China’s Development Model:

An Alternative Strategy for Technological Catch-Up

Working paper

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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 latercomers 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 their two-stage catch-up strategy is that they first take advantage of the modularization of manufacturing in an industry, source technology externally, and are intensely market-oriented in their product innovation; only later do they pursue internal capabilities in technological development to generate process and product innovations.

1. INTRODUCTION

In the decades that the topic has received attention, two approaches and explanations have emerged to explain the process by which developing countries (those far behind the technological and manufacturing frontier) may be able to "catch up"; namely, accelerate their development and reduce the gap between themselves and the technologically and economically advanced countries. One extends the early neoclassical growth models (e.g., Solow, 1956) in which technology freely spills across country borders and this drives convergence. Another, in contrast, is based in historical, institutional and evolutionary traditions and rejects such a simplifying assumption about technology. Technology and innovations are not seen as flowing freely across country (or organizational) boundaries. Instead, technology and especially the innovative process from which it arises and is applied is closely related to specific firms, networks and economic institutions (Freeman, 1987, Nelson, 1993). In this perspective, 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; otherwise, it will continue to lag behind (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.

While the role of government vs. market has been central to some analyses of latecomer Asian countries (e.g., World Bank,1993; Amsden 1989), others approach the analysis from the perspective of technological learning and national systems of innovation (Kim, 1997). Lee and Lim (2001), for example, emphasize that the technological regime plays an important role as context and in explaining why some industries in some countries have caught up and others not. They argue that the technological regime affects the nature and success of the innovative activities of those firms trying to catch-up. To understand outcomes, they classify industries based on the degree to which industry-related innovations are predictable and frequent. Regimes in which innovation is more predictable and frequent will give latecomers more opportunity to catch up; such as was the case for DRAM and automobile industries in Korea. In the opposite case, latecomers will have less opportunity to catch up; the PC and consumer electronics industries in Korea also illustrate this situation.

Although such a perspective may help explain the catch-up process in Korea, it does not match the Chinese case very well. Indeed, in China the automobile and IC industries have developed much less (in terms of indigenous technological innovation) that the PC and consumer electronics industries.

Furthermore, not all countries have the opportunity or ability to capitalize on the chance to catch up. 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 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.

The purpose of this paper is to identify the key features of the Chinese catch-up process to propose an alternative model of catch-up that takes into account key features of the current environment, some of which differ critically from that in which other countries, such as Japan and Korea, emerged. We draw on evolutionary economics and work on innovation systems to do this. 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—technology outsourcing, dis-integration of the industrial innovation process, and China's institutional setting—have resulted in China's catch-up process differing significantly from that of Japan and Korea. These factors suggest that we must modify existing frameworks to include the role of modularization and technology outsourcing in analyzing the catch-up process.

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 look specifically at the mobile phone handset industry to illustrate the catch-up process in China. Finally, we discuss the general implications of our framework for both research and policymaking.

2. CATCH-UP: THE JAPANESE AND KOREAN MODEL

Work on catch-up as it relates to national innovation systems (Freeman, 1987; Nelson, 1993) has been based on three assumptions. The first is that there are advantages to late development. Gerschenkron (1962), in his study of the catch-up process in Germany's steel industry in the 19th century, observed that pioneering firms and countries had already established a growing world market, so latecomer firms did not have to face all the uncertainties, costs and difficulties of opening up entirely new markets. He argued that it was very important for latecomer to target progressive and dynamic industries to compete globally through investing in the most modern equipment and plants.

The second assumption is that the institutional context in which technology is embedded is central to the catch-up process, thereby focusing attention on historical patterns and institutions. Freeman (1987) explicates this linkage through his study of Japan's experience in catching up with developed countries. Similarly, Perez and Soete (1988) extend this perspective into normative directions, arguing that there is a "window of opportunity" for countries to catch-up if they implement appropriate social, industrial and technology policies. They also mention three other enabling condition: enough time to learn, sufficient productive capacity, and locational and other resource endowments (especially human capital relevant for new technologies). More generally, the literature in this perspective identifies three steps in the catch-up process: technology importation, learning/adaptation/assimilation, and in-house R&D. Without in-house capability, it is unlikely that companies in catching-up countries will be able to understand the imported technology and make further incremental innovations (Odagiri and Goto, 1993).

The third assumption, based in Vernon's (1966) product cycle theory, is that the "dense" R&D activities and radical innovations open up a product innovation space. As the industry matures, leading companies will shift production to developing countries. These can create opportunities for firms and countries with a capacity to learn to catch up. Of course, this also implies that the innovation model in latecomer countries will differ from that of developed countries.

Research on the US experience much earlier, and Japan and Korea more recently, reflects these assumptions and approaches. Studies of their catch-up experiences show that technology imports and diffusion were important for firms and industries in these countries in the initial period because in-house R&D capability was weak. American firms in the nineteenth century imported much new technology from Europe. These imports, such as in railways, cotton textiles, and other leading manufacturing industries of the period, enabled American entrepreneurs to build firms that eventually overtook the rest of the world. (Freeman, 2002).

Technology imports alone were not sufficient; institutional imitation and innovation were also necessary. For example, the US was able to replicate the "scientific spirit" and support for technical invention from England. To this was added a more indigenous set of values and systems leading to the labor-saving, capital-intensive, and standardized production system by which America was able to exploit its rich natural resources and large domestic market (Abramovitz and David,1994).

Japan in the 1950s and 1960s extensively imported technology, especially in the automobile, machine tools and other heavy industries. Up to 1988, Japan was the world's leading importer of technology in major countries (Odagiri and Goto, 1993:86). For example, it imported the basic oxygen furnace method from Austria as part of its developing its own competitive iron and steel industry, and manufacturing technology from Ford and GM for its auto industry. .In iron and steel industry, Japan imported basic oxygen furnace method from Austria. From the 1960s, when the Japanese economy grew rapidly and faced more competition from American and European firms, private firms began to spend more on in-house R&D, and in 1989 the aggregate national rate was only slightly below that of the US and Germany.

