Made in China:
The Rise of the Chinese Domestic Firms in the Information Industry

by

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Abstract

This research uses a multi-case analysis approach to study China's catching-up as a late-industrialized economy in the information and communications technology (ICT) industries. The significant contributions of this study are: the staged catching-up theory framework, the findings from the cases, and the policy implications.

This study contributes to the late-industrialization literature by filling its theoretical gap–how domestic firms can catch up when there is strong MNC presence and what is the role of innovation capability. I develop a staged catching-up theory that can be used as a framework to analyze the successful catching-up process of domestic firms in a late industrialized economy while facing strong MNC presence. The theory describes the behavior of domestic firms, the behavior of MNCs, and the role of government, as well as the spatial implications of each stage.

The case studies prove that Chinese domestic firms in the information industries have followed a path of catching-up that can be described by the staged catching-up theory, and innovation capability and self-developed technologies were the ultimate driving force that has enabled leading domestic firms to catch up with the MNCs in the telecom-equipment and PC manufacturing industries. This research validates that government involvement has rewarded the companies' efforts in building innovation capability and developing proprietary technologies.

This research has implications for how China can catch up, especially through developing domestic firms' innovation capabilities, in high-tech manufacturing areas despite the strong presence of MNCs. Also relevant is how other countries or regions, either late industrializing countries or less-developed regions in developed countries, can use the findings from this research to facilitate the development of their local firms in high tech industries. The research stresses that domestic firms should prioritize building innovation capability from the very beginning to ramp up their competitiveness and to survive in the filtration stage, even though its benefit may not be so distinguished in the growth stage. It also suggests domestic firms focus on in-house R&D development to build their innovation capability, supplemented with external alliances, since the latter's effectiveness is conditional on the strength of the former.

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List of Abbreviations

Companies and Organizations

BUPT	Beijing University of Posts and Telecommunications
DDT	Datang Telecom Technology Co., Ltd
GDT	Great Dragon Telecom
MEI	Ministry of Electronics Industry
MII	Ministry of Information Industry
MPT	Ministry of Posts & Telecommunications
NUPT	Nanjing University of Posts and Telecommunications
PTIC	Posts & Telecommunications Industry Corporation
WTO	World Trade Organization
ZTE	Zhongxing Telecom Equipment Corp.

Technical Abbreviations

ATM	Asymmetric Transfer Mode
CDMA	Code Division Multiple Access
DWDM	Dense Wavelength Division Multiplexing
FDD	Frequency Division ??
Gbps	Gigabits per second
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication (cellular phone technology)
IP	Internet Protocol
LAN	Large Area Network
OADM	Optical Add Drop Multiplex
PDSS	Public Digital Switch System
R&D	Research and Development
TDD	
SDH	Synchronous Digital Hierarchy

SONET	Synchronous Optical Network
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division - Synchronous Code Division Multiple Access
WDM	Wavelength Division Multiplexing
3G	Third Generation (mobile communications)

Other Abbreviations

IT	Information Technology
JV	Joint Venture
MNC	Multinational Corporations
OBM	Original Brandname Manufacturer
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
R&D	Research and Development
RMB	Renminbi, Chinese currency, US $ 1 is approximately 8.4 RMB
S&T	Science and Technology

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1 Introduction

This study is about China's catching-up as a late-industrialized economy in the information and communication technology (ICT) industry. In the realm of late industrialization, much research has been done to explain what could be the causes for countries like the newly industrialized economies (NIEs) to take off. Most debates have focused on the role of the government versus the market (Patrick 1977; Chen, 1979; Aikman, 1986; Friedman, 1980; Fei, 1983; Berger 1979; Saxonhouse, 1985; Bhagwati, 1988; Hasan 1976; Mason 1980; OECD 1972; Rosovsky 1972; Amsden, 1989; Wade, 1990; Singh, 1992; Sakakibara and Cho, 2002).

Some other theorists proposed technology-based views to examine the trajectory of developing countries in terms of catching up with the advanced countries. In the context of import substitution, Leonard-Barton (1995) described a bottom-up model that starts from import kits, progresses to localization of parts and components, then to product redesign, and finally to the stage of product design. For the export-led East Asian NIEs (Hobday, 1995), the linear model goes from cheap labor assembling, to the second stage of original equipment manufacturing (OEM), then to original design manufacturing (ODM), and finally to original brand-name manufacturing (OBM). The linear trajectory of technology learning characterized by following the footsteps of the forerunners is consistent with the product life cycle theory (Vernon, 1966).

More recently, latecomers have been observed that do not follow the path or the linear trajectory of technology learning. The fact that every country is a beginner for the newly emerging techno-economic paradigm (Schumpeter, 1942) implies that latecomers can catch up with more advanced countries by leapfrogging or direct innovation at the technological frontier (Perez, 1988), as was illustrated by the catching up of Korea's CDMA mobile phone industry (Lee and Lim, 2001).

In the case of China, some studies have implicitly followed the bottom-up/path-following model to analyze China's catching up in various industries (Fainstein and Howe, 1997; Naughton, 1997). Some other studies (Shen, 1999; Lu, 2000; Xu, 2002) analyzed the rise of domestic firms in the telecom equipment and computer industries and emphasize self-developed technologies for their development.

Reviewing the development history of China's three ICT industries (telecom-equipment, PC, and cell phone), I noticed that domestic manufacturers have achieved a remarkable success in catching up vis-à-vis the multinational corporations (MNCs) in terms of gaining domestic market share. This experience is unique because few latecomers were successful in catching up when there was a strong MNC presence. Japanese or Korean firms as latecomers succeeded in catching up, but they did not face a strong MNC presence in their domestic market at the time. In addition, domestic firms focused on innovation rather than imitation during the catch up process.

The theoretical debates mentioned above disagree on whether or not latecomer manufacturers should prioritize in self-developed technologies, especially innovation capability, or should focus on imitating or assimilating somewhat obsolete technologies of more advanced countries. For this research, I focus on studying how innovation capability has played a role in Chinese domestic firms' catching up with the MNCs. Thus I form the following research question and study three groups of Chinese manufacturers in the ICT industries:

What have been the roles of innovation in promoting the catching-up by domestic firms to MNCs in China's ICT industries? How have the leading domestic firms acquired that innovation capability and what has been the role of the government during the process?

Acquiring innovation capability here refers to improving the ability for innovation and self-developed technologies, which is in direct contrast to the strategies of imitating or assimilating obsolete technologies of more advanced countries. In this research, I study leading domestic firms of the information industry in the People's Republic of China (China) from the middle 1980s to 2002 to contribute to this understanding. I develop a "staged catching-up theory" that helps in analyzing the catching up process of domestic firms in late industrializing countries.

Three sectors of nationally owned companies studied in this paper are: telecommunication (telecom) equipment, cell phone, and Personal Computer (PC) manufacturing. Telecom-equipment manufacturing consists of five sub-sectors: transmission systems, switching systems, access systems, data communications, and mobile communications. Mobile communications includes both equipment for mobile base stations and handset manufacturing. In this research, I divide domestic telecom-equipment manufacturers into two groups: telecom-equipment manufacturers and cell-phone manufacturers. The telecom-equipment manufacturers are firms, such as Huawei, Zhongxing, DaTang, and Julong that make products in all or most of the five subsectors mentioned. The cell-phone manufacturers are firms, such as Eastern Telecom, Haier, Hisense and TCL that mainly produce cell phones and have few products in other subsectors of the industry.

Telecom-equipment manufacturers have grown rapidly in the last two decades. In the 1980s, China relied nearly 100% on imports for its acquisition of telecommunication equipment (Zhang, 2000). Within two decades, domestic telecom-equipment manufacturers have progressed to hold a significant market share of the industry, especially in switching systems, access systems, and transmission systems. Successful domestic firms, such as Huawei, Zhongxing, DaTang, and Julong have become sources of national pride (Xin, 2000).

Within a short period of four years, domestic cell-phone producers have achieved a remarkable growth since they entered the market in the late 1990s: they rose from holding less than 3.2% of the domestic market share in 1999 (Xin, 2000) to around 51.3% for the months of January to April 2003. The fast rate of growth is outstanding because foreign firms had dominated the cell-phone market since the market started to grow in China in the late 1990s. For instance, in 1999, three leading foreign companies, Motorola, Nokia, and Ericsson, together held around 82.7% of the market share (31.9%, 29.4%, and 21.4%, respectively).[1]

Like the other two groups of manufacturers, domestic PC manufacturers have grown rapidly in recent years. Despite fierce competition imposed from their foreign rivals, such as IBM, Compaq, and Hewlett-Packard, domestic firms have won more than half of the PC market share, increasing from less than 30% in 1991 (Lu, 2000, p.1) to approximately 86% in 2000 (ING BARINGS, 2000). Legend, the largest domestic producer, alone held a 30% domestic PC market share in 2001 (Legend, 2002). In 2002, most of the ten largest PC producers in China were domestic producers (MII, 2003).

Within this context, I offer the following hypotheses to answer the research questions:

Innovation capability and self-developed technologies have been the driving force to Chinese domestic firms' catching up with the MNCs and have determined who are the leading domestic firms in these industries. Government involvement has rewarded the leading companies' efforts in building innovation capability and developing proprietary technologies.

The rest of the material is organized as follows: I start with a review of late industrialization and staged theories of industrial evolution in Chapter 2. Chapter 3 introduces the staged catching-up theory and its spatial manifestation. Chapter 4 reviews the role of the government in late industrialization. Chapter 5 presents the methodology. Chapters 6-10 are case analyses: chapters 6 and 7 cover telecom-equipment manufacturers; Chapters 8 and 9 cover PC manufacturers, and chapter 10 addresses cell-phone manufactures. Chapter 11 states the conclusion.

[1] Meanwhile, Siemens, Phillips, and Toshiba had 14.1% of the market share.

2 Late Industrialization

How can late industrializing countries develop their high tech industries via nationally owned firms? I start with theories that offer opportunities for developing countries in today's economy. Next, I examine the main strategies that have been used or proposed for late industrialization. Then, I review efforts to understand industrialization in dynamic perspective, such as stage theory, product cycle, profit cycle, and MNC-assisted growth theories. These theories have provided nutrition in building the theory of staged catching-up. I move on to introduce a view of late industrialization that emphasizes the role of a trio of actors: domestic companies, MNCs, and the host government. The staged catching-up theory focuses on these three actors and their interactions during the different stages of industrial development.

2.1 Opportunities for Latecomers

Do developing countries have an opportunity to catch up, especially in high-tech industries? Several theorists have offered positive answers. As early as 1942, Schumpeter mentioned "creative destruction," a notion that seems to fit perfectly as a description of what is happening in today's economy -- new technologies, business models, and architectures are simultaneously destroying old sources of value, while creating new opportunities for profit. It is this shift of the technological paradigm that suggests opportunities for latecomers.

More specifically, information and communication technologies are increasingly taking the form of configurational technologies since both modular design and the use of open standards can facilitate the substitution of internal components (Williams 1997). Shen (1999) distinguishes three types of technologies. First are discrete technologies: stand-alone technologies designed to carry out specific and common functions independent of context. An example is a word processor or computer-controlled machine tool. Second are system technologies: these typically relate to a wider range of activities than discrete technologies, and are thus more tightly linked to particular application settings. System technologies typically need to be adapted for use in developing countries in order to fit them to their different requirements and circumstances. System technologies, such as certain telecom-switching systems, tend to be rather rigid in their construction and may be difficult or costly to adapt. Finally, there are configurational technologies. These technologies match the complexity of systems technologies (in the range of applications for which they can be used), but are designed to allow great flexibility in development and application. Development costs are reduced by drawing upon existing component technologies, which can be selected according to the particular uses of the final product. This allows developing countries to reconfigure such solutions to their local needs and exigencies. The existence of configurational technologies extends the scope for recipient-side innovation because it makespossible foreign technologies to be locally configured to meet local criteria.

Although Schumpeter and Williams offered theoretical evidence of opportunities for latecomers, it is difficult for domestic firms in developing countries to utilize the opportunities effectively -the competition is fierce because of the coexistence of domestic firms and MNCs. Neither author discusses specifically how domestic companies can compete in the presence of MNCs.

The telecom-equipment, cell-phone, and PC-manufacturing sectors studied in this research are industries that have risen amid the shift of the technological paradigm described by Schumpeter. Moreover, the technological development of these industries has increasingly taken the form of configuration technologies. For instance, in the optical transmission sub sector, there is less vertical integration than in other industries, and optical component suppliers are clearly separated from the system providers. Furthermore, the component suppliers offer better component integration to the system providers (Smith-Gillespie, 2001). Seizing the opportunities, China's telecom-equipment, cell phone, and PC manufacturing producers did achieve a certain level of industrial competitiveness despite fierce competition with the MNCs. I seek a theoretical framework to explain the successful competition of domestic firms in the presence of the MNCs.

First, how do companies compete? Based on research in ten leading trading nations, in a four-year study, Porter (1990) reached the conclusion that companies achieve competitive advantage through acts of innovation. He proposed a "diamond" model as a new way to understand the competitive position of a nation in global competition, saying that a nation's capacity to innovate is affected by four broad attributes: (1) factor conditions; (2) demand conditions; (3) related and supporting industries; and (4) firm strategy, structure, and rivalry. However, Porter did not specifically analyze competitiveness developed by latecomers; instead, he focused on industrial competitiveness achieved by developed countries. This research, on the other hand, will focus on latecomers' competitiveness and study their building of innovation capability.

2.2 Strategies for Catching-up

Several main strategies were proposed for or found in late-industrializing countries: the bottom-up linear model, the path model, and the latecomer advantage and disadvantage model. Underneath these models are prescriptions for how late industrialized countries can effectively catch up.

Bottom-up Linear Model

The bottom-up linear model describes a progressive, path-following pattern for latecomers to catch up. In the context of import substitution, Leonard-Barton (1995) described a bottom-up model that starts from import kits, progresses to localization of parts and components, then to product redesign, and finally to the stage of product design. In the context of export-led East Asian newly industrialized economies (NIEs) (Hobday, 1995; Johnstone, 1989), the linear model goes from cheap labor assembling, to the second stage of original equipment manufacturing (OEM), then to original design manufacturing (ODM), and finally to original brand name manufacturing (OBM).

Hobday (1995) explains that the reason the bottom-up linear model takes root is that many developing countries are isolated from (1) main international sources of technology and (2) international markets.

Path Model

To explain the process of innovation capability building in selected industries in Korea, Lee and Lim (2001) found three different patterns of catching-up: (1) path- following (PC, consumer electronics, and machine tools); (2) path-skipping (DRAM, auto); and (3) path-creating (CDMA and mobile phone). The path-skipping and path- creating could be interpreted as "leapfrogging" in terms of catch-up. Their findings point out other, though radically different, alternatives for latecomers to catch up. I found that even though China's ICT industries have some characteristics described by the path-skipping and path-creating patterns, the whole process of catching up is much more complicated and a staged catching-up theory is needed to analyze an industry's development in various stages.

One of Lee and Lim's findings that caught my attention is that important R&D projects (except in the automobile industry) involved both private and public capability and that entry was driven not by an endogenous generation of knowledge and skills, but by collaboration with foreign companies. This implies collaboration with foreign companies is more important than endogenous R&D development. Contrary to this conclusion, , I have found that the innovation capability of Chinese firms was mainly driven by internal investment in R&D, and collaboration with foreign companies is secondary. This is discussed in detail in chapter 7.

Latecomer Advantage and Disadvantage Model

Rather than focusing on disadvantages, the latecomer advantage and disadvantage model provides a more balanced analysis. By examining three Japanese and three Korean semiconductor companies, Cho, Kim, and Rhee (1998) identify and categorize successful latecomer strategies into two groups: strategies for overcoming latecomer disadvantages and strategies for utilizing latecomer advantages. Strategies for overcoming disadvantages include focusing on specific area, thin margin or loss bearing, and volume building, whereas strategies for utilizing advantages include odd timing, time compression, human-embodied technology transfer, benchmarking, technological leapfrogging, and resource leveraging.

Amsden and Chu (2002) stated that to utilize the second-mover advantage, companies should: (1) exploit scale economies with market concentration because product maturity leads to declining profit margin and standardization; (2) exploit economies of scale and scope, especially those that are unique to latecomers (e.g., information, signaling, and risk); (3) upscale their project execution skills by investing internally in managerial and technological capabilities (for nationally owned companies) for efficient operation of large-scale facilities; (4) ramp up extremely fast to grow from small to large using resources available in de-bugged technology, capital, and human resources; and (5) displace foreign-owned firms by nationally owned firms (a kind of de-globalization) as skills grow stronger.

China's Catching-up Models

Some studies have implicitly followed the bottom-up/path-following model to analyze China's catching up in various industries (Fainstein and Howe, 1997; Naughton, 1997). In contrast to the liner bottom-up model, Lu (2000) argues that China's computer industry has followed a top-down approach (starting with product redesign/design, then walking up or down the ladder) because it has a strong science and technology base and a large domestic industry to break the barriers to the top-down model.

2.3 A Dynamic Perspective

Theories that suggest a recurring, recognizable path or pattern of development can help us to understand the evolution and development of industries and the nature of the competition at the various stages of the industries. In this sense, they provide us a dynamic perspective of industrialization. Rostow (1991) used historical evidence to identify the stages of development of nations, from traditional society to mature ones with high levels of material consumption. According to the stage theory, economic variables, as well as social and cultural characteristics, affect the rate and manner of progressing through these stages. It also suggests that developing countries that have accumulated a critical amount of capital and technology can reach a "takeoff" point in their growth trajectories. Beyond that point, the growth and stability of the countries will depend on their ability to employ existing and emerging technologies.

The product-cycle model (Kuznets, 1930; Burns, 1934) describes an evolutionary development path for individual sectors. The output has a bell-shaped curve over time, with the highest output after the initial state. Vernon (1966) further expanded the product-cycle model by examining how product innovation and the subsequent transfer of production technology determined the pattern of trade between two countries--an industrialized country, which produces only products that have been recently innovated (new goods), and a less-developed country, which produces only products for which the production technology is internationally available (old goods).

Markusen's profit-cycle model (1985) argues that individual industrial sectors develop along a recognizable path in which profit and other economic variables (such as employment, firm entry, market power, and occupational structure) change in a predictable fashion. Corresponding to each stage are the distinct spatial tendencies of the sector. Profit-cycle theory incorporates Schumpeterian and Marxist work on innovation and capitalist dynamics, Mandel's superprofits, product-cycle theories of business economists, and the oligopolistic model from industrial organization.

Profit-cycle theory divides each industry's development into five sequential stages according to profitability: zero profits, super profits, normal profits, normal-plus or normal-minus profits, and negative profits. The zero-profit stage corresponds to the initial birth and design stage of an industry. The super-profit stage corresponds to the stage when the firms in the industry can obtain super profits from their innovative edge and the absence of immediate competition. The normal-profit stage corresponds to the stage of open entry, movement toward market saturation, and absence of substantial market power. The normal-plus or normal-minus profit stage corresponds to the post-saturation stage, where either successful oligopolization boosts profits again, or predatory and excessive competition squeezes profit. The negative-profit stage corresponds to the obsolescence stage of the sector.

Key variables across the profit cycle are investment, output, and employment. In addition, the numbers of plants and companies present in the sector over time, concentration ratios, and occupational composition are important variables of the profit-cycle model.

2.4 Theory of MNC-assisted Growth

Ozawa (2000) presents an analytical framework to examine co-evolutionary changes in a country's (especially a catching-up country's) economic structure within the context of the global economy. A quadruple hierarchical paradigm along the axes of industries, factors of production, consumption, and countries was presented. He pointed out that MNCs' firm-specific assets (product and process technologies, organizational and managerial skills, and market networks and capacities) could serve as powerful driving forces for economic development in host countries. Government can function as a macro-organizational facilitator. Both MNCs and government serve as catalysts for structural upgrading.

2.5 Trinity of Industrial Development

Rostow's stage theory suggests "takeoff" opportunities for developing countries when they can accumulate needed capital and technology. Though relevant in helping us understand the general context of late industrialization, the framework that he provided is too general for this study, because we focus on only high-tech industry's catch up with the MNCs. Meanwhile, the product lifecycle model indicates a path-follower pattern for catching-up, and it focuses on the pattern of output rather than the motivation or behavior of the decision maker. The profit-cycle model explains why MNCs have a strong presence globally, along with the challenges faced by latecomers to break the stage barriers. Markusen's profit-cycle theory has successfully characterized the industrial process in the United States. Although the development path of industrial sectors in developing nations can also be characterized by the five stages of the profit-cycle model, analysts cannot use the this model directly for industrial sectors in developing countries without modification.

Ozawa's theory has realistically incorporated MNCs and the government into catching-up economies' industrial upgrading in a general sense. However, even though Ozawa mentions that the government can function as a macro-organizational facilitator, he does not give further description and examples of what government can do. In addition, domestic producers are completely missing in his theory. Furthermore, Ozawa's framework focuses on a rather macro level, i.e., the structural upgrading of a country.

It would be of more value to use a sectorial approach to examine at the industry level how domestic firms could catch up within a context where MNCs and government can serve as catalysts. Thus, taking elements from profit-cycle theory and the theory of MNC-assisted growth, I propose a "staged catching-up theory." This is a sectorial analytical framework for investigating domestic producers' development in catching-up economies, which emphasizes the role of three actors: domestic producers, the host government, and MNCs.

Domestic firms survive in an environment where the government and MNCs interact with each other. This ongoing interaction determines two important variables: (1) the degree of state control and (2) the penetration degree of MNCs. The degree of state control is a synthesis variable for many indicators. Generally we can look at two types of control exercised by the government: (1) over imports and (2) over setup of manufacturing units by foreign firms. Thus, we can divide the industrial environment into three categories according to the degree of government control:

- Case I. Complete control of the domestic market
- Case II. Some intermediate degree of control of domestic market
- Case III. No control of domestic market (totally free market)

In Case I, the government exercises complete control of the market. There are high barriers for import of goods and no allowance for MNCs' manufacturing units, and few domestic consumers will be able to buy foreign products because of the scarcity and high price of those products. The sector will consequently have a normal sectorial path as described by Markusen. Development may lag one or two stages behind developed countries, but it will have a faster pace· Case I may describe some industries in certain developing economies, but it was not the situation for China's information industry. At the beginning of the reforms in the late 1970s and early 1980s, the Chinese government did not stop the market penetration of foreign products. As a consequence, like most developing countries, China had a stage when no domestic production occurred and the consumers of products relied on imports. At later stages, although the government increased tariffs, it still allowed MNCs to set up manufacturing units.

For most developing countries, the government is weak, i.e., it can exercise only a limited degree of control, or sometimes simply none, as Case II and Case III reflect. For Case II or Case III, if MNCs are allowed to set up manufacturing units, then the sectorial path is much more complicated because we have two groups of firms in the host country: indigenous firms and MNC-controlled firms. From the perspective of MNCs, the host country is an international dispersion location for the MNCs when they are in the normal or normal-plus/minus stage of the profit cycle of the sector.

However, the indigenous firms may do one or both of the following: (1) seek short-term profit by producing mass quantities to satisfy the large present demand, (2) seek long-term profit by using current profits to develop their innovation capability, so as to increase their future competitiveness. Examples of the first case are consumer electronics (e.g., TV) in China: most firms in the sector have experienced only a very short period of super-profit, after which their profits decline to normal. Examples of the latter are the Chinese fixed telecom-equipment producers. In both cases, interaction among the government, MNCs, and domestic firms are complicated and will result in different dynamics at various stages.

The following chapter (Chapter 3) provides an analytical framework to describe this dynamic process of industrial development, especially the process that domestic firms usually go through during the catching up given certain background and preconditions. Further, a framework for understanding the spatial behavior of the industry is also presented in Chapter 3.

3 Staged Catching-up Theory

This chapter presents a staged catching-up theory to describe the dynamic process of late industrialization when there is presence of multinational corporations (MNCs). At each stage, I analyze the characteristics of the market, the behavior of domestic firms, the role of the government, and the behavior of MNCs.

This framework incorporates insights from the following sources that were reviewed in the previous chapter: Schumpeterian growth dynamics, staged theory, product-cycle theory, Markusen's profit-cycle theory, and Ozawa's theory of MNC-assisted growth.

3.1 The Theory

Continuous efforts in improving innovation capabilities of domestics firms by both the firms and the government can lead the domestic firms' catch up with the multinational corporations (MNCs). I describe this process by a sequence of four characteristic stages:

- **Preparation stage**: prior to the birth of the industry in the host country (only MNCs appears in the market);
- **Growth stage**: the stage of highest-profit rates for producers -- domestic firms are born and grow in different segments of the industry from MNCs;
- **Filtration stage**: the stage where the market moves towards saturation; decreasing profits eliminate less competent domestic firms;
- **Globalization stage**: the post-saturation stage of the domestic market, when domestic firms become MNCs themselves, thus finalizing their catching-up process.

These sequential temporal stages of the catching-up process correspond to different behaviors of domestic firms, MNCs, and the host government. They also manifest different spatial patterns.

3.2 Stage I: Preparation Stage

The first stage corresponds to the preparation for the catching-up process, which could also be called the pre-birth of the national industry. The prelude starts when the host country allows the MNCs to enter its market, either through foreign direct investment (FDI) or, in the case of China, by imports of foreign goods of various industries. In China, this occurred in the 1980s, when the country just started its "Open-Door" policy and the economy was transitioning from a traditional closed planning system to an open-market economy.

MNCs generally start with exporting finished products to the host country to explore the new market. But they may progress further to set up their own manufacturing sites in the host country to take advantage of local resources for production.

The government plays a large role in this stage by allowing the appearance of MNCs in the domestic market, though serious constraints might still be imposed on MNCs. In

China, during the transition from the planned economy, the government was quite conservative in dealing with foreign companies and exercised high control over MNCs compared to other open economies.

Some domestic firms are established to benefit from the appearance of the MNCs by engaging in the trading business or acting as their sales agents. These experiences can provide them with chances to become acquainted with the foreign products and to prepare for entering into the market when the time is ready.

3.3 Stage II: Growth Stage

Market demand starts to soar. The industry is in the highest profit-rate stage in the host country. After the exploration in the first stage, the MNCs start systematically to export their major products to the market of the host country. Some of them start to set up their manufacturing sites in the host country. At this stage, the MNCs mostly focus on only major segments of the host country's market, thus leaving some room for domestic producers to grow.

Attracted by the high profits of the industry, domestic firms start to enter the available segments of the market. Many domestic firms grow fast during this stage. These small firms compete with a variety of strategies. Because of the market segmentation, the domestic firms differentiate their products (ala monopolist competition); thus, the domestic producers are not directly confronted with the MNCs.

At this stage, three types of government intervention are vital: import control, foreign direct investment (FDI) control, and specific industrial policy. First, import control directly affects the export decisions of MNCs. Second, if the country has a great market potential and certain advantageous production factors, the MNCs are motivated to set up their manufacturing units in the country. If they are allowed, they will try to do this through wholly owned subsidiaries, or, if they are not allowed to set up this type of plant, they will enter into joint ventures. (Fan, 2001) High import control will further enhance this tendency. Third, the government can have specific industrial policies to protect certain segments of an industry so that they will not be dominated by MNCs, thus ensuring that domestic firms will have some room to grow.

3.4 Stage III: Filtration Stage

Market demand continues to soar. While certain subsectors' profits drop to normal, the industry expands and maintains super profits in newly expanded subsectors. Domestic producers and MNCs compete head-to-head at this stage. Their competition in the same market segments may be due to one of two possibilities: MNCs expand into the segments that used to be occupied solely by the domestic producers; or, domestic producers expand outside their original market segment and compete directly with the MNCs in originally MNC-dominated segments.

Because their dominant position is threatened or changed, MNCs have to drop prices for products in those segments where domestic producers have entered. Profit in those subsectors has declined from super to normal. MNCs might successfully cooperate with some domestic firms (for instance, IBM and Alcatel cooperated with Chinese firms to set up IBM-Great Wall joint ventures and Shanghai Bell), thus transforming their operations in the host country to become part in the MNCs' global production chain. At this stage, MNCs have a much better comprehension of the business environment of the host country. They focus on localization of their manufacturing and sales functions in the host country. They even start to move some high-end R&D functions (mostly oriented to later stages of product development) to the host country.

Facing MNCs with advanced technologies and large scales of production, weak domestic producers are quickly filtered out of the market. Only very competitive domestic producers survive this fierce competition. The surviving domestic firms have core competencies in areas such as technological capacity, managerial and organizational skills, and marketing network and capability. These producers know their advantages and disadvantages vis-à-vis the MNCs. The domestic producers focus on developing the core competencies, at which the MNCs are strong, while they maintain their advantages in the local market, such as after-sales services, etc.

The government can assist the industry to enter the filtration stage and make domestic firms better prepared. First, the government can facilitate this competition by removing the barriers, if any, previously created to protect the domestic producers. On the other hand, the government may use certain industrial policies, such as customer coordination for domestic producers, financial support, R&D support, etc., to strengthen the positions of domestic producers in the competition.

3.5 Stage IV: Globalization Stage

The competition in the domestic market becomes fiercer, even more than in the international market. In terms of R&D, domestic firms directly cooperate with international partners who have world-leading technologies. Domestic producers start to explore the international market by exporting to external markets, seeking foreign capital through foreign equity markets, or setting up manufacturing sites inforeign countries. In this sense, domestic producers become MNCs themselves and thus finalize the catching-up process of the industry.

The original MNCs may leave for other markets if the market in the host country has been saturated. They may also enhance their functions in the host country if there exist some advantageous factors that are not easily replicable in other catching-up economies.

At this stage, as domestic producers become mature and more capable vis-a-vis the MNCs, government intervenes less often. Most interventions from the government are indirect, such as science and technology (S&T) projects to encourage the R&D advancement of the domestic producers in the industry. The government may assist domestic producers' endeavors in the international market. For instance, the State

Council and Ministry of Posts and Telecommunications (MPT) greatly facilitated Great Dragon's exporting to Russia.

3.6 Key Variables across the Staged Catching-up Process

In Table 3.1, I summarize the change in the sector across the four stages, using the same sectorial features as that of Markusen's profit cycle theory (1985). These are: output, price, cost, profitability; production features such as employment, occupation structure, subcontracting, and advertising and sales; and industry structure features such as entry, concentration, size of firm, vertical integration, and modal class of ownerships. These features provide an aggregate picture of various business behaviors during the catching-up process. This also makes it possible for me to compare the staged catching-up theory and the profit-cycle model. Further, to distinguish between MNCs and domestic firms, I have three sub-categories (total, MNCs, and domestic firms) for most of the features. (See Table 3.1)

The evolution of the first several variables (output, price, cost, profitability) is product-based, or broadly, sub-sector-based. A high-tech industry, such as telecom is characterized by emerging new sub-sectors, with a certain time lag in between. So while subsector A's products might be in the stage with a saturated market, dropping price and profitability, sub-sector B's products might just be getting started with increasing demand, and high profitability.

The evolution of the production features and industry structure are sectorial-oriented, i.e., these features represent industry's evolution or the catching up process more precisely. We can see that domestic firms' employment growth and level are much more dramatically changed than the MNCs. In terms of occupation structure, domestic firms will keep a high *R&D staff / total employee* ratio all throughout the stages.

Variables of industrial structure have an interesting dynamic evolution. Throughout the stages, domestic firm sizes keep expanding. Entry barrier changes from high in the preparation stage to low in the growth stage, but starts to rise again in the filtration stage; concentration changes similarly from high to low to high; With the staged catching-up theory, the change of the variables is very easy to comprehend. Initially, as only large MNCs exist in the domestic market, the entry barrier is high, as no domestic firm knows how to enter the industry. During the growth stage, some opportunity, such as a segment of the market with low barrier of entry, shows up, and many small domestic firms start to enter the market, leading to a low concentration. During the filtration stage, competition eliminates uncompetitive domestic firms, barrier to entry rises again, and strong firms expand quickly, thus leading to high concentration again. These features carry further into the globalization stage.

Table 3.1Business Behavior During the Catch Up Process

Catch-up Stage	Ownership	Preparation	Growth	Filtration	Globalization
Output, cost, price, profits, investment					
Output					
Level	Total	low	moderate	moderate/high	high/moderate
	MNCs	low	moderate	moderate/high	moderate
	Domestic	n.a.	low/moderate	moderate/high	high/moderate
Growth	Total	moderate	rapid+	moderate+	moderate+/moderate-
	MNCs	moderate	rapid+	moderate+	slow/slow-
	Domestic	n.a.	rapid++	Rapid	moderate+/moderate-
Price					
Level		high	high/moderate	moderate/low	stable to slow
Growth		rapid-	moderate-	moderate-	stable to slow
Unit Cost	Total				
	MNCs	high/moderate	moderate	Low	low
	Domestic	n.a.	high/moderate	moderate to low	low
Profitability					
	MNCs	high	high/moderate	Moderate	low/moderate-
	Domestic	n.a.	high/moderate	Moderate	low/moderate-
Production Features					
Capital/labor ratio					
Employment					
Level	MNCs	low	moderate	moderate/high	high to moderate
	Domestic	n.a.	low	Moderate	moderate/high
Growth	MNCs	moderate	rapid	moderate+	slow/slow-
	Domestic	n.a.	rapid++	Rapid	moderate+/moderate-
Occupation Structure					
Engineering	MNCs	low	low	low/moderate	low/moderate
Managerial	MNCs	high	high	moderate/high	moderate
Production	MNCs	high	high	High	high
Engineering	Domestic	n.a.	moderate/high	High	high/moderate
Managerial	Domestic	n.a.	low	moderate to high	high to moderate
Production	Domestic	n.a.	low/moderate	Moderate	high
Subcontracting	MNCs	low	moderate	Moderate	moderate to high
	Domestic	n.a.	high	Moderate	moderate to high
Advertising, Sales	MNCs	low	low to moderate	Moderate	high to moderate
	Domestic	n.a.	moderate	moderate to high	high to moderate
Industry Structure					
Entry		high to moderate	low/moderate	moderate to high	high
Concentration		high	low/moderate	moderate to high	high
Size of Firm	MNCs	large/medium	large/medium	Large	large
	Domestic	n.a.	small	medium to large	large
Vertical Integration	MNCs	extensive	extensive	Modest	modest
	Domestic	n.a.	modest	modest/extensive	modest
Modal Class of Ownership	MNCs	corporate/conglomerate	corporate/conglomerate	corporate/conglomerate	corporate/conglomerate
	Domestic	n.a.	corporate: single plant	corporate: multiplant	corporate/conglomerate

Source: The author, based upon the same features and conventions as in the profit-cycle theory (Markusen, 1985).

