1999	Large gap	Large
GPRS	2000	2000	2000	2000	Limited gap	
CDMA95	1996	1996			Limited gap	Middle level
CDMA2000 - 1X	2001	2003？			Limited gap	Large
3G	？	？	？	？	Gap narrowed	Very large
Light switches system					Limited gap	Very large

Sources: Gao Shiqi, 2004.p.375.

Table 14 The share of granted patents in TDD and SCDMA in TD-SCDMA

	Siemens	Datang	Huawei	ZTE	Nokia	Motorola	Qualcomm	Others
Share in TDD %	21.6	12.2	10.1	7.4	4.1	2.7	6.1	35.8
Share in SCDMA	21.2	15.2	12.1	24.2				27.3

Source: IPR in TD-SCDMA, http://www. Norson.com/ 2006.

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