Japan was not only faster that other countries in terms of speed of adoption, but also in terms of the extent to which it improved on that technology (Odagiri and Goto, 1993). This feature—incremental process innovation—eventually became a core competence that enabled them to compete successfully against incumbent firms from developed countries. They invested heavily in both reversing engineering and in-house R&D in their catch-up process, and invested particularly heavily in production process innovation. They not only quickly learned and mastered imported technology, but exerted constant effort to improving efficiency within their plants (Odagiri and Goto, 1993).

Reverse engineering and the propensity to improve imported technology, coupled with particular features of the Japanese social system, gave rise to an innovation system specific to Japan. In this system, firm managers think of the production process as an integrated system, from product and process design to manufacturing. Freeman (1987) attributes their success in many manufacturing industries to their innovation management that reintegrated R&D with engineering design, procurement, production and marketing, even in the largest organizations. Japanese R&D is closely related to the work of production engineers and process control. While Japanese firms have made fewer radical innovations compared to American firms, their incremental innovations have resulted in better products in terms of quality and function (Freeman, 1988).

In analyzing the Korean case, Kim (1997) drew on 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 proposes 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).

In all of these cases, the role of government and other institutions are also cited. In Japan, the government, especially the Ministry of International Trade and Industry (MITI), was able to judge 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). The educational system and enterprise training, in this sense, also supported the accumulation of necessary skills to support innovation activities (Freeman, 1988). In Korea, the government also acted as a catalyst to promote innovation in Korean firms (Kim, 1997). Indeed, Freeman suggested that other countries (like Korea and others in Asia) would be likely to try to emulate the features of Japan's "national innovation system" (Freeman, 1988:330). In one sense, Korea's catch-up process can be described as following the Japanese model in a more efficient way.

Japan and Korea share another feature; namely, they both restricted the role of foreign direct investment (FDI) in their catch-up process. Japan is unusual in that it generates more outward than inward direct investment. From 1973 to 1990, this ratio increased from 6.44 to 16.90. While Japan invested 4.5% of GDP abroad in 2001, inward FDI was one of the lowest of any OECD country and represented only 2% of global inward FDI flows (Kimura and Schulz, 2004:31). Analysts explain this feature as a result of Japan's particular industrial structure, the difficulty of cross-border mergers and acquisitions, and the cross shareholdings and close bonds among Japanese firms. To this can be added government policies that have created structural market distortions for foreign investors (Dunning, 1996).

Technology imports provide one example. Although Japan is willing to buy foreign technology, the government has deliberately limited the modality to licensing rather than significant FDI by foreign firms. The post-war protection policy not only guaranteed the growing domestic market to Japanese producers, but also encouraged foreign producers to sell their technologies because they could not take advantage of their technological superiority by investing directly into Japan (Odagiri and Goto, 1996:261).

The Korean government also implemented policies that strongly promoted domestic innovation in Korea, including restrictions on FDI, restriction of shares of foreign technology licensing, and government procurement policies favoring technology developed by domestic enterprises. Following such systematic measures, Korea has quickly caught up in particular industries, such as autos, shipbuilding and electronics. Like Japan, Korean firms spend a large amount of money in assimilating imported technology, with Japan and the USA being the most important sources. From 1962 to 1993, Korean firms imported US$ 120 billion of capital goods from Japan, about half of its total capital goods imports in that period (Kim, 1997:40).

3. NEW ENVIROMENT FOR CATCH-UP

During the era in which Japan and Korea caught-up, manufacturing technology was considered 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 latest technology 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.

3.1 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.

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 2002, 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.

3.2. 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 8% 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. Using Freeman's term, China has a window of opportunity framed differently from that of previous latecomer countries and firms. If Japan and Korea's catch-up model is a closed one, that of China is an open one with three specific features.

Firstly, information technology has 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 (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.

Second, modular production—enabling low cost and high product variety—emerges with global competition. A module is a subset of a product's functional structure, and interfaces are standardized and interdependencies among modules are reduced as much as possible. Modular products may be machines, assemblies or components that accomplish an overall function through the combination of distinct building blocks or modules (Chen and Liu, 2005:772). Kodama observed the process of modularization in computer industry. In 1980s, the computer industry was composed of vertically integrated firms. Companies like IBM, DEC, Fujitsu and NEC were vertically integrated: making their own chips, their own platforms, their own software and their own applications. But entering 1990s, the industry shifted to a horizontal competition. Intel and Motorola were competing chips, Sharp and NEC in the display field, Microsoft in software (Kodama, 2004).

Modularity allows the outsourcing of design and production of components and subsystem within the product system architecture. In some industries such as autos and electronics, modularization has progressed more quickly than in process industries such as pharmaceutical and chemicals. The implication of modularization for innovation is that companies in developing countries, whether they are assemblers or suppliers, can enter the innovation competition more easily than before. They may not be good in technological innovation, but they can excel and succeed commercially by sourcing modules and assembling them. If they are a supplier, they can specialize and achieve economies of scale as they supply their modules to multiple assemblers.

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 technology 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.

Third, related to the globalization of technology, global technology outsourcing gives Chinese companies a new way to make quick product innovations. Certainly, the 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.

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.

The result is that a strategy based on market-oriented innovation and technology outsourcing has become the primary approach for China's leading companies. The technology may come from anywhere, although most of the core, proprietary technology comes from the USA, Japan, Europe and Korea. This has enabled Chinese companies to rapidly catch up in product innovation competition at higher levels of technological sophistication, not just at the low-margin end.

The contrast with Japan is instructive. Although Japanese firms did establish some R&D facilities in other developed countries and also contracted out some research, in-house R&D and shop-floor innovation dominated the Japanese innovation system. Product innovation based on international technology sourcing is very different from the innovation that is the basis for Japanese firms' competitiveness in manufacturing industries. Fujimoto (2001) has classified Japanese manufacturers as adept in industries in which product and process architectures are highly integrated ("integral" rather than "modular" architecture) and closed (versus open). In more modular and open product architectures, Japanese firms are less competitive. These, however, are the types of products and industries in which China's strongest global competitors have emerged.