3.7 Acquiring Innovation Capability

What kind of force drives the upgrade of domestic producers, thus pushing the domestic industry to progress from one stage to another? Innovation capability is the driving force that is behind the catching-up of market-share of domestic firms. Throughout the stages of the catching-up process, only those who have innovation capability can exploit the best of the opportunity. In the growth stage, innovation capability is reflected in the company's capability to identify and develop products in segments different from the MNCs' market. In the filtration stage, the importance of innovation capability is demonstrated by the fact that self-developed technology is necessary for domestic companies to compete against the MNCs in the same market. In the globalization stage, improving innovation capability to the level of the MNCs becomes more urgent, because domestic firms need to satisfy the sophisticated requests from customers in other markets.

How do the domestic firms acquire their innovation capability throughout the stages of development? I view two preconditions as vital. First, the industry itself should not be a mature industry, i.e., the industry should still be in the process of creating numerous innovations, as with telecom-equipment. Second, the firms must be equipped with resources for developing their innovation capability, either through state promotion of R&D, or through firms' investment in R&D from their revenue, or through directly acquiring other technologically advanced firms. Group advancement, i.e., a group of domestic firms advancing their innovation capability together, along with research institutes and universities, will be a very efficient way to supply such resources.

The first precondition is required because it provides a window of opportunity for indigenous firms. Indigenous firms acquire their capabilities in the subfields that are already a mature technology for MNCs (such as switching systems), but because of the linkage between the subfields of the sector, if a new subfield emerges, they may be able to leverage their ability to develop new products in the new subfields. In this sense, continuous emergence of new subfields in the sector means continuous opportunities for the indigenous firms to catch up with or even surpass the MNCs.

The second precondition is required because the development of innovation capability in an emerging sector requires a huge amount of resources. Thus, the firms either have to be extremely profitable, or they must have some other resources to invest in R&D, or both. It is hard for firms that cannot even balance their account to invest 10% of their revenue in R&D. As Markusen points out, state promotion of R&D could be very useful to help the sector fulfill this precondition.

In-house R&D development, supplemented with external alliances, is the key channel for domestic firms to build up their innovation capability. I need to emphasize that without a major in-house R&D development effort, external alliance or other forms of technology transfer will be less efficient, as internal development affects the ability to absorb the transferred knowledge. Studies of large and medium-size enterprises in China's industry have confirmed that technology transfer affects productivity only through its interaction with in-house R&D (Hu, Jefferson, and Qian, 2003).

Because of the disintegrated value chain, many international firms who have cutting-edge technology and have specialized in certain aspects of the process are willing to cooperate with domestic firms to benefit from the expanding market. By cooperating with these international firms, domestic firms can obtain a short cut in catching-up with the technological capabilities of the MNCs. Further, acquisition and merger may be considered an effective way to advance innovation capabilities over the short term. Though most small-to-medium firms are unable to afford such approaches, for large companies who diversify into new fields of manufacturing, this will be a reasonable choice.

If both preconditions are satisfied, indigenous firms can follow a spiral path between super profits and normal profits as the sectors try to develop various products in different subfields. In contrast, the MNC-controlled firms in the host country, serving only as the production base for their parent companies, have hardly any of these dynamics.

3.8 Spatial Manifestation of the Catching-up

How is the catching-up process of domestic firms reflect in space, then? I derive the spatial behavior of the industry that is corresponding to each stage.

Industrial location theory originated from concerns of early spatial analysts about traditional basic costs of the industries. Prior to the 1960s, most location theorists (Weber, 1929; Isard, 1956; Beckmann and Thisse, 1986) believed that basic costs, such as transportation costs from supplier to market, access to material inputs, and the availability or cost of labor were the dominant determinants of industrial location. This classical location theory is also called Weberian location theory after Alfred Weber (1929), who provided a method for finding the optimal location for a firm, given distance to raw materials and the final market.

The basic cost factors have declined in their relative importance, as other location factors became more important. Those other factors include technical competence of the labor force, state and local taxes, regional business climates, and quality-of-life factors. Markusen, Hall, and Glasmeier (1986) pointed out that because high-tech production does not rely on either raw materials or a high value-to weight ratio, it does not necessarily use the location calculus specified in the Weberian model. High-tech industries' locations are usually determined by variables such as availability of skilled labor, proximity to academic institutions, amenity and quality of life, etc., rather than the friction cost (Blair and Premus, 1993).

From the viewpoint of economies of scale, Polenske (2002) has proposed two types of economies of scale that may enhance regional growth, namely, agglomeration economies/diseconomies and dispersal economies/diseconomies. In contrast to the popular term of "agglomeration economies/diseconomies", she created "dispersal economies/diseconomies" (2001). She proposed a clear investigation of these two factors on regional development. For instance, using three cases - China's coke-making industry, Haier, and Chicago metal industry - Polenske and Li (2003) found supply chains produce at least two types of dispersal economies -- transportation and inventory cost saving and service-level improvement.

To link the dynamics of industrialization with location and the profit cycle, Markusen (1985) derived the spatial behavior of sectors and the consequent regional location patterns from the profit-cycle behavior: concentration, agglomeration, dispersion, relocation, and abandonment. At the initial stage, the sector's location is confined to one or a few locations. At the super-profit stage, firms tend to cluster with each other and draw linked sectors and a skilled labor force to them at the initial site. In the third stage -- the normal-profit stage -- as market competition and cutting costs become major concerns of the firms, firms tend to disperse their additional production units from the core, but the sites are closer to markets and have cheaper labor and land than the core. The aggregate spatial outcome of the fourth stage, the normal-plus or normal-minus stage, is relocation. The sector may close plants in one region while expanding production in others. In the last stage, the negative-profit stage, firms retire their production.

3.9 Location Pattern of the Staged Catching-up

According to the staged catching-up theory, both domestic and MNC companies, but especially domestic companies, have distinct resource requirements at various stages of the catching-up model. Because regions are unequal in terms of market demand and factor supply, their attractions for a business vary. I derive the hypothetical spatial behavior of the sectors and the location pattern of firms from the catching-up model. During the preparation stage, the sector generally is confined to one or a very few locations, which I call "**concentration**." This is a direct result of MNCs' first appearance in the host country's market. MNCs usually choose the areas where the business environment is favorable (for instance, special economic zones,) as their starting points for exploring the host country's market, either for exports or FDI. Domestic firms, mostly involved in the trading business or acting as sales agents for foreign producers, similarly favor locations with a good business environment (mostly special zones) or wherever the foreign firms choose to place a hub for their operations in the host country.

In the growth stage, the sector is found to have operations in many sites of the country, which I call "**expansion**." MNCs emphasize manufacturing capacity, usually expanding their operations through relocating their manufacturing sites. Meanwhile, many small domestic start-up firms begin to grow rapidly with a need for manufacturing capacity as well as other resources. Locations of firms are not confined to a few sites, but expand to many sites in regions with favorite business climates.

In the filtration stage, because decreasing profits eliminate less competent domestic firms, the domestic firms diminish in numbers. However, the surviving domestic firms grow in size. The sector is characterized by several large MNCs and several medium, but competitive, domestic producers, all of which are multi-plant corporations. MNCs focus on localization of their manufacturing and sales functions in the host country to decrease their production costs. Similarly, concerned about market share and production costs, domestic firms expand their manufacturing capacity to achieve economies of scale. The sector is found to have fewer locations, of larger scale, for manufacturing functions. Furthermore, companies' R&D functions cluster in only a few locations where highly skilled labor is concentrated. Because MNCs may move some high-end R&D functions to the host country, they will choose locations for their R&D functions similar to those of domestic firms to access the skilled labor pool. In addition, market access will be another criteria because high-end R&D often involves close contact with the customers. I call this phenomenon "**consolidation**," where manufacturing and R&D sites of firms congregate in only a few locations. In contrast, both MNCs and domestic firms start to form a relatively complete national sales network, though with regional concentrations.

In the last stage, the industry's location is found to span national borders, which I call "**globalization**." Domestic firms become MNCs themselves and set up sales offices and factories in foreign countries. They also establish their new R&D centers where the cutting-edge knowledge is in order to utilize international professional expertise in research and development. Adding of external locations for the R&D function is novel compared to the MNCs from the developed countries, which relocated to developing countries to take advantage of the low costs and the expanding markets.

Concentration, expansion, consolidation, and globalization are staged spatial manifestations of firms and the industry during the catching-up process. The staged theory provides insights in understanding what are the primary resources (marketing, manufacturing, or R&D) that companies focus on developing in each stage, how that has posed requirements for location, and what are the spatial manifestations of the industry. On the other hand, firms' location decisions are a result of balancing agglomeration and dispersal economies/diseconomies. For instance, when at the growth stage, companies place a high priority on faster expansion of manufacturing capacity. Dispersal economies prevail over agglomeration economies as many firms were established in different locations. While in the filtration stage, agglomeration economies became more dominant for manufacturing and R&D functions, because companies compete for manufacturing capacity by economy of scale and strengthen their R&D functions by gathering in locations of prominent knowledge network clusters. Factors important to dispersal economies, such as cost saving of inventory, and transportation and service improvement, are not essential to R&D. This leads to the spatial result that the R&D function of firms only concentrated in a few locations. At the globalization stage, firms' R&D function dispersed to global locations in a concentrated manner, i.e., even though the geographic region has been extended, only certain locations are preferred. While at the same time, firms' market function has always tended to disperse.

This chapter offers the staged catching-up theory that can be used as an analytical framework to describe the dynamic process of the latecomers' catching-up. The driving force behind the staged catching-up are continuous efforts in improving innovation capabilities of domestic firms by both the firms and the government. This chapter also derives the spatial behavior that corresponds to each stage.

The following chapter (Chapter 3) provides an analytical framework to describe this dynamic process of industrial development, especially the process that domestic firms usually go through during the catching up given certain background and preconditions. Further, a framework for understanding the spatial behavior of the industry is also presented in Chapter 3.

4 The Role of the Government in Late Industrialization

Among the research that has been done exploring the causes countries like the newly industrialized economies (NIEs) take off, most debates have focused on the role of the government versus the market (Patrick 1977; Chen, 1979; Aikman, 1986; Friedman, 1980; Fei, 1983; Berger 1979; Saxonhouse, 1985; Bhagwati, 1988; Hasan 1976; Mason 1980; OECD 1972; Rosovsky 1972; Amsden, 1989; Wade, 1990; Singh, 1992; Sakakibara and Cho, 2002). Some focused on the role of the government in innovation capability building for domestic firms (Bell and Pavitt, 1992; Freeman, 1987; Nelson, 1992; Lundvall, 1992; Hobday, 1995)

This chapter reviews literature that focused on two central issues: (1) government vs. market in late industrialization and (2) government role in innovation capability building.

4.1 Government Vs. Market

There are two variant neo-classical views to explain the East-Asian success: the free market (FM) theory and the stimulated free-market (SFM) theory. Neoclassical theorists see efficiency in resource use as the principal general force for economic growth. They attribute the East-Asian success to the fact that the superior market in East Asia, with fewer price distortions, produces a more efficient allocation of resources than markets in other countries.

The FM theorists say that the East-Asian Newly Industrialized Countries (NICs) do better than other newly industrialized countries because the markets for goods and factors of production were freer, i.e., the East-Asian states seldom interferes in the working of the market.(Patrick, 1977; Chen, 1979; Aikman, 1986; Friedman, 1980; Fei, 1983).

The SFM theorists recognize the existence of market distortions and industrial policies in East Asian, but say that industrial policies merely offset existing market distortions, creating overall neutrality in resource allocation. (Berger, 1979; Saxonhouse, 1985; Bhagwati, 1988)

In direct contrast with the neoclassical view, several earlier South Korea (Hasan 1976; Mason 1980) and Japan (OECD, 1972; Rosovsky, 1972) analysts have emphasized the directive role of the state in East Asia. Wade proposes a political-economy approach, which he called government market (GM), that treats capital accumulation as the principal general force for economic growth. According to the GM theory,[2] the East-Asian success is a result of a higher level and different composition of investment than in less-successful countries. The difference in investment is due mostly to government actions to constrain and accelerate the competitive progress, carried out by a relatively authoritarian and corporatist state. (Wade, 1990, pp 26-27)

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[2] Wade's GM theory builds on both the idea of the development state (Johnson 1982; White 1988) and on the older development economics' understanding of the nature of the development problem.

Amsden (1989), on the other hand, specifically states that government policy makers deliberately got some prices "wrong," so as to change the signals to which decentralized market agents responded, and they also used non-price means to alter the behavior of market agents. The resulting high level of investment generated fast turnover of machinery, hence a fast transfer of newer technology into actual production.

Wade criticized that the FM and SFM theories are silent on the political arrangements needed to support their policies. In contrast, he maintains that his GM theory has emphasized the developmental virtues of a hard or soft authoritarian state in corporatist relations with the private sector. A centralized bureaucracy was conferred with enough autonomy to influence resource allocation in line with a long-term national interest, with which short-term profit-maximizing sometimes is in conflict.

Wade rejects claims that the East-Asian success is a result of free-market principles or a result from government intervention only. He states that the East-Asian success was rooted in the way allocation decisions were divided between markets and public administration and the synergy between them.

4.2 The Advocate Role of the State

In "Asia's Next Giant," Amsden (1989) examines the industrialization process of South Korea. She explores state intervention, shop-floor management, and the big-business group *chaebol*. She drew attention to the interesting phenomena that the government imposes strict performance standards on those industries and companies that it aids. Her analysis is very powerful evidence for the strong role of the state in economic development.

Singh (1992) maintains that the superior performance of the Asian countries is due to the fact that they are less subject to interest rate, demand, and capital-supply shocks of the world market. He argues that it is the world-market force over which the developing countries had no control that caused the crisis of economic development in the Third World in the 1980s. Singh points out the flaws of the orthodox perspective on economic policies of the success of the East-Asian NICs in 1980s. The orthodox perspective attributes the success to the economic policies, such as extensive liberation policies, privatization, deregulation, liberalization, and closer integration with the world economy proposed by international financial institutions. Empirical evidence from Japan, Taiwan (Sachs, 1987),[3] and South Korea (Amsden, 1989) all support the role of the state and negate the orthodox view.

Later in his critical analysis of the *World Development Report* (1991) of the World Bank, Singh (1994) argues that the best way to promote industrialization and economic development in many developing countries is for the government to pursue a vigorous

[3] Sachs (1987) points out Taiwan is more heavily dependent on state-owned enterprises than any country in Latin America (except Venezuela).

"industrial policy." Government policymakers in Japan,[4], South Korea,[5] and Taiwan,[6] three of the fastest growth East Asian countries, have guided the market towards planned structural change, and they integrated their economies with the world economy in the directions and extent to which it was useful for them to do so. He criticized that the report authors misinterpreted the East-Asian countries as having a neutral passive state with a "market-friendly approach to development," or a deep integration with the world economy.

4.3 The Role of the Government in improving Innovation Capabilities

Amid the policy debate on industrial technology in developing countries, Bell and Pavitt (1992) emphasized technological capability as a source of competitive advantage but rejected the traditional wisdom that production capacity leads automatically to technological capability. They point out that market-related institutions tend to undervalue technological accumulation. They therefore argue that the "market-failure" approach is useful in defining government's role in funding education, training, and basic research.

They also present a classification of acquisition of technology by firms into four categories of technological development: (1) supplier-dominated firms, (2) scale-intensive firms, (3) science-based firms, and (4) specialized-supplier firms (p. 264). Firms in each category have their distinctive method of acquiring technology.

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[4] Each sector of the Japanese economy has a cliental relationship to a ministry or agency of the government. The ministry, in addition to its various statutory means of dealing with the economic sector, holds a general implied administrative responsibility and authority that goes well beyond what is customary in the United States and other Western Countries. Although Ministry of International Trade and Industry (MITI) plays the most prominent role, its operations are not distinctive. The industrial bureaus of MITI proliferate sectoral targets and plans; they confer, they tinder, they exhort. This is economics by admonition to a degree inconceivable in Washington or London. Business makes few major decisions without consulting the appropriate government authority; the same is true in reverse. (Caves and Uekusa, 1976) The Japanese government's role in promoting industries is very crucial in that "Japan may be called a country of the Government industrial complex" (Nino, 1972). MITI's vice-Minister Ojimi has described Japan as a plan-oriented market economy (Nino, 1972).

[5] The following aspects of South Korea's industry policy have drawn most attention: 1. The use of long-term credit at negative real interest rates to foster particular industries. 2. The heavy subsidization and the coercion of exports. 3. The strict control over multinational investment and foreign equity ownership of South-Korean industry. 4. A highly active state technology policy. 5. State promotion of large-scale conglomerate firms, government encouragement of mergers of specific corporations, and, in general, state restrictions on the free entry and exit of firms. (Amsden 1989; Wade 1990)

[6] Taiwan is one of the developing mixed economies that have the largest public enterprise sector. Public enterprises have contributed one-third of the gross fixed capital formation in Taiwan from 1950-1975, a period which witnessed the most rapid economic and industrial growth in that country. The public sectors has been used as the chosen instrument for a big push in many sectors. Public enterprises have played a central role in creating new capacities. Incentives and pressure are brought to bear on private firms as well– import controls and tariffs, entry requirements, domestic-content requirements, fiscal investment incentives, and concessional credit are devices used by the government as "administrative guidance." (Wade, 1990:pp. 110-11)

They conclude that "successful technological accumulation depends on (a) the acquisition of foreign technology; (b) investment in education, training, and research; (c) economic incentives for innovation and imitation; (d) continuous growth of demand; and (e) institutions and policies designed to encourage firms to accumulate technology."

Therefore, Bell and Pavitt imply that government should get involved in education, training and research, as well as establish institutions and policies designed to encourage firms to accumulate technology.

Other theorists, such as Friedrich List (Lundvall, 1992, p. 16), also indicate the need for governmental responsibility for education and training and for developing an infrastructure supporting industrial development. To these theorists, production of new technology is not something only related to firms, but to a system of private firms, government, and universities. They use the National System of Innovation (NSI) to refer this complicated system. Freeman (1987) explicitly uses the concept of NSI to analyze the organization of R&D and of production in firms, inter-firm relationships, and the role of government (especially MITI) in Japan. Nelson (1992) presented studies of the US NSI and analyzed the combined public and private character of technology and the role of each party in producing new technologies. He emphasized the important role of institutional set-ups for NSI. Based on the belief that the international competitiveness of nations is founded on innovation, Lundvall (1992) also pointed out that NSI can play a role in determining the long-term dynamics of an economy.

Governments in NIEs have been actively involved in improving NSI in general and helping firms in high-tech sectors to advance their innovation capabilities. Those involvements mainly include increased investment in education, government institutes and policies for encouraging firms to accumulate technology.

Korea increased steadily its investment in education from 2.5% of the government budget in 1951 to 22% in 1987. It also set up large government-funded institutes, such as the prestigious Korea Institute for Science and Technology (KIST), to carry out R&D and to train engineers and researchers. These institutes obtained more than 90% of government research funding during the 1980s. (Hobday, 1995)

Though government technological and industrial intervention had little effect during the 1960s and 1970s, Taiwan's government supplied the educational and infrastructure support needed for electronic industrial development to overcome the barrier of entry. The government controlled Industrial Technology Research Institute (ITRI) trained engineers in advanced semiconductor technologies and transferred technology to local firms. Further, ITRI incubated several firms which became the core of the domestic chip-manufacturing industry. (Hobday 1995)

To encourage upgrading of the R&D part of the manufacturing for electronics and IT industries, Singapore's government set up several technology institutes in the early 1990s, such as Institute of Manufacturing Technology, Institute of Microelectronics and Magnetic Technology Institute (EDB, 1992).

Even in the laissez-faire Hong Kong, government agencies played an important role in helping companies to improve their innovation capabilities. For instance, the Hong Kong Productivity Council (HKPC), funded mainly by the administration, was established in 1967 to provide technological support for local firms. HKPC assists small and medium - size firms by subsidizing training programs and consultancy, by making modern electronics facilities available, and by helping companies to design new products. For instance, in 1992, HKPC organized 2 consortia: one involved 15 firms to design a palmtop computer; the other involved 8 firms to produce a cordless telephone. These projects brought new innovations to the market and helped small firms to overcome their size constraints. (Hobday 1995)

4.4 Chapter Conclusion

Most debates on late industrialization focus on government vs. market. Another important aspect is the government role in improving innovation capabilities of the nation, in general, and domestic firms in high-tech industries, in particular. For this study, I assume in my case analysis that the government has set up goals to help domestic firms and has been able to adjust its behavior/policies with feedback from the environment to maximize the effectiveness of its involvement. Thus, I will focus on analyzing the changed role of the government: What role has the government played during the catching up process in china? What caused its involvement to change?

Further, I will study the role of the government in firms' improvement of innovation capabilities. My main questions are: What has the government done to help firms improve their innovation capabilities? What caused their role in the process to change?

5 Research Methodology

I have used a multi-case study for this research, supplemented with simple regression analysis. I have chosen three to five domestic firms from each of three manufacturing groups in China and analyzed their development history and innovation capabilities from their founding date to the end of 2002. The three manufacturing groups are: (1) telecom-equipment manufacturers, (2) computer manufacturers, and (3) cell-phone manufacturers. In this chapter, I explain the reasons for using multi-case analysis of these three industries in China, criteria of selecting firms, data collected for answering the research questions and testing the hypothesis in chapter 1and the data-collection process. The detailed description of regression analysis can be found in Chapters 7 and 9.

5.1 Why Choose Case Analysis?

I have chosen multi-case analysis mainly for the following reasons: First, the qualitative-case approach allows me to conduct an in-depth analysis of the phenomena (Ragin, 1994), i.e., a longitudinal assessment of business environmental changes and corresponding changes in companies. Second, choosing a multi-case analysis rather than a single-case analysis allows me to "identify similarities within subsets of cases that distinguish them from other subsets"(Ragin, 1994, p. 124). I was able to find commonalities of firms in the same industry and to distinguish firm-specific characteristics.

In order to ameliorate the disadvantages of case analysis, for each manufacturing group I provide a brief introduction of the industrial background, which covers industrial structure, major suppliers, and market characteristics, both globally and domestically. Thus, the detailed firm-level analysis is solidly rooted in the industrial context.

In addition, for this study, the limited time available to finish my research work makes it impossible to conduct an extensive study for three different industries. Further, there are no publications providing the detailed statistical data that I would need to conduct the industrial analysis, which means I would have to conduct my own data collection at the industrial level, i.e., prepare my own survey forms to send to thousands of companies and ensuring most of them had returned the survey form with reliable answers. This amount of work would not be feasible for a single researcher to do. However, in the future, this approach could be used for similar research projects.

5.2 Why China?

China has a very interesting institutional setting. The so-called "market economy" started in the 1980s and brought China great changes. Having experienced economic transition over the last twenty years, China now has a huge market for information infrastructure and other IT products. More and more individual consumers have their own cell phones and personal computers. For instance, in 2002, China had 170 million cell-phone subscribers,[7] the most subscribers of any country in the world. The

[7] *www.umtsworld.com/industry/marketshare.htm as of Oct. 28,2002*

exponential growth of phone and Internet usage has imposed requirements for the country's telecommunication infrastructure and drives the telecom equipment market to expand rapidly as well. On the supply side, the Chinese government and enterprises are trying hard to catch up in the high-tech sectors. As a result, the share of the PC market held by domestic producers has increased from less than 30% in 1991 to approximately 86.4% in 2000.[8] Meanwhile, domestic telecom equipment producers have shown increasing performance in various areas of the industry, measured by their growing market shares vis-à-vis the MNCs.

Second, few studies have been done for China's domestic firms in the information industry. Shen (1999) tracked the early development history of a domestic firm, Great Dragon Information Technology (GDT), in contrast with a joint venture from the 1980s to the early 1990s. He described the acquisition of Public Digital Switch System (PDSS) technological capabilities in the two contrasting cases: "System-12", in which the foreign technology was transferred into China as a complete system through a joint venture (Shanghai Bell); and "HJD04", a locally developed system which utilized available foreign components and design tools and was developed by GDT. Shen's analysis provides insights into China's "dual-track" technology policy of "walking on two legs" in the early development stages of telecommunications.

Lu (2000) documented in detail the development history of four major domestic firms in the IT sector–Stone, Legend Group, Founder, and Great Wall–from their founding dates in the 1980s to the late 1990s. He argued "the Chinese computer enterprises followed a unique mode of technology learning, which [was] coupled with unique organizational and institutional arrangements" (Lu, 2000, p. 3). Rather than the "bottom-up" model–starting with the assembly of imported kits, then the localization of parts and components, then product redesign, then design of original product–the Chinese firms have followed a "top-down" model of technological learning, i.e., starting with product design or redesign, and then going forward or backward to transfer technologies at other levels. Lu contributed "technology capability" and "enterprise governance" to this model of technological learning.

Xu (2002) examined the development history of two generations of high-tech companies in China's IT sector. The first-generation companies, Legend, Founder, and Great Wall, appeared in the mid- and late 1980s, competing in computer-related areas. The second-generation companies, Sohu, Sina, and Netease, are internet-related companies. Xu's analysis focused on the relationship between external resources and the building of organizational capability. Xu shows that external resources are important, but that rich resources do not guarantee success if they fail to help build organizational capabilities, and might even become a hurdle to sustain a competitive edge. Firms build their organizational capabilities through its development process rather than just from richer or "better" external resources.

Further, there are Chinese books written on China's high-tech companies, such as Xin (2000), Xu (2000), and Zhang (2000). However, they are not scholarly literature and

[8]See details in Chapter 5.

were written for popular audiences with no attempt to provide an intellectual understanding of the issues of concern in the present research. Nevertheless, they provide some details on the telecommunication and PC industry's development and can serve as part of the evidence.

5.3 Why Choose These Three Groups of Manufacturers?

First, I am interested in the information industry because of my own technical background in electrical engineering and computer science. My technical background helps a great deal in communicating with engineers and understanding companies' R&D choices. Second, the Ministry of Information Industry (MII) oversees these three groups of manufacturers. It will help us to distinguish the industrial-level issue within the same institutional setting. Third, these groups of manufacturers vary in their degree of success and their developmental paths. It will be interesting to compare the factors that have caused their variation.

5.4 Companies

I have chosen twelve companies from the three sectors according to the following criteria:

- Are they major players in their field by the measures of market share, sales revenue, appearances in media reports, etc.?
- Do they have a large impact on the development of the industry?

Based on these criteria, I selected three to five firms from each manufacturing group. They are: Huawei, Zhongxing, Julong, and Datang as the telecom equipment producers; Eastern Telecom, Panda Electronic, Haier, and TCL as cell phone producers; and Legend, Great Wall, and Founder (Fangzhen) as PC manufacturers (Table 5.1).

These twelve companies are only a subset of the companies in the three manufacturing groups. They were the major players in the market in 2002 or leaders in the 1990s. The selection of these companies represents the successful cases from the industry; analysis of their development history will shed insight on how to succeed as latecomers. Further, I use China's 100 largest electronic companies as a base to analyze each company's innovation capability.

Table 5.1 Companies Chosen for Case Analysis

Company Name	Date of Establishment	Employment	Sales Revenue (in US$ billion)	Profit (in US $ million)
Telecom-equipment Manufacturers				
Huawei Technology Corporation 华为技术有限公司	1988	18,000	2.7	319.8
Shenzhen Zhongxin Technology Corporation 深圳市中兴通讯股份有限公司	1985	12,916	1.3	96
Datang Telecom Technology Co., Ltd. 大唐电信科技产业集团	1998	4,183	0.247	36.1
Great Dragon Information Technology 巨龙通信设备有限责任公司	1994	2,500	0.24	4.2
PC Manufacturers				
Legend Computer Group Corporation 联想控股有限公司	1984	11,220	3.9	169.3
Peking University Founder Group Co. 北京北大方正集团公司	1986	6,000	1.4	29.5
China Great Wall Computer Corporation 中国长城计算机集团公司	1986	n.a.	2	n.a.
Cell-phone Manufacturers				
TCL Holding Co., Ltd. TCL 集团有限公司	1981	30,000	2.5	86.1
Haier Group Co. 海尔集团公司	1984	30,000	7.3	241.9
Hisense Group Co. 海信集团有限公司	1969	10,000	1.9	26.1
Eastern Communications Group Co. Ltd. 东方通信有限公司	1958	2,200	1.3	45.7
Panda Electronics Group Co., Ltd 熊猫电子集团有限公司	1936	n.a.	2.6	117.2

Source: website of each company.

Note:

1. Eastcom's profit is 2001's data.
2. Great Wall's Revenue is RMB 16.2 billion, about $1.96 billion, Eastcom's renenue is RMB 10.5 billion, about $1.27 billion, both are 2001's data.
3. Using exchange rate: 1 USD = 8.27740 CNY
4. n.a. = not available.

Huawei, Zhongxing, Julong, and Datang are four representative domestic firms that arose in the 1990s. Julong developed the first large switching system (HJD04) in China, which led to the take-off of Chinese telecom equipment production in the 1990s. Datang was established in 1998 by a research and development institute within the Ministry of Information Industry (MII) in Xi'an. It is an R&D-oriented enterprise, and most of the employees are researchers in the field of telecommunications.[9] Zhongxing, headquartered in Shenzhen, has a broad range of products in all the subsectors of the telecom equipment industry. All three of these companies are state-owned. Huawei, which is the biggest of the 4 firms, is a privately owned company located in Shenzhen. Zhongxing and Huawei have been rated as the most innovative enterprises in China.[10] I have explored whether or not innovation capability, which is shared by all these firms, is the most crucial resource for firms in this subsector by asking relevant questions during interviews.

In the cell-phone market, several producers, such as TCL, Haier, Hisense, and Panda Electronic, are large consumer electronic producers that diversified into the cell phone production. As the largest domestic producer in 2002, TCL is well known for its innovative concept of jewelry cell phones. Hisense, an electronic enterprise famous for its R&D orientation, started cell-phone production in late 2001 but has achieved substantial growth since then. Marriages to Motorola and Ericsson played an important role for Eastcom and Panda Electronic, to become leaders in the cell-phone industry in the earlier days. However, the marriage had its negative consequence as both companies were discouraged from developing their own brands. I conducted a comparative review of the strategies of each firm and their development histories to seek insight into why they have grown and if their growth is sustainable.

Legend is the leading PC producer in both China and Asia Pacific with a 30.2% market share domestically in 2001 and a 13.6% market share in Asia Pacific in the third quarter of 2001. Founder is the second largest PC producer in China, but its main business also has roots in Chinese electronic publishing systems and software development. Great Wall is the manufacturer that produced the first domestic PC and later formed several joint ventures with IBM. Their strategies for market entry provide evidence for a different resource focus other than innovation capability.

In some cases, I have chosen the companies not according just to how successful they have been but because of their glorious past, such as GDT and Great Wall, which were market leaders at the beginning and were models for other domestic firms, but now lag behind other companies.

5.5 Question-Hypothesis-Data

To answer the research questions, I specify the following four detailed questions and offered hypothesis for each of them. I will gather data to test the hypothesis.

(1) Why have domestic firms caught up with the multinational corporations (MNCs) in the telecom-equipment, PC, and cell-phone industries?

[9] Company brochure.
[10] www.chinanex.com.

Hypothesis: Leading domestic firms in China's information industry have followed a path of catching-up that can be described by a staged catching-up theory.

To investigate the staged process of catching up, I will get time-series data on domestic firms' market share and firms' annual data on revenue and employment. Based on these time-series data and other information of the market and industry, I can roughly divide the stages described by the staged-catching up theory.

It is relatively easy to differentiate between the preparation stage and the growth stage because during the preparation stage there exist few domestic firms in the market, while many domestic firms should start to appear at the beginning of the growth stage. Thus, I use the date when many domestic firms were established and more specifically, started their manufacturing production as an indication for the start of the growth stage. During the growth stage, domestic firms' market share will experience great increase while the foreign firms' market share will correspondingly decrease. Consequently, domestic firms' revenue and employment are expected to experience high growth.

To differentiate between the growth stage and filtration stage is not as easy. Instead of just looking at increasing number of domestic producers, I will examine the market segments of domestic firms and MNCs. During the growth stage, domestic producers differentiate their products from the MNCs. During the filtration stage, domestic producer and MNCs compete head-to-head in the same market segments with sophisticated products. I therefore can use the overlay of domestic producers' market segments with the MNCs' as an indicator of entering the filtration stage. Further, the less competent domestic producers will be forced to exit or be left behind by the increasing competition. The decreasing profit-rate and number of domestic producers can also help to indicate the start of the filtration stage.

How do we differentiate between the filtration stage and the globalization stage then? The most important characteristics of the globalization stage is the exploration of international markets and international R&D cooperation. Thus, when these practices become common to leading domestic firms, it symbolizes the start of globalization stage.

I therefore will use data on demand, profitability, occupational structure, and industry structure (concentration, size of firms) of the different stages to show this evolution. In addition, I will investigate domestic firms' choices of location and competitive strategies, as well as MNCs' behaviors and government involvement during the different stages.

(2) What role has innovation capability played in the development of China's domestic firms in the telecom-equipment, computer, and cell phone industries?
Hypothesis: Innovation capability and self-developed technologies have been the key to Chinese domestic firms' catching up with the MNCs and have determined who are the leading domestic firms in these industries.

To investigate what role innovation capability has played in the development of China's domestic firms in the telecom-equipment, computer, and cell-phone industries, I will first examine if self-developed technologies have enabled domestic firms to produce products they otherwise would have been unable to produce. In detail, I will examine the products:

- that were dominantly produced by MNCs: e.g., public digital switch systems (PDSS);
- that have been produced specifically for the Chinese market by domestic firms only: e.g., Chinese language add-on cards for personal computers;
- that have been produced at the same speed as the MNCs: e.g., 2.5G GSM and CDMA cell phones
- that no one has ever produced: e.g., 4th generation electronic publishing systems, China's 3G standard (TD-SCDMA).

I will also examine if self-developed technologies have enabled domestic producers to produce at a cost less than that of MNCs and thus gain market shares. I will examine products such as PDSS, PCs, and 2G and 2.5G cell phones in all three industrie.

Moreover, I will check if leading domestic producers in these industries have also been leaders in terms of innovation capability. A strong correlation between leadership and innovation capability supports the hypothesis that innovation was the key to the successful development of the leading firms. Since I have chosen only leading firms to analyzing the relationship, the sample data are very small, between 6 –8 data points. Nevertheless, the explanation power of innovation capability will be demonstrated. To measure innovation capability, I will gather data on firms' R&D output, such as degree of involvement of national S&T projects, rank from the peers, and numbers of patents. To measure leadership in a market, I will use market share and ranks from Ministry of Information Industry (MII).