4. CHINA'S ALTERNATIVE CATCH-UP MODEL

The preceding description of the fundamental features of China's catch-up process suggests elements of an alternative model of catch-up (Figure 1). In the first stage, innovations are market-oriented and incremental. Local knowledge and cost advantages are the basis of competitiveness. With little in-house R&D, firms learn to effectively source and implement externally developed technology. Modularization, as within a global production network observed in different stages in different industries, facilitates this sourcing. The firms are able to source new technologies faster and easier and more quickly translate these into new products. At this stage, even leading firms may have little or no core product technology of their own. In the second stage, leading companies have gained economies of scale. They also have capabilities in design, marketing and branding. They use their financial resources and marketing capabilities to bring together core technologies from outside. The advantages and disadvantages of this "open" catch-up model compared to a "closed" one are presented in Table 3. The key features of this open catch-up model are discussed in more detail below.

4.1 Market-oriented innovation

Market-oriented innovation based on technology outsourcing is the not the invention of Chinese companies. Many US firms spent relatively little on R&D but, by contracting out or merging new technology firms, have grown successfully. Cisco Systems, the world's leading router manufacture, acquired fifty high tech ventures from 1995-2000, and this has enabled them to respond to market needs more rapidly. Dell spends relatively little on R&D, but the top PC maker has the capability to deliver more diverse PCs to more closely match customer needs. As Chesbrough (2003) shows, American firms shifted from the closed innovation paradigm to the open innovation paradigm.

The fast growing firms in China are usually very young, like Haier, Huawei and Legend. 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. On the other hand, in order to compete with local and international firms in China, they have had to find partners with which to ally.

Robertson and Langlois (1995) found that partnerships tend to make companies more market-oriented and more capable of transforming a changing environment into market opportunities. Furthermore, because Chinese companies have limited capabilities in in-house technology development, they rely more on international outsourcing, and also more focused on the exploration of new market opportunities, also in line with a market-oriented innovation model.

Haier, the home appliance manufacturer and one of the leading companies in China, is one of the most adept in terms of differentiating markets and serving them through incremental product innovations. Their development philosophy is based on the market telling engineers what and how to design. In washing machines, for example, the developed a dual-use washing machine that can be used to wash vegetables in addition to clothes. This was driven by them "listening" to the "abnormal" users of their products. Altogether, to adequately match customer needs from different regions, urban and rural users, and income levels, they now offer over 400 refrigerator models. Figure 2 shows how Haier differentiates its markets as a basis for new product development.

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 Haier (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.

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 the opposite trend for design patents. This reflects the nature of product innovation in China: foreign technology coupled with Chinese design.

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.

4.2 Learning from technology outsourcing

The technology outsourcing 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 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 2002, of the R&D expenditures by large and midsize companies, two-thirds goes to technology imports.

Technology markets have also become an important new way of sourcing technology. Large and midsized companies spend more money on technology buying from technology market than they spend on internal R&D. Technology market records the technology trading among firms, university and research institutes. The technology sellers can be universities, research institutes, local firms and foreign firms. In 2002, the contribution of local universities and research institutes in technology selling is about one third of the total selling (Table 6). Most of locally contracted research by firms to universities and research institutes is included in the amount attributed to technology markets. In 2002, about 73% of technology selling went to enterprises, with local firms accounting for 88% of total business buying (Table 5). Clearly, buying technologies from other firms, especially foreign firms, and contracting out research to universities are the key ways of technology sourcing.

International technology alliances and mergers have become more and more important for Chinese firms to become international competitors once they have grown to a certain scale based on their market-oriented innovation and low cost strategies. Their next key challenge is how to move from low to high value-added manufacturing and higher value-added activities. At this stage, limited technological capabilities and lack of branding are common bottlenecks. International technology alliances and mergers with other multinationals' relevant business become their good optional strategy.

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.

TCL, a consumer electronics manufacturer, signed an agreement in 2004 with Thomson, a French company, to create a joint venture called TTE Corporation. The new venture has the capability of producing 20 million TV sets with revenues of US$ 4 billion, making it one of the largest TV makers in the world. This brought two benefits to TCL; first, to get the Thomson and RCA brands that it can use to enter the American and European markets, and to acquire R&D capabilities to help TCL upgrade from low- to high-end production (Liu, 2004a).

More recently, the announcement that Legend would buy IBM's PC division for US$ 1.75 billion sent shockwaves through the business world. IBM will get 18.9% of equity share of Legend. The acquisition will expand Legend's operations from US$3 billion in revenues to US$ 10 billion. In the future, Legend will focus on manufacturing and IBM will focus on in designing, sales and service outside of China. Legend's basic objectives in buying IBM are the as in TCL's case: to acquire a brand and core technology in order to become a high-end and global PC maker (Kotler, 2004).

4.3. Performance

Pavitt's industries classification has been widely used for innovation research (Pavitt, 1984), and we use the degree of modularity of production to see if there are systematic differences in industrial performance. Usually, processing industries like chemicals and pharmaceuticals are not easy to modularize and will have a low degree of labor of division. In such industries, we would expect Chinese companies to not be catching up as quickly as in other industries, such as electronics, in which modularity and division of labor is perhaps the highest of all industries. We would expect there to be more product innovation and a higher rate of growth in such industries. For the automobile industry, modularity and division of labor is somewhere between that of chemicals and electronics; for example, the modularity of PCs is higher than that of the auto industry because the engine control system cannot be modularized (Kodama, 2004). Taking the share of new product sales in an industry as an indicator of innovativeness, we find that transportation equipment is the most innovative industry in China now, followed by electronics (Table 7). The less innovative industries are chemicals. The propensity of patents applications leads to the same conclusions; namely, electronics is the most productive in terms of patent applications, and chemicals is the least. The electronics industry is also the fastest growing in China; its share of the total industry was 5.9% in 1997 and increased to 11.6% in 2002. Both new product and patent application comparisons offer prima facie support for our proposition that modularity is an important variable to explain the innovation performance of industry in China.