(3) How have domestic firms acquired their innovation capability?
Hypothesis: In-house R&D development, supplemented with external alliances, is the key channel to build up their innovation capability.

I will examine the following two major channels for building innovation capability:
(a) Internal investment. Strong internal investment usually means (i) high R&D spending as a percentage of revenue, and (ii) high R&D staff as a percentage of total workforce. Furthermore, I will gather MNCs data for these two indicators for comparison, because different industries define high internal investment differently.
(b) External alliance. Indicators include (i) domestic and foreign R&D partners, and (ii) the nature of joint R&D activities.

In addition, I will investigate what special channels the domestic firms have utilized to build their innovation capability. I will also investigate joint ventures' technology transfers from the foreign partners, because that was expected to be a major venue for building innovation capabilities. When data is available, I also use some simple regression analysis to indicate the explanation power of R&D spending to innovation capability and a company's revenue.

(4) What factors have enhanced the building of innovation capability and what role has the government played during the process?

Hypothesis: Government involvement has rewarded companies' efforts in building innovation capability and developing proprietary technologies through a positive feedback system composed of: network clustering, disintegration of the global value chain, and sub-sector linkage.

I will examine the following four factors:
(1) Government involvement:
–What kind of support has the government offered and which kinds have been most effective in improving innovation capability?
–How has the government chosen National S&T program participants? Is it a merit-base selection based on strength of innovation capability?
(2) Network Clusters: clustering of firms and the evolution of firms' R&D locations
(3) Global Value Chain Disintegration: Have the industries moved towards disintegration? Have the manufacturers move towards specification?
(4) Sub-sector (inter-industry) linkage: how has sub-sector linkage enabled leading firms to quickly diversify into emerging sub-sectors because basic R&D and other knowledge-assets are convertible between sub-sectors or even industries?

5.6 Data Collection

I have relied on two major sources for data. First, I have collected documents such as annual reports, company brochures, employee handbooks, and journal articles. Second, to get an intuitive insight of the companies, I spent several months to interviewing employees of the companies and government officials through two field trips to China.

At the initial stage of the research, I read books and papers in the research area to familiarize myself with the literature and find the most interesting research questions. I also collected secondary data about the industry and companies to get a sense of the industry and to narrow down the candidates for case study. During my research, the Internet has been a great supplemental resource. I usually start to know a company by visiting their website and searching "GOOGLE" for any information related to the company . The result of Internet research is unpredictable, though. The Internet has loads of information on some companies (for instance, Legend); while it has little information on others (e.g., Great Dragon). The secondary data collection continued throughout the research process.

I have taken two field trips to complete data collection and conduct interviews at the twelve companies selected for case study. The first trip was taken from December 2001 to January 2002, when I mainly conducted research at ZTE, Huawei, Datang, Great Dragon, Legend, Founder, and Eastcom. The second trip was taken from December 2002 to January 2003, when I mainly studied the rest of the firms in the list, namely, Great Wall, Haier, TCL, and Panda Electronic, as well as doing some follow-up research on the previous seven firms. In addition to the field trips, I have also used telephone and email to contact people for the information I needed when I was in the United States.

I interviewed people at the selected firms (managers, R&D engineers, and marketing people), government officials (MPT/MII), local government officials, and researchers at universities related to all three industries (Table 5.2). I learned the companies' general development histories and resource focuses from the managers. Engineers at the companies and researchers at universities offered me information on the key technologies of the leading products, how and by whom R&D projects were chosen, and how the projects were conducted. Government officials gave me a general overview of the industry and offered insights into how and why the government got involved.

The interviews usually lasted for two to three hours. Most interviews happened at the interviewee's office or in their company conference rooms. Some of them were conducted in a company's dining hall, or at a local restaurant or coffee house. Most interviewees did not want me to use a tape recorder; therefore, I used a notebook to record important points of the interview. Furthermore, some interviewees preferred not to disclose their names as references. The following table shows the number of people that I interviewed for each company or organization.

Table 5.2 People Interviewed

	Number of People Interviewed
Companies	**27**
Huawei Technologies	4
Zhongxing Telecom	8
Datang Telecom	5
Great Dragon Information Technology	1
Legend	2
Founder	2
Great Wall	0
Eastcom	1
Panda Electronics Group (PEG)	0
TCL Corporation	1
Haier Group	1
Hisense	2
Organizations	**8**
System Reform Office, State Council	1
Ministry of Information Industry	2
State Information Center, Planning Commission	4
Ministry of Science and Technology	1
MNCs	**4**
Universities	**4**
Service Providers	**3**
Others	**5**
Total	**51**

Source: The author.

Before the interview, I usually send out a brief introduction of myself, the research, and the outline of the interview questionnaires to the interviewee, because some people prefer to view the questions beforehand to decide if they are the appropriate person to answer the questions. Sometime, they will refer me to another person. I usually start the interview with a brief introduction of myself and learn about the interviewee's background and position in the company and organization. Then I asked the questions. Sometimes I followed the question outline; sometimes I pick up interesting points made by the interviewee and follow up on them.

The difficulties of access to companies varied. In general, I needed a personal network or *Guanxi* connection to get initial access. Then, I used the so-called "snowball procedure," -- through the initial access person, I was able to interview more people in the same company. For the most important interviewees, I tried to follow up with emails or phone interviews. In some cases, I had several interviews with a single individual. Interviewees in the domestic companies were generally interested in the IT industry and how companies function in the United States. As a friendly exchange, I spent some time answering their questions on these matters. Sometimes, I would even exchange views about the technological development of the IT industry, especially regarding data communications, but I did these exchanges after the interviews, so that it would not influence their answers.

For instance, I gave a presentation on my master's thesis, "The Design and Implementation of General Purpose Translator for IPV6 and IPV4 networks (GT64)," to ZTE Nanjing R&D Institute in January 2002. My master's thesis was finished at the MIT Laboratory of Computer Science (LCS) and represents the cutting edge of research in the IPV6 field, currently an important issue in the field of data communications. Domestic companies as well as researchers in China have kept well informed about current research in this area and are actively involved in the development as well. Later, the company published a summary of the thesis in their IPV6 special issue of the company's technological magazine "ZTE Technology."

I have also obtained approval from the MIT Committee on the Use of Humans as Experimental Subjects (COUHES) to conduct my interviews in China. The COUHES (website: http://web.mit.edu/committees/couhes/) reviews research projects that utilize humans as research subjects and devises procedures to ensure that subjects are protected against risk, and that their rights, privileges, and privacy are protected. The appendix includes the application to COUHES and the interview questions and informed consent forms.

6 Staged Catching-up of Telecom-equipment Manufacturers

Domestic telecom-equipment manufacturers in China have made impressive progress in gaining market share vis-à-vis the multinational corporations (MNCs). Guided by the following research questions, I apply the staged catching-up theory to analyze the development process in this chapter:

- Why have the domestic firms caught up with the multinational corporations (MNCs) in the telecom-equipment industry? Can we identify distinct stages of this evolution?
- What has been the role of the government in this staged catching-up of the industry?

I organize the chapter as follows: to offer a general background for the analysis, I begin with a brief introduction of the global telecom-equipment market and current leaders of each sub-sector. Next, in Section 6.2, I analyze the catching-up of domestic firms with the MNCs in China's telecom-equipment industry and identify the stages of this evolution. In Section 6.3, I examine what role the government has played in developing the industry and compare different policies' effectiveness. I provide conclusion remarks in Section 6.4. In the next chapter, I focus on investigating the role of innovation in the staged catching-up process.

6.1 Overview of the Telecom-Equipment Industry

The telecom-equipment industry is one of the most R&D intensive industries--the average R&D spending of leading MNCs (as a percentage of revenue) was around 10%-20% in 2002 (MIT Technology Review, 2003). The industry has several global leaders, such as Alcatel, Cisco, Ericsson, Lucent Technologies, Nortel Networks, and Nokia, which had average revenues of over $20 billion in 2002. In addition to these telecom-equipment manufacturers, Siemens and Motorola, two giant electronics companies, also lead in the field of telecom-equipment—their revenue in 2002 were $77 billion and $30 billion, respectively. Most of these companies had a significant drop of 20% in their revenue of 2002 compared to that of 2001.[11] Telecom-equipment manufacturers had a harsh year in 2002 because of the slowdown of the economy in general and the drop in demand coming from the cutback of telecom-infrastructure spending in North America, Europe, and Asia Pacific.

6.1.1 Leading firms in Sub-sectors

Telecom-equipment manufacturing can be roughly divided into the following five sub-sectors: optical transmission systems, switch systems, access systems, data communications (router and Ethernet switches), and mobile communications.

[11] Except Cisco and Siemens, who increased their revenues by 17.8% and 2.1%, respectively from 2001 to 2002.

The following descriptions explain the function of each sub-sector: optical transmission systems are optical lines that transport telecom traffic; switching systems reside at those points where different lines connect with each other, and determine which traffic goes to which line; access systems connect the network with the end user. Data communication uses Internet Protocol (IP) networking technologies (routers and Ethernet switches) to transmit voice and data. It employs the same infrastructure described above, except that router or Ethernet switches have replaced the telephone switch. Mobile communication refers to the wireless part (the part without any physical connection) of the telecom network. It is an extension of the telecom network since the traffic coming from the wireless point may need to use the fixed telecom network for long distance telecommunications.

Examining the global market for telecom equipment, I summarize current leaders of each sub-sector in Table 6.1. I divide mobile communication into two main segments: mobile equipment and mobile handsets. I leave the details of global and domestic mobile-handset manufacturers to Chapter 10. Details of each sub-sector can be found in Appendix 6.1.

Table 6.1 Leading Firms in Sub-sectors of the Global Telecom-equipment Industry, 2001

Sub-sectors	Leading Firms (Top Three)
Optical transmission systems	Alcatel, Lucent, Nortel
Switch systems	n.a.
Access systems	DSL: Alcatel, Siemens, Lucent Cable Modem: Motorola, Toshiba, Ambit
Data communication	Router: Cisco, Juniper Networks Ethernet Switch: Cisco, Nortel, Enterasys
Mobile communication	Ericsson, Motorola, Nokia, Lucent

Source: The author, from Appendix of this chapter.
Note: DSL stands for Digital Subscriber Line.
n.a. = not available.

Table 6.1 reveals that several companies, such as Alcatel, Nortel, Motorola, and Lucent, lead in at least two sub-sectors, while companies like Cisco or Nokia are very specialized in data communication or mobile communication. This implies that a similar technological base exists for different sub-sectors so that when a company excels in one sub-sector, it is comparatively easier for it to diversify into, and do extremely well in, another sub-sector.

6.1.2 The Growth of China's Telecommunication Infrastructure

China's telecommunication infrastructure has experienced tremendous advancement in the past two decades. China had one of the poorest telecommunication infrastructures in the world. However, not until the end of the 1970s did it become clear that China's weak telecommunication infrastructure had constrained its economic expansion. Thus, the government had given great priority to strengthen to meet the accelerated growth in demand for telecom services. Consequently, the capacity of China's telecommunication infrastructure has undergone magnificent growth from 1980 to 2000 (Table 6.2). Fixed capital investment increased nearly 200 times during the two decades. The switchboard capacity grew more than 40 times-from 4.43 million lines in 1980 to 178.26 million lines in 2000. Accordingly, the numbers of both fixed-line and mobile phone subscribers have grown exponentially. The number of fixed-line subscribers increased more than 70 times during that period--from 2.14 million to 144.83 million. From 1990 to 2000, the number of mobile-phone subscribers jumped astonishingly 4700 times-from 0.02 million to 84.53 million users, which creates a remarkable average growth rate of 141% per year.

Table 6.2 Growth of China's Telecommunications Infrastructure, 1980- 2000

Categories	1980	1990	2000	Average Growth Rate, 1980-1990 (%)	Average Growth Rate 1990-2000 (%)
Switch board capacity (million lines)	4.43	12.32	178.26	10.87	31.56
Fixed-line subscribers (million)	2.14	6.85	144.83	12.49	36.17
Mobile phone subscribers (million)	n.a.	0.02	84.53	n.a.	141.07
Fixed capital investment (billion RMB)	1.34[a]	4.92	213.50	30.03[b]	52.29
Revenue (billion RMB)	3.90	15.55	479.27	n.a.	n.a.
Penetration rate (%)	0.43	0.60	18.12	n.a.	n.a.
Teledensity (%)	0.45	1.01	14.08	n.a.	n.a.

Source: China Transportation and Communication Society (various years).
Yearbook of China Transportation and Communication. Beijing. (Wong, 2002: p. 47)
Note: a. 1985 figure; b. 1985-1990
n.a. = not available.

6.1.3 MNCs' Operation in China

Echoing the market growth, most of the global leading firms started their operations in China in the 1980s and 1990s. Tables 6.3 lists seven major MNCs in China: Cisco, Ericsson, Lucent Technologies, Motorola, Nokia, Nortel Networks, and Siemens; all of whom have also appeared in Table 6.1. I attach a brief introduction of each firm's operations, facilities and major products in China in the appendix. Among the seven MNCs, Siemens and Motorola have the most employment (20,000 and 13,000). Motorola distinguishes itself by its large investment in China–by 2002, it had invested $3.4 billion from the point it established subsidiaries in China in 1987. It also had the highest sales revenue ($5.7 billion) among all seven MNCs in 2002.

Table 6.3 Major MNCs in China's Telecom-equipment Industry, Company Statistics, 2002

Company Name	Year Entering China	Employment 2001	Employment 2002	Investment Amount in China (in billion US$)	Sales (in billion US$) 2001	Sales (in billion US$) 2002
Alcatel China	1983	5,000	6,500	0.8	n.a.	2.0
Cisco Systems China	1994	500	300	n.a.	1.0	n.a.
Ericsson China	1985	4,000	4,500	0.6	1.7	n.a.
Lucent Technologies China	1993	n.a.	3,000	n.a.	n.a.	n.a.
Motorola China	1987	13,000	13,000	3.4	4.9	5.7
Nokia China	1985	5,500	5,000	20	2.9	n.a.
Nortel Networks China	1972	2,600	2,600	n.a.	1.6	n.a.
Siemens China	1994	21,000	21,000	0.5	3.4	3.5

Source: The Author, summarized from http://www.chinanex.com and websites of each company above. (www.alcatel.com.cn, www.cisco.com.cn, www.ericsson.com.cn, www.lucent.com.cn, www.motorola.com.cn, www.nokia.com.cn, www.nortelnetworks.com.cn, www.siemens.com.cn)

Note:

1. n.a. = not available.
2. Alcatel of France entered China's telecom market in 1983 by forming China's first joint venture in telecom equipment manufacturing called Shanghai Bell with Belgian government. Alcatel's investment in China exceeded $0.8 billion in 2002. Sales in 2002 are expected to $2 billion.
3. Cisco didn't have a China office until 1994. In 1998, it upgraded its China presence to a limited company in order to reinforce its competitive position in China. Cisco's employee numbers are estimated numbers. Cisco's sales in 2001exceeded $1.0 billion.
4. Ericsson of Sweden began selling in China as early as 1892. It returned to China in 1985. Ericsson's investment in China exceeded $0.6 billion in 2002.
5. Lucent China was stemmed out from its parent AT&T China in 1996.
6. Motorola's investment in China was about RMB 28.5 billion ($3.4 billion) by 2002. Its sales in 2002 were RMB 47 billion ($5.7 billion).
7. Nokia had $1.5 billion export in 2001 and $2.2 billion export in 2002. Nokia's investment had amounted to Euro 2.3 billion (nearly $2 billion) by the end of 2001. Its sales in 2001 were Euro 3.4 billion Euros ($2.9 billion).
8. Nortel China's revenue is 9% of the company in 2001.
9. Siemens began selling telecom product to the Chinese as early as 1872 (a manual telegraph receiver). In 1994, the company began its formal operation in China. Siemens' sales was euro 3.6 billion ($3.5 billion).

The presence of MNCs has facilitated the building of China's telecommunications infrastructure; however, it has also posed great challenges for domestic firms. Despite the challenges, domestic firms have advanced from being far behind in every sub-sector in the 1980s, to catching up in the switch market in the middle 1990s, to capturing the access market in the late 1990s, and to becoming competitive in the markets of optical transmission, data communications, and mobile communications in the new millennium.

Why have the domestic firms caught up with the MNCs in the telecom-equipment industry? Can we identify distinct stages of this evolution? Next, I apply the staged catching-up theory to examine the development history of domestic firms from the 1980s to 2002.

6.2 Catching up in Stages

The staged catching-up theory can be used to describe the catching-up process of the domestic firms with the MNCs in the telecom-equipment industry. Using this theory, I identify the four stages for the telecom-equipment industry: preparation stage (early 1980s-early 1990s), growth stage (early 1990s-middle/late 1990s), filtration stage (middle/late 1990s-2000), and globalization stage (2000-2002). To demonstrate this staged process, I rely on two major sources: (1) the catching-up of domestic firms in the sub-sector of switch equipment (they developed Chinese public digital switch systems (PDSS) during the preparation and growth stages); and (2) major leading domestic firms' development during the four stages. I have a detailed analysis of the catching-up in the switching equipment sub-sector in the appendix. Here I focus on the development of several leading domestic firms.

6.2.1 Staged Development of Major Domestic Firms

The growth of major domestic manufacturers in the telecom-equipment industry constitutes a significant portion of the history of the industry. I used the following four domestic firms as my primary candidates to examine the staged development of the industry: Huawei, ZTE, DTT, and GDT, for the reasons stated in the "Research Methodology" chapter. Chinese people use the term "Great China" to describe those four companies, because if you combine the first characters of the companies' names in the reverse order (Ju –Great Dragon, Da – DTT, Zhong – ZTE, Hua - Huawei), you will create the phrase "Great China" in Chinese. The phrase reflects China's pride in these domestic companies that have risen quickly and competed confidently with the giant MNCs. Tables 6.4 and 6.5 summarize these companies' general information.

Huawei and ZTE were established in the middle of the1980s, while DTT and GDT were established in the middle of the 1990s. The size of Huawei and ZTE are much larger than that of DTT and GDT. For instance, Huawei and ZTE have over 22,000 and 12,000 employees, respectively, comparable to the workforces of the two largest MNC's in China, Siemens and Motorola, who have about 21,000 and 13,000 employees, respectively. In comparison, DTT and GDT only have about 4,000 and 2,500 employees, respectively. The revenue and profits of these companies also illustrates this size difference. The four companies have similar major product ranges, but Huawei and ZTE have many more R&D and production facilities than DTT and GDT.

Table 6.4 Major Domestic Telecom-equipment Manufacturers in China, 2002

Company Name	Date of Establishment	Employment	Sales Revenue (in US$ billion)	Profit (in US $ million)
Huawei Technology Corporation 华为技术有限公司	1988	18,000	2.7	319.8
Shenzhen Zhongxin Technology Corporation 深圳市中兴通讯股份有限公司	1985	12,916	1.3	96.0
Datang Telecom Technology Co., Ltd. 大唐电信科技产业集团	1998	4,183	0.247	36.1
Great Dragon Information Technology 巨龙通信设备有限责任公司	1994	2,500	0.240	4.2

Source: Summarized from http://www.chinanex.com, each company's website as of January 2003
Note: DTT and GDT's data on"Sales Revenue" and "Profit" was 2001.

Table 6.5 Major Domestic Telecom-equipment Manufacturers in China, Facilities and Products

Company Name	Major facilities	Major Products
Huawei Technology Corporation 华为技术有限公司	Headquarter in Shenzhen, 6 research centers in major cities of China, the company also has research facilities in the US (Santa Clara and Dallas), Russia, India, and Sweden.	Central office: C&C08, iNET; transmission: OptiX high-end optical cross-connect series with throughput up to 1.6 terabit per second, DWDM system, multi-STM-16 (Metro-3000), multiservice platform (Metro-6100), flexible access (FA16); data communications: ATM switch, routers, ISDN terminals, IP telephony systems; broadband switch and access systems; mobile communications: GSM900/1800, GPRS, CDMA (IS-95A and CDMA2000; wireless local loop (WLL): intelligent network and others.
Shenzhen Zhongxin Technology Corporation 深圳市中兴通讯股份有限公司	11 wholly owned research facilities across the country, the US (New Jersey) and Korea; 26 sales offices and customer support centers across China.	Switching: ZXJ10 central office, network control core (Softswitch); access systems: fiber optic access point (AXA10), PCS system (ZXPCS), wireless local loop (ZXC10-SCWLL); optical systems: transmission unit (Unitrans ZXSM-150/600/2500), DWDM (Unitrans ZXWM-32); mobile systems: ZXG10-GSM, ZXC10-CDMA, and CDMA2000-1X; data communications: integrated access router; broadband wireless access; and videoconferencing products.
Datang Telecom Technology Co., Ltd. 大唐电信科技产业集团	Headquarters in Beijing, 5 subsidiaries, 2 R&D centers in Beijing and Shanghai	High-capacity CO (SP-30, has 65% market share in high-end switch sector), SDH and DWDM equipment, access equipment; wireless data (broadband access, WLL, WLAN and multi-service access); mobile systems (switch or GSM, CDMA, HLR and messaging), WCDMA system; microwave; multimedia; microelectronics and terminal equipment
Great Dragon Information Technology 巨龙通信设备有限责任公司	A research center, a wholly owned subsidiary and two with controlling interest, plus two oversea joint ventures	HJD04E high-capacity exchange (PSTN and ISDN); user access unit; OpenIN intelligent network; HIP-Phone office system; EASTAR-WLL access system; WAN-2000 broadband wireless access system; GDC/GS-2000 distributed mobile switching system; GSM base station; CDMA system; data communications: OmniRouter-880, IP telephony system (access, router, terminal, fax); SupNet series (hub and switch).

Source: Summarized from http://www.chinanex.com as of Jan. 2003.

Table 6.6 Huawei, ZTE, DTT, and GDT's Revenue (billion RMB), 1985-2002

Company	ZTE	Huawei	Datang	GDT
Date of Establishment	1985	1988	1998	1995
1985	*	b.e.	b.e.	b.e.
1986	n.a.	b.e.	b.e.	b.e.
1987	n.a.	b.e.	b.e.	b.e.
1988	n.a.	n.a.	b.e.	b.e.
1989	n.a.	n.a.	b.e.	b.e.
1990	n.a.	n.a.	b.e.	b.e.
1991	n.a.	n.a.	b.e.	b.e.
1992	n.a.	n.a.	b.e.	b.e.
1993	0.1	n.a.	b.e.	b.e.
1994	n.a.	n.a.	b.e.	b.e.
1995	n.a.	1.4	b.e.	b.e.
1996	0.3	2.6	0.4	n.a.
1997	0.6	4.1	0.5	n.a.
1998	2.0	8.9	0.9	2.6
1999	2.5	12.0	1.1	1.2
2000	4.5	22.0	2.4	n.a.
2001	9.3	25.5	2.1	0.4
2002	11.0	22.1	2.1	n.a.

Source: *ZTE Annual Report 98-2002, Major Operation Revenue (ZhuYinYeWu)*
DDT Annual Report 1999-2002, Major Operation Revenue (ZhuYinYeWu)
Top 100 Electronics Companies by MII 1999 (for 1998 performance) for GDT's data
Chinanex.com for GDT's 2001 dat.

Note:

1. b.e. = before establishment, no data.
2. n.a. = not available.
3. before 1998, the revenue refers to Xi'an Datnag Telephone Corporation.
4. * 0.00035

Table 6.6 and Figure 6.1 use the revenue data to illustrate the development of these four domestic firms. The revenue paths of these major domestic firms, especially Huawei and ZTE, demonstrate that their performance was distinct during each of the different stages. The table and the figure provide the evidence to support the hypothesis that China's telecom equipment industry has experienced the development process described by the staged catching-up theory.

During the preparation stage (early 1980s-early 1990s), ZTE and Huawei had little growth (DTT and GDT were not established) in revenue. During the growth stage (early 1990s-middle/late 1990s), all four companies had rapid growth with an increase in revenue of between 40% and 100% per year. During the filtration stage (middle/late 2000), Huawei and ZTE further increased their speed of expansion and, correspondingly, their revenues exhibited an exponential growth with an annual increase of up to 200%. Meanwhile, DTT struggled to keep up the revenue level, while GDT's revenue disappointedly slipped to bottom. During the globalization stage, all four companies had difficultly maintaining the speed of growth because at the same time the companies started their globalization process, their revenues were affected by the bear market of the world telecom-equipment industry.

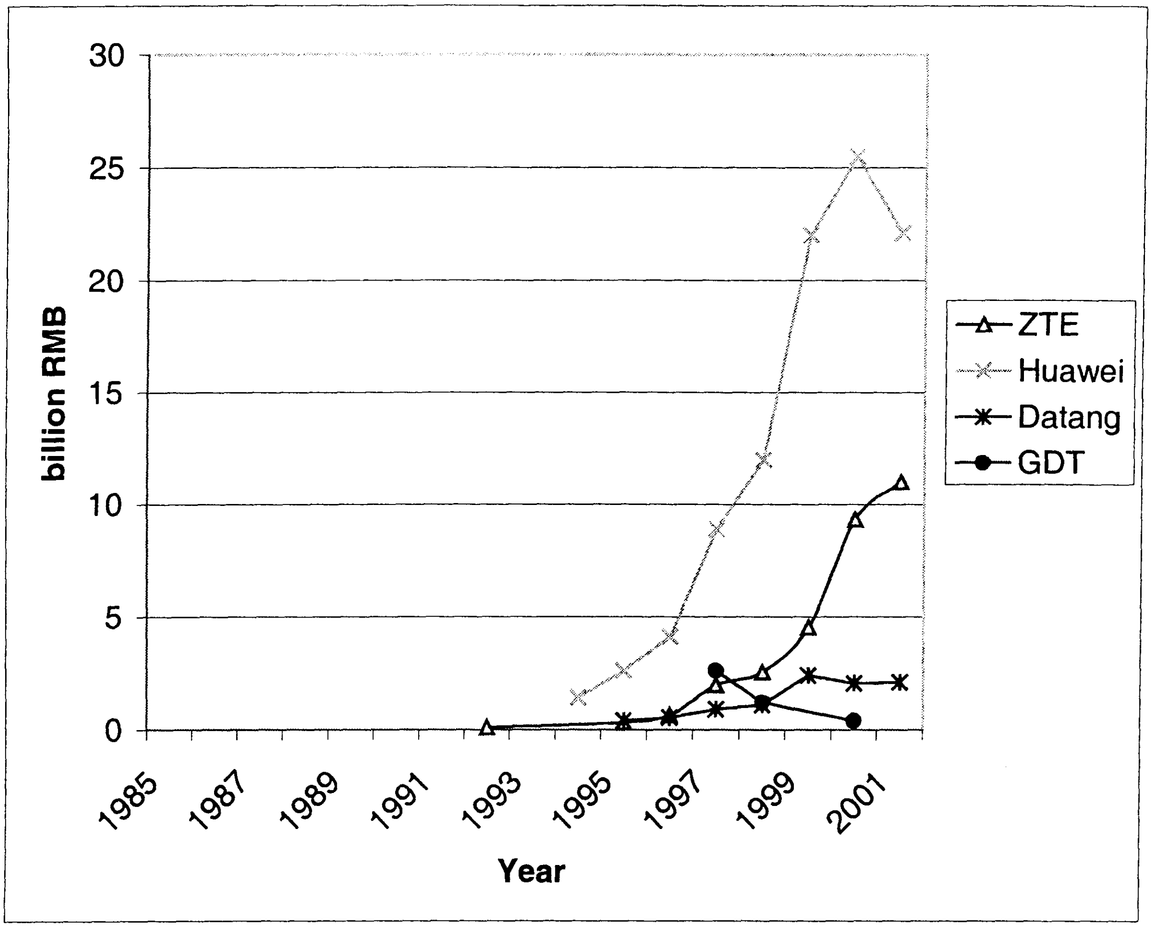

Figure 6.1 Huawei, ZTE, DTT, and GDT's Revenue (1985 –2002)

I will illustrate the staged catching-up process by examining each company's development path during the four stages and I review the companies in the order of their date of establishment.

6.2.2 Shenzhen Zhongxing Technology Corporation (ZTE)

ZTE (深圳市中兴通讯股份有限公司) was started as Zhongxing Semiconductor Co., Ltd. in February 1985 by three parties. Two components were from within the former Ministry of Aerospace Industry (MAI) and the other was a company from Hong Kong. Within seventeen years, the company grew from a trading company and a manufacturing factory that did simple processing to China's second largest company in the telecom-equipment industry. ZTE is engaged with the following areas of telecommunications: optical transmission, data communications, and mobile equipment. The workforce grew from several hundred in the 1980s to more than 12,000 in 2002. The company's revenue leapt from RMB 0.35 million in 1985 to RMB 11 billion in 2002.

I review ZTE's development in each of the four stages as following:[12]

Preparation stage (1985-1992): Zhongxing Semiconductor was established in Shenzhen as a joint investment in 1985. No. 691 Factory under the former MAI was the main shareholder with a 66% share of the company; other parties included Great Wall Industrial Co. (Shenzhen office) under MAI, and Yunxing Electronics Trading Co. (Hong Kong). The company originally planned to manufacture products in microelectronics; however, the production technology and market needed were not available at the time. The company therefore started to produce watches, electronic keyboards, and telephones to accumulate capital. In June 1986 the company started an eight-person R&D team to develop a 68-unit analog small-scale switch. Although the company staff were knowledgeable in electronics, they were not familiar with switch technology. The company therefore invited Shan'xi Posts and Telecommunications Bureau to be a partner for the project. In less than one year, the R&D group successfully developed the ZX-60 and secured certification and licenses from MPT. Afterwards, the company decided to develop its own digital-switching system despite the dominant market presence of the MNCs in China. To improve the technology capability of the company, it cooperated with the Beijing University of Posts and Telecommunications (BUPT). The development successfully resulted in the ZX500 Digital Switch for C5 end office, which was certified by MPT in November 1989.

Growth stage (1993-1996): Zhongxing Telecommunications Equipment Co., Ltd. (ZTE) was registered with initial capitalization of RMB 3 million in March 1993, and the company started to operate as a private company but with national ownership.[13] A research and development institute was established in Nanjing to develop a large-scale digital switching system as well as core networking and data communications devices. In November 1995, the ZXJ10 large-scale PDSS was successfully developed and was licensed by MPT. This was one of the three main switches that were developed by domestic producers. ZXJ10 was kept as the company's core product and enabled the company to move towards diversification into other areas of telecommunications. In 1996 ZTE was chosen as one of 300 key state-run enterprises (increased to 520 later) by the State Council.

Filtration stage (1997-2000): ZTE was listed on the Shenzhen Stock Exchange on November 18, 1997. It was the first large domestic telecom-equipment enterprise to be listed on the stock market. ZTE started to diversify into different sub-sectors of the industry, especially in access equipment and optical transmission. During this stage, ZTE

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[12] ZTE divided its development history into 3 periods (ZTE, 2001): 1985-1992, 1993-1996, and 1997-present based on its production characteristics. The first two periods match the first two stages of the staged catching-up theory. I further divided 1997-present into two stages: 1997-2000 and 2001-present and these two stages will correspond to the two later stages of the industry described by the staged catching up model.

[13] *Guo You Min Yin* in Chinese. State-owned, but not state-operated.

established six more R&D facilities throughout the country and in South Korea. ZTE was evaluated by investors as the company with the most potential in 1998[14] and it won the third position in the same category[15] in 2001.

Globalization stage (2000 - 2002): After exponential expansion in the filtration stage, ZTE started to experience some sluggishness in revenue growth, as the whole industry suffered slow-down. The company has coped with the situation by reorienting itself to focus on mobile and data communications as their new growth opportunity. For instance, mobile equipment contributed to more than 40% of its revenue in 2002. Since 1999, ZTE has been chosen as a major participant for the development of various communication technologies (especially in the mobile and data communications area) in the prestigious national science and technology program "863 Plan." By the end of 2002, ZTE had taken 19 important "863 Plan" projects, covering 3G, high-speed data communications, integrated access systems, an optical transmissions. During this stage, ZTE established two R&D institutes in Xi'an and Chongqing.

I summarize the distinct characteristics of ZTE during different stages of development in Table 6.7. The revenue and asset value had little growth in the preparation stage, but rapid and exponential growth in the growth and filtration stages, and then slowed in growth in the globalization stage. Accompanying this change has been the increased numbers of branches of the company and their location strategies, as well as competition strategy and government involvement. The priority for location changed from being close to a good businesses environment, to nearness to R&D skilled labor, to market access, and finally to international locations of R&D and market access. Competition strategies changed from focusing on small-scale switch equipment to large-scale switches, to other equipment in the transmission equipment sub-sector, access equipment, and data communications and mobile communications equipment.

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[14] *Stock Daily* (newspaper in Chinese), November 25, 1998 (report on 100 public companies).

[15] *China Stocks* (newspaper in Chihinese), June 18, 2001(report on 50 public companies with greatest potential).

Table 6.7 ZTE's Stage Development (1985-2002)

Stages	Stage 1: 1985-92 Preparation Stage	Stage 2: 1993-96 Growth Stage	Stage 3: 1997-2000 Filtration Stage	Stage 4: 2000-Present (2002) Globalization Stage
Revenue (RMB)	350,000 (1985)	0.1 billion (1993); 0.6 billion (1996)	1.35 billion (1997);	11 billion (2002)
Asset (RMB)	0.28 million (1985)	3 million (1993); 0.4 billion (1996)	0.25 billion (1997)	12.4 billion (2002)
Branches established	Zhongxing Semiconductor Co., Ltd (1985); Shenzhen R&D institute (1986)	Zhongxing Telecommunication Equipment Co., Ltd (ZTE) in Shenzhen; 3 R&D institutes in Nanjing and Shanghai	6 R&D institutes in Beijing, Shenzhen, and South Korea	2 R&D institutes in Xi'an and Chongqing, cooperated labs in P.R. C. and U.S., S. Korea, etc.
Number of Branches	2	4	n.a.	12 R&D facilities, 3 branches in Shan'xi, Beijing, Shanghai.
Competition strategy	identify products (C5 countryside switching market) and industry R&D	focus on large-scale switch R&D, market expansion,	R&D in access equipment, optical transmissions, product diversification, get more investment from the capital market, management	R&D in mobile equipment and 3G, data communications, international cooperation, export
Location Variables	business environment	the availability of the R&D skill-pool	the availability of the R&D skill-pool, market-access	R&D skill-pool, International,
Government involvement at ZTE		Local government awarded ZTE for its excellence; It was also recognized by national government as one of the important national enterprises and chosen as one of the "Torch" Program enterprises.	Torch program awarded ZTE for its excellent performances. State Economic and Trade Commission (SETC) selected ZTE as one of National Technology Centers that enjoys beneficial policies. SETC and MII selected ZTE as one of the national aided enterprises.	Central government selected ZTE as a leader or participant for R&D projects of national S&T program - "863 Plan". Involved in total 19 "863 Plan" projects by 2002

Source: ZTE Handbook, 2001. ZTE Website : www.zte.com.cn.

6.2.3 Huawei Technology Corporation (Huawei)

As the largest telecom-equipment maker in China, Huawei (华为技术有限公司) reached sales revenue of RMB 22.1 billion in 2002, which was about two times that of the second largest producer ZTE (RMB 11 billion). Established in 1988, Huawei has a similar growth path as ZTE's. I also review Huawei's development in the preparation, growth, filtration, and the globalization stages.

Huawei was set up in 1987 in Shenzhen with a registered capital of RMB 20,000 (Xiao, 2002). The company started by selling small-scale telephony-switches and fire alarms and consulting for various machinery producers. In the first two years, the company also served as a sales agent for an HAX[16] switch for a Hong Kong company. With the capital accumulated by this low-risk, profitable business, Huawei chose to undertake switch manufacturing several years later. Advised by professors from Huazhong Science and Technology University, Huawei started to develop small-scale switch systems in the late 1980s and early 1990s--the preparation stage of the industry's development. Huawei's small-scale switch systems, like ZTE's, gained success in the market for telecom bureaus in the countryside.

During the growth stage (early 1990s-middle/late 1990s), Huawei's development was propelled by its self-developed large-scale switch systems--C&C08. It is also C&C08 that brought the fast growth of Huawei and distinguished Huawei from other domestic producers later in the filtration stage. Huawei has maintained its leadership position and the fastest expansion in the industry ever since the early 1990s, as Figure 6.1 illustrates.[17] It is worth noting that, at the time, most businesses in Shenzhen were trading companies and the Special Economic Zone was experiencing a real estate and stock "bubble economy."

From the middle/late 1990s to 2000, the filtration stage of China's telecom-equipment industry, Huawei gained more momentum of growth than during the previous growth stage by diversifying into other sub-sectors of the industry through its technological advantages accumulated from R&D in large-scale switching equipment.

From 2000 to 2002--the globalization stage of the industry, Huawei has been proactive in globalizing its sales network and R&D facilities. In addition to its extensive sales network in China, Huawei has 30 overseas offices. Its broadband products are being used in 150 cities across China, Asia, and South America. Huawei's Quidway NetEngine has become a strong contender in high-end router market and has been sold in more than ten countries beside China. Huawei's overseas sales were $550 million in 2002, almost 20% of the company's total revenue.[18] Further, Huawei has five overseas R&D centers in United States, India, and Sweden.

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[16] One kind of switch.

[17] For instance, Huawei has fast production growth every year from 1997-1999: it produced 4.1 million switches in 1997 with a 20% market share, 7 million in 1998 with a 24% market share, and 3.8 million in the first half of 1999 with a 35% market share (ZTE, 2001).

[18] Chinanex.com, Company section. website: www.Chinanex.com.

6.2.4 Datang Telecom Technology Co., Ltd. (DTT)

The great Tang Dynasty is one of the most splendid periods in Chinese history. Datang Telecom Technology and Industry Group, with headquarters located in Beijing (capital of China), [and] services nation wide, is ambitious for [the] whole world at the same time. It is determined to contribute to the creation of another most splendid dynasty of national information industry!

- Datang Telecom Technology and Industry Group
- http://www.catt.ac.cn/english/

DTT (大唐电信科技产业集团), initiated by the Chinese Academy of Telecommunications Technology (CATT) of the MPT, was founded in 1998 through investment capital. The company was built upon Xi'an Datang Telephone Corporation, a joint venture established in 1993 by CATT (the l0th Research Institute) of the MPT and International Telephone and Teledata, Inc. (ITTI), a company started by a group of Chinese scholars in the United States.

When DTT was established in 1994, the domestic industry was in the middle of the growth stage. DTT joined the other domestic producers in the competition through its self-developed technology SP-30 in the middle of the 1990s. Figure 6.1 indicates that compared with Huawei and ZTE, DTT's growth path has been flatter. It had neither enough time nor enough accumulated experience for expansion, because it became a telecom-equipment manufacturer in the middle of the growing stage, much later than Huawei and ZTE. When the industry started to move into the filtration and globalization stages, DTT was slow in responding. It has put little effort in exploring the international market during the globalization stage. For instance, data from MII[19] indicates that DTT had little revenue from exports in 2002, only 0.2% of the total revenue, which implies that DTT is far behind its rivals in developing international markets. Despite all these, DTT's development of China's own 3G standard, TD-SCDMA, has won the company great respect and will potentially bring great fortune for the company.

6.2.5 Great Dragon Information Technology Corporation, Ltd. (GDT)

GDT (巨龙通信设备有限责任公司) has its roots in military communications with its original investor being the Joint Chiefs of Staff in China. In 1994, GDT became a commercial company when many military factories were ordered to convert themselves to civilian enterprises. GDT is a company under the Post and Telecommunications Industry Corporation (PTIC) of MII. GDT consists of a research center (GDT Information S&T Research Institute), a wholly owned subsidiary, two subsidiaries with majority control, and two overseas joint ventures. Currently, GDT has about 2500 employees and assets of 3 billion RMB.

GDT is the only company here that shows an overall decline in terms of revenue in recent years. I include GDT as one of the cases because GDT has a glorious past and its decline,

[19] MII, 2002.

which is associated with its slow response in diversifying into other emerging sub-sectors, reflects the competitive nature of the industry. I divide GDT's development history into four periods: the first period (1991-1993), the second period (1994-1996), the third period (1997-2000), and the fourth period (2000-present), which corresponds well to the preparation, growth, filtration and globalization stages of the industry.

During the pre-establishment stage of GDT (1991-1993), China's first PDSS system (HJD-04) was developed by the group who later founded GDT. Even though GDT was not formally established until 1994, HJD-04's development started long before. HJD-04 was developed as a joint project involving two participants: a military R&D institute (the Center for Information Technology, Zhengzhou Institute of Information Engineering of the People's Liberation Army), and a state-owned factory that was an industrial procurement unit of the MPT (Luoyang Telephone Equipment Factory or LTEF). In 1991, HJD-04 was certified and licensed by MPT and manufacturing started the next year. Since 1994, the telecommunications networks of the government and the military have used the system and its related products extensively. In 1993, the National Science Commission approved the proposal to establish the National Digital Switching System Engineering and Technological Research Center (NDSC) in Zhengzhou, which later became the main research institute under GDT.

GDT was successfully leading the whole industry during the growth stage. For instance, in 1997, GDT produced 6 million switches, 30%-40% of total production by domestic firms. However, GDT has been unsuccessful in maintaining its leadership position ever since the industry entered the filtration and globalization stages. For a detailed discussion on GDT's changed position from leading to lagging behind, please refer to Appendix 6.5.

6.3 Role of the Government

The Chinese government's involvement changed over the four stages of development of the telecom-equipment industry. During the preparation stage, the government had little involvement and it mainly focused on supporting developing domestic switch technology. During the growth stage, after several domestic producers developed their own switch equipment, the government became much more involved and offered direct support in finance, marketing, and export, especially to the first Chinese PDSS producer-GDT. As a result, GDT rose as the leader of the industry in the growth stage. During the filtration stage, even though it still supported export and marketing for major domestic firms, the government became less involved. Instead, it was involved indirectly through selecting suitable candidates in the national science and technology (S&T) program, such as "863 Plan". During the globalization stage, the government was involved little and focused on supporting developing cutting-edge technologies and standards in the mobile and data communications sub-sectors. For instance, the government showed its great support to TD-SCDMA, the Chinese 3G standard developed by DTT, by allocating a great portion of the frequency spectrum to the standard. I review the industry environment and the evolution of government support in detail in the following paragraphs.

In the early 1980s, China had to import many whole systems of switching equipment (too many to coexist in China's market) because the government was under pressure to satisfy the domestic demand and to resolve the shortage of capital. The government resolved the capital shortage by using international lenders all over the world. Most importantly, foreign switch vendors asked their governments to lend capital to the Chinese government for purchasing their equipment. It is this environment and the decisions made by the government to use foreign capital that formed the characteristic of "whole system importation" of the switch-equipment market at the time.

From the late 1980s to the early 1990s, China's switch equipment market was characterized by "joint production with foreign manufacturers." Seven joint ventures were established during the time and this development of the industry was echoing the government's policy "to exchange technology with the market." At the time, the government thought that setting up joint ventures was an effective way to get technology from the foreigners. The government stated in the policy that offering technological help through joint ventures is the precondition for foreign producers to enter the Chinese market for switches. The period from the early 1980s to the early 1990s corresponds to the preparation stage of the telecom-equipment industry.

The Chinese government never gave up pursuing domestically produced switch equipment. R&D on switches started in the early 1980s, long before HJD-04 was developed successfully in 1991. On March 12, 1991, the DS-30 switch, the first attempt at a Chinese public digital switch system (PDSS), was certified by the MPT. MPT Telecom S&T Research Institute's First Institute and Tenth Institute jointly developed DS-30, whose functions reached international standards. At the end of 1991, HJD-04, was certified and licensed by the MPT. HJD-04, the first commercially produced Chinese domestic PDSS equipment, also signified the era for domestic production as several other companies such as Huawei, DTT, ZTE, and Jingpeng, all developed their own switches.

The Chinese government has encouraged the development and production of domestic switches via R&D involvement of nationally owned institutes during the preparation stage and capital support during the growth stage. It is under this support that domestic producers quickly rose and gained domestic market share, for instance over 50% market share in 1997, not including JV production. (See detail in Appendix 6.4).

However, during the growth stage of the industry, the main problem for domestic switch equipment producers was the shortage of capital for both domestic suppliers and domestic customers. Domestic suppliers were in urgent need of capital to increase production capacity and improve technology. Meanwhile, in order to buy domestic switches, domestic customers had to own large amounts of capital.

To facilitate the domestic production of switches, in 1995, the government stopped accepting foreign loans for imported switches. Furthermore, from 1996 on, the government imposed an import tariff on telecom-equipment. The government financially helped both the demand and the supply side. It facilitated trust loans for customers who bought large quantities of telecom products from domestic producers, especially for companies within the MPT system. For instance, by the end of 1997, with the help of the State Council, GDT's customers received loans totaling 1.4 billion RMB from the People's Bank, the largest national bank, to purchase products from GDT. Second, the government facilitated financial aid for technology improvement in certain key products. On the supply side, stated-owned banks offered loans to domestic producers to improve their production capacity. For example, the Construction bank loaned 0.7 billion RMB to GDT in November 1996 for technology improvement in a specialized circuit board production line and a development center.

MPT played a vital role in encouraging customers to use the domestic products. In 1993, as domestic switches achieved the MPT's standards , MPT urged provincial and city-level telecommunications bureaus to give priority to purchasing domestic products when the function/price ratio was the same. MPT helped domestic firms to access the domestic market by holding conferences for domestic suppliers and customers and encouraging suppliers to support national brand products. MPT organized two conferences for domestic switch producers, and one for mobile equipment. In April 1996, at the first "Domestic Switches Customer Coordination Conference" held by MPT, six domestic producers met with representatives from 30 provincial and city telecommunications bureaus and signed 5 million orders and settled 7 million orders. In 1997, at the second "Domestic-developed Switches Customer Coordination Conference," 17 million orders were signed and 18 million orders were settled. In that year, the market share of domestic producers (excluding joint ventures) was over 60%.

During the filtration and globalization stage of industry development, the government mostly focused on encouraging companies to build innovation capability, which I will investigate in detail in later sections. The government helped domestic producers to expand into international markets in addition to the domestic market. For instance, the central government helped GDT to obtain a license from Russian Telecommunications. As the first domestic PDSS producer, GDT gained great support from the government. Here, I offer a brief history of GDT during the preparation, growth, and filtration stages to demonstrate government's role in the development of domestic firms.

GDT was formally established in 1994 to produce the HJD-04, China's first PDSS. The government support for GDT before its establishment is mainly reflected in its effort to develop domestic PDSS technology in the preparation stage. China started R&D on switch technology in the early 1980s. In 1983 China established an R&D project to develop its own PDSS technology under a state scheme to promote technological innovation, which was successfully completed in 1986.[20] The project resulted in the earliest Chinese switching system, the DS-2000, which was based on knowledge of the Japanese system F-150. Later, a more advanced version, DS-30, was developed, but it was not until HJD-04's birth that China's first commercial PDSS arrived.

[20] As early as in September 1984, a project of a digital program-controlled private automatic branch exchange (PABX) was started as a prelude for getting into switch technology (Shen, 1999).

During the growth stage (1993-1996) of the industry, the government provided support in five main areas: company setup, financing, R&D, marketing, and export. First, several government agencies initiated the proposal to set up GDT. In June 1993 the National Science Commission, the Ministry of Electronics, and MPT filed a joint petition with the State Council, proposing to start an enterprise group that would enlarge the production of domestic PDSS. In the next five months, national leaders such as Jiang Zemin, Li Peng, Zhu Rongji, Li Lanqing, and Zou Jiahua showed concern and interest towards the petition and finally approved the proposal.

Second, the government offered GDT financial help through loans. With the State Council's intervention, major national banks, such as the People's Bank, the Manufacturing and Trade Bank, and the Construction Bank, all lent GDT's customers a great amount of trust loans[21] for purchasing products from GDT. The loans totaled 1.4 billion RMB by the end of 1997. In addition, the Construction Bank, a major state-owned bank, loaned 0.7 billion RMB to GDT in November 1996 for its technology improvement in specialized circuit board production and for setting up the development center.

Third, the government supported GDT's R&D activities by recognizing their excellence in certain research fields and enrolling them into National Science and Technology (S&T) programs. For instance, HJD-04 received awards such as MPT S&T Progress First Award, China Electronic S&T Ten Achievements, and National S&T Progress First Award. GDT's HJD-04E and its related research became a project enlisted in the "863 Plan" in February 1992 and part of the National Science and Technology Special Plan.

Last, the government actively supported GDT in exporting its products. GDT exported HJD-04 to North Korea in 1994, the first time that China had exported its PDSS. In January 1996, the National Science Commission set up meetings with the National Economic and Trade Commission to discuss the export of HJD-04. After a face-to-face interchange between the Chinese and Russian governments,[22] in December 1996, GDT obtained a license to export HJD-04D to Russia. Moreover, the government became directly involved in coordinating market demand for domestic suppliers. The second "Domestic Switch Customer-Producer Coordination Conference" organized by MPT helped GDT to obtain 3,870,000 orders.

During the filtration stage of China's telecom-equipment industry (1997-2000), GDT expanded its product range from switching systems to mobile communications and data communications. The company also started to cooperate with many companies, institutions, and governments, both domestic and foreign. In this stage, the government continued its financial, R&D, and export support. Financially, the government increased its loans to GDT customers, reaching a total of RMB 8 billion for 1998 and 1999. In terms of R&D support, the government enrolled GDT in more national S&T programs.

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[21] The loan was designed for GDT's customers. Many local telecom bureaus were short of capital to purchase the switch equipment. The government used the loan to encouraged telecom service providers to purchase GDT's products.

[22] Summarized from GDT's event calendar from the company's website.

For instance, GDT was listed as an *industrial base* for the "863 Plan" and gained six projects from the "863 Plan." Furthermore, the government continued to support GDT's exports to other countries. Exports to Russia were further facilitated by the close contact of the Chinese and Russian governments. In particular, in February 1998, Premier Li Peng visited Russia, and officials from the two governments signed a cooperation agreement between GDT and Russia Telecom. As a former military unit, GDT's product was preferred by the military -- HJD-04 has been used to replace the No. 5 Switch from the United States as the main switch for Beijing Military Network in the late 1990s.

6.4 Chapter Conclusion

This chapter examined the development of China's telecom-equipment industry and concluded that domestic firms have caught up with the MNCs in the four stages described by the staged catching-up theory: the preparation stage (early 1980s to early 1990s), the growth stage (early 1990s to 1996), the filtration stage (1997-2000), and the globalization stage (2000-2002). Evolution of markets' and companies' economic indicators, such as revenue, demand, profitability, production structure (employment, occupation structure), industry structure (concentration, size of firms), government involvement, and location choices, as well as the individual development histories of ZTE, Huawei, DTT, and GDT, all have confirmed that China's telecom equipment industry has gone through the first three stages and is now at the beginning of the globalization stage.

Analyzing the development history of major companies in the industry, I found that even though the companies had different backgrounds when they started, they have shared some commonalities and utilized similar strategies to deal with the changes and challenges posed by the market and the environment. Table 6.8 summarizes findings, in the light of Table 3.1 "Business Behavior During the Catching-up Process."

Table 6.8 Characteristics of China's Telecom-equipment Industry and Domestic Firm's Development Early 1980s-2002

Stages	Stage 1 (Preparation)	Stage 2 (Growth Stage)	Stage 3 (Filtration Stage)	Stage 4 (Globalization Stage)
Profit margin	high for switches	high for switches	medium for switches, medium to high to other equipment	low for switches, but medium to high for other products
Market characteristics (demand)	strong demand for switches	strong demand for switches; growing demand for other products	decreased demand for switches, increase demand for other products	low demand for switches; strong demand for other products
Industrial structure	many small companies from different backgrounds	Quite a few small to medium size firms	consolidated industry; leading firms invested heavily in R&D	several distinct large companies with some specialized small companies
Number of suppliers	numerous foreign suppliers	numerous JVs and domestic producers of switches	coexistence of JVs and domestic producers in all subsecors of the industry	coexistence of JVs and domestic producers in all subsectors of the industry
Focus of resource development of domestic firms	doing R&D in switch technology	doing R&D in large scale digital switches	doing R&D in access equipment, optical transmissions, diversifying to other areas, and increasing manufacturing capability	doing R&D on data and mobile communication, increasing management efficiency, exploring international markets
Occupational structure	varied	increasing R&D ratio	increasing R&D ratio	high R&D ratio
Government policy at the industry level	Whole-system import and joint venture production for switch equipment, R&D support in switching technology	Financial support for domestic firms (loans for their trusted customers and financial aid for technology improvement); S&T program for switching technology; export support; customer coordination	National S&T programs for various technologies in telecom-equipment industry, export support; customer coordination	National S&T programs for various technologies, especially in mobile and data communications, mobile frequency resource support for the Chinese standard TD-SCDMA
Locations of domestic firms	business environment, R&D resources (where the innovation is)	R&D resources (skilled labor pool), manufacturing base	R&D resources (skilled labor pool), manufacturing base	R&D resources (skilled labor pool, market-access, international locations

Source: Summarized from previous sections.

Note: Stage 1: late 1980s-early 1990s; stage 2: early 1990s-middle/late 1990s; stage 3: middle/late 1990s-2000; stage4: 2000-present (2002).

Demand for switch equipment has gone from high to low, while the demand for other sub-sector's equipment has risen since the filtration stage. Corresponding to the change in demand, profitability for switch equipment has kept decreasing from high to low profit margin, while the profit margin for other equipment has been rising since the filtration stage. The sector's employment has kept growing; however, the speed of growth has changed from rapid to slow. Also, the occupation structure has been characterized by increasing R&D staff ratio until now it has a high *R&D staff / total Employment* ratio. In terms of the industry structure, the industry has become more concentrated, i.e., the number of firms has decreased. Firms have varied their priority of location in the different stages.

In this chapter, I also demonstrate that the government has displayed different involvement in the four stages of the development of the telecom-equipment industry. Porter (1990) emphasized that the government should play a supportive and indirect role that should encourage change, promote domestic rivalry, and stimulate innovation. However, Amsden (1989), Singh (1992, 1994), and Wade (1990) stressed the importance of government policies and justified government's direct intervention, especially from the experience of the newly industrialized countries (NICs) of East Asia. In this research, I have found the intervention was critical to domestic producers at the earlier stages of their development. During the preparation stage, the government decision of importation to satisfy the domestic demand and "to exchange technology with the market" formed the character of the switch-equipment market – first, "whole system importation," and later, "joint production with foreign manufacturers." During the growth stage, it is also the government's persistent R&D and capital support, in addition to its support in market access, that led to the successful development and the expansion of production of domestic switching equipment. It is therefore fair to conclude that government intervention has promoted the development of domestic firms from the preparation stage to the growth stage. During the filtration and globalization stage, the government became less involved and focused mainly on helping domestic firms to build knowledge-based assets, which helps to build the innovation capability of leading domestic firms.

In sum, this chapter has illustrated that Chinese domestic telecom-equipment manufacturers have followed a path of catching-up that can be described by the staged catching-up theory, and government intervention has promoted this process. Does innovation matter during this catching-up process, then? This question will be answered in the next chapter.

Appendix 6.1 Global Telecom-Equipment Market

Access Market

The global access market consists mainly of two segments: DSL and cable modem. Digital Subscriber Line (DSL) refers to a type of digital modem that operates on standard phone lines. The downstream (data to the user) and upstream (data from the user) data traffic can operate at symmetric or asymmetric speeds. [23] Cable modem refers to a modem that operates over the ordinary cable TV network cables. "Cable" is short for Cable TV (CATV) Network. "Modem" is Modulator-DEModulator.[24]

Digital Subscriber Line (DSL)

In 2001 global service providers spent $2.3 billion on DSL equipment. Among them, Europe and the Asia-Pacific region led the global market with 66% of the ports shipped.[25] DSL equipment for service providers here is defined as network systems that stay within the network and support the major types of high-bandwidth data: Asymmetric Digital Subscriber Line (ADSL), Single-line High-bit-rate Digital Subscriber Line (SHDSL), and Very-High-Bit-Rate Digital Subscriber Line (VDSL). Over 19 million DSL ports were shipped in 2001, 98% of them coming from ADSL, the most popular DSL technology for incumbent service providers, due to its availability, ease of deployment, and cost structure (RHK, 2002).

Table 6.9 shows that Alcatel led in market share by 41%, which is far ahead of Siemens (13%) and other followers, namely, Lucent (10%), Fujitsu (8%), and Cisco (8%). Alcatel was able to maintain leadership in the DSL market in part due to its strong relationships with incumbent service providers around the world.

Global demand for DSL is still growing and the prices for DSL equipment are continuing to drop. As a result, competition between vendors is intensifying. Current leading international DSL vendors are coming under increasing pressure from equipment manufacturers in East Asia, primarily in China, Korea, Japan, and Taiwan (RHK, 2002).[26]

Cable Modem

Cable modem includes the following segments: standards-based equipment - Data Over Cable Service Interface specification (DOCSIS)[27] equipment, proprietary equipment, and Digital Video

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[23] Source: http://www.bandwidth.ie/downloads/dsl_info.pdf as of May 1, 2003.

[24] Source: Cable-Modems.org. 2003. "The Cable Modem Reference Guide," http://www.cable-modems.org as of May 1, 2003 (Cable-Modems.org, 2003).

[25] "2001 was a growth year for Europe as incumbent service providers, led by Deutsche Telekom, ramped up deployment of DSL in order to remain competitive and gain additional broadband subscribers. Asia-Pacific showed similar deployment growth, accounting for 30% of global DSL equipment revenues. North American deployments grew slightly in Q4 01, but revenue growth is expected to decline in 2002",said Ian Cox, Senior Analyst with Broadband Access Networks at RHK (RHK, 2002).

[26] *BroadBand Access Networks: Global -2001 DSL Market Share.* RHK Telecommunications Industry Analysis website: http://www.rhk.com/pressrelease.asp?id=151 as of Oct. 28, 2002.

[27] DOCSIS is the dominating cable modem standard. It defines technical specifications for both cable modem and Cable Modem Termination System (CMTS) (Cable-Modems.org, 2003).

Broadcast /Digital Audio-Visual Council (DVB/DAVIC)[28] standard equipment. Within several years, DOCSIS has grown rapidly to become the main type of equipment shipped. In 1999 DOCSIS cable modems accounted for less than half the cable modems shipped.[29] However, in the second quarter of 2000, DOCSIS modems accounted for 68% of worldwide cable modem shipments; proprietary modems represented 31% of shipments, and DVB/DAVIC modems had only 0.4% share.[30] In the last quarter of 2001, DOCSIS modems represented more than 85% of all shipments and 75% of revenue.[31] The cable modem market overall has been growing rapidly as well. It is expected to grow by 30% to 50% in the next few years[32] as demand for broadband access continues to rise.

Table 6.9 DSL Global Market Share, 2001

Company	Share
Alcatel	41%
Siemens	13%
Lucent	10%
Cisco	8%
Fujitsu	8%
Inovia	7%
NEC	6%
Samsung	5%
Others	2%
Total	100%

Source: RHK, 2002

Currently, Motorola is the market leader in the DOCSIS segment, followed by Toshiba. Ambit Microsystems, a Taiwanese manufacturer, ranked third in terms of worldwide market share (see Table 6.10). It is worth noting that Taiwanese manufacturers have become the world's largest suppliers of cable modems. According to the Market Intelligence Center[33] of the Institute of Information Industry (Taipei, Taiwan), the world shipment of cable modems amounted to over 8.1 million units in 2001. Taiwan's cable modem shipments accounted for 65.6% in 2001 and were expected to rise to 67.8% in 2002. The main reason for this phenomenon is that more first-tier cable modem vendors are placing Original Equipment Manufacturing/Original Design Manufacturing (OEM/ODM) orders with Taiwan manufacturers, who have the lowest prices, in order to bring costs down as the prices for cable modems fall.[34]

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[28] DVB/DAVIC standard is also known as DVB-RCC and as ETS 300 800. Very few vendors have developed equipments for this standard and it is fighting he EuroDOCSIS standard for the European market (Cable-Modems.org, 2003).

[29] http://www.cable-modems.org/articles/market as of Oct. 28, 2002.

[30] http://www.cable-modem-internet-access.com/market/ as of Oct. 28, 2002.

[31] www.joohong.co.kr/eng/news/press/content.asp?idx=4 as of Oct. 28, 2002.

[32] http://www.telecom.globalsources.com/MAGAZINE/TS/0208/CABLE01.HTM as of Oct. 29, 2002.

[33] http://216.239.39.100/search?q=cache:sDakIKsbbiYC:www.amigo.com.tw/news/20011202.pdf+market+share+for+Cable+Modem&hl=en&ie=UTF-8 as of Oct. 28, 2002.

[34] http://www.telecom.globalsources.com/MAGAZINE/TS/0208/CABLE01.HTM. Most Taiwan cable modem manufacturers produce for several major OEM/ODM buyers, including Com21, Scientific-Atlanta,

Alongside Taiwan's prosperity in the cable modem market, there is a growing number of mainland companies producing cable modems as well, such as Chongqing JingHong Hi-Tech, Star Networking Technology, and WeiFang Beida Jade Bird Huaguang Technology.[35] Some of them are well prepared for the future cable modem market, which will shift toward next-generation digital services such as voice and video. For instance, to develop its cable modem, Star Networking has formed a technical partnership with Texas Instruments (TI), which specializes in voice-enabled cable modem technology with DOCSIS 1.1-ready technology and digital signal processors.

Table 6.10 Cable Modem (DOCSIS) Market Share, Q2 2002

Company	Total Units	Total Share
Motorola	825,000	32.12%
Toshiba	448,000	17.44%
Ambit	433,000	16.86%
S-A	272,000	10.59%
Thomson	200,000	7.79%
Com21	57,000	2.22%
Linksys	51,161	1.99%
Terayon	32,000	1.25%
Other	250,000	9.73%
Total	2,568,161	100.00%

Source: Company Reports, Kinetic Strategies.[36]

Optical Transport Market

The optical transport market can be divided into the following five segments:[37]

1. Dense Wave Division Multiplexer[38] (DWDM) – Long Haul Terrestrial.
2. DWDM – Metropolitan
3. Synchronous Optical Network/Synchronous digital Hierarchy[39] (SONET/SDH) – Asynchronous disconnected Mode (ADM)
4. SONET/SDH – Multiservice

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and Toshiba. Three reasons account for the price decrease of cable modems: increase in data rates, established chip designs, and DOCSIS standards.

[35] http://www.telecom.globalsources.com/MAGAZINE/TS/0208/CABLE02.HTM as of Oct. 29, 2002.

[36] http://www.cabledatacomnews.com/au02/aug02-1.html as of Oct. 28, 2002.

[37] Dell'Oro,2002. http://www.delloro.com as of Oct. 28, 2002. Different research companies vary in their definitions of the optical transport market. For instance, RHK defines the optical transport market to include all major categories of equipment used in optical fiber networks: SONET/SDH, MSP, OED, traditional and superband DCS, WDM, OADM, and OCS equipment.

[38] DWDM is a fiber-optic transmission technique that employs light wavelengths to transmit data parallel-by-bit or serial-by-character. (International Engineering Consortium. 2003. http://www.iec.org.)

[39] SONET and SDH are a set of related standards for synchronous data transmission over fiber optic networks. SONET is short for *Synchronous Optical NETwork* and SDH is an acronym for *Synchronous Digital Hierarchy*. SONET is the United States version of the standard published by the American National Standards Institute (ANSI). SDH is the international version of the standard published by the International Telecommunication Union (ITU). (Techfest.com, 2003. http://www.techfest.com.)

5. Optical Switch

Alcatel led the overall optical transport market in 2001 with a 16% share, followed by Lucent at 12% and Nortel at 11%. The global market for optical transport declined by 34% in 2001, as optical transport markets in North America and Europe were hit hard by the economic recession. However, the Chinese market grew by 70% to $1.9 billion.[40] China is viewed as one of the world's most dynamic markets for communications equipment and "the market with the strongest growth."[41] Many of the world's largest and best-known suppliers have established joint ventures in China, and they supplied approximately one-half of the market's need in 2001. The remaining half has come from domestic companies. Those domestic companies have gained rapidly in expertise and are now taking aim at North American and European markets.[42] For instance, Huawei has emerged as the country's strongest optical transport manufacturer and now has significant impact and potential in Europe.[43]

Table 6.11 Optical Transport Global Market Share, 2001

Company	Share
Alcatel	16%
Lucent	12%
Nortel	11%
Fujitsu	9%
Ciena	6%
Marconi	6%
NEC	6%
Siemens	5%
Tycom	5%
Tellabs	4%
Cisco	3%
Others	17%
Total	100%

Source: ISP-Planet[44], 2002

Router Market

We can divide the router market into three segments (Smith-Gillspie, 2001):

- *Core Routers.* These are used in the backbone of the networks. They are developed for maximum throughput and capacity.

[40] Reported by Strategies Unlimited, a Silicon Valley-based market research firm. http://www.strategies-u.com/PressRelease.asp?Release=43 as of Oct. 29, 2002.
[41] Stephane Teral, director of European and global optical transport at RHK. http://www.isp-planet.com/research/2002/opticbbone_020225.html as of Oct. 29, 2002
[42] http://www.strategies-u.com/PressRelease.asp?Release=43 as of Oct. 29, 2002.
[43] http://www.alcatel-sbell.com.cn/en/news/detail.asp?lngRecordID=896 as of Oct. 28, 2002.
[44] http://www.isp-planet.com/research/2002/opticbbone_020225.html as of Oct. 29, 2002

- *Edge Routers.* These are used for line aggregation such as broadband (DSL and cable modem) and corporate access (T1, T3, OC-3). These routers have smaller footprints and higher interface densities and flexibility.
- *Service Routers.* Telecom carriers use these to deliver services to customers. They are generally smaller boxes with a greater amount of application software than other types of routers.

Revenues of the global router market slipped 3%, from $1.67 billionn in the fourth quarter of 2001 to $1.62 billion in the first quarter of 2002.[45] Cisco is the market leader in all router categories. For all of 2000, the core router market was $2.4 billion; according to the Dell'Oro report, Cisco had 71% of the market, while Juniper Networks had 28%. For the 3rd and 4th quarters of 2001 (Table 6.12), Cisco maintained over 80% market share, while Cisco's main rival Juniper Networks, retained 8% to 11%. However, Juniper Networks is very competitive in the high-end market, where its core router market share is around 30%.

Table 6.12 Global Router Market Share, Q3 and Q4, 2001

Company	Total (Q3)	Total (Q4)	Core Routers (Q3)	Core Routers (Q4)
Cisco	82.70%	84.40%	65%	69%
Juniper Networks	11%	8.50%	32%	27%
Other	6.30%	7.10%	3%	4%

Source: Dell'Oro, 2002[46].

Ethernet Switch Market

Table 6.13 Global Switch Market Share, Q4 2001 and Q1 2002

Company	Q4 2001	Q1 2002
Cisco	60.2%	66.0%
Nortel	7.3%	5.7%
Enterasys[47]	5.0%	3.0%
3Com	4.6%	4.2%
Extreme	3.9%	4.2%
Others	19.0%	16.9%
Total	100.0%	100.0%

Source: Summarized from Network World Fusion[48] (05/20/2002) and Dell'Oro Group[49](02/2002).

[45] May 17, 2002, http://www.vnunet.com/News/1131853 as of Oct. 28, 2002.
[46] http://www.bayarea.com/mld/mercurynews/business/2676972.htm and http://www.rametronics.com/news_25.html as of Oct. 28, 2002.
[47] Exterasys Networks had less than 3% market share, down from 5% in the previous quarter. This is due to the administrative shakeups and financial troubles it has encountered.
[48]http://www.nwfusion.com/news/2002/0520cisco.html
[49] http://www.delloro.com/PRESS/PressReleases/ES021502.shtml

Ethernet switches can be divided into the following segments[50]:

1. Ethernet Switches – Layer 2 Ethernet
2. Ethernet Switches – Layer 3 Ethernet
3. Ethernet Switches – Layer 4/7 Server Load Balancing (SLB)
4. Wireless Local Area Network (LAN)
5. Network Interface Cards (NICs)

Cisco has maintained dominance in the switch market, even though the market as a whole was down by 4% from the previous quarter (Q4, 2001). Of the $2.65 billion worldwide sales of Ethernet switches in the first quarter of 2002, Cisco has "grabbed a bigger share of a shrinking pie" - it grew its share from 60% (Q4, 2001) to 66%. Nortel remained a distant second with 5.7%. Other players include Enterasys, 3Com, and Extreme. (Table 6.13)

Mobile Equipment Market

I have divided mobile communication into two main segments: mobile equipment and mobile handsets, leaving the mobile handset market details until Chapter 10.