5. CASE: CHINA'S MOBILE HANDSET INDUSTRY

The mobile handset industry has entered a boom stage since 1998 in China. From 1998-2003, the annual market growth rate reached more than 50%. By the end of 2003, the number of mobile handset users in China reached 270 million, making China the largest country of handsets users in the world (Figure 3). The mobile handset industry is also one of the fastest growing industries in China.

In the early years of Chinese handset market, Motorola almost controlled the market. Later on, Nokia and Ericsson joint Motorola as dominant firms. In 1999, foreign brands had a share of 92.2%. Local brands only had 5.3%. But the rise of local firms and the decline of foreign firms is remarkable since 1999. In 2003, local firms overtook foreign firms for the first time, capturing 54.7% of the domestic market (Figure 4). Such developments suggest that the Chinese model of innovation is effective in this industry.

The structure of this industry's technology system is depicted in Figure 5, showing four stages of technological capability for mobile phone handsets. The first is total OEM production in the form of SKD or CKD production in which all parts and modules are imported. In the second stage, enterprises master the skill of architecture and shape design, the design of application software, and mass production. Protocol software and chips, however, still must be procured from other companies. This is also a stage for solution cooperation. The third stage represents higher technological capabilities; the enterprise has the skill to develop radio frequency and broad band circuit and layer 2 & 3 protocol software, but has to rely on others to supply chips. Finally, the enterprise has the capability to develop the chip for radio frequency, base band and layer 1 software (Wen, 2004).

Because of the transition of mobile handset manufacturing from an integrated (Figure 6) to disintegrated process (Figure 7), Chinese companies have had a window of opportunity to enter the market and improve their technology capabilities. In the integrated stage, the manufacturing company did everything, from chip design, manufacturing, distribution to the maintenance for the users. They had to maintain long-term supplier relationship so that they had reliable supplies of critical components (Xie and white, 2005). In that time, the market was monopolized by Motorola and Nokia.

Later, the manufacturing of the mobile phone handset became increasingly more disintegrated (Figure 7). In the value chain, TI and Philips are the main suppliers of the chips for mobile phone handsets, while Japanese and Korean companies have the comparative advantage on design of the handsets. Some, like Qualcomm, are the standard and software suppliers. Besides that, some technology providers in this industry provide subsystems or modular architectures, this makes OEM much easy. Wavecom, a NASDAQ-listed French firm began to supply WISMO modules in 1997. A modular contains all of the digital, base-band and radio frequency hardware and software that assemblers need for a complete wireless solution (Xie and White, 2005). Now, if an assemble producer has the capacity to forecast the market need and provide best solution to the potential market needs, outsourcing its technology to different suppliers, integrated those technologies into the final product, then, the company may win the competition. This is just the base for the rising of the local mobile phone handset makes in China.

In order to catch up, flexible companies with weak R&D capability, facing strong competition from foreign companies armed with the local market advantages, began to enter the handphone market based on a strategy of internationally outsourcing their design and technology. The largest local mobile phone handset maker in China, Ningbo Bird, grew based on this strategy, and has seen a dramatic increase in its market share (Table 8).

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.

Chinese companies have continuously acquired 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. Local Chinese universities and research institutes have contributed very little, except as suppliers of engineers.

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. In 2002, local handsets companies spent US$ 1 billion on technology from Korea's LG, PANTECH, SK, Samsung and others

(Lu, 2004:213). 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 success of handset makers in China is also related to the integration of foreign technology with local knowledge. The Chinese market is a low-end market, but that does not mean there is no space for innovation, even though it may have a low profit margin and often entails higher distribution costs. 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, 2005:16). This was the same 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. Similarly, many local companies have a strategy of winning markets based on design; for example, Haier's pen-shape handsets and TCL's rhinestone-studded handsets.

6. CONCLUSIONS

We have argued that the Chinese experience in catching up represents a model that is fundamentally different from that of Japan and Korea. It is based on a global division of labor among firms, modular product and production technology, and technology outsourcing. This model characterizes the industries in which China has caught-up successfully, and is in contrast to the pattern observed in industries in which China has failed to catch up via the same process that Japan and Korea successfully followed; i.e., that based on technology imports, adaptation and incremental process innovations. Leading Chinese companies begin as assemblers, source necessary technology widely from outside, and introduce market-oriented innovations. Chinese firms combine low-cost with product flexibility, and have successfully competed with multinationals within China. In later stages, they may acquire technology, and in some cases develop technological innovation capabilities, through alliances and partnerships; often, these external sources substitute for in-house technology development. Later, however, they will use international alliances and acquisitions to acquire core, proprietary technology in order to enter higher-end markets and higher value-added activities. The success of this model, however, is heavily dependent on the structure of a particular industry's technology system.

In some sense, the essence of innovation model in Chinese firms is similar with what is called "outsourcing innovation"(Business Week, March 21, 2005), it means that, "most leading Western companies are turning toward a new model of innovation, one that employs global networks of partners", to cut costs and reduce the lead time for new product development. What we saw in China shows that this is not only happened in developed countries, leading companies in China are doing the same, but with different resource. Western companies outsource non-core technology and design to firms in developing countries, but Chinese firms, with similar purpose, have been innovating by outsourcing core technology to foreign firms by holding core market knowledge.

REFERENCES

Abramovitz, M.A., David, P.A., 1994. Convergence and deferred catch-up: Productivity Leadership and the waning of American Exceptionalism. CEPR Publication no 401. Stanford University.

Amsden, A., 1989. Asia's next Giant: South Korea and Late Industrialization. Oxford University Press, Oxford.

Archibugi, D., Pietrobelli, C., 2003. The globalization of technology and its implication fro developing countries: windows of opportunity or further burden? Technological Forecasting & Social Change 70, 861-883.

Bell, M., Pavitt, K.L.R. 1993. Technological accumulation and industrial growth: contrasts between developed and developing countries. Industrial and Corporate Change 2, 157-210.

Business Week, 2005, Outsourcing Innovation, March 21, pp.50-57.

Cantwell, J., 1997. The globalization of technology: what remains of the product cycle model? In Archibugi, D., Michie, J., (Eds.), Technology, globalization and economic Performance. Cambridge University Press, Cambridge.