Five large companies are dominant in the mobile equipment market: Ericsson, Lucent, Motorola, Nokia, and Nortel. In addition, there are several regional and second-tier OEMs such as Siemens, Alcatel, Hughes Network Systems, NEC, Hitachi, Fujitsu, Samsung, Hyundai, and LGIC (see Table 6.14). Mobile service providers contract with mobile equipment producers to plan, manufacture, integrate, install, and, in many cases, manage their mobile networks (BT Alex.Brown, 1999a). Ericsson is the market-share leader globally, based on its leadership in two important segments, GSM and TDMA. Nokia has also gained market share in the GSM market (it is number two), based in part on its dominance of the GSM 1800 segment (BT Alex.Brown, 1999b).

Table 6.14 Mobile Infrastructure Market Shares (all standards combined)

Company	Market Share*
Ericsson	32%
Motorola	17%
Nokia	12%
Lucent	11%
Nortel	8%
Other	20%

Source: BT Alex.Brown (1999b)

*: Based on percentage of global installed base.

Lucent is strong in Code Division Multiple Access (CDMA) (ranking first) and Time Division Multiple Access (TDMA) (ranking second), which are the largest digital standards in the United States, but has been less active in international markets. Motorola has been a pathfinder in the mobile industry and has won a significant Global System for Mobile Communication (GSM) and CDMA contracts. Although Motorola has had problems due to its lack of an internally manufactured switch, it is solving these issues through closer partnerships with Alcatel and Cisco, which supply its switches. Nortel has also been a significant player in all digital standards, and

[50] Dell'Oro Group (http://www.delloro.com as of Oct. 28, 2002).

the company's mobile infrastructure business has reportedly been gaining momentum (BT Alex.Brown 1999b).

Appendix 6.2 Multinational Companies in China

It is widely recognized that the Chinese telecommunication equipment market is one of the most competitive markets in the world (Xin 2000). Most of the large MNCs, either system providers or OEMs, compete directly against domestic Chinese firms in the Chinese market. In addition, major component suppliers have entered the Chinese market through direct manufacturing operations in China or by providing components to Chinese firms. I briefly introduce the seven MNCs in China (Table 6.15).

Alcatel China

Alcatel of France entered China's telecom market in 1983 by establishing China's first joint venture in telecom equipment manufacturing (Shanghai Bell) through its subsidiary Belgium Telephone. At the time, China was in seriously short supply of basic telephone exchange equipment. Alcatel benefited from the strong demand by supplying central office (CO) and other equipment. Alcatel was also the first to bring the GSM cell phone system to China (1993), which now has a user base of 120 million. Alcatel started China's first GPRS (general packet radio service) trial network in 1999. In recent years, Alcatel has been facing intense competition in China's telecom market. In October 2001 Alcatel acquired Shanghai Bell and now controls 51% of the company.[51] Recently, Shanghai Bell formed a mobile communication department with Korea's Samsung, thus making mobile communication in China even more fiercely competitive.

Cisco Systems China

Cisco Systems opened its first China office in 1994, much later than other foreign companies in the same industry. Cisco China relies primarily on local partners' channels for sales, rather than on its own sales force. Most products sold are IP backbone routers and concentrators, broadband systems, and data switches (all data-communication products). Because the construction of IP networks has slowed down, Cisco may face serious challenges ahead in developing new markets, as traditionally the Chinese market is weak in data communications in terms of traffic volume and number of customers.

Ericsson China

Ericsson has one of the largest investments (exceeding $600 million) among foreign telecom companies. Ericsson's initial success comes from its early entry and selling central office (CO) switches (AXE10) in the mid- to late- 1980s. The company has adjusted its strategy from voice-centric to Internet and IP platforms. Early in 2001, Ericsson announced it would cease cell-phone production (except in China, because of the robust growth of cell-phone users there) and instead concentrate on mobile infrastructure and other system-wide products. Nevertheless, the handset sales of Ericsson in China have slipped from the third to the fourth place because of the strong competition.

Motorola (China) Electronics

[51] This was one of the conditions proposed by the European Union for China to enter into WTO.

Motorola is the largest foreign investor in China's electronics (including telecom) industry. It has invested $3.4 billion over the past 14 years. Motorola cell phones have the largest market share in China (32%). Motorola has moved aggressively in the CDMA area. It won the largest contract for supplying a CDMA system for China Unicom to be deployed by 2002, worth $407 million. Motorola is one of the few companies that offer both CDMA infrastructure and handsets. In the cell-phone market, Motorola now faces intense competition from Nokia, Ericsson, and Siemens, as well as Chinese companies such as Eastcom, which started two joint ventures with Motorola for producing base station systems and Motorola cell phones.

Nokia China

Currently, China is the second largest market for Nokia, trailing only the US market. Nokia is also the second largest cell-phone supplier in China with a market share of 30% (after Motorola). Nokia is one of the major firms in the Star Net Industrial Park in Beijing. The company has limited product offerings beyond the GSM cell-phone family, which might put the company in a vulnerable position if the new service (GPRS, WAP, 3G) does not take off in China as soon as anticipated.

Nortel Networks China

Nortel is a strong supplier of high bandwidth fiber optic transmission systems. Its largest joint venture, Guangdong Nortel, won a contract in 2001 from China Unicom to provide a CDMA network worth $275 million. Nortel competes with Lucent Technologies in high-speed backbone transmission systems and with Cisco Systems in IP network and broadband equipment.

Siemens China

Siemens China employs 21,000 in China. It has five joint ventures for telecom products; the company also has a wide range of products in communication, automation and control, medical equipment, energy, power transmission, transportation, and lighting manufactured in China. In the telecom area, Siemens China provides switch products and GSM systems and handsets. It competes with Motorola, Nokia, and Ericsson in the latter. It is now the third largest cellphone supplier in China.

Table 6.15 Major Multinational Corporations in China's Telecom-equipment Industry Facilities and Major Products, 2002

Company Name	Facilities	Major Products
Alcatel China	17 facilities in China, including: 6 research (new product dev. And eng. Services), 11 wholly owned or joint venture facilities	SDH/DWDM transmission systems, broadband access, wireless systems and terminals, IN, OSS and network management
Cisco Systems China	technology support center in Beijing (one of the four support centers in the world), 4 regional offices	IP backbone routers and concentrators, broadband systems, and data switches
Ericsson China	10 JVs, 4 WOSs, and 26 sales offices, 6 R&D centers or projects	CO switches(AXE-10, in mid- and late-1980s), mobile (infrastructure and handsets), data communications and consumer electronics
Lucent Technologies China	7 manufacturing facilities (JVs and WOSs), 8 regional sales offices, 2 Bell Labs branches (Beijing and Shanghai), and four R&D centers.	optical transmission systems (SDH and DWDM), Internet backbone (ATM and IP switches), CO switch (5ESS) and wireless systems.
Motorola China	one wholly owned factory, one holding company, 8 joint ventures, 18 R&D centers, 26 sales offices, and a software development center for ASICs	mobile switches, base stations, and handsets for GSM and CDMA, walkie-talkies, IC chips, and broadband products, such as HFC, cable modems and adaptors.
Nokia China	22 local offices, five joint ventures and two research centers,	mobile base stations, controllers, mobile switch access equipment, digital switching and transmission equipment, and various handsets in China
Nortel Networks China	4 joint ventures, 2 research centers, and various sales office	High bandwidth fiber optic transmission system (10Gps high-speed transmission products), ATM switch, wireless Internet, IN, and VoIP Solution.
Siemens China	5 joint ventures in telecom products including BISC, total 40 manufacturing facilities and 28 local offices.	CO switches (EWSD switching family), GSM systems and handsets in the field of telecom equipment

Source: The Author, summarized from http://www.chinanex.com and websites of each company above. (www.alcatel.com.cn, www.cisco.com.cn, www.ericsson.com.cn, www.lucent.com.cn, www.motorola.com.cn, www.nokia.com.cn, www.nortelnetworks.com.cn, www.siemens.com.cn)

Note:

1. After Alcatel's acquisition of Shanghai Bell, all Alcatel facilities in China will be subsidiaries under Alcatel Shanghai Bell.
2. Nokia: Originally had 8 joint venture, but in March 2002 (or 2003), Nokia announced that it will form a new joint venture for handset production (including CDMA) which will replace four handset joint ventures (two in Beijing, one in Guangdong, one in Jiangsu). The new JV will be the largest handset manufacturer with combined production and exports.
3. Simens provides products and services in communications, automation and control, medical equipment, energy, power transmission, transportation and lighting in China.

Appendix 6.3 China's Telecommunication

Overview of the Network

1. Optical Fiber Network

Starting in the early 1990s, the Ministry of Post and Telecommunications (MPT) decided to devote ten years to building an optical fiber network (50 fiber optical main lines) to cover capital cities of all provinces and 70% of the regional cities. By the end of 1998, MPT had finished its "8-Horizontal, 8-Vertical" main line optical transmission network. In 1999 and 2000, respectively, 290,000 kilometers (km) and 150,000 km new optical fiber lines were built in China, reaching a total of 1,440,000 km. (ZTE, 2001).

2. Fixed-line Communication

By 2000 China's national capacity for local phone switches had reached 0.18 billion units, making it the nation with the largest number of the switches in the word; the phone rate reached 15% of the total population. (ZTE, 2001).

3. Mobile Telecommunication

Having started in 1984, China's mobile telecommunication has only 18 years of history. By 2000, total cellular phone users reached 7.1 million, which was 45% of the annual new phone ownership. The R&D on mobile communication started in the late 1980s. In the middle- and late-1990s, analogue mobile technology (1G) was replaced by digital mobile technology (2G or 2.5G) in most developed countries. Currently, GSM1800 has entered the commercial usage stage. The GSM network covers 308 regional cities, 91% of all regional cities, and 2000 counties or local cities, i.e., 88% of all local cities. The network is able to connect with 80 operators from 48 countries/regions for automatic roaming. Moreover, 3G R&D and the test networks in Beijing, Shanghai, and Guangzhou have been started. (ZTE, 2001).

4. Data Communication

Data communication, centered on computer technology and network technology, is the future of telecommunication. By the end of 2000, over six million people had used data and multimedia communication in China.

In sum, currently China has a telecommunication network that is mainly based on the optical network, complemented by satellite and digital microwave networks. Data transmission has been incorporated into the network, which is controlled by switches. Moreover, China has participated in the Asia-Europe Land Optical Fiber and Fiber Link Around the Globe (FLAG) International Deep Sea Optical Fiber projects, which will increase communication capability and further integrate the country with the world. (ZTE, 2001).

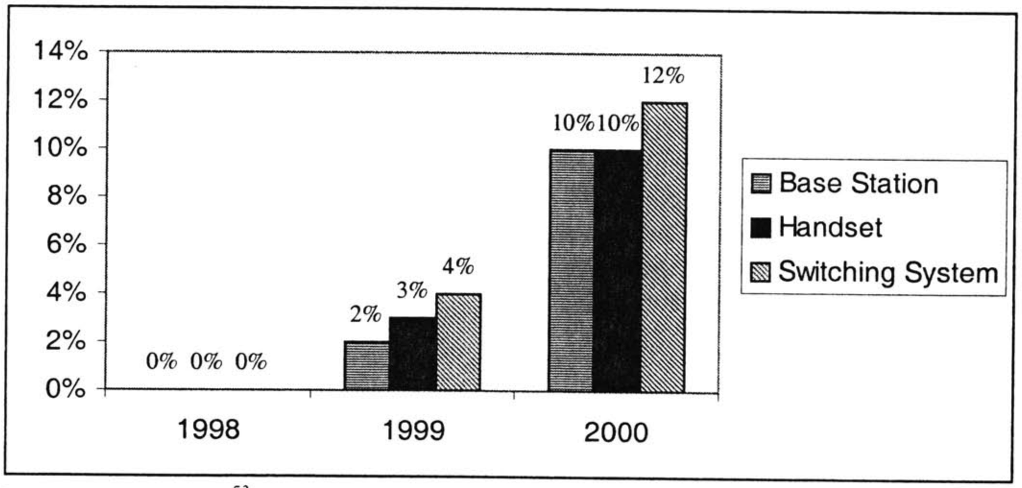
5. Other subsectors

In 1998 local manufacturing supplied 98% of the switching equipment for fixed local networks. In the area of optical transmission, domestic manufacturers' products had a substantial percentage as well. In 1998, 50% of optical transmission systems were produced by domestic manufacturers. In 1998 China developed its own 2.5 High Speed Optical Transmission Equipment. Currently, the ATM Broadband switching equipment is only one or two years behind the leading MNCs. In the area of access systems, domestic producers now supply 50% of the market need.[52] ZTE by itself held 34% of the domestic share in 2000. However, in the subsectors, such as mobile communication and data communication, foreign products have retained most of the market share.

Though starting late and still far behind, China has again made successful group progress since 1998 in the area of mobile switching base stations (Figure 6.1). Datang, Huawei, ZTE, and Jingpen have successfully developed mobile switches and base station network equipment. Datang and Huawei's products have been certified and licensed, and can be connected with foreign-produced equipment in the same networks. In 1998, Datang's GSM System was certified by MPT. In Novemeber 1998, Huawei's GSM System was certified and licensed. In 1999, Datang's GSM System started in Shanghai Congming Island. At the "Domestic GSM System Customer Coordination Conference," Great Dragon, Datang, ZTE, Huawei, and Jinpeng signed contracts for 7 million orders.

From importation to successful development, China has needed only 4 years to catch up in GSM Systems. The following figure shows the progress of Chinese domestic producers in the mobile equipment market.

Figure 6.2 Market Share of Chinese Domestic Vendors in Mobile Equipment Supply



Source: Yan Xu, 2001[53]

In all subsectors, the government has focused on having sound policies on capital injection, loans, and supply and demand coordination. The government hoped that domestic producers can obtain domestic market share in a short period of time with the support of sound policies. Besides gaining domestic market share, Chinese firms have also started to enter the international market, though mostly in Eastern Europe, Russia, Africa, and South America. In 1999 the total revenue from exporting telecommunication equipment and systems reached US$ 46.6 billion. (Xin 2000).

[52] Many of the world largest and best-known suppliers established joint ventures in China and they supplied approximately one half of the market's need in 2001. The remaining half came from domestic companies. These domestic companies have gained rapidly in expertise and are now taking aim at North American and European markets. (See 7.1.1 section.)

[53] *http://www.chamber.org.hk/streaming/ppt/yanxu/wto-hkgcc/sld001.htm*
Xu, Yan, xuyan@ust.hk, Sep. 10, 2001

Characteristics of the market

At present, China's telecommunication market can be characterized by the following:

1. It is the largest telecommunication market in the world.
2. The development of telecommunication is ahead of the national economy's development.
3. China's telecommunication network has been transformed from a fixed phone network to broadband integrated service digital network, at the same pace as implementation of this technology abroad.
4. The development of the market has evolved through "exchanging capital with the market" and "exchanging technology with the market" to going global.
5. The government supports the domestic producers with beneficial policies.
6. The Chinese telecom market has sufficient supply, or supply exceeds demand.
7. In terms of regional development, the east coastal region has been the main focus; the center and west regions are far behind.
8. The market for telecommunication operators is not controlled any more by a monopoly; the competitive operator environment is ready to be open to the global market (as mandated by China's accession to WTO).
9. Several nationally-owned enterprises with self-developed technologies have arisen.
10. China will still be the focus in the world of most telecommunication MNCs; competition will become fiercer.

Appendix 6.4 The Catching-up in Switching Equipment

China's market of telephone switches has experienced from total dependence on foreign equipment, to joint production with foreign manufacturers, to supplying the market with mostly self-developed switches (Table 6.16).

I divide the process of catching up of the switch equipment into three periods: early 1980s to late 1980s, late 1980s to early 1990s, and early 1990s to late 1990s. The market was characterized by foreign-import systems in the first period, to joint ventures (JVs) with a 60% of the market share at the end in the second period, to almost 100% domestic production in the third period.

The first and second period of the switch-equipment market (from the early 1980s to the early 1990s) happened during the preparation stage of China's telecom-equipment industry, i.e., the industry is preparing the domestic firms for the late catching-up process. During this stage, telecom-equipment MNCs started exporting finished products to China; later, they set up their own manufacturing sites in China. The third period (early 1990s to middle/late 1990s) of the switch-equipment market occurred during the growth stage of the industry. Domestic firms started entering the available segments of the market, i.e., the small-scale switch equipment, and then developed their own large-scale PDSS equipment. The market share of domestically produced switch equipment and the sizes of the companies (in terms of revenue and employment) expanded quickly during the period. The following paragraphs present a historical review on how China transformed itself from total foreign-dependence to self-dependence in the field of switch equipment.

Table 6.16 China's market of Telephone Switches, Early 1980s to Late 1990s

Periods	Supply Characteristics	Demand Characteristics	Market Characteristics
Early 1980s -late 1980s	Import all needed systems	Urgent demand with customer lack of capital	All foreign imported switches
Late 1980s - early 1990s	Joint production with foreign manufacturers	Strong demand	60% market share for 9 JVs.
Early 1990s - late 1990s	Self-development	Strong demand to nearly saturated market	98% market share for domestic producers (including JVs)

Source: ZTE (2001) and Xin (2000).

First Period: Whole System Importation (*Early 1980-Late 1980s*)

From the early to the late 1980s, China's switch market was characterized by importing whole systems because domestic producers were unable to supply the needed equipment to service providers. In 1982, the Fuzhou Telecom Bureau imported the first digital switch (Fujitsu F150). Local telecom bureaus subsequently imported digital switches from Belgium, France, Japan, and Italy. The following are some of the examples:

- In 1984 the Ministry of Posts and Telecommunication (MPT) spent 35 billion yen from a fund that Japan provided to import 520,000 switches and build the first 600 km of fiber optic lines in China.
- In 1985 the Beijing Telecom Bureau imported 100,000 switches from France.
- In June1985 Guangzhou imported 26,000 switches from Sweden.
- In 1988, the Beijing Telecom Bureau imported 155,000 E10B switches from Alcatel CIT.

Why did China import so many whole systems during this period? Two demand-side factors motivated the importation. First, service providers had urgent need to satisfy the domestic demand for phone installation--several hundred thousand business units and households were waiting for phone installation in the 1980s. Second, service providers needed abundant finance to purchase the switch equipment, and importation of the equipment can partially solve the funding problems. Even though most telecom service providers were very eager to improve their telecom networks, they were short of capital to purchase the equipment. To resolve the problem for the service providers as well as to enhance their own marketability, foreign switch vendors asked their governments to get involved. For instance, to facilitate the importation of switch equipment from France, the French government lent Beijing Telecom Bureau a mixed loan. Foreign capital evolved from a single kind of loan to rental and other kinds of loans-government loans, mixed loans, commercial loans, and mortgages. The local telecom bureaus, supervised by MPT, used the loans to buy switches for city phones (30 million units) and long distance (2 million units). Further, they built inter-/ intra-provincial long distance, optical fiber lines (50,000 km), microwave lines (30,000 km), satellite earth stations (18), automatic letter sorting systems (28), and other telecom infrastructures.

However, the large amount of importation caused too many models to be coexisting in China. The main models included: Alcatel (E10), Siemens (EWSD), NEC (NEAX), AT&T (5ESS), Nortel (DMS), Ericsson (AXE10), and Fujitsu (F-150). Moreover, there were huge loans that China had to pay back. Loans for imports for the period from 1984 to 1990 totaled $1.16 billion and $5.16 billion for the period from 1991 to 1995.[54] The lenders, both public and private, were from all over the world: Canada, Sweden, Japan, Belgium, Spain, Germany, France, the United States, Australia, the United Kingdom, Norway, Finland, Switzerland, Italy, Israel, Hongkong, and Taiwan, as well as some international organizations, such as the World Bank, and the Asian Development Bank. (ZTE, 2001).

Second Period: Joint Production with Foreign Manufacturers (*Late 1980s–Early 1990s*)
From the late 1980s to the early 1990s, the Chinese government set up the policy "to exchange technology with the market,"[55] i.e., the foreign producers could be in the Chinese market for switches if and only if they agreed to offer some technological help to the Chinese. Consequently, several joint ventures were established (Table 6.17). Among them, Shanghai Bell, a joint venture (JV) of Ministry of Posts and Telecommunications with Belgium Bell Corporation established in 1984, was the first one, and it produced S-1240 local switches. Other major ones included joint ventures with Nokia, Ericsson, NEC, AT&T, and Nortel Networks.

Table 6.17 Major Joint Ventures Established in China for Producing Switches, 1984-1995

Name of Joint Ventures	Foreign Partner	Model	Establishment Starting Date
Shanghai Bell	Belgium Bell	S-1240	1984
Beijing International Switching Corp	Siemens	EWSD	1990
Beijing Ericsson Telecommunication System Limited Corp	Ericsson	MD110	1991
Tianjin RiDian Electronics Telecommunication Industrial Limited Corp	NEC	N-61	1992
Qingdao AT&T Keji Telecommunication Equipment Limited Corp	Lucent	5ESS	1993
Guangdong Nortel Telecommunication Equipment Limited Corp	Nortel	DMS	1995

Source: ZTE, 2001.

By 1996 nine joint ventures produced switches and gained over 60% of the domestic market share. The establishment of those JVs contributed to the domestication of switch products. Products from those JVs reached the international standard. Some local producers of the JVs developed their capability in production and learned a great deal from their JV partners. For instance, Shanghai Bell controlled S-1240's software and hardware technology. Telecom-service providers directly benefited from the JVs as the price for the switches was much lower than before. For instance, after Shanghai Bell's establishment, the price of the S-1240 dropped dramatically from $210 in 1987 to $130 in 1989. Having the S-1240's software and hardware technology, combined with other lower production cost (such as labor, land, etc) in China, Shanghai Bell can produce S-1240 switches at a lower cost than the foreign parent (Belgium Bell), which led to the price drop. (ZTE, 2001; Shen, 1999)

Third Period: Self-development (*Early 1990s-Middle/Late 1990s*)

[54]This period is also called "the eighth five years" in China.
[55] *"You Shichang Huan Jishu"* in Chinese.

The Chinese government never gave up the hope of developing pure domestic switch products. In December 1991, HJD-04, which was jointly developed by the Liberation Army Information Engineering Institute in Zhengzhou (Henan Province) and Luoyang Telephone Equipment Factory (LTEF), was certified and licensed by the MPT and thus closed a fifteen-year gap of switch technology between developed countries and China. By the end of 1994, the production capacity of HJD-04 reached 4 million lines, and its domestic market share was over 15%. In December 1996, HJD-04 passed the test for entering Russia's telecommunication network, thus becoming the first Chinese switch to obtain a foreign license.

Later, several other companies developed their switches as well, such as Huawei's C&C08, DTT's SP-30, ZTE's ZXJ-10,[56] Jingpeng's EIM601, and Beijing HuaKe's EIM-601. By 1998 the domestic products had gained a market share of more than 98% (including JVs). China took only 10 years in catching up in the ten thousand unit switch equipment (from importing to developing its own) successfully.

Table 6.18 Switch Production Capacity of Major Firms in China, 1997 (in million units)

Companies	Production Capacity
Joint Ventures	**12.5~15**
Shanghai Bell	5~6
BISC	2.5~3
Tianjin NEC	2~3
Qingdao AT&T	1
Guangdong Nortel	1
Suzhou Fujitsu	0.5
Nanjing Ericsson	0.5
Domestic Firms	**13~15**
GDT (HJD04)	6
Huawei (C&C08)	2
Beijing HuaKe (EIM-601)	1
ZTE (ZXJ-10)	1
Wenfang Huaguang (JSN-1)	1
Legend (LEX-5000)	0.5
All others	1.5~3.5

Source: ZTE, 2001.

The main strategy of the most successful domestic producers was to start switch marketing in the countryside towns and villages, because the equipment requires less technological complexity than in urban areas. After they had accumulated some knowledge of customers and lower-end

[56] Detailed comparison of Huawei's C&C08 and ZTE's ZXJ-10 can be found on pages 22-23 of *ZTE Handbook* (2001).

switch technology, they upgraded themselves by developing the large-capacity switches used for cities. This strategy was called "the countryside encircling the city."[57]

In 1997 domestic switch production capacity on switches reached 13 to 15 million units (See Table 6.18), while JV production capacity totaled 12.5 to 5 million. Together they made about 30 million production capacity and occupied 98% of domestic market. In addition to the major joint ventures mentioned in the second period, domestic firms, such as GDT, Huawei, Beijing Huake, ZTE, and Wenfang Huaguang, had large production capacities, especially GDT, whose production of 6 million units gained it a 20-24% market share, was leading all other companies (including JVs) at the time.

Appendix 6.5 GDT: From Leading to Lagging Behind

In recent years, GDT has suffered from a decline in revenue, especially from sales of its core central office products, as demand has diminished and competition has risen. As a result, the company has slid in market share in almost all product categories. For example, MII ranked GDT 28th in telecom/electronics sales in 1998, but only 54th in 1999. The company declined to participate in the rankings in 2000 and MII removed the company from the list in 2001 for poor financial performance. In 2001, GDT reported only 400 million RMB ($48.2 million) in revenue and 90 million RMB ($10.8 million) in operating loss, much worse than the company had expected.

Thus, GDT changed from being the leader in domestic switch products to being the least competitive company among the four major telecom equipment manufacturers. GDT's rise and fall in the past decade indicates the fierce competition in China's telecom equipment market. Analysts say the main reason for GDT's decline is that it missed the opportunity for an IPO in 1998 and lacked a competitive mechanism within its capital and management structure. The company also failed to pursue new technology and develop products in demand.[58]

On July 28, 2002, GDT started its third restructuring to resolve the problems that the company faced: (1) ownership and management structure, (2) proprietary technology ownership, and (3) capital structure. Though GDT has a separate committee of shareholders, board of directors, and control commission, the inherent multi-interest corporate structure has led to continuous conflicts among different parties. For instance, the shareholders represent capital providers, technology providers, debt owners, and suppliers. Under such a structure, it is unavoidable to make random decisions, as well as changing the management team and the company's strategies relatively frequently. Consequently, the company missed good opportunities for growth even in the areas in which it had strong roots. For instance, GDT started R&D in access equipment one year ahead of other companies, but it was unable to seize the growth opportunities later.

Ownership of proprietary technology is another problem that keeps plaguing GDT. In 1996 disputes occurred between technology owners of HJD04, which affected GDT's normal operation severely. The problem was finally resolved after one year's negotiation and bargaining, but this

[57] This is the same as Mao Zedong's strategy in the anti-Japanese war and civil war in the 1930s and 1940s. Mao's strategy was to root the development of the communist party in the country side, then attack the Japanese and the Republic Party who occupied the urban areas.
[58] www.chinanex.com as of Oct. 20, 2002.

left the situation that even though the switch technology belongs to GDT, the company does not have full control over it.

Insufficient capital is another bottleneck for GDT's development. GDT has only one way to obtain investment capital–bank loans. To accommodate its high operation cost, GDT has borrowed a large amount of cash from its production units. To make things worse, it also takes a long time to receive the payment from GDT's customers. At the beginning of 1999, GDT got contracts, but it could provide no products. The situation soon stimulated a vicious cycle–because the customers could not get their ordered products, they slowed down their purchasing and decreased orders from GDT, which dramatically decreased the cash GDT could receive. GDT then borrowed more cash from its production units to balance its operation cost; but, short of production capital, the production units were not able to produce orders normally. (Yao, 2002).[59]

[59] Yao, Chuanfu. 2002. "Julong's Restructuring, save or reborn?", *People's Posts and Telecommunications (Chinese Newspaper, Ren Min You Dian),* November 19, 2002.

7 Innovation Capability of the Leading Telecom-equipment Manufacturers

This chapter answers the following research questions:

- What role has innovation capability played in the development of China's domestic telecom-equipment manufacturers?
- How have the firms acquired their innovation capability?
- What factors have enhanced the building of innovation capability and what role has the government played during the process?

I start with investigating the role innovation has played in the development of Chinese domestic firms in Section 7.1, both at the initial and later stages. I examine the relationship between innovation capability and industrial leadership. In Section 7.2, I study two major channels that domestic firms use to acquire their innovation capability: (1) in-house R&D development and (2) external alliance. I further explore the factors, such as the government, as well as network clustering, configuration technologies, and sub-sector linkages, which have enhanced the building of innovation capability in Section 7.3. I present concluding remarks in Section 7.4.

7.1 The Role of Innovation Capability

The case studies of the domestic telecom-equipment manufacturers prove that innovation capability and self-developed technologies have been the key to their catching up with the MNCs and have determined who are the leading domestic firms in the industry. I will demonstrate the relationship between innovation capability and industrial leadership through both a simple regression analysis and some examples at the company level.

7.1.1 Regression Results on Innovation Capability

In the appendix of this chapter, I adopt the liner regression model to investigate the relationship between "Leadership in the Telecom Equipment Industry" (dependent variable, Y) and "Rank in Innovation Capability" (independent variable, X). Appendix 7.1.1 exhibits the regression analysis results of the six leading domestic telecom-equipment producers. With an R^2 value at 0.69, the model is significant, indicating that innovation capability has a strong explanatory power to leadership position of domestic firms in the industry. The following figure shows the strong correlation between "Evaluation of Innovation Capability" and "Rank in Telecom-equipment Industry."

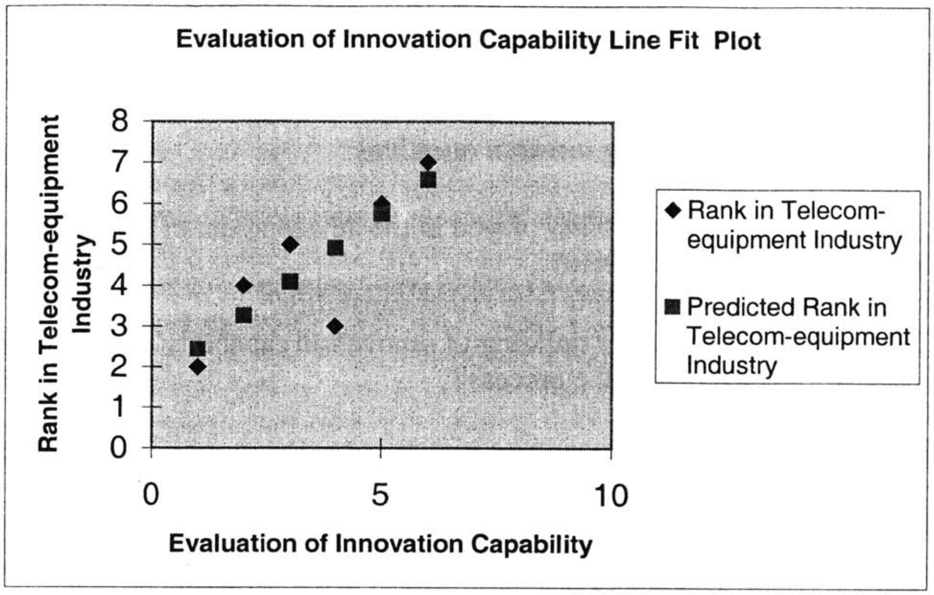


Figure 7.1 Rank in Telecom-equipment Industry vs. Evaluation of Innovation Capability Line Fit Plot

I further investigate the relationship between "Rank in Innovation Capability" and "R&D Spending" in Appendix 7.1.2. Here, "Innovation Capability" is a dependent variable (Y). First, I use "R&D Spending (in million RMB)" as an independent variable (X), and then I replace it with "Percentage of the R&D Spending of the Revenue" to factor out the effect of firm size. Both regression results are significant, with R^2 at 0.51 and 0.67, respectively. Figure 7.2 illustrates the correlation between "R&D Spending as % of Revenue" and "Innovation Capability." The simple regression analysis provides evidence that the innovation capability of leading telecom-equipment companies is related to their internal R&D spending.

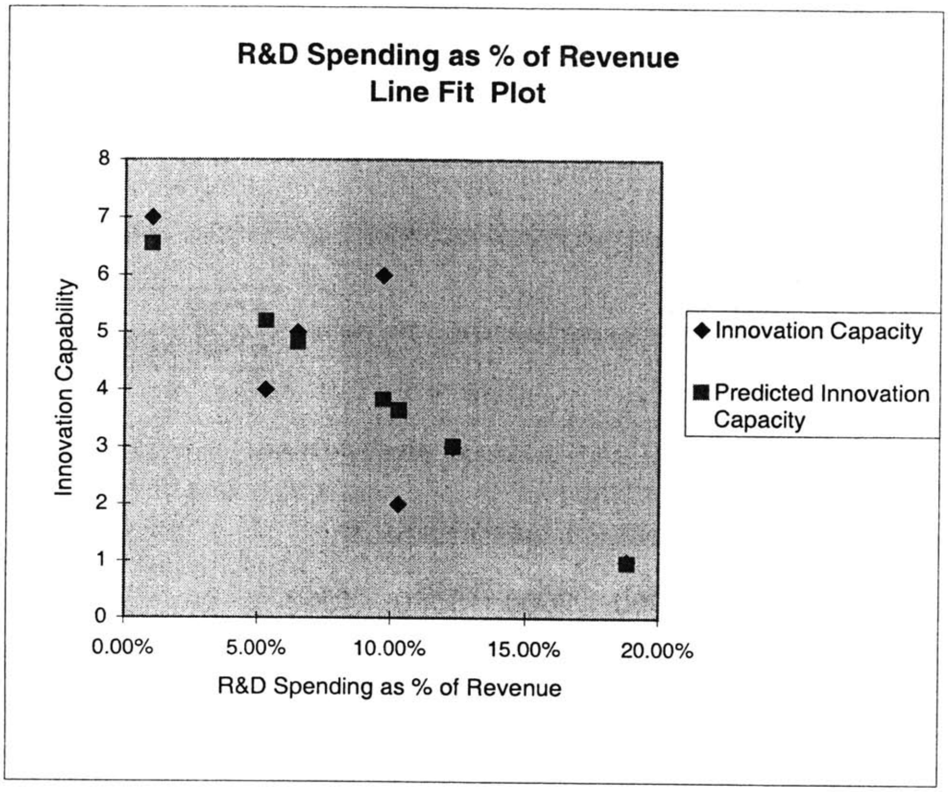


Figure 7.2 Innovation Capability vs. R&D Spending as % of Revenue Line Fit Plot

I then examine the relationship between "Revenue", "Profit" and "R&D Spending (in million RMB)". Appendix 7.1.3 displays the results of the analysis. Figure 7.3 and 7.4 show the line plot of "Profit vs. R&D Spending" and "Revenue vs. R&D Spending". With R^2 at 0.61 and 0.72, it indicates that "R&D Spending" has strong explanation power for both the leading companies' revenue and profit. The fact that "Profit" vs. "R&D Spending" has an R^2 at 0.72, higher than that of "Revenue" vs. "R&D Spending" implies that it is more likely that companies with higher R&D spending have a higher profit rate than companies with lower R&D Spending.

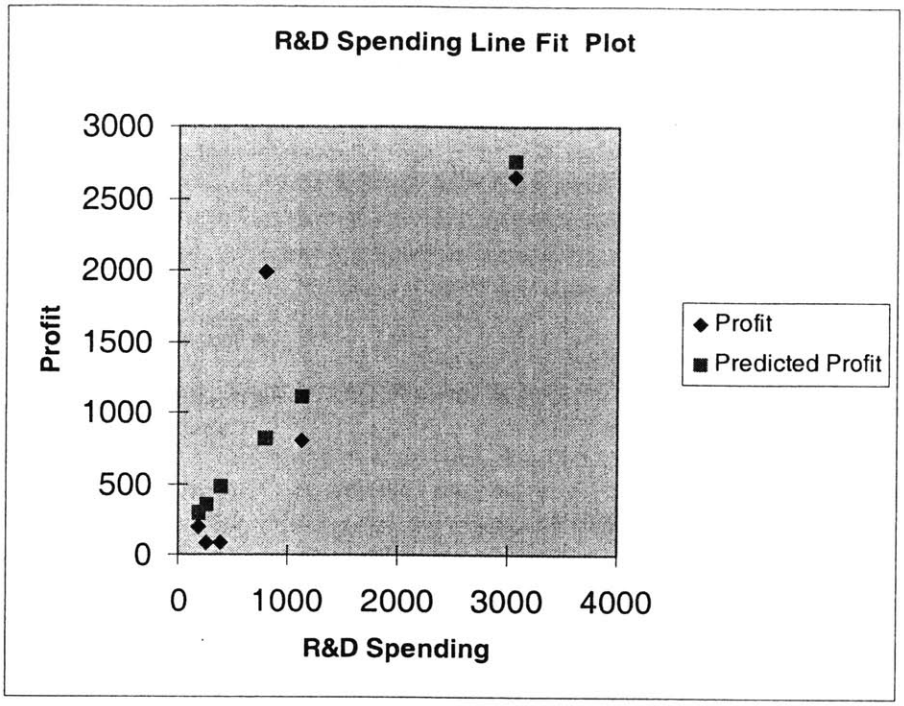


Figure 7.3 Profit vs. R&D Spending Line Fit Plot

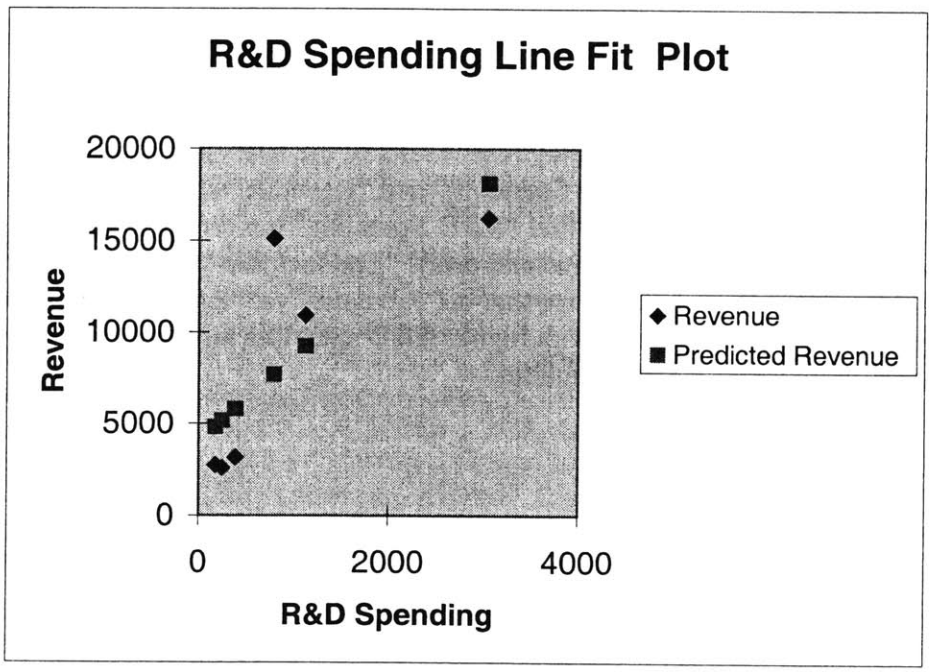


Figure 7.4 Revenue vs. R&D Spending Line Fit Plot

7.1.2 Innovation Capability as the Driving Force for the Staged Catching-up

The first momentum of China's domestic telecom-equipment manufacturers took place when they had access to domestically developed technology-public digital switch systems (PDSS). Without this technology developed mainly by Wu Jiangxing and his team in GDT, it would have been impossible for domestic firms to produce PDSS that could compete with those of MNCs. In addition to serving as a main source of income, PDSS also provided domestic firms with valuable R&D and manufacturing experience at the earliest stages of their development; without that experience, it is unlikely that domestic firms could catch up in other sub-sectors later on. Therefore, it is the self-developed technology (PDSS) that enabled several current leading companies to transform themselves from trading companies to equipment manufacturers. After domestic producers such as GDT, Huawei, ZTE, and DTT developed the PDSS, they began to steadily capture market share from the MNCs. For instance, in 1997 the market share of domestic producers (excluding joint ventures) was over 60%, leaving MNCs with less than half the market.

Furthermore, leading domestic firms have always focused on developing their innovation capability, no matter what stage they were in. After accumulating a certain amount of capital in the preparation stage, they all quickly started developing PDSS in the growth stage. The experiences of Huawei, ZTE, and GDT were amazingly similar to each other in the 1980s and early 1990s in terms of developing public switching systems. For instance, ZTE started with ZX-60, then ZX500. Huawei started with C&C 800 and GDT started with HJD-04. To facilitate the building of innovation capability, they all had some kind of cooperation or partnership with universities or research institutes from the beginning.

At the filtration stage, as the switch market became saturated, most of these companies started to look at other sub-sectors such as access systems and transmission systems. Even though the resource focus of this stage expanded to increasing manufacturing capability, developing markets, and building good customer relationships, developing innovation capability was kept as a priority over other capabilities and R&D remained the most important competitive advantage of the leading domestic firms over others. Because the leading companies accumulated strong innovation capability in developing switching equipment technology, they were able to quickly build their innovation capability in other emerging sub-sectors and dealt well with the transition from the growth stage to the filtration stage.

In the globalization stage of development, the leading domestic firms have expanded their innovation capability into virtually every sub-sector, especially in data communications and mobile communications. Companies have started to cooperate with the first-tier MNCs in R&D, as well as maintaining relationships with domestic research institutes and universities. Moreover, the companies have been actively participating in national science and technology programs. Though the resource focus of this stage is on improving management efficiency,[60] accumulating capital for further expansion, and developing international markets, innovation capability has been chosen as the most critical capability to develop. The fact that leading domestic firms always choose R&D as the most important resource to develop implies a higher return on investment in innovation capability than any other resources.

7.1.3 Innovation Capability and Leadership of the Industry

Table 7.1Major Domestic Firms in Telecomm-equipment Industry: Leadership and Innovation Capacity

Company Name 单位名称	Rank in Telecom-equipment Industry	Evaluation of Innovation Capacity
Huawei Technology Corporation 华为技术有限公司	2	1
Shenzhen Zhongxin Technology Corporation 深圳市中兴通讯股份有限公司	4	2
Datang Telecom Technology Co., Ltd. 大唐电信科技产业集团	5	3
Shanghai Bell Co., Ltd. 上海贝尔有限公司	3	4
Wuhan Telecommunication Science Institute 武汉邮电科学研究院	6	5
Changfei Optical Fiber and Optical Cable Co., Ltd. 长飞光纤光缆有限公司	7	6

Source:

MII. April 2002. "2002 Top 100 Chinese Electronics Companies" Website: http://www.mii.gov.cn.

MII. April 2001. "2001 Top 100 Chinese Electronics Companies" Website: http://www.mii.gov.cn.

PTIC website: www.ptic.com.cn; Shanghai Bell website: www.alcatel-sbell.com.cn; State Intellectual Property Office of P.R. China, website: www.sipo.gov.cn.

Note:

1. Shanghai Bell Co., Ltd. started in 1984 as a joint venture among Shanghai Telecom Administration, Alcatel and Belgian government). In May 2002, Shanghai Bell became majority owned by Alcatel (50% plus one share) and changed its name to Alcatel Shanghai.
2. Posts & Telecommunications Industrial Corporation (中国普天信息产业集团公司, PTIC) was listed by MII as the largest electronics enterprise in China measured by sales revenue in 2001 and 2002. It was the telecom-manufacturing arm under the then Ministry of Posts & Telecommunications (now MII). PTIC was established in 1980. It became a state-own enterprise (SOE) in 1998, and has transformed to a holding group in 1999. For example, Shanghai Bell one of the largest manufacturers in China, is a joint venture between PTIC and Alcatel, until Alcatel gain majority control in May 2002. Since PTIC is such a large and special manufacturing group, I do not include it in the innovation capability analysis.
3. For detailed information see the Appendix.

[60] The companies have grown much larger, which poses challenges for these companies because managing such large enterprises requires management expertise more than ever.

Table 7.2 Major Domestic Telecom-equipment Manufacturers: Innovation Capacity

Company Name 单位名称	Rank in Innovation Capacity	Rank in R&D Input	Rank in R&D Output	R&D Spending (% of Revenue) 2002	R&D Spending (% of Revenue) 2001	Profit (% of Revenue) 2002	Patent	R&D Staff (% of Employee) 2001	Employee with Bachelor's or higher degree
Posts & Telecommunications Industrial Corp. (PTIC) 中国普天信息产业集团公司	7	7	7	1.0%	3.0%	4.10%	n.a.	n.a.	n.a.
Huawei Technology Corporation 华为技术有限公司	1	1	1	18.8%	12.0%	16.4%	271	46.50%	85%
Shenzhen Zhongxin Technology Corporation 深圳市中兴通讯股份有限公司	2	2	2	10.3%	12.0%	7.3%	217	46%	72%
Datang Telecom Technology Co., Ltd. 大唐电信科技产业集团	3	3	3	12.3%	11.8%	2.9%	7	41%	93.87%
Shanghai Bell Co., Ltd. 上海贝尔有限公司	4	6	4	5.3%	n.a.	13.1%	19	n.a.	n.a.
Wuhan Telecommunication Science Institute 武汉邮电科学研究院	5	5	5	6.5%	n.a.	8.8%	4	n.a.	n.a.
Changfei Optical Fiber and Optical Cable Co., Ltd. 长飞光纤光缆有限公司	6	4	6	9.7%	57.2%	3.5%	2	n.a.	n.a.

Source:

MII. April 2002. "2002 Top 100 Chinese Electronics Companies" Website: http://www.mii.gov.cn.

MII. April 2001. "2001 Top 100 Chinese Electronics Companies" Website: http://www.mii.gov.cn.

PTIC website: www.ptic.com.cn; Shanghai Bell website: www.alcatel-sbell.com.cn; State Intellectual Property Office of P.R. China, website: www.sipo.gov.cn.

Note:

1. Even though Posts & Telecommunications Industrial Corporation (中国普天信息产业集团公司, PTIC) had the highest revenue as a telecom-equipment industry in both 2001 and 2002, it has very low innovation capacity and its profit rate is 4.10%. Because PTIC's complicate structure and history (it is composed of many different factories that were belong to MII before), I didn't listed PTIC in this table for comparison.

2. Huawei has gained 329 patents, according to Huawei'swebsite: www.huawei.com.cn as of June 27, 2003.

Strength in innovation capability and self-developed technology has determined who are the leading domestic firms in telecom-equipment industry. Table 7.1 lists major domestic firms in the telecom-equipment industry. I rank companies' leading position in the industry by their sales revenue and the evaluations by the Ministry of Information Industry (MII, 2003). I create indexes of innovation capability for each company by aggregating evaluations from professionals of the field, taking companies' R&D input and R&D output into account. The R&D input includes two indicators: firms' R&D spending as a percentage of the sales revenue and firms' R&D staff as a percentage of total employment. The R&D output includes indicators such as companies' patent numbers and participation in national S&T programs. Table 7.1 illustrates that a strong correlation exists between companies' leadership and innovation capability. For instance, Huawei, the leader in the industry, also heads in innovation capability.

Table 7.2 shows a more detailed investigation of innovation capability of these companies than Table 7.1. Domestic leading firms, such as Huawei, ZTE, and DTT, generally spend over 10% of revenue in R&D each year. For instance, Huawei spent 18.8%, ZTE spent 10.3%, and DTT spent 12.3% of their revenues in R&D in 2002. This level is comparable to the international R&D spending standard in the telecom-equipment industry, i.e., from10% to 20% (Table 7.3). Furthermore, Huawei, ZTE, and DTT all achieved an *R&D staff / total employment* ratio over 40%. Shanghai Bell, a joint venture with Alcatel and the Belgian government, though large in terms of size, has low innovation capability compared with its industrial leadership. Shanghai Bell spent only 5.3% of its revenue in R&D and the R&D staff was 31% of the total employment in 2002, significantly lower than other leading domestic firms.

Telecom-equipment MNCs in China have less R&D input than the domestic firms, measured by R&D spending as a percentage of revenue and R&D staff members as a percentage of employment in China. As I mentioned in Chapter 6, multinational corporations that have a major presence in China are also global leaders in the industry. Table 7.3 compares seven major MNCs' R&D statistics worldwide and in China. These MNCs had an average global R&D spending of 15% of sales revenue, with Cisco, Ericsson, and Nortel as leaders (21.4%, 20.1%, and 18.7%, respectively) and Siemens and Nokia as distant followers (7.8% and 9.6%, respectively). In contrast, they invest much less in R&D to their Chinese branches than their Chinese peers (R&D staff as a percentage of the total workforce is much lower).

Table 7.3 Major MNCs in the Telecom-equipment Industry, R&D World-wide and in China

Company Name	World-wide							China		
	R&D Spending (in million of dollars)	Total Revenue (in million of dollars)	R&D Spending (% of Revenue)	R&D Staff	Total Employment	R&D Staff (% of Employment)	R&D Spending per Employee (in dollar)	Employment in China	R&D Staff in China	R&D Staff (% of Employment)
Alcatel (France)	2,567	22,698	11.3	18,700	99,314	19	25,845	6500	2000	31
Cisco (U.S.)	4,777	22,293	21.4	n.a.	38,000	n.a.	125,711	300	n.a.	n.a.
Ericsson (Sweden)	4,516	22,447	20.1	n.a.	85,200	n.a.	53,002	4500	n.a.	n.a.
Lucent (U.S.)	3,520	21,294	16.5	n.a.	77,000	n.a.	45,714	3000	467	16
Motorola (U.S.)	4,358	30,004	14.5	n.a.	111,000	n.a.	39,261	13,000	1300	10
Nokia (Finland)	2,672	27,925	9.6	20,463	53,849	38	49,628	5,000	300	6
Nortel (Canada)	3,380	18,033	18.7	n.a.	53,600	n.a.	63,061	2600	110	4
Siemens (Germany)	6,028	77,329	7.8	53,000	484,000	11	12,455	21,000	n.a.	n.a.

Source: Company's global data is adapted from MIT Technology Review (2003 Jan.).

Note:

1. All data are 2002 data, unless specified. The global data of the companies are for fiscal years ending between June 1, 2001 and May 31, 2002
2. Alcatel's R&D spending was 13.5% of revenue (euro 2.2 billion) in 2002 and 11.3% in 2001.
3. Cisco's employment in China was estimated at 300 in 2002.
4. Ericsson's employee was 61,000 as of June 22, 2003 (Ericsson website, www.ericsson.com). Because the company has continued suffering from loss since 2001, Ericsson decided to cut its workforce to below 60,000 by the end of 2003. (Chinanex.com)
5. Number for Lucent Technology R&D staff include Qingdao Lucent (239), Lucent Optical Network (200), and Bell Lab Research China (28).
6. Lucent Technology's total employee was 40,000 as of Dec. 31, 2002 (Lucent website: www.lucent.com). It was significantly different from the data recorded by *MIT Technology Review*, because the company had a huge layoff in 2002.
7. Nokia claimed that it has over 38% of personnel works in R&D. (Nokia's website: www.nokia.com, About Nokia-Research & Venturing - Career in Research as of June 2003).
8. Siemens had less than 3,752 R&D staff in other countires outside of U.S., Europe, and India in 2002. Nearly 50% of its total R&D expenditure was in the information and communications. (Siemens website: www.siemens.com).
9. Average R&D spending as a percentage of revenue is 15% for all seven companies.

I have reviewed ZTE's stages of development and GDT's early development of switch technology in the previous chapter. Here, I would like to offer three examples showing how innovation capability drove the domestic telecom-equipment companies to catch up to the MNCs. The first example is about Huawei's vision on innovation capability: it shows how Ren Zhenfei, the founder of Huawei, insisted on building innovation capability from the beginning and thus gave Huawei an competitive edge over others at later stages. The second example talks about how Huawei used its local advantage and innovation capability to advance in the global system for mobile communications (GSM) and third generation mobile communications systems (3G) in later stages. The last example demonstrates the challenges that DTT has faced in developing China's own 3G standard, TD-SCDMA, and why government support has been crucial.

7.1.4 Ren Zhenfei and Innovation capability of Huawei

Huawei has always invested a heavy percentage of revenue in R&D, higher than any other domestic firm or any MNC in China in the telecom-equipment industry (Table 7.2). Huawei's high internal R&D investment is a direct result of its founder's determination to improve the company's innovation capability. Originally an army officer, Ren himself is definitely known to have personal charisma, reflected in his vision for his company, even though no media have been able to interview him since he started the company. As Huawei's founder and sole leader, Ren Zhenfei believed that the country's "exchange market with technology" policy would lead to the loss of the domestic market to the MNCs. Not only were the Chinese unable to obtain foreign technologies, but domestic companies had also been put at a disadvantage. (Xiao, 2002)

Thus, Ren set up goals for Huawei at the very beginning "to develop the national industry, not to set up joint ventures with foreign companies, to follow closely global cutting-edge technology, to insist on self-development, to gain domestic market share, and to explore the international market and compete against international rivals." Through these goals, Ren aimed to build Huawei into a world-class and technologically advanced telecom equipment manufacturer from the very beginning. He ignored the lucrative stock and real estate businesses in the early 1990s and "was stubborn enough to put all his eggs in one basket"–the heavy investment in R&D has ranged from RMB 80 million to over 100 million per year in recent years. Even in the earlier years of Huawei, the company had a high R&D/employee ratio, namely, 500 R&D staff and only 200 production staff.

Ren Zhenfei and his company are well respected by many Chinese because Huawei, a purely Chinese company, has achieved great success in the telecom equipment field, surpassing not only domestic peers but also many joint ventures set up by MNCs.

It is worth noting that Ren Zhenfei has been appreciative of government policies that have played a vital role in Huawei's development. Ren has commented (Xiao, 2002, p. 127) the following

> *...Huawei was somewhat naïve to choose telecom equipment as its business domain in the beginning. Huawei was not prepared for such an intensified competition when the company was just established. The rivals were internationally renowned companies with assets valued at tens of billions of dollars. If there had been no government policy to protect (nationally owned companies), Huawei would no longer exist...*

7.1.5 Huawei in GSM and 3G

Domestic producers, including Huawei, entered into the global system for mobile communications (GSM) area much later than the MNCs. However, Huawei achieved unexpected success in the value-added part of GSM, such as integrated gateways, mobile intelligent networks, General Packet Radio Service (GPRS), and short message centers. For instance, in the field of mobile data communication, such as short messaging, Huawei's equipment has more than 50% of the domestic market. The key to Huawei's success lies in its fast and precise reaction to customer requests as well as its self-developed technology, as shown in the following examples. For instance, in 1999, China Mobile proposed a plan of prepaid fees for cell phones. MNCs were unable to provide the system or reacted reluctantly. Based on its accumulated R&D experience in GSM, Huawei developed the product within a very short time. The new product-mobile intelligent network-can be conveniently overlaid with existing networks. Within several months, Huawei's mobile intelligent network equipment had over 30 million users and monopolized China's domestic market for a while. Even in 2002, it had around 80-90% of domestic market. Later, the product became popular in Southeast Asian countries as well.[61]

A follower in the area of GSM, Huawei has upgraded itself to keep pace with the global development of the third generation wireless communications system (3G). Huawei introduced "Code Division Multiple Access (CDMA) 2000 1XEV-DO" with speeds up to 2.4 Megabits Per Second (Mbps) in 2002. During the same year, it had a series of achievements with Wideband Code Division Multiple Access (WCDMA). (*China Electronics News*, January 17, 2003)

- At the beginning of the year, it passed the MTnet test.
- In June 2002, it made a commercial terminal call based on the R99 protocol.
- In September 2002, in its Shanghai WCDMA external experimental network, Huawei successfully made the first world WCDMA intelligent call based on CALMEL III.
- In October 2002, it established China's first 3G Open Lab with NEC and introduced the smallest WCDMA large-scale base station to-date.
- In December 2002, at International Telecommunications Union (ITU), Huawei introduced WCDMA core network equipment based on soft switches.

Huawei's achievements came from its early start and heavy investment in 3G. As early as the end of 1995, Huawei started R&D in CDMA. In 1998 Huawei started to develop WCDMA products. From 1998 to May 2002 Huawei invested RMB 3 billion in WCDMA and its R&D staff has totaled 3,500, including people from its U.S., Swedish, and domestic R&D centers. It has operated over 20 WCDMA experimental networks worldwide. (*China Electronics News*, January 17, 2003)

[61] *China Electronic News* (Chinese newspaper), January 17, 2003.

7.1.6 DTT and TD-SCDMA

DTT and Siemens jointly developed the Chinese 3G standard, Time Division - Synchronous Code Division Multiple Access (TD-SCDMA), which was accepted by the Institute of Electrical and Electronic Engineers (IEEE) in May 2000 as one of the third-generation mobile communications standards. TD-SCDMA used new technologies that represent future directions for wireless communications, such as synchronized CDMA, intelligent antennas, software-based wireless, and high-speed data transmission. Intelligent antennas and software-based wireless are unique to TD-SCDMA. In addition, TD-SCDMA is claimed to have high spectrum utilization because TD-SCDMA uses the Time Division Duplex (TDD) model and only needs a single channel for bi-directional communications.[62] For instance, TD-SCDMA needs only 1.6MHz of spectrum resources, while Wideband Code Division Multiple Access (WCDMA) requires 10MHz of bandwidth (5MHz in each direction).

The current (2002) allocation of international 3G frequencies is actually to TD-SCDMA's advantage. In Europe, 3G frequencies have been auctioned for both Frequency Division Duplex (FDD) and TDD. In Asia Pacific, except for Japan and Korea which only auctioned FDD licenses, Singapore, Malaysia, and Taiwan auctioned both FDD and TDD, while Australia auctioned TDD and FDD to different service providers. The United States has cleared 31 MHz of frequency resources to be used for TDD in 2002, but even the largest continuous frequency segment available has only 4MHz. Since WCDMA needs 10MHz and CDMA 2000 needs 8MHz for both directions, it seems only TD-SCDMA can use the current frequency resources for 3G in the United States.[63]

Compared to other standards, TD-SCDMA has much less support and R&D investment (Table 7.4). For instance, WCDMA has 27 companies as main supporters, which includes NTT DoCoMo of Japan, Ericsson and Nokia in Europe. CDMA 2000 has most support from North America and Korea, such as Qualcomm, Nortel Networks, Motorola, and Samsung. Distinguished domestic companies, such as Huawei, ZTE, and Jingpeng, are also supporters of WCDMA and CDMA 2000. WCDMA and CDMA 2000 have invested $40 billion and $10 billion in their development, while TD-SCDMA has only invested less than $1 billion. Further, worldwide, there are over 50,000 and 10,000 R&D staff work on WCDMA and CDMA 2000, while less than 3,000 for TD-SCDMA. (Table 7.4)

For a while, it seemed the Chinese government had no special interest in this domestically produced standard and would put the three standards in a quite equal position; whereas the two incumbent operators, China Mobile and Unicom, seemed to favor the other two standards (GSM-GPRS-WCDMA and CDMA-CDMA2000 1X-CDMA2000 EV) over TD-SCDMA. DTT, however, a small company by international

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[62] Communication World (Chinese Magazine, *Tong Xin Shi Jie). August 18, 2002. p. 36.*

[63] *Communication World* (Chinese magazine), July 28, 2002, p 10-11.

standards with only $0.2 billion annual sales revenue, started a no-return journey by focusing almost all its attention on TD-SCDMA.

It was not until October 23, 2002, that DTT finally obtained signals of support from the government. The government was planning for the future expansion of TD-SCDMA, as indicated by an announcement made on that day. The Ministry of Information Industry (MII) announced[64] that it allocated 155 MHz [65] of TDD resource to TD-SCDMA and a total of 120 MHz symmetrical FDD resource to WCDMA and CDMA 2000 (60 MHz each). TD-SCDMA obtained 155 MHz asymmetric TDD ranges: 1880-1920MHz, 2010-2025MH, and 2300-2400MHz. In addition to the 55 MHz of the core frequency range assigned by IEEE, TD-SCDMA obtained the extended 100 MHz, 2300-2400 MHz, which used to belong to the military. This frequency division demonstrates the support of the Chinese government for TD-SCDMA, the Chinese 3G standard. Just one week later, on October 30, 2002, responding to this announcement, seven telecom-equipment manufacturers--Southern Hitech, Huali Group, Huawei, Legend, ZTE, China Electronics Group, and China PuTian Group--joined DTT to form the *TD-SCDMA Industrial Alliance*, with the support of three government agencies - the State Planning Commission, MII, and the National Science and Technology Department. (*Renmin Youdian*, October 31, 2002).

Table 7.4 Three Standards of 3G: Support and their R&D

Standard	Supporting Companies	Government and International Organization	R&D staff (globally)	Investment (per year)
WCDMA	27 companies of WCDMA Alliance, including NTT DoCoMo, Nokia, Ericsson, and Chinese companies such as Huawei, ZTE	15 countries in EU, Japan and countries with GSM standards, allocated frequency	50,000	$40 billion
CDMA 2000	Over a dozen companies in CDMA Development Group, including Qualcomm, Motorola, Samsung, Nortel, and Chinese companies such as ZTE, Jinpeng	U.S., South Korea and countries with CDMA standard, allocated frequency	10,000	$10 billion
TD-SCDMA	Datang, Siemens	China, finished frequency allocation recently	Less than 3,000	less than $1 billion

Source: Communication World (Chinese magazine), November 28, 2002, p. 14-17.

[64] It is entitled as "Announcement about the Third Generation Public Mobile Communication System Frequency Planning."

[65] I note that many countries have assigned the core frequency range to either WCDMA or CDMA 2000. If TD-SCDMA only has part of the core frequency, it will be difficult to expand globally even if it is successful in China, thus unable to roam internationally. However, if the commercialization of the new expanded frequency range is successful, it will potentially affect other neighboring countries since the 2300-2400 MHz frequency range is free for most of them.

Having China's own 3G standard makes it possible for Chinese manufacturers not only to pay no patent fee for TD-SCDMA, but also to be offered a much lower fee using other standards. For first- and second-generation mobile communications, China paid billions of dollars in patent fees and other intellectual property fees related to the mobile standards. For instance, for every CDMA cell phone produced by Chinese manufacturers and every customer initialized by China Mobile, China needed to pay a $2 patent fee to Qualcomm. After the development of TD-SCDMA, nine companies from the WCDMA alliance announced that it would cap the cumulative royalty rate to patent holders for its Chinese partners to be less than 5%, much lower than for other countries. (*Economic Observation*, Januaray 6, 2003)

The cumulative royalty cap--which would apply both to mass market phones and network equipment--would limit the total patent-based royalty on any given item to 5% of the sale price, regardless of how many patents are involved (and who holds them).[66]

However, there are still great challenges facing DTT and the industrial alliance before commercialization of TD-SCDMA products. These challenges come from limited capital resources, tight time constraints, and insufficient human resources.[67] Currently, there are three major funding sources for TD-SCDMA: (1) government funding for the 3G development group (the government had invested RMB 70 million by November 2002); (2) loans from banks; and (3) DTT's funding from various sources. In 2003, the company plans to get RMB 1 billion capital for investment. In addition to the existing channels for capital, DTT plans to license some of its technologies to other manufacturers.

Compared to WCDMA and CDMA, which have over a decade of experience, TD-SCDMA has less than a three-year history. Though its speed of development is much faster than the other two, the commercialization will not be realized until 2004 or 2005. Furthermore, acquiring more technical expertise to work for TD-SCDMA commercialization is another task with which DTT has to deal. Because TD-SCDMA uses the same core network, no development would need to be done for the core network part. DTT has developed the access equipment, and it plans to introduce it (including base station and its controller) to the market in the second half of 2003. They will develop the chipset at the same time. DTT plans to have TD-SCDMA handsets appear in the market in the first half of 2004.[68]

7.2 Channels for Acquiring Innovation Capability

I have evaluated Huawei, ZTE, and DTT as leaders in innovation capability. How have these domestic firms achieved this status? Here I examine two major channels: in-house

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[66] *Mobile Business Daily*, May 13, 2002. "Nokia Proposes Patent Fee Cap for 3G Systems". http://www.mbusinessdaily.com/story/INDUSTRY/MBZ20020513S0002 as of Jan 31 2003. In May 2002, Nokia proposed to promote the spread of Wideband Code Division Multiple Access (WCDMA) for 3G nets by capping the royalty rate paid to patent holders at 5%.

[67] Interview #19.

[68] *Communication World* (Chinese Magazine), November 28, 2002.

R&D development and external alliance. I found that in-house R&D development, supplemented with external alliance, is major revenue for leading domestic firms to build their innovation capability.

7.2.1 Internal Development

In-house R&D has turned out to be the most important factor for domestic firms to improve their innovation capability. Domestic leading firms have invested a large amount of capital and devoted a large percentage of their workforces in R&D activities, much more than most of the other electronics companies in China and multinational corporations in the telecom-equipment industry in China. As shown in the previous section (7.1) and Table 7.2, domestic firms invested heavily in R&D. Leaders in innovation capability, Huawei, ZTE, and DTT, invested 18.8%, 10.3%, and 12.3% of their revenues in R&D in 2002, listed as the top three by MII in terms of "R&D spending as percentage of revenue" of "China's 100 largest electronics companies" in 2002. Moreover, this level is comparable to leading MNCs' levels of R&D spending in the telecom-equipment industry as shown by Table 7.3, whose average R&D spending was 15% of revenue in 2002. Taking Huawei, the leader in innovation capability and the telecom-equipment industry, as an example, it was listed as the 7th largest electronics company in China by revenue, but its R&D expenditure topped all other companies listed in "China's 100 largest electronics companies" in 2002.[69]

Furthermore, the occupation structure of their employees illustrates that leading domestic telecom-equipment companies had 30%-40% of their workforce devoted to R&D in 2002 (Table 7.5 and Figure 7.5), significantly higher than most MNCs' operations in China (Table 7.3). For instance, Lucent, Motorola, Nokia, and Nortel each have 16%, 10%, 6%, and 4%, respectively, of employees working in R&D.

Table 7.5 Occupation Structure of Major Telecom Equipment Manufacturers, 2002

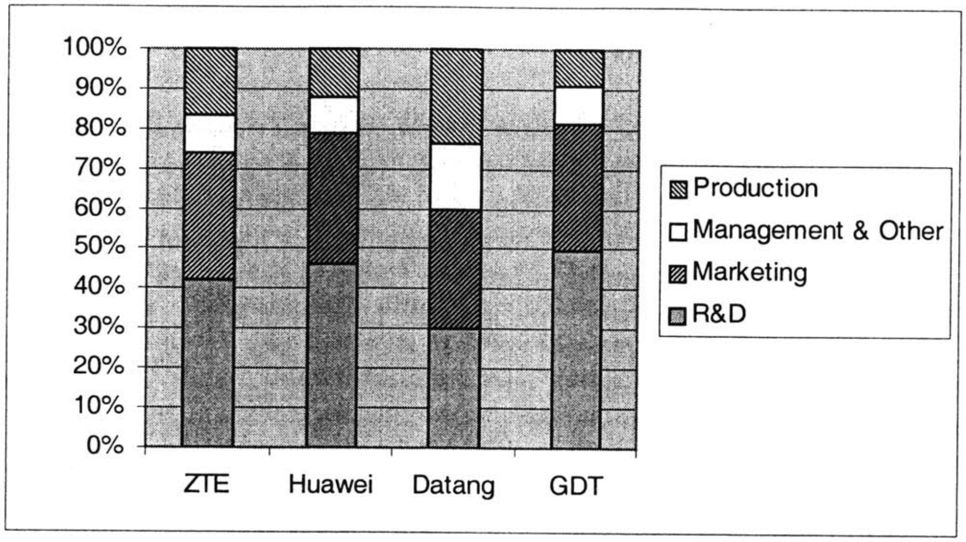
Year	ZTE	Huawei	Datang	GDT
Total	12916	18000	4183	2500
R&D	42%	46%	30%	54%
Marketing	32%	33%	30%	35%
Management & Other	10%	9%	17%	10%
Production	17%	12%	24%	10%
Average Age	28	n.a.	n.a.	n.a.
Ph.D.	2%	n.a.	1%	n.a.
Master and Above	31%	n.a.	22%	n.a.
Bachelor and Above	75%	85%	73%	85%

Source:
ZTE Annual Report 2002; DDT Annual Report 2002; Huawei's website; GDT's website

Note:
GDT's data is for Year 2001.

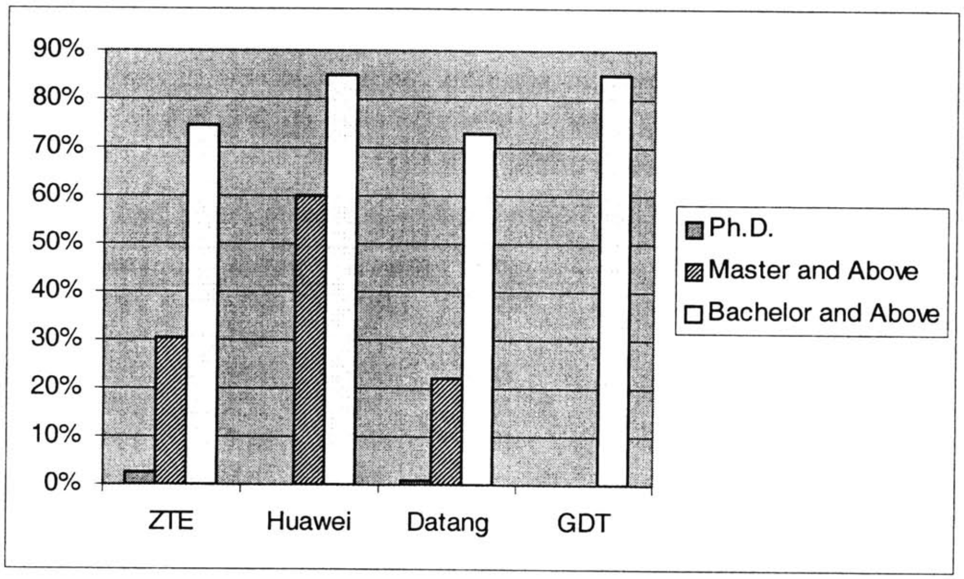
[69] Moreover, Huawei's *R&D/Revenue* ratio is the highest among all four telecom companies.