Cesaroni, F., 2004. Technological outsourcing and product diversification: do markets for technology affect firm's strategies? Research Policy 33, 1547-1564.

Chen, Kuo-min, Liu, Ren-Jye, 2005. Interface strategies in modular product innovation. Technovation 25, 771-782.

Chen, D., Liu, L., 2003. The Truth of Huawei(in Chinese), Modern China Press, Beijing.

Chesbrough, H.W., 2003. Open Innovation, the New Imperative for Creating and Profiting from Technology. Harvard Business School Press, Massachusetts.

Dunning, J.H., 1996. Explaining Foreign Direct Investment in Japan: Some Theoretical Insights. In Yoshitomi, M., Graham,E.M., (Eds.) Foreign Direct Investment in Japan. Edward Elgar, Cheltenham, UK.

Freeman, C., 1987. Technology Policy and Economic Performance. Pinter, London.

Freeman, C. 1988. Japan: A new national system of innovation? In Dosi, G., Freeman, C., Nelson, R. et al. Technical Change and Economic Theory, Pinter, London, 340-348.

Freeman, C.,2002. Continental, national and sub-national innovation System---complementarity and economic growth. Research Policy, 31, 191-211.

Fujimoto, Takahiro. 2001. Theory of industry in view of architecture, in business architecture: strategy design of products, organizations, processes (in Japanese). Yuhikaku.

Gerschenkron, A., 1962. Economic Backwardness in Historical Perspective. Harvard University Press, Cambridge, MA.

Hu, Y., 2002. Haier, Made in China: Competition Strategy and Core Competence (in Chinese). Hainan Press, Hainan.

IMD, 2004, World Competitiveness Yearbook. Lausanne.

Kim, Linsu, 1997. Imitation to Innovation. Harvard Business School Press, Mass. Boston.

Kimura, T., Schulz, M., 2004. Industry in Japan. The Japanese Economy 32, no.1, pp.5-14.

Kodama, Fumio, 2004, Measuring emerging categories of innovation: modularity and business model. Technological Forecasting & Social Change 71, 623-633.

Kondo, R., Watanabe, C., 2003. The virtuous cycle between institutional elasticity, IT advancement and sustainable growth: can Japan survive in an information society? Technology in Society 25, 319-335.

Kotler, M., 2004. Kotler on Legend's merging with IBM's PC business (Translated in Chinese). 21cn Economic Report, December 12.

Lee, Keun, Lim, C., 2001. Technological regimes, catching up and leapfrogging: finding from the Korean industries. Research Policy 30, 459-483.

Lee, Keun, Kim, M. The Rise of China and the Korea firms looking for a new division of labor. Proceedings of the conference on "China and East Asia," organized by the KIEP, May 2004.

Liu, Xielin, White, S. 2001.Comparing innovation systems: a framework and application to China's transition context. Research Policy 30, 1091-1114.

Liu, Xuchuan, 2004. The opening of joint venture of TCL and Thompson. July 31, Economic Observer (In Chinese).

Lu, Jun, 2004. The expanding of local handset maker (in Chinese). Journal of Sichuan University (edition of Social Science). Special issue.

Nelson, R.R.(Ed.) 1993. National Innovation System: A comparative Analysis. Oxford University Press, Oxford.

Odagiri, H., Goto, A., 1993. The Japanese System of Innovation: Past, Present, and Future. In Nelson, R.R.(Ed.) 1993. National Innovation System: A comparative Analysis. Oxford University Press, Oxford. pp.76-114.

Odagiri, H., Goto, A., 1996. Technology and Industrial Development in Japan. Clarendon Press, Oxford.

Perez, C., Soete, L., 1988. Catching up in technology: entry barriers and windows of opportunity. In Dosi,G., et al.(Eds.), Technical Change and Economic Theory. Pinter, New York, pp.458-479.

Pisano, G., 1990. The R&D boundaries of the firm: an empirical analysis. Administrative Science Quarterly 35, 153-176.

Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy 13(6).

Robertson, P.L., Langlois, R.N., 1995. Innovation, networks, and vertical integration. Research policy 24, 543-562.

Solow, R.M., 1956. A contribution to the theory of economic growth, Quarterly Journal of Economics 70, 65-94.

South Weekends(nanfanzhoume), 2002. Huali enters CDMA market(in Chinese), March 15.

Vernon, R., 1966. International investment and international trade in the product Cycle. Quarterly Journal of Economics 80, 1909-217.

Veugelers, R. Cassiman, B., 1999. Make and buy in innovation strategies: evidence from Belgian manufacturing firms. Research Policy 28, 63-80.

Wen, K., 2004. Catch up: Technology, Market and Capability: the Case of China Handset Industry. PhD dissertation, Chinese University of Science and Technology.

World bank, 1993. The East Asian Miracle: Economic Growth and Public Policy.

Oxford University press, New York.

Xie, W., White, S., 2005. Windows of opportunity, learning strategies and the rise of China's handset makers. Forthcoming in International Journal of Technology Management.

Table1 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	1:1.54:0.06
1993	95.2	159.2	6.2	1:1.67:0.06
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	
2000	353.6	245.4	18.2	1:0.69:0.05
2001	442.3	285.9	19.6	
2002	560.2	372.5	25.7	1:0.66:0.04

Source: China Science and Technology Statistics Yearbook, 1991-2003, Beijing.

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

Year	1991	1995	1996	1997	1998	1999	2000	2001	2002
R&D/sales	0.49	0.46	0.48	0.52	0.53	0.60	0.71	0.76	0.83

Source: China Science and Technology Statistics Yearbook, 1991-2003, Beijing.

Table 3 The comparison of closed and open catching up model

Closed catching up model	Open catching up model
Technology importation very important	Technology importation very important
FDI is and the effect of globalization of technology is limited	FDI is welcome and globalization of technology is permeating
In-house R&D is most important	Partnership with outside technology supplier is most important
Integration of R&D, manufacturing and marketing within firms is important	Modularization leads advantage
On the job training and skill accumulation are necessary for mastering the technology	integration outsourcing technology and market niche needs is important
Industries with integration of manufacturing process, like automobile, machine tool industries	Industries are dis-integrated with modularization: electronics.
Result: incremental processing innovation	Market oriented incremental product innovation

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

	1991	1995	1998	1999	2000	2001	2002
Sum of three patents granted in China	24616	45064	67889	100156	105345	114251	132399
Invention patent	4122	3393	4733	7637	12683	16296	21473
From Domestic owners	1311	1530	1655	3097	6177	5395	5868
Share of domestic owners	31.8	45.1	35.0	40.6	48.7	33.1	27.3
From foreign owners	2811	1863	3078	4540	6506	10901	15605
Share of foreign owners	68.2	54.9	65.0	59.4	51.3	66.9	72.7
Utility model patent	17327	30471	33902	56368	54743	54359	57484
From domestic owners	17200	30195	33717	56094	54407	54018	57092
Share of domestic owners	99.3	99.1	99.5	99.5	99.4	99.4	99.3
From foreign owner	127	276	185	274	336	341	392
Share of foreign owners	0.7	0.9	0.5	0.5	0.6	0.6	0.7
External design patent	3167	11200	29254	36151	37919	43596	53442
From domestic owners	2667	9523	26006	32910	34652	39865	49143
Share of domestic owners	84.2	85.0	88.9	91.0	91.4	91.4	92.0
From foreign owners	500	1677	3248	3241	3267	3731	4299
Share of foreign owners	15.8	15.0	11.1	9.0	8.6	8.6	8.0

Source: China Science and Technology Statistics yearbook, 2003, Beijing.

Table 5: The technology-related expenditure of large and medium sized industrial firms

million RMB

	1999	2000	2001	2002
Expenditure on R&D	24,993	35,359	44,234	56,017
Expenditure on R&D/sales	0.60	0.71	0.76	0.83
Expenditure on technology importation	20,755	24,542	28,587	37,250
Expenditure on technology importation via expenditure on R&D	1:0.83	1:0.69	1:0.65	1:0.66
Government funds	4,967	4,321	4,106	5,371
Government fund/industrial R&D(%)	19.9	12.2	9.3	9.6
Expenditure on technology buying from technology market	33,108	45,735	57,363	64,200
Expenditure on R&D via technology buying from technology market	1:1.32	1:1.29	1:1.30	1:1.14
Including				
Expenditure for contract research in universities	5,373	5,545	7,246	8,958
Expenditure for contract research in research institutes	3,455	3,792	2,536	3,627
Contract research to university and research institute/technology buying from technology market(%)	26.6	20.4	17.1	19.6

Source: China Science and Technology Statistics Yearbook, 2000-2003, Beijing.

Table 6 Technology sellers in technology market

（in billion RMB, %）

	1999		2000		2001		2002	
	amount	%	amount	%	amount	%	amount	%
Total	52.3	100	65.1	100	78.3	100	88.4	100
Research institutes	16.4	31.3	16.6	25.6	18.2	23.2	18.7	21.2
Universities	6.2	11.9	11.1	17.0	8.6	11.0	7.3	8.2
Industrial firms	10.9	20.9	14.3	21.9	28.6	36.5	35.9	40.6
Trading organization	9.9	19.0	10.4	15.9	10.8	13.8	13.9	15.7
individual	1.2	2.2	2.0	3.1	1.3	1.7	0.7	0.8
Others	7.7	14.8	10.7	16.5	10.8	13.8	12.0	13.5

Source: China Science and Technology Statistics Yearbook, 2000-2003, Beijing.

Table 7. Performance of some sectors in China

billion RMB

	1997	1998	1999	2000	2001	2002
Total of all industries sales	3630	3746	4191	4985	5851	6745
Chemicals						
sales	248	249	272	316	388	426
As of total industries%	6.8	6.6	6.5	6.3	6.6	6.3
New products sales	17.0	23.4	27.9	33.2	38.3	49.5
as of sales %	6.8	9.4	10.3	10.5	9.9	11.6
Patent application	210	246	274	767	778	770
Pharmaceuticals						
sales	73	82	89	113	128	190
As of total industries%	2.0	2.2	2.1	2.3	2.2	2.8
New product sales	9	10	12	17	20	25
As of sales %	12.3	12.2	13.5	15.0	15.6	13.2
Patent application	257	275	283	547	735	1000
Transportation equip						
sales	291	293	347	390	489	630
As of total industries%	8.0	7.8	8.3	7.8	8.4	9.3
New product sales	77	87	11	14	18.7	24.3
As of sales %	26.5	29.7	31.9	36.3	38.2	38.5
Patent application	222	806	365	541	1105	2085
electrical machinery						
sales	178	180	204	241	286	334
As of total industries%	4.9	4.8	4.9	4.8	4.9	5.0
New product sales	47.4	55.9	75.0	83.1	104.8	122.8
As of sales %	26.6	31.0	36.8	34.5	36.6	36.8
Patent application	1090	1177	1708	2213	2626	4387
Electronics						
sales	215	281	353	471	668	780
As of total industries%	5.9	7.5	8.4	9.4	11.4	11.6

New product sales	62.4	102.4	129.1	215.9	250.0	294.9
As of sales %	29.0	36.4	36.6	45.8	37.4	37.8
Patent application	275	556	883	1358	2233	3888

Source: China Science and Technology Statistics Yearbook, 1998-2003, Beijing. Based on Author's calculation.

Table 8 The production volume of Bird mobile phone handsets

thousand units

Year	1999	2000	2001	2002	2003
Volume	200	700	2,500	7,000	12,000

Source: Wen (2004:104)

Table 9 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: Keun Lee and Mihnsoo Kim (2004), Yang Jie, An introduction to Mainland Mobile handsets Industry (In Chinese), publisher?.