Figure 7.5 Occupation Structure of Major Domestic Telecom Equipment Manufacturers, 2002



Source: Table 7.5.

Figure 7.6 Education Level of the Workforce, Major Domestic Telecom Equipment Manufacturers, 2002



Source: Table 7.5,
Note: the data of "Ph.D." and "Master and Above" are unavailable for GDT's workforce and the data of "Ph.D" is unavailable for Huawei's workforce.

An examination of the workforce's education level indicates that these companies probably have the most educated workforce in China (Figure 7.6). Each of the four companies has over 70% to 80% workforce with bachelors degrees and 20% to 60% with

Master's degrees or higher. For instance, among Huawei's 22,000 employees, more than 85% have bachelors or higher degrees, and about 60% hold a master's or PhD degree.

According to one interviewee, MNCs have two disadvantages in R&D in China, which implies that domestic firms have two advantages.[70] First, unlike major domestic companies, such as ZTE, Huawei, DTT, and GDT, foreign firms (joint ventures or wholly owned subsidiaries) do not have high-level R&D staff in China, but instead they are staffed mostly with marketing and local R&D people (for simple customization). This view is in line with the view of Amsden et al (2000) that higher-level R&D, i.e., exploratory and advanced development, should be located close to production or markets. The reason could be that MNCs worry about leaking of their tangible knowledge, especially in a country that has issues with enforcement of intellectual property. Second, while foreign firms are suffering separation of their marketing people from the core R&D staff in the home country, domestic firms have their marketing people closely connected with their R&D staff. Thus, once domestic firms grasp the needs of service providers through marketing people (and sometimes even through the R&D people themselves), their R&D departments can develop solutions and provide the desired products and services in a timely fashion.

Corresponding with a large investment in R&D are the R&D facilities of the companies. Huawei and ZTE both have over ten R&D facilities within China and abroad. DTT has two R&D centers in Beijing and Shanghai, while GDT has one R&D center in Beijing. Huawei has six R&D centers in Beijing, Shanghai, Nanjing, Hangzhou, Xi'an, and Chendu, as well as the Huawei Technology Center in its Shenzhen headquarters. Furthermore, Huawei has five overseas R&D offices: in Dallas and Silicon Valley in the United States, and in Sweden, India,[71] and Russia. These overseas offices connect the company closely with the latest developments in microelectronics and telecom technology. (Huawei, ZTE, DTT, and GDT's websites)

Since 1986, ZTE has built 12 R&D facilities within and outside China (Table 7.6). Among all these R&D facilities, ZTE regards its Nanjing R&D Institute as the most distinguished.[72] It developed the ZXJ large switching system, the first brand product of ZTE, and has undertaken R&D of key projects of the national "863 Plan." These R&D centers and joint laboratories have enabled ZTE to utilize the skilled labor pool of the locations and continue to learn from its technologically advanced partners.

[70] Interviewee #13.
[71] The Huawei India Software R&D Institute became the first Chinese company to obtain the certification from the CMM 4 International.
[72] Interviewee #8 and #13.

Table 7.6 ZTE R&D Facilities

Name	Date	Location	Main Activities
Nanjing R&D Institute	September 1993	Nanjing	developed ZXJ10 large switching system, data network, network value-added service products and network core equipment; undertaking R&D of key projects of National "863" Plan; current five series of products: data network, wired network, intelligent network, network billing and Soft Switch.
Shanghai R&D Institute	August 1994	Shanghai	covers an area of almost 5000 square meters; currently engaged in research and development of router of ISDN, access server of IP, POTS based on ISDN network, ATM, HFC and CATV.
Shanghai R&D Institute II	July 1997	Shanghai	engaged in research and development of mobile communication system.GSM 900/1800 mobile communication system ZXG10 has been widely applied at home and abroad; the first Chinese mobile communication network planning & optimization software "C PlanMaster has been successfully applied to network construction; has developed GSM dual-band series handsets (ZTE189, ZTE289 and ZTE389), CDMA UIM handset (ZTE802) and PHS handset. 3G product of WCDMA (ZXW10) is being researched now.
Shenzhen R&D Institute	1986	Shenzhen	mainly engaged in research and development of SDH transmission series, videoconferencing system, telecom power supply, centralized monitoring system, automation of electric substation and production testing equipment.
Beijing R&D Institute	October 1998	Beijing	engaged in research and development of WDM and new generation of optical transmission system.
Xi'an R&D Institute	April 2000	Xi'an	engaged in research and development of wireless communication technology
Chongqing R&D Institute	September 2000	Chongqing	engaged in research and development of intelligent services and network management products.
ZTE Post Doctoral Station	November 1998	Shenzhen	has presented 10 R&D projects and come to over 20 cooperation agreements with key universities and domestic research institutes.
Shenzhen TI-ZTE DSP Joint Lab	September 1998	Shenzhen	engaged in tracing and introducing the latest DSP technology and training R&D presonnel.
National Technology Center	April 1999	n.a.	engaged in research following, project selection and project management
R&D Center of Mobile Communication Engineering Technology	May 1999	n.a.	the center is strongly supported by Shenzhen municipal government in financing and policies.
Holding Company in Korea	July 1999	S. Korea	ZTE Korea FutureTel Co., Ltd. is engaged in the research of CDMA handset.

Source: the author, summarized from ZTE's website: www.zte.com.cn as of 10/22/2002.

7.2.2 External Alliance

External alliance will facilitate the building of innovation capability, however, that is only complementary to internal development. All four companies have joint R&D facilities with domestic and foreign companies and institutes. Most foreign cooperation started in the filtration stage and globalization stage, especially globalization stage.

Among them, Huawei has the most cooperation with international MNCs. Huawei has actively undertaken joint R&D laboratories with foreign companies, such as Texas Instruments (TI), Motorola, International Business Machines Corporation (IBM), Intel, Ageare, ALTERA, SUN, Microsoft, and NEC, focusing on various telecom technologies. In addition to its own R&D facilities, ZTE has joint laboratories with Beijing University of Posts and Telecommunications (BUPT), Motorola, and Xi'an Electronic Engineering Institute in China. Similarly, DTT has joint R&D activities with domestic and international partners, such as MII Beijing Design Institute, Electronics S&T University, TI, BUPT, and JAS South Korea, in addition to its two R&D centers in Beijing and Shanghai. GDT also has wide cooperation with different institutes and companies domestically and abroad, such as China HP, C&S Technology and Space from South Korea, etc. Details of the four companies' joint efforts can be found in Appendix 7.4.

In my view, Huawei, as well as ZTE and DTT, have utilized their cooperation with foreign MNCs who are leaders in late technologies as a complementary approach to developing its innovation capabilities in addition to its internal development. As Hu, Jefferson, and Qian (2003) pointed out, the contribution of technology transfer was found, through their analysis of Chinese large and medium size enterprises, to be conditional on its interaction with in-house R&D. Chinese firms generally do not consider foreign cooperation as an effective tool for technological improvement, but may be used as a complementary tool. For instance, one of the senior R&D managers at Huawei's Beijing R&D center pointed out (quoted in Smith-Gillespie, 2001, p. 82),

> *"Huawei does not view R&D cooperation with foreign companies as an effective mechanism to gain technological competitiveness," since "there is no reason for foreign firms to transfer their most advanced core technologies to a Chinese partner over whom they do not have management control."*

7.3 Factors Affecting Improving Innovation Capability

The case studies have confirmed that government involvement in accumulating knowledge-based assets is crucial for improvement of the innovation capabilities of domestic firms in the telecom-equipment industry. It has helped to build a positive feedback system that rewards the companies' efforts in building innovation capability and developing proprietary technologies.

The positive feedback system for innovation capability is composed of:

- (1) network clustering of R&D functions, which makes innovation easier as firms communicate and exchange ideas--location matters
- (2) disintegration of the global value chain, which acts as a catalyst for innovation in specific areas
- (3) sub-sector linkage, which rewards innovation efforts by faster diversification into other sub-sectors

7.3.1 The Government

The Chinese government has used the national S&T programs to encourage R&D activities by domestic companies. These programs select companies and research institutes for the projects according to their strengths in the corresponding fields, and provide them with funding for cutting-edge research. For instance, ZTE has been involved in 19 projects of the "863 Plan." Huawei, DTT, and GDT have gained several research projects from the "863 Plan" as well.

Sometimes the government also directly provided funding for technology improvement of certain key products to the firms studied here. For instance, the Construction Bank loaned RMB 0.7 billion to Great Dragon in November 1996 for technology improvement of a specialized circuit board production line and a development center. The effectiveness of this kind of aid is still in doubt for firms' long-term innovation capability.

There are two distinguished national S&T development programs: the Torch Program and "863 Plan." Initiated in 1988, the Torch program[73] aims to make technological development more market-oriented and facilitate commercialization of technology. Sponsored by the State Science and Technology Commission, the main tasks of the Torch Program include:

1. Develop a favorable environment for high tech industry.
2. Set up high-tech zones and high-tech business start-up service centers.
3. Execute Torch projects in seven high-tech industries mainly geared towards the market need.
4. Facilitate international cooperation of Chinese firms in high-tech industries.
5. Train high-quality human capital.

The National High-tech Development Plan or "863 Plan" aims to foster high-quality fundamental research in China. The history of the plan can be traced to March 3, 1986, when four respected scientists, Wang Dayan, Wang NieChang, Yang Jiaxi, and Chen Fangyong, wrote a letter to the State Council, advising on how to catch up with the developed countries and develop China's own technology in high-tech industries. This letter drew great attention from Deng Xiaoping, who later requested the State Council react quickly. In the following half year, the State Council organized about 200 scientists and researched strategies for developing high technology, which finally led to the National High-tech Development Plan Outline ("863" Plan Outline), approved by the State Council. Considering the prevailing situation in China, a developing country that has limited resources for developing all kinds of high technologies, the 863 Plan suggested that China should focus on 7 areas and 15 topics. The 7 areas are: biotechnology, astro-technology, information technology, laser technology, automation, and energy technology. The "863 Plan" will select experienced scientists and researchers for these projects. As a government organized national science and

[73] Souce: http://www.chinatorch.gov.cn/

technology program, the "863 Plan" especially encourages participation from domestic enterprises.[74]

Projects in "863 Plan", most of which are basic research[75] (or even pure science), are impractical to conduct at the individual company level because of their high cost/benefit ratio and long (or infinite) time horizon (Amsden, Goto, and Tschang, 2000). Through participating in national S&T projects, companies can become familiar with the knowledge breakthroughs in the field, thus facilitating higher-level R&D at the company level, such as applied research, exploratory development, and advanced development.[76] The gathering of R&D staff from different companies and universities has helped to form virtual networks among participants, which has stimulated innovation and encouraged idea exchanges, and to some extent has brought effects similar to those of physical network clusters.

For instance, even though ZTE claims that it has received little financial aid directly from the government for its R&D, it has emphasized that the government has helped ZTE and other domestic firms to grow by providing a good industrial environment, especially through encouragement of companies' R&D activities by awarding national S&T projects to those companies. The following illustrates ZTE's involvement in national S&T technology programs chronologically. (ZTE website, 2002)

- 1996: ZTE was chosen by the Ministry of Science and Technology (MST) as one of the high-tech enterprises to spearhead the "Torch program."
- 1998: MST awarded ZTE for its excellent performance record in the Torch Program during 1996 and 1997.
- 1998: The State Economic and Trade Commission (SETC) designated ZTE as one of the national "Centers of Technology Development".
- 1999: ZTE took part in the "863 Plan" for the development of various communications technologies in 3G, integrated access over optical fiber, and optical transmission systems.
- 2000: ZTE took part in another three technologies' development in "863 Plan": the base band processing for 3G base station systems, the 3G core network, and 3G systems integration.
- By the end of 2002, ZTE took 19 projects in "863 Plan", covering 3G, high-speed data communications, integrated access systems, and optical transmissions. The seven finished projects covers topic in WCDMA, core router, OADM and integrated access systems

[74] Source: www.863.org. 2003. "History of 863".
[75] Basic research aims to search for new knowledge for radically new marketable products and pure science searches for intrinsic knowledge.
[76] For a detailed description of R&D categorization, please see the paper "New Classification of R&D for International Comparisons (With a Singapore Case Study)" by Amsden, Goto and Tschang (2000).

Table 7.7 DTT's R&D projects that are funded by the government, 2001

Finishing Date	Category	Name	Partners
9/1/1999	"863 Plan" Project	WCDMA	n.a.
2/21/2001	"863 Plan" Project	Integrated Access System	China S&T University, BUPT
3/26/2001	"863 Plan" Project	China High Speed Information Network Core Router	National Defense S&T University
7/6/2001	"863 Plan" Project	Optical Cross Connection Equipment (OXC)	Tshinghua University
7/6/2001	"863 Plan" Project	OADM	Tshinghua University
2/21/2001	"863 Plan" Project	Full-Service Network Access System	Electronic S&T U., MII 34 Research Institute
n.a.	National Electronics Development Fund	n.a.	
8/1/01	National Debt Supported Project	DWDM	
11/7/1999	National Debt Supported Project	Data Mobile Communication GSM cell phone SIM chip	n.a.

Source: summarized from DTT's website

Note: The wireless communication branches of Datang started WCDMA project on September 1st, 1999. The project DWDM was approved by MII to be supported by tapping into China's national debt on August 1st, 2001.

DTT has participated actively in R&D projects funded by the government, especially because, as noted above, DTT started as the first public company formed by a state-owned research institute. Its deep historical connection with the government, but most importantly its strength in innovation capability, gave it a great advantage in winning government funded projects in the telecommunications area. For instance, in 2001 alone, DTT had six projects that were funded by the "863 Plan"; one project that was funded by the National Electronics Development Fund; and two projects that were funded as the National Debt Supported Projects. These projects had a wide range, covering almost every aspect of telecom-equipment, from access systems and transmission systems to data communications and mobile communications (see Table 7.7).

7.3.2 Network Clustering

Does geographical clustering contribute to the development of innovation capability of domestic firms in China's telecom equipment industries? If so, how has it contributed? I answered these two questions in the following discussion.

The network cluster theory attributes firms' technological capabilities to informal linkages through geographical proximity. The concentration of R&D functions of the studied firms by location has confirmed that space does matter. A few locations such as Beijing and Shanghai have become the best sites for R&D for domestic firms as well as multinational corporations when they enter the filtration stage. For instance, Beijing hosts the R&D centers of Huawei, ZTE, DTT, and GDT, with most of them clustered in the Zhong Guan Cun area (which is called "China's Silicon Valley") along with numerous other IT companies. That the firms located R&D functions in (and in some cases even moved their R&D headquarters to) these locations indicates that the firms place a high value on network clusters that provide proximity to elements they need to build technological capabilities, formally or informally. The results correspond to those of Jefferson and Zhang (2002), who found that there exists a strong association between overall R&D productivities of cities and their composite measure of citywide R&D capabilities in eleven East Asian cities, including five cities in China.

In addition to domestic network clusters, domestic firms have also taken advantage of international network clusters to improve their technological capabilities, as shown by the R&D locations of some firms. For instance, Huawei has overseas R&D centers in Silicon Valley, Dallas, Bangalore (India), and Sweden, to take advantage of network clusters that involve the most advanced technologies in data communications, signal processing, software development, and wireless communications. Similarly, ZTE has its CDMA R&D institute located in South Korea, whose R&D and usage of third-generation CDMA cell phones is far ahead of the rest of the world.

7.3.3 Disintegration of the Global Value Chain

Configuration technologies refer to those technologies matching the complexity of systems technologies, but that are designed to allow great flexibility in development and application (Shen, 1999). Williams (1997) pointed out that information and communications technologies (ICT) in particular are increasingly taking the form of configurational technologies because both modular design and the use of open standards can facilitate the substitution of internal components.

Bjorkman et al (2001) explaines that the change of telecom operators' business range is the driving force for the industry to move from "monolithic" to "component-based network elements." With the convergence of communications services involving voice and data, service providers now provide a diverse range rather than a single kind of service. This affects the telecom-equipment manufacturers who choose to specialize in one area rather than providing equipment for a diverse range of services. Service operators thus need to deal with several vendors offering equipment for different services. Because of these changes, a "component-based system architecture" model thus has replaced the original monolithic one, in which manufacturers provided telecom operators with monolithic equipment. As Bjorkman et al. stated, several forums have been set up to facilitate the component-based network architecture, such as Multiservice Switching Forum (MSF), Opensig and OpenArch, IEEE P1520, The International Softswitch Consortium (ISC), Parlay, and IETF.

Corresponding to Shen and Bjorkaman's analysis, Smith-Gillespie (2001) reviewed the development of global telecom markets, and concluded that the industry is heading toward the separation of component manufacturing from system provision, and component suppliers possess much of the industry's knowledge and technology.

The telecom-equipment industry's trend towards configuration technologies has made innovation in specific areas possible and faster for domestic producers. It also contributed to cooperation between the major Chinese telecom system providers and international components suppliers. The major Chinese telecom companies have been able to focus on building their key technologies and acquiring other parts from suppliers.

Smith-Gillispie (2001) documented the technology supplier relationships between Huawei and other MNCs, such as IBM Microelectronics, Motorola Computer Group, Texas Instruments, VocalTech, Intel, IBM, and SDL, in the area of data communications. ZTE, similarly, has TI, Motorola, and Vertel Software that provide certain platforms for them to develop advanced applications. The R&D manager from ZTE explained that this strategy, which allows the company to concentrate on developing its own "core technologies" and purchase the rest from suppliers, can satisfy customers' "comprehensive solutions" requests. (Smith-Gillispie, 2001)

7.3.4 Sub-sector Linkage

Sub-sector linkage rewards innovation efforts through faster diversification into other sub-sectors. The accumulation of innovation capability in one sub-sector has been used to develop products in other sub-sectors of the industry, especially when the industry has new sub-sectors emerging continuously. This "immature" nature of the industry has provided firms in the developing world with many chances to catch up.

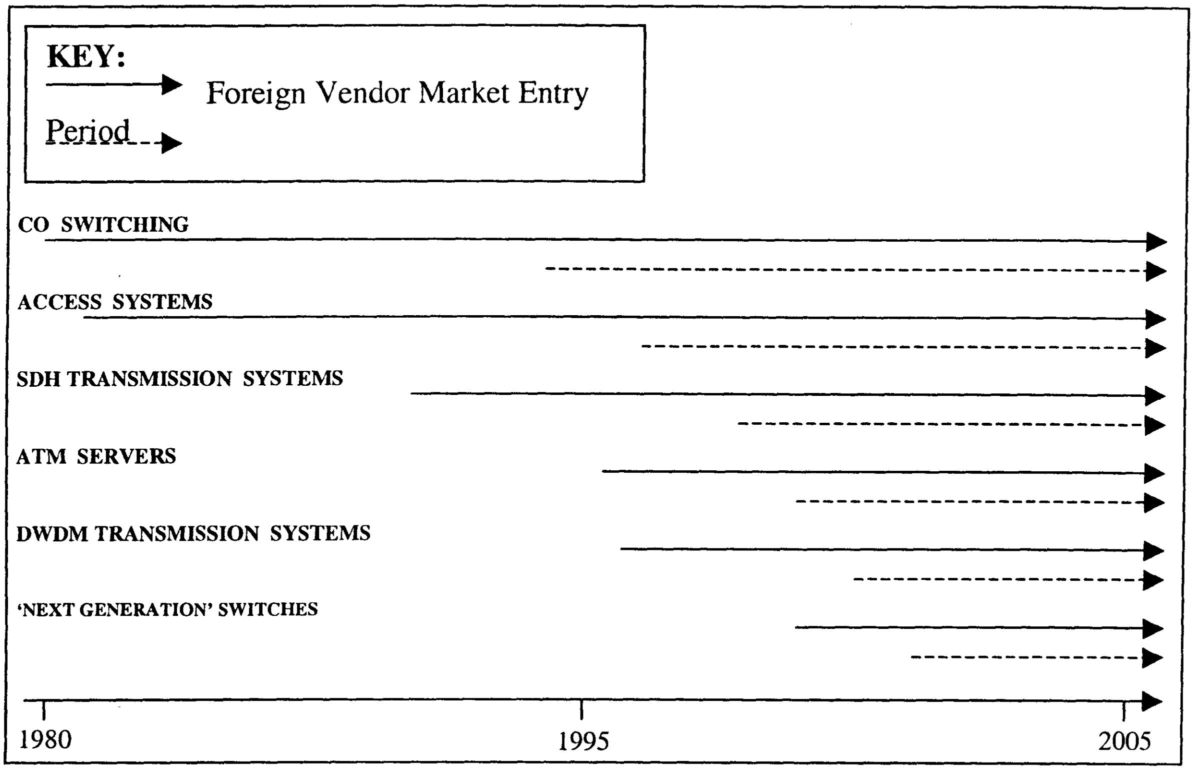
The shortened time needed by domestic companies to catch up with foreign MNCs' technology clearly shows that there exists strong sub-sector linkage in China's telecom equipment industry. Pyramid Research (1999) observed a trend that the technology development cycle for the Chinese manufacturers has become shorter and shorter, as illustrated by Figure 7.7. As indicated by this research, China required just ten years to move from importing to successfully developing its own ten-thousand-line switch equipment. Domestic producers entered the area of optical transmission in the early and middle 1990s. However, by 1998 domestic manufacturers produced fifty percent of new optical transmission systems. Currently, ATM broadband switching equipment is only behind the leading MNCs by one or two years. Similarly, in the area of access systems, domestic producers now supply 50% of the market need. In the area of mobile switching base stations, even starting late and still far behind, China has again made impressive progress since 1998. For example, Chinese firms progressed from importation to successful development of their own GSM Systems in only four years.[77] The three companies studied here have quickly diversified their R&D and products from switches to other sub-sectors. The accumulated knowledge and expertise in switching R&D has

[77] In other sub-sectors, such as mobile communication and data communication, foreign products have retained most of the market share.

provided them with bases from which to explore other sub-sectors. The effect is to accelerate the process of catching up.

Figure 7.7 Indigenous Technology Development Cycle

Source: Pyramid Research (1999a), adapted from Smith-Gillspie(2001)



It is now evident that developing and using sub-sector linkages has become necessary for firms to progress; otherwise, firms will fail to keep up with the industry and be forced to exit. For instance, GDT, which was the leader in switch technology in the early 1990s, has been slow to diversify to other sub-sectors. As the market demand for switches has decreased, the company has gotten into serious trouble. How to quickly reorient it and catch up with its peers in other sub-sectors is a great challenge that GDT is facing now.

7.4 Chapter Conclusion

Using simple regression analysis (in 7.1) and some examples, I have demonstrated that innovation capability and self-developed technologies have been the key to Chinese domestic firms' catching up with the MNCs and have determined who are the leading domestic firms in these industries. Furthermore, I have found that in-house R&D development, supplemented with external alliance, is a key channel for domestic firms to build up their innovation capabilities.

The Chinese government has used the national S&T programs, such as the "Torch Program" and the "863 Plan", to encourage commercialization of technologies and fundamental research in China. Through a selection process that awards projects to companies with a strong innovation capability, the government's involvement has rewarded companies' efforts in building innovation capability and developing proprietary technologies. The government's involvement in accumulating knowledge-based assets has enhanced the function of the positive feedback system that awards company's effort in building their innovation capability. The positive feedback system is composed of: network clustering, disintegration of the global value chain, and sub-sector linkage, all of which value the same quality-innovation capability.

Appendix 7.1 Regression Analysis of Innovation Capability

Regression Results, Leadership and Innovation Capability

Companies	Rank in Telecom-equipment Industry	Evaluation of Innovation Capacity
Huawei	2	1
ZTE	4	2
DTT	5	3
SH Bell	3	4
Wuhan Telecom Sci. Ins.	6	5
Changfei	7	6

Regression Statistics	
Multiple R	0.8285714
R Square	0.6865306
Adjusted R Square	0.6081633
Standard Error	1.1710801
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	12.014286	12.014286	8.7604167	0.0415627
Residual	4	5.4857143	1.3714286		
Total	5	17.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.6	1.0902162	1.4675988	0.2161194	-1.4269318	4.6269318	-1.4269318	4.6269318
Evaluation of Innovation Capacity	0.8285714	0.2799417	2.9598001	0.0415627	0.0513271	1.6058158	0.0513271	1.6058158

Regression Results, Innovation Capability and R&D Spending

Companies	**Innovation Capacity**	**R&D Spending**	**R&D Spending as % of Revenue**
Putian	7	613.26	1.00%
Huawei	1	3049.63	18.80%
ZTE	2	1129.78	10.30%
DTT	3	390	12.30%
SH Bell	4	793.29	5.30%
Wuhan Telecom Sci. Ins.	5	178.53	6.50%
Changfei	6	250	9.70%

Note: R&D Spending in millino RMB in 2002

Innovation Capacity (Y) vs. R&D Spending (X)

Regression Statistics	
Multiple R	0.717842727
R Square	0.515298181
Adjusted R Square	0.418357817
Standard Error	1.64752244
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14.42834906	14.428349	5.3156204	0.0692897
Residual	5	13.57165094	2.7143302		
Total	6	28			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.422488042	0.876599539	6.1858212	0.0016099	3.1691209	7.6758552	3.1691209	7.6758552
X Variable 1	-0.001554756	0.00067435	-2.3055629	0.0692897	-0.0032882	0.0001787	-0.0032882	0.0001787

Innovation Capacity (Y) vs. R&D Spending as a % of Revenue (X)

Regression Statistics	
Multiple R	0.821775553
R Square	0.675315059
Adjusted R Square	0.610378071
Standard Error	1.348419693
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	18.90882166	18.908822	10.399544	0.0233397
Residual	5	9.091178343	1.8182357		
Total	6	28			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	6.857790217	1.022285421	6.7082931	0.0011144	4.2299262	9.4856543	4.2299262	9.4856543
X Variable 1	-31.30599612	9.707790173	-3.2248324	0.0233397	-56.260624	-6.3513678	-56.260624	-6.3513678

Regression Results, Revenue, Profit and R&D Spending

Companies	**R&D Spending**	**Revenue**	**Profit**
Huawei	3049.63	16228.95	2654.37
ZTE	1129.78	10926.14	797.2
DTT	390	3163.18	90.43
SH Bell	793.29	15101.07	1984.25
Wuhan Telecom Sci. Ins.	178.53	2744.49	201.47
Changfei	250	2571.98	90.79

Note: Revenue, Profit, and R&D spending are all in million RMB.

Profit (Y) vs. R&D Spending (X)

Regression Statistics	
Multiple R	0.8487109
R Square	0.7203102
Adjusted R Square	0.6503877
Standard Error	649.49144
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4345600.3	4345600.3	10.301558	0.0326012
Residual	4	1687356.5	421839.13		
Total	5	6032956.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	138.76229	370.59334	0.3744328	0.7270869	-890.17192	1167.6965	-890.17192	1167.6965
613.26	0.860946	0.2682406	3.209604	0.0326012	0.1161892	1.6057027	0.1161892	1.6057027

Revenue (Y) vs. R&D Spending (X)

Regression Statistics	
Multiple R	0.7831571
R Square	0.613335
Adjusted R Square	0.5166687
Standard Error	4461.7145
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	126306695	126306695	6.3448713	0.0654332
Residual	4	79627585	19906896		
Total	5	205934280			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3975.9089	2545.8098	1.5617462	0.1933758	-3092.4069	11044.225	-3092.4069	11044.225
X Variable 1	4.6415626	1.8426922	2.5189028	0.0654332	-0.4745818	9.7577069	-0.4745818	9.7577069

Appendix 7.2 External Alliance of Domestic Manufacturers

Table 7.8 Part of Huawei's Joint R&D Facilities

Partner	Date	Purpose
Agere	9/1/2001	Under the terms of the multi-million dollar deal, Huawei will use Agere's network processors and other chip products in its line of networking equipment.The two companies will also co-develop chip products as well, according to Agere.
IBM	9/20/2000	As part of an agreement whereby IBM will supply Huawei with key components, the two companies have launched a collaborative R&D effort to make their respective products and technologies work more closely together, allowing customers to incorporate both in their products.
Intel	n.a.	Huawei and Intel have signed a memorandum of understanding in order to establish a joint laboratory within Huawei's Shenzhen headquarters. The laboratory will develop components based on Intel's 'Internet Exchange Architecture'.
Lucent Technologies	n.a.	Huawei and Lucent announced in 2000 the establishment of a joint lab to focus on microelectronics and optoelectronics. According to Huawei, the two parties will enter into closer technical cooperation based on the incorporation of Lucent's advanced components into Huawei's products. The joint lab will also serve as a platform for both companies to exchange technologies via a variety of technical seminars and conferences. The joint lab will also work with Lucent's Bell Labs which has facilities in Beijing and Shanghai.
Motorola	1997	Motorola and Huawei set up joint laboratories for communication system research in 1997. On August 9, 2000, it entered the agreement for development of GSM Equipment and end-to-end solutions
NEC	10/23/2002	NEC and Huawei jointly established "3G Internet Open Lab" in Shanghai. The objectives of establishing the Open Lab are to create an open platform to support the 3G mobile developments in China and to provide end-to-end total mobile solutions for mobile operators. Through developing new applications by third party, network providers and mobile operators can work hand-in-hand to develop a value chain in order for clients to achieve a leading market position and reap in their profits.
Sun	12/20/2000	Joint Laboratory
Texas Instruments	9/18	Huawei and Texas Instruments have established a joint laboratory within Huawei's facility in Shenzhen to develop digital signal processors (DSPs) for its equipment.

Source: Data about IBM, Intel, Lucent, and Texas Instrument were from (Smith-Gillspie, 2001, Table 6.1, p. 83), others summarized by the author from the websites of Huawei (www.huawei.com.cn).

Table 7.9 ZTE's Joint R&D Facilities

Partner	Purpose
Beijing University of Posts & Telecommunications (BUPT) [1]	On November 13, 1999, a joint lab was set up in Beijing with BUPT to perform research on optical communication systems, particularly in the development of OADM equipment. This is one of the major tasks of the government's '863' program (see *Chapter 5*). On August 15, 2000, a second joint lab was set up in Shenzhen with BUPT to carry out research on optical transmission systems.
University of Electronic Science & Technology of China (UEST) [2]	ZTE and UEST (a 'national key university') have set up a joint R&D center to focus on wireless communications, particularly in third-generation wireless technology.
Texas Instruments (TI)	ZTE and TI have established a joint laboratory within ZTE's Shanghai Institute II to focus on the development of the latest DSP (digital signal processing) technology. TI will provide a software design platform and technical support.
Motorola	ZTE has set up a joint lab with Motorola in Nanjing. The cooperation will be based in the fields of data and mobile communication. Phase I of the project is devoted to developing data communication products such as IP phone gateways and access servers.

Source: ((Smith-Gillspie, 2001), p.96, Table 6.5
Note:

1. BUPT began R&D activities on high-speed digital optical fiber communication systems and DWDM systems at the end of the 1970s. Several key products have emerged from the university's research, such as coherent optical communication systems, 8x2.5Gb/s OTDM optical transmission systems, bi-directional DWDM systems, optical internet, key components of WDM optical fiber systems, systems architecture configurations, and ATM optical exchange technology.

2. UEST is a national key university that trains engineers in the field of information technology and is involved in the national 'informatization' initiative.

Table 7.10 DTT's Joint R&D Facilities

Starting Date	partner	Joint Facility/Joint Research Area
3/9/1999	MII Bejing Design Institute	Joint Research Plan
6/1/1999	Electronic S&T University(ESU)	DTT-ESU Optical Communication Research Center
8/1/1999	TI	Beijing, Xi'an DSP Joint Technology Applied Center
1/1/2000	TI	DSPS Beijing Laboratory
9/7/2000	BUPT	BUPT-Datang Telecommunication Technology Research Center
6/20/2001	South Korea, JAS	CDMA Indoor Coverage System

Source: Summarizedby the author from DTT's website.

Table 7.11 Cooperation Activities of GDT

Date	Partner	Activities
January 1998	Russia Government	Russia Telecom and GDT's Cooperation in various fields
April 1998	MIC, U.S.	Information Technology Area
August 1998	Beijing University	China Enterprise Management Cases Projects
November 1998	Cuba Government	$3 billion cooperation plan
February 1999	China HP	Intelligent Network Cooperation
April 26, 1999	Israel NBASE	Cooperation in Data Communication , $50 million worth projects
August 1999	NDSC	"863 Plan" approved
August 31, 1999	Guizhou Province Information Center	Information Development Cooperation Agreement
August 19, 1999	Columbia Compass	Joint Venture
January 7, 2000	Fujian Dongwang Network	Strategic Partner Agreement
June 19-20, 2000	C&S Technology, South Korea	Joint Development Agreement
July 15, 2000	Space, South Korea	Joint Development Agreement

Source: GDT.