Figure 1. Two stage catch-up observed in China

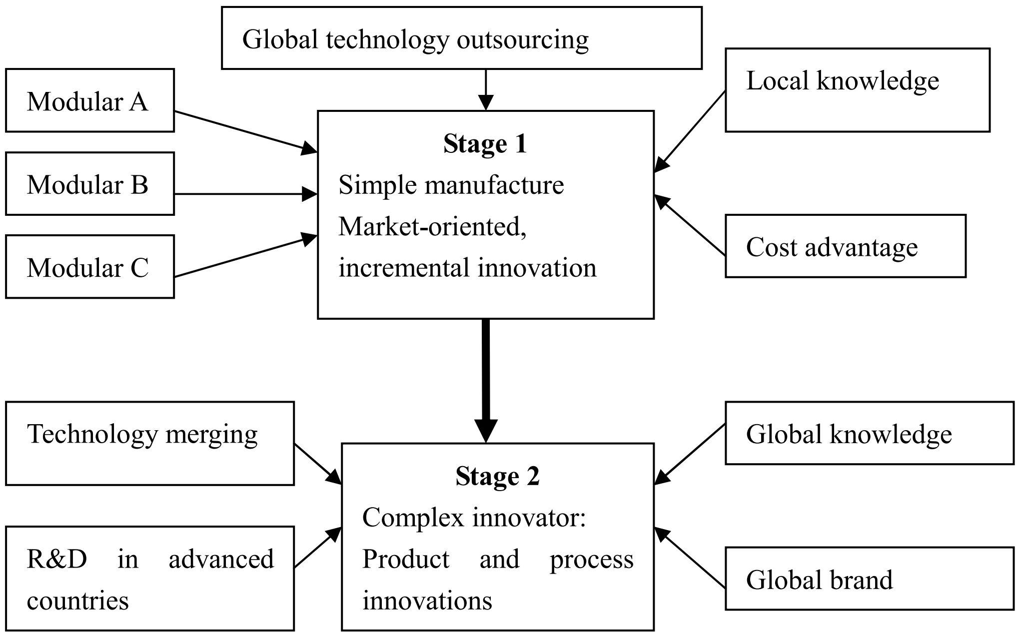
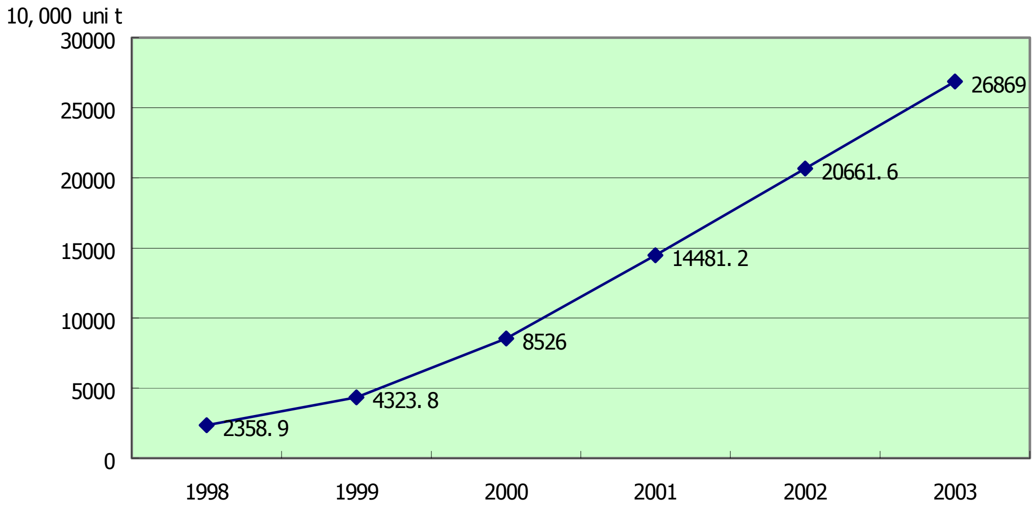


Figure 2 Haier's differentiation of markets

Stratification White collar: Separate parts (air condition) Middle size or small size (Wash-machine) Elegance outlook Blue collar: Large and middle size (wash-machine) Luxurious outlook	Overseas Advanced countries USA Germany Japan France Developing countries Argentine Vietnam Iran…..
Style European strict Square door White color Asian elegant arch door color figure American ……	Regions North Large refrigerator Cool only air condition South Cool & warm air condition None-freezing refrigerator Rural twin cylinder(wash-machine) …. Seashore drying wash-machine ---

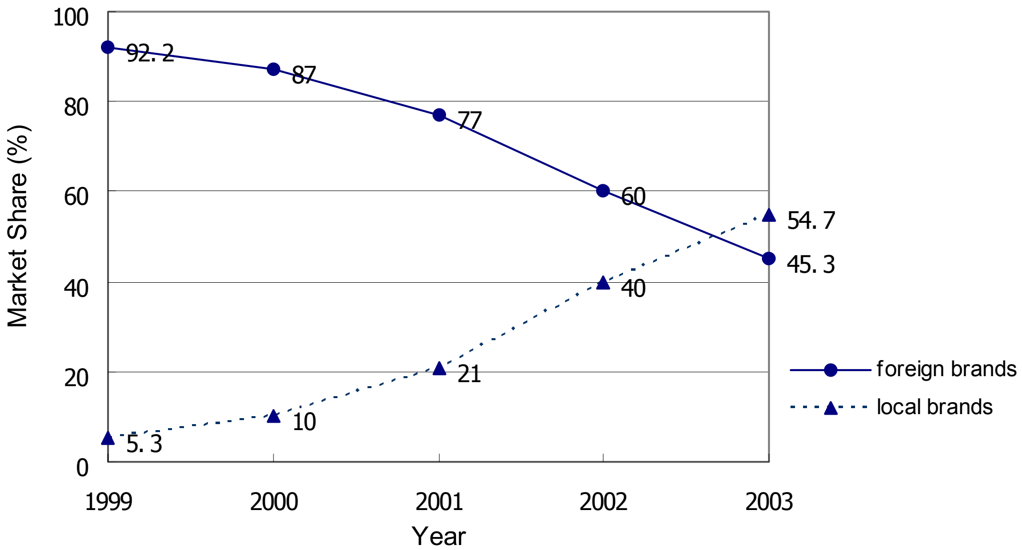
Source: Hu(2002:221).

Figure 3　The number of handset holders in China



Source: from http://www.mii.gov.cn/

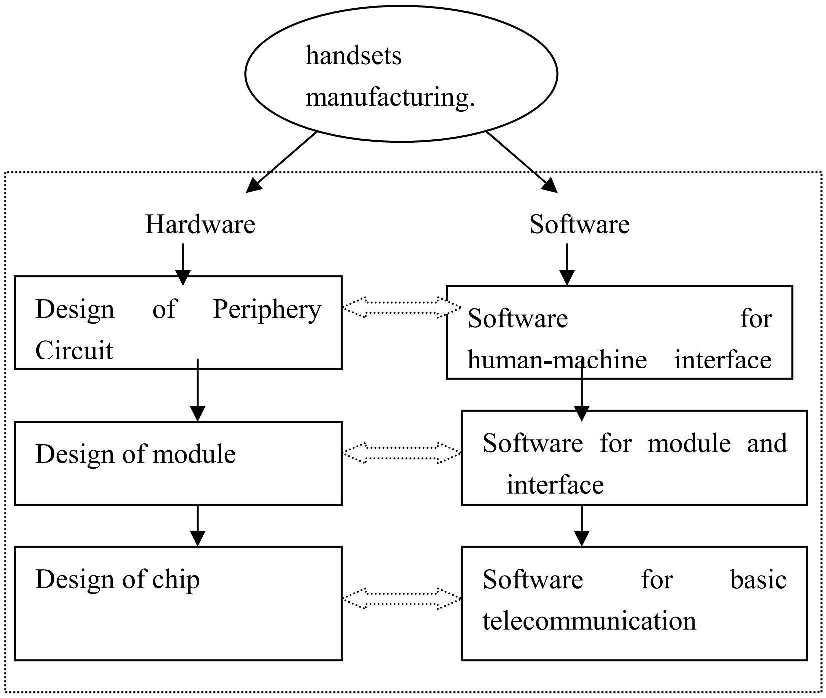
4　the market share of foreign and local brands in handset industry in China.



Figure

Source: *2003 Yearbook of China's Electronics Industry*, p. 275. Ministry of Information Industry.

Figure 5 Structure of technol ogical system of handsets



Source: Wen(2004,p.83).

Figure 6 Integrated handset manufacture

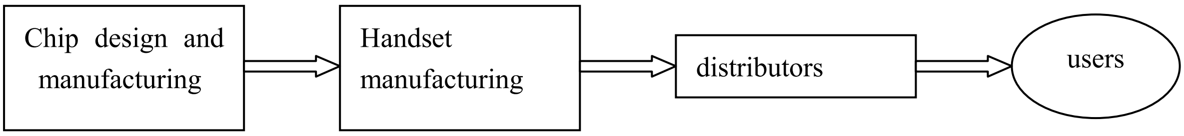
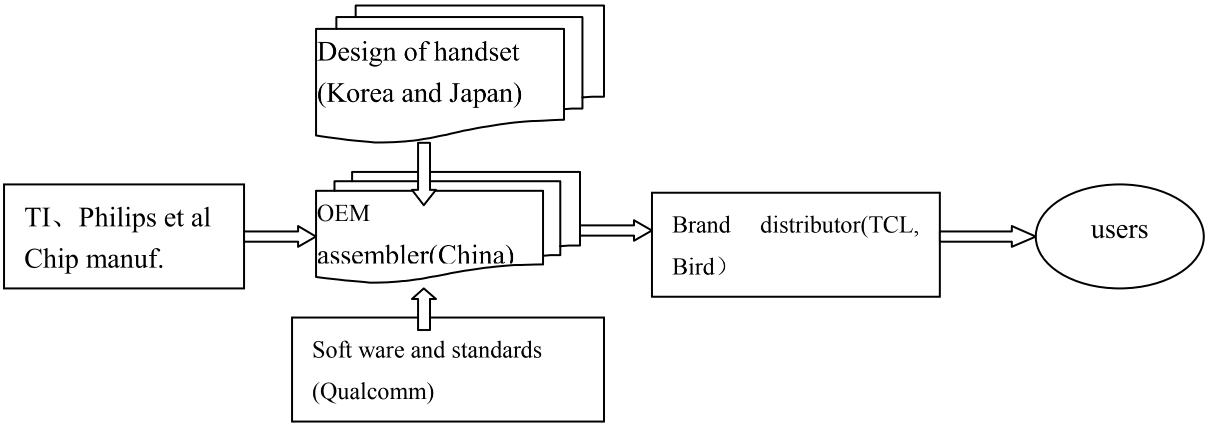
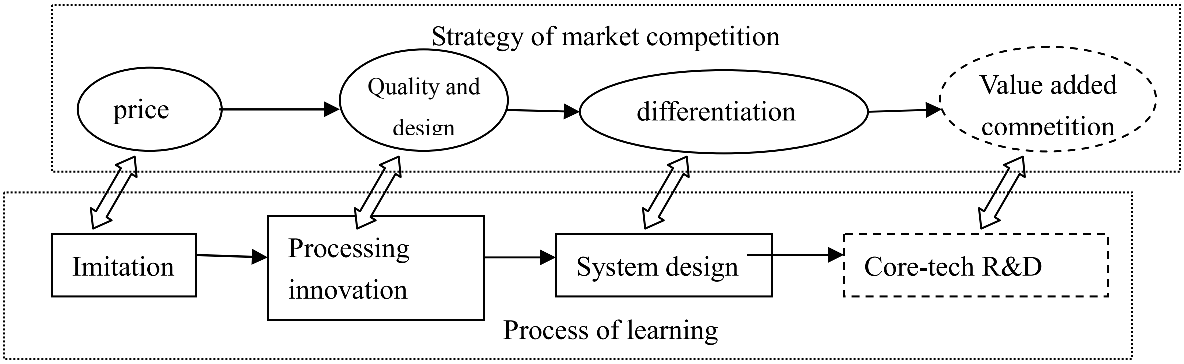


Figure 7 Dis-integrated manufacturing process of mobile handset



Source: Wen (2004, p.52)

Figure 8 Ningbo Bird's catch-up process



Source: Based on Wen (2004, p.90).