Appendix 7.3 Opportunities and Challenge

ZTE's Opportunities and Challenges

ZTE has actively expanded into the international market. Its products can be found in more than forty countries in Asia Pacific, South Asia, Middle East, North America, Eastern Europe, Latin America, and Africa. Currently, ZTE has formed two overseas joint ventures: one in Pakistan and another in the Republic of Congo (former Zaire), operating cell phone, toll, and international services.[78] ZTE is said to be preparing for an IPO on the NASDAQ, pending approval from regulatory authorities. However, ZTE feels that it still does not have enough knowledge of international markets to go to the U.S. Stock Exchange and it is short of such expertise.[79]

In August 2002, ZTE announced that its foreign shares would be listed on the Hong Kong Stock Exchange. The international capital obtained will be used for (1) R&D investment (mainly in the areas of mobile communication, data communication, and optical transmission), (2) international market expansion (to set up global-sales networks and decrease production costs through new global logistic centers), and (3) global acquisition for key technologies (to speed up cycles for developing new products and to attract international technical expertise). The company hoped the new movement to the Hong Kong Stock Exchange would not only set up new channels for investment capital, but also help to build an international recognized brand name. Further, it hoped that the transparency and efficiency of its operations could be improved.[80]

According to its manager, ZTE has grown rapidly and thus the largest problem facing ZTE is efficient management. ZTE now has 12,000 employees distributed in more than a dozen locations; the sheer size of the company has posed serious challenges to ZTE. How to manage such a large company is very different from several years ago when the company had only several hundred or a thousand people. ZTE officials stated that they need to learn from their peer Huawei who has asked help from IBM to strengthen its management.[81]

Huawei's Opportunities and Challenges

Huawei's technology leadership has brought Huawei higher revenue and profit compared with other domestic producers. For instance, revenue has increased from RMB 12 billion in 1999 to RMB 25.5 billion in 2001. However, since 2001, the company seems to have had difficulty in maintaining growth amid decreased spending by operators and uncertainty around 3G mobile services. Huawei reported revenues ($2 billion) and profits ($319.8 million) for 2002, far below the previous projection of $4.2 billion in revenue for the year.[82]

Huawei has stated[83] that the challenges it faces are technology advancement, management, and lack of capital. Technology advancement has always been the competitive advantage of Huawei, but it is not easy to keep this leadership amid the fierce competition. From in-house R&D

[78] On December 14, 2000, ZTE and the Republic of Congo's Ministry of Telecommunications signed joint agreement which ZTE will operate as a telecom service in Congo.
[79] Interviewee #13.
[80] *Communication World* (in Chinese), September 8, 2002, p. 11-12.
[81] Interviewee # 13.
[82] www.chinanex.com as of Oct. 28, 2002.
[83] Interviewee #2.

activities to cooperation with domestic and foreign companies and institutes, it has tried multiple approaches to improve its technological capacities. So far, Huawei has advanced itself from a follower to a leader in various fields of industrial technology. Mobile communication, mentioned above, is one of these examples.

Moreover, Huawei has realized that such a large enterprise needs a modern management system. Huawei therefore invited IBM to improve its management system. Furthermore, as a private company, Huawei cannot get investment capital it needs from the stock market, unlike other public companies such as ZTE, Datang, and GDT. The availability of capital will remain a constraint on Huawe's future development.

Cisco's Suit against Huawei – Challenges from Globalization

Another challenge for Huawei comes from its effort to market globally. As the largest telecom equipment producer in China, Huawei has a very good understanding of the competition rules and business environment in China. However, in the international market, even though it is a significant low-cost competitor, it seems that Huawei still needs to learn a great deal in terms of international rules of competition. In January 2003 Huawei was sued by Cisco, which claimed that Huawei had unlawfully copied Cisco's intellectual property.[84] It alleged that Huawei had misappropriated Cisco's IOS software, including source code, copied Cisco documentation and other copyrighted material, and infringed numerous Cisco patents.[85] Later, Cisco filed new papers claiming that Huawei was attempting to remove evidence from the U.S. by taking the products off its U.S. website.[86]

Quite ironically, not long ago, Cisco CEO John Chambers was asked if it was possible Huawei was violating Cisco's intellectual property rights. He responded that he had confidence that the Chinese government and World Trade Organization would "do the right thing" to prevent or stop unfair business practices. In a statement, Cisco stated that Huawei had refused Cisco's numerous attempts to resolve these issues. Mark Chandler, vice president and general counsel for Cisco, said, "As a result, Cisco has no choice but to protect its technology and the interests of its shareholders through legal action." [87]

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[84] Cisco filed the suit in the U.S. Court for the Eastern District of Texas.

[85] Cisco's main charges were around Huawei's Quidway routers and switches. First, Cisco alleges that Huawei copied portions of the Cisco IOS source code and included the technology in its operating system for its Quidway routers and switches. Cisco alleges that Huawei's operating system contains a number of text strings, file names, and bugs that are identical to those of Cisco's IOS source code.
Cisco also claims that Huawei copied extensively from Cisco's copyrighted technical documentation and included whole portions of Cisco's text in Huawei's user manuals for Quidway routers and switches.
In addition, Cisco charges that Huawei copied Cisco's command line interface (CLI) and corresponding screen displays. Cisco asserts that "Extensive" portions of Cisco's CLI and help screens appear verbatim in Huawei's operating system for its Quidway routers and switches.
Lastly, Cisco charges that Huawei is infringing at least five Cisco patents related to proprietary routing protocols and has included these technologies in its Quidway routers and switches.
(http://www.nwfusion.com/newsletters/optical/2003/0127optical2.html as of March 10, 2003)

[86] Huawei denies all of Cisco's allegations and said it had stopped the sale and distribution of the products in the US. The company said Cisco "is using the litigation process to enhance its market position." The company said it is developing other products that will not be subject to Cisco's claims. (www.igigroup.com newsletter as of February 7, 2003).

[87] http://www.nwfusion.com/newsletters/optical/2003/0127optical2.html as of March 10, 2003.

If what Cisco alleged is true, then Huawei still is far from catching up in the area of data communications. The protective atmosphere in China for domestic firms, which might prevent Cisco from suing Huawei in China, does not exist in the international market. The lessons for Huawei are that the firm should follow the international rules of competition and have a good understanding of the host country market.

Datang's Opportunities and Challenges

In 2001 DTT's revenue fell 14.4% to 2.1 billion RMB and its profit fell 48.4% to 36.1 million RMB compared with 2000. The fact that the company has lost central office switch (CO) market share to rivals and spent heavily on R&D has eroded the company's bottom line.[88] Datang has been slow in expanding production to other telecom-equipment areas, such as data communication, optical transmission, and mobile communication. Most of its products compete with those of other domestic producers, such as Huawei, ZTE, and PTIC, without any strong advantage in performance and price.

One manager[89] from Huawei commented that even though Datang is very strong in R&D, and has great achievements in R&D projects, this research-oriented company has difficulty in converting R&D results into products. Furthermore, data from MII indicates that Datang had little revenue from exports in 2001, which implies that Datang is far behind its rivals in developing international markets. DTT's future is said to (by the analyst from ChinaNex) be precarious as the company still carries the baggage of its past as a government research entity while in desperate search of a winning business model.[90]

As I have shown, companies such as Datang and GDT have had unsatisfactory performance in recent years. Even though Datang is the leader in many fields of research, it has had trouble in converting its R&D results to products. Except for Datang's collaboration with Siemens, Datang and GDT have no foreign collaboration, unlike Huawei and ZTE. Datang needs to develop quickly its resources of management expertise, its skills of converting R&D results to products, and its access to the international market.

GDT: From Leading to Lagging Behind

In recent years, GDT has suffered from a decline in revenue, especially from sales of its core central office products, as demand has diminished and competition has risen. As a result, the company has slid in market share in almost all product categories. For example, MII ranked GDT 28th in telecom/electronics sales in 1998, but only 54th in 1999. The company declined to participate in the rankings in 2000 and MII removed the company from the list in 2001 for poor financial performance. In 2001, GDT reported only 400 million RMB ($48.2 million) in revenue and 90 million RMB ($10.8 million) in operating loss, much worse than the company had expected.

Thus, GDT changed from being the leader in domestic switch products to being the least competitive company among the four major telecom equipment manufacturers. GDT's rise and fall in the past decade indicates the fierce competition in China's telecom equipment market.

[88] www.chinanex.com as of Oct. 20, 2002.
[89] Interviewee #2.
[90] www.chinanex.com as of Oct. 20, 2002.

Analysts say the main reason for GDT's decline is that it missed the opportunity for an IPO in 1998 and lacked a competitive mechanism within its capital and management structure. The company also failed to pursue new technology and develop products in demand.[91]

On July 28, 2002, GDT started its third restructuring to resolve the problems that the company faced: (1) ownership and management structure, (2) proprietary technology ownership, and (3) capital structure. Though GDT has a separate committee of shareholders, board of directors, and control commission, the inherent multi-interest corporate structure has led to continuous conflicts among different parties. For instance, the shareholders represent capital providers, technology providers, debt owners, and suppliers. Under such a structure, it is unavoidable to make random decisions, as well as changing the management team and the company's strategies relatively frequently. Consequently, the company missed good opportunities for growth even in the areas in which it had strong roots. For instance, GDT started R&D in access equipment one year ahead of other companies, but it was unable to seize the growth opportunities later.

Ownership of proprietary technology is another problem that keeps plaguing GDT. In 1996 disputes occurred between technology owners of HJD04, which affected GDT's normal operation severely. The problem was finally resolved after one year's negotiation and bargaining, but this left the situation that even though the switch technology belongs to GDT, the company does not have full control over it.

Insufficient capital is another bottleneck for GDT's development. GDT has only one way to obtain investment capital–bank loans. To accommodate its high operation cost, GDT has borrowed a large amount of cash from its production units. To make things worse, it also takes a long time to receive the payment from GDT's customers. At the beginning of 1999, GDT got contracts, but it could provide no products. The situation soon stimulated a vicious cycle– because the customers could not get their ordered products, they slowed down their purchasing and decreased orders from GDT, which dramatically decreased the cash GDT could receive. GDT then borrowed more cash from its production units to balance its operation cost; but, short of production capital, the production units were not able to produce orders normally. (Yao, 2002)[92]

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[91] www.chinanex.com as of Oct. 20, 2002.

[92] Yao, Chuanfu. 2002. "Julong's Restructuring, save or reborn?", *People's Posts and Telecommunications (Chinese Newspaper, Ren Min You Dian),* November 19, 2002.

8 Staged Catching-up of PC Manufacturers

Domestic PC manufacturers have experienced a catching up process that is similar to that of the domestic telecom-equipment manufacturers. In this chapter, I identify the distinct stages of the process by focusing on leading domestic firms' development paths and I examine government intervention at the industry and the firm level.

I organize the chapter in the following way. I start the chapter with a brief introduction of the global PC market in terms of demand, supply, and industry trend, as well as the demand and supply of China's PC market. In Section 8.2, I investigate the catching up of domestic firms with the MNCs in China and identify the four distinct stages for their development. In Section 8.3, I analyze the Chinese government's policies surrounding (or directed at) the PC industry and how those policies affect MNCs versus domestic firms.

8.1 Global PC Industry

The personal computer (PC) industry has, overall, been one of the most dynamic segments of the electronics industry since the early 1980s, both in terms of growth and the creation of new models of firm and industry organization.

8.1.1 The Global Production Network

The global PC industry was a pioneer in developing a new form of industrial organization-the global production network, which is based on horizontal specialization rather than vertical integration. Firms compete within a horizontal industry segment and grow by capturing market share and achieving economies of scale, rather than by extending vertically into upstream or downstream activities (Dedrick et al., 2002). Global relocation of economic activities has implications for the competitiveness of companies and prosperity of countries (Berger et al., 1999). Global multinational corporations have been founded either to establish central-controlled production and distribution networks with local subsidiaries carrying out sales and service functions in national markets, or to establish highly autonomous national or regional business units with full responsibility for product development, manufacturing, distribution, and service functions within each market (Dedrick et al, 2002).

The globalization of the PC industry has to pay a debt to International Business Machines Corporation (IBM), who created the dominant IBM PC architecture in the middle of 1960s, an open modular architecture that allowed suppliers to develop components and peripherals that utilized a standard interface with the core CPU and operating system, standards set mostly by Intel and Microsoft (Langlois, 1992). PC component and peripheral manufacturers thus can design products with little interaction with the PC assembler, as long as they meet the interface standards. Since then, joined by new companies, these historically vertical computer companies have transformed themselves to specialize in one industry segment or another (e.g., PCs, motherboards, hard drives) and concentrate most of their resources on one or two major activities. Before, these companies operated in all industry segments and carried out the major functions of product innovation, operations, and customer relations internally. (Dedrick et al, 2002)

Table 8.1PC Components and Their Major Producing Countries/Region

Components	Major Producing Country	% of Raw-Material Cost
Hard Disk Drive	United States (Seagate)	18
Monitors	P.R. China	17
CPU	United States (Intel)	16
DRAM	United States, Taiwan	6
CDRom	P. R. China Based manufacturers	6
Others (Motherboards, etc.)	P.R. China	37
Total	n.a.	100

Source: Salomon Smith Barney, 2000.
Note: n.a. = not applicable.

The global production network has a strong flavor of geographic specialization. Table 8.1 reveals which country produces the majority of each of the components. Formed by the middle of 1990s, the global PC industry is characterized by U.S. firms specializing in design, advanced components (such as microprocessors), software, and services, Asia providing much of the hardware manufacturing, and Europe mostly producing hardware, software, and services for its own markets (Dedrick et al., 2002).

8.1.2 PC Manufacturers

As a PC is a modular product assembled from standard parts that can be produced almost anywhere by anyone, a PC assembler adds limited value, and there is little innovation involved in the assembling process.[93] Given the low entry barrier to the PC industry, what makes a good PC manufacturer? The value added part of PC assemblers comes directly from customer relationships, or indirectly through branding, marketing, and quality assurance. Therefore, the successful market players must have a well-recognized brand, reliable quality, large production scale, and a strong distribution network. All these qualifications require considerable time to develop. (HSBC, 2000)

Currently, Dell, HP, IBM, Fujitsu-Siemens, and NEC are the top five global PC manufacturers in terms of market share. According to International Data Corporation (IDC), two giant PC makers, Dell and HP, shipped a total of 10 million PCs, over 30% of the worldwide market share in the third quarter, 2002. Dell accounted for 16.0% of the desktops, notebooks, and Intel- and Advanced Micro Devices, Inc. (AMD)-based servers shipped worldwide, a 23% growth in 2002 compared with 2001. In contrast, HP's

[93] This can be seen by the declining profit margin captured by PC manufacturers: PC makers captured 49% of the profits in the PC industry in 1990, while component suppliers, including Intel and Microsoft captured 51%; the share of PC manufacturers dropped to 27.5% in 1995, and in 2000 to just 13% (Dedrick et al.,2002).

shipments accounted for slightly less, at 15.5% of the market share.[94] IBM kept a distant third with a 6.0%. Fujitsu-Siemens and NEC rounded out the top five worldwide with 4.3% and 3.3% of the market share, respectively.[95]

8.1.3 Market Trends

There are two distinguishing characteristics in the current PC market. First, the global-market demand has slowed recently. Second, PC component prices have dropped sharply. PC demand has grown at double-digit rates since the late 1970s, driven by dramatic improvements in hardware performance and rapidly growing software applications. The demand has accelerated in the late 1990s, as falling component costs allowed the PC makers to lower prices while software applications, especially internet and multimedia software, drove the demand higher. In mid-2000, however, PC demand declined sharply mainly because: (1) the worldwide economic growth rate slowed, (2) corporations slashed their IT expenses to save money, and (3) consumer demand was satiated. In addition, few applications require more powerful hardware.

Recently, component costs have kept decreasing and this has benefited computer manufacturers. For instance, Intel cut Pentium IV, Pentium III (PIII) CPU prices in late January 2001. Other components prices also dropped sharply from their mid-2000 highs. For the CPU processor, the battle between Intel and AMD has caused faster processor cycles and kept prices low.[96] The component supply side looks benign for all computer manufacturers, and especially for those with large volume. The prices of RAM are unlikely to increase significantly, because the semi-conductor industry continues to struggle with over-capacity. For instance, the Intel CPU Px PIII 800 chip's price dropped from close to $600 in May 2000 to around $200 in January 2001. During the same period, Intel's 64M (8Mx8) P100 DRAM price dropped from $6.8 to less than $3.[97] Peripherals, such as printers, scanners, digital cameras and Personal Digital Assistants (PDAs, electronic handheld information devices), have come down in price, and that is also beneficial for computer manufacturers as they usually bundle peripherals as part of special deals to lure customers.

In addition to falling demand and prices for components, Dedrick and Kraemer (2002) identified the following key industry trends:[98]

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[94] Gartner Dataquest's data however shows that Dell and HP have a 15.8% and 15.7% market share, respectively, together comprising about 30,000 units of shipment in Q3 2002. Gartner, Inc. provides research and analysis of the information technology industry. Check the following website for detailed information of the company: www.dataquest.com.

[95] http://www.zdnetindia.com/biztech/enterprise/news/stories/68832.html as of 12/26/2002

[96] Intel periodically slashes processor prices aggressively when introducing new chips. New components come on to the market at a premium, but Intel does huge price cuts in older, obsolete components.

[97] ING Barings, 2001, p.3. (Figure 4 and Figure 5).

[98] Internet and electronic commerce have helped PC manufacturers respond to the increasing the clock-speed, and demand for customization; Dell and Gateway's mass customization is a classical example. Some PC manufactures have outsourced much of the production process to concentrate their resources in one or a few key elements in the production process. (Dedrick et. al, 2002; Kraemer et. al, 2002b).

- Competitive advantage in the PC industry is driven more by sales, distribution, and customer relationships than by manufacturing or product innovation.[99]
- There is a shift toward mobility in data communications and computing, which has boosted sales of mobile IT products (notebooks, PDAs, and other devices). The increased sales indicate new opportunities for growth and innovation on the part of PC manufacturers, but also pose challenges as firms in the PDA and wireless industries begin to compete with PC manufacturers.
- Offering solutions representing a combination of hardware and services (rather than just hardware PC) to customers has been the new strategy taken by many PC manufacturers, imitating IBM's business. However, the transition requires a strong local presence, leading to higher overhead costs and a loss of economies of scale.[100]

8.1.4 Demand for PCs in China

In 1990, China had only 500,000 PCs for more than 1.2 billion people. By 2000, the 1.3 billion Mainland Chinese purchased more than seven million PCs in a single year (Kraemer and Dedrick, 2002a). The urban penetration rate is 7% and around 30% for large cities, such as Shanghai, Beijing, and Guangzhou. This rate is still very low compared to the penetration of North America and Western Europe, where the PC penetration rate could be above 70% in large cities. Also, 60% of the Chinese population still live in rural areas, compared with 10-30% in North America and in Western Europe.[101] Thus, analysts from KIM ENG (2001) estimated that Mainland China's market still has a long way to go before even coming close to saturation. In addition, demand will fluctuate, but in the long-term it will continue to be strong (KIM ENG, 2001).

8.1.5 Supply of PCs in China

Corresponding to the rising demand in recent years, China's PC production has also increased dramatically. Table 8.2 reveals the fast growth path of China's PC production as a percentage of the world market from 1985 (0.0%) to 1999 (5.5%), especially the outstanding growth of the period from 1995 (1.9%) to 1999 (5.5%). Currently, domestic producers supply the majority of the PCs to China's market. All top three PC manufacturers to China's market were domestic ones, namely Legend, Founder, and Tongfang in the third quarter of 2001 (Table 8.3). Further, China's domestic PC producers have moved fast in entering the international market. During the same period,

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[99] Dell's direct sales model works well for the United States, United Kingdom, and a few other countries where the direct sales channel is well established, while in other high-growth markets, such as China, India, and Korea, it's still questionable whether or not this model can work well. (Dedrick et. al, 2002).

[100] Gateway withdrew from overseas markets and concentrates on the United States, perhaps out of concern for this requirement. (Dedrick et. al, 2002).

[101] People's Daily (May 19, 2002) estimated that China's population is around 60% rural. The Daily Statistics Canada (www.statcan.ca) estimated that in 1996, 31.4% of Canada's population, about 9 million people, lived in predominantly rural regions. The US 2000 Census classifies 25% of the total population as rural (United States Department of Agriculture, website: www.usda.gov). Belgium had 97.3%, and the United Kingdom had 89.5% population dwelling in urban areas in 2002. (www.un.org).

Legend, Founder, and Tongfang were ranked the first, seventh, and tenth largest producers in the Asia-Pacific market.

Table 8.2Top 10 countries' share of global computer production

Country	1985	1990	1995	1999	1999 Rank
United States	49.2%	27.0%	26.5%	26.5%	1
Japan	18.9%	29.2%	25.2%	16.7%	2
Singapore	1.2%	3.9%	7.3%	7.7%	3
Taiwan	1.0%	3.3%	5.6%	6.5%	4
China	**0.0%**	**0.4%**	**1.9%**	**5.5%**	**5**
United Kingdom	4.6%	5.1%	4.7%	5.0%	6
Germany	5.7%	5.6%	2.8%	3.4%	7
Ireland	1.5%	2.1%	2.2%	2.9%	8
Malaysia	0.0%	0.2%	1.8%	2.8%	9
Brazil	2.8%	2.6%	2.3%	2.7%	10
Others	15.1%	20.6%	19.7%	20.3%	n.a.
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**n.a.**

Source: Kraemer and Dedrick, 2001, p.8. (Calculated from Reed Electronics, *Yearbook of World Electronics Data*, 2000).

Table 8.3 China & Asia Pacific PC Market Share, 2001Q3

China												
Company	Legend	Founder	Tong-fang	Dell	IBM	TCL	ACER	Great Wall	Hisense	HP	Others	Total
Share	32	10	5	5	4	3	3	3	3	2	30	100
Asia Pacific												
Company	Legend	IBM	Compaq	Dell	Samsung	Hongji	Founder	HP	Trigem	Tong-fang	Others	
Share	14	7	6	5	5	4	4	4	2	2	47	100

Source:International Data Corporations.

Merrill Lynch's (2000d) analysts have summarized several characteristics of China's current PC industry:

- The growth of China's PC industry is the fastest in the world and driven by domestic factors.
- The driver of China's PC growth has been in transition from corporate spending to individual purchases because retail prices have recently fallen under an affordability threshold.
- Foreign brands mainly sell to the corporate sector, while local brands target the consumer market. Foreign brands lose because of their lack of price-value appeal and after-sales services.
- PC margins are not universally sinking in China. Some companies, such as Legend, maintain their margin by beefing up their time-to-market and shortening inventory turnaround.

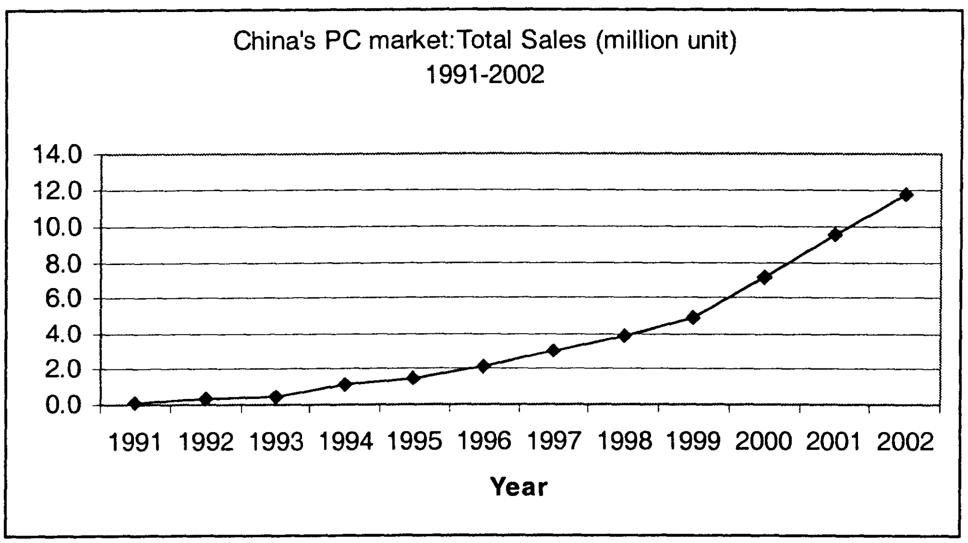
8.2 Catch Up in Stages: China's PC Industry

Domestic producers are the driving force that pushed China's computer industry from being non-existent in the 1980s to becoming the world's third-largest computer producer in 2002.[102] China's computer industry is developed through the staged catching-up of domestic firms with the MNCs. In this section, I examine the catching-up process of the domestic firms with the guidance of staged catching up theory. Furthermore, I review the development path of three leading firms-- Legend, Founder, and Great Wall—as their experiences represent the experience of successful firms during the catching-up process.

8.2.1 The Development of the Industry

The development of China's PC market from 1991 to 2002 was phenomenal, as it is illustrated in Figure 8.1. The market expanded during the 11-year period at an increasing pace--the total sales have an exponential growth from nearly zero million units in 1991 to nearly 12 million units in 2002.

Figure 8.1 The Growth of China's PC market: 1991-2002



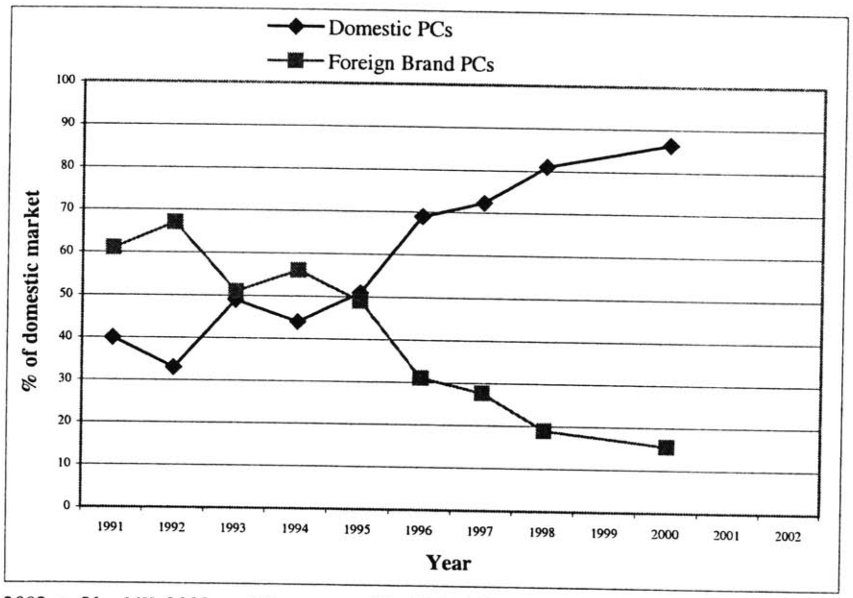
Source: Xu, 2002, p. 51., MII, 2003, and Kraemer and Dedrick, 2001, p.8 (Yearbook of World Electronics Data, 2000).

The celebrities of this fast expansion are the domestic PC manufacturers. They caught up with the MNCs in market share and thus upgraded China from importing to producing most of the PCs for the domestic market. Figure 8.2 vividly displays the process of domestic firms' catching up vis-à-vis the MNCs. Domestic firms started with a 40% market share in 1991; during 1993 to 1995, domestic firms shared half of the market with

[102] China's sales reached $23 billion in 2000. Chinese PC exports increased from $227 million in 1990 to more than $10 billion in 1998 (ManufacturingNews.com, 2002). PC export in 2002 reached 3 million units in 2002 (MII, 2003).

the MNCs; after 1995, the share for domestic firms kept rising until it was just under 90% in 2000. Correspondingly, the share for MNCs kept dropping to just over 10%.

Figure 8.2 Domestic and Foreign Brand PCs' market share in China's PC market, 1991-2002



Source: Xu, 2002, p. 51., MII, 2003, and Kraemer and Dedrick, 2001, p.8 (Yearbook of World Electronics Data, 2000).

According to the staged catching-up theory (Chapter 3), there are four stages of the catching-up process and each has distinct characteristics. Based on the characteristics of the market and industrial structure, I divide the catching up process for China's domestic PC industry into the four distinct stages declared by the theory: the preparation stage (early 1980s to late 1980s), the growth stage (late 1980s to early 1990s), the filtration stage (early 1990s to middle/late 1990s), and the globalization stage (middle/late 1990s to present, i.e., 2002). Table 8.4 describes major events during different stages of the industry. The following paragraphs explain why this division is appropriate.

Table 8.4 Development of the Chinese Computer Industry

Date	Event
1980	First domestic micro-computer DJS-062
1981	Huaguang ESP prototype passed test
	First nationwide IT exhibition
1983	Wubizixing, Chinese-language input method, was invented by Wang Yongming
	Yinghe I, China's first mainframe computer was built
	Yan Yuanchao developed the first Chinese version of DOS operation systems, CCDOS
1984	The State Council launched a team, led by Vice Prime Minister Li Peng, to promote the electronic industry
	The Computer Bureau of MEI released its strategy for the domestic PC industry: transfer, absorb, develop, and innovate
	Deng Xiaoping's speech: Computing skills need to be taught first to our kids. Thereafter the Ministry of Education established computing training center in 27 cities
	Legend's predecessor, the New Technology Company, was established
1985	China Computer Associate was founded
	GW 0520CH, the first domestic PC with Chinese language processing capacity, was released. This marked the beginning of China's domestic PC industry
	HP China was established in Beijing
	Founder's predecessor, Peking Like New Technology Company, was founded by Peking University.
1986	Great Wall's predecessor, China Computer Development Company (CCDC), was founded by the Fourth Ministry of Electronic Industry.
1987	Founder ESP entered the market and was sold to more than 40 newspapers and printing houses within a year
1988	Ufsoft released the first Chinese financial software product
	Intel China was established
	The State Council approved "Torch Program"
1989	Jinhan released WPS, the first Chinese world processing product
	Legend brand PC's debut
1990	National Artificial Intelligence Computer Research Center was established in Beijing
1991	State Council announced "Computer Software Protection Regulation"
1992	Legend released first 486-based PCs in China
	Great Wall signed a contract with Microsoft and officially purchases MS-DOS5.0
	Large-scale computer Ying He II was built
	IBM China was established in Beijing
1993	Newly restructured MEI viewed the computer industry as a main sector of IT industries
	Legend's annual sales of motherboards surpassed 5 million units
	Legend released the first Pentium (586)-based PC in China's market
	DEC, AST, COMPAQ expanded their operation in China
1994	Legend went public on the Stock Exchange of Hong Kong
1995	Founder went publish on the Stock Exchange of Hong Kong
	Microsoft China Ltd. And Microsoft China Research Center was established in Beijing
1996	Led by Vice Prime Minister Zou Jiahu, the State Council IT team was founded
	Domestic brands captured 18% of brand PC market share
	National 909 Project launched to produce Large Scale Intergraded Circuit (LSIC)
	Dong Da Aer became first publicly-listed domestic software company
1997	Ying He III mainframe computer was built
	Great Wall Shenzhen Ltd., Xiang Computer went public

	Jingshan WPS97 was released. In a year, WPS97's sales exceeded Msword97
1998	Ministry of Information Industry was established
	Legend built its millionth computer

Source: Adapted from Xu (2002, p. 53-54).

Throughout the **preparation stage** (early 1980s to late 1980s), China's computer market was small and almost negligible, as was the domestic computer industry. Table 8.4 shows that the most significant events during this period were several computer-related research achievements, such as the first domestic micro computer-"DSJ-062"-in 1980, the first domestic mainframe computer-"Yinghe I"-in 1983, and the first domestic PC with Chinese language processing capacity-"GW 0520 CH"-in 1985. Furthermore, major domestic firms such as Legend, Founder, and Great Wall, were all established during this period, even though they did not manufacture computers at the time. Whether or not Chinese firms start to produce computer related products is an important criterion for me to draw the line between the preparation and growth stage.

In the mid-1980s, many startup companies were formed to provide foreign-brand PC distribution, computer training, and computer services and they clustered in the ZhongGuanCun Area in Beijing. The ZhongGuanCun area was designated in 1988 as the first high-tech development zone in the country[103] and later was called "the Silicon Valley of China" because of the dense clustering of high-tech companies in the area. The area provides close proximity to several leading Chinese universities and research institutes such as Peking University, Tsinghua University, and the Chinese Academy of Sciences (CAS). In fact, the two most dominant PC manufacturers-Legend and Founder-themselves are closely affiliated with Peking University and the Institute of Computation Technology of CAS.

I call the period from the late 1980s to the early 1990s the **growth stage** of the China's PC industry because domestic companies started manufacturing products for previously untapped segments of the market; this is one of the prominent features of the growth stage described by the staged catching-up theory. During the early and mid-1980s, Chinese language processing was the biggest barrier for PC development in China. Consequently, in the late 1980s, Chinese language-input methods, a localized operating system, Chinese-language add-on cards, Chinese-language typewriters, and Chinese typesetting systems became key product categories for local companies to deliver PC-related technology. Companies with such technologies soon distinguished themselves from those involved only with trading and distribution. (Xu, 2002).

The **filtration stage** (early 1990s to middle/late 1990s) was characterized by direct confrontation between domestic and foreign producers (including MNCs that set up subsidiaries in China) in China's PC market. The difference between the growth stage and the filtration stage is that during the growth stage, Chinese firms did not directly compete against the MNCs, while during the filtration stage, they did. At the start of the filtration stage-the early 1990s, the IT market was boosted by increasing demand and resulted in an amazing annual growth rate of 200% in 1992. The Chinese government

[103] See Xu (2002).

lowered the import tariffs on electronic goods in the early 1990s, thus attracting more foreign producers to sell PCs in China's market. Meanwhile, following the footsteps of Hewlett Packard (HP) and Intel, who established operations in China in 1985 and 1988, respectively, more MNCs, such as IBM, DEC, AST, and Compaq expanded their operations in China in the early 1990s. These foreign producers brought fierce competition to China's PC market and they posed a great challenge to domestic producers. The domestic brand PCs, however, fought back after several years of struggle. During this stage, domestic firms also explored different ways of improving themselves as modern enterprises. For instance, Legend, Founder, and Great Wall all went public for more capital for expansion, and Legend and Founder have also restructured their management teams.

The globalization stage is characterized by domestic firms' dominance in the domestic market and their expansion in the international market. In 1996, Legend became the domestic market leader while the leading domestic firms started exploration in the international market, starting from the Asia Pacific market. This symbolized the start of a new stage of China's PC industry--the **globalization stage.** During the globalization stage, domestic PC companies dominated China's domestic market; for instance, they had an 83% market share in the first half of 2000.[104] Although foreign firms have generated most of the country's exports, domestic PC companies have grown fast and aim to become major players in the world's markets. To compete in worldwide markets, Asia-Pacific is the first step. Legend, Founder, and Tongfang, the top three PC manufacturers in China's market were listed in 2001 as being among the 10 largest PC producers in the Asia-Pacific market. Legend has led both China's domestic and the Asia-Pacific markets with distinguished market-share percentages-33.0% in China and 13.6% in Asia Pacific in the third quarter of 2001 (Table 8.3). (KIM ENG, 2002).

8.2.2 Legend, Founder, and Great Wall

Having explained Chinese domestic PC manufacturers' development as a group, I now focus on examining the evolution of the three leading domestic producers-Legend, Founder, and Great Wall-during the staged development of the industry (Tables 8.5 and 8.6). Even though they are the three largest domestic PC manufacturers in China with total revenue of several billion dollars in 2002, their sizes are not comparable to international giants such as IBM and HP, who achieved $85 billion and $45 billion sales revenue in fiscal year 2002 alone. The Blue Giant "IBM" and has about 300,000 employees world-wide, while HP has about 86 thousand employees, much larger than even the largest domestic firm (Legend) with its 12,000 employees (MIT Technology Review, 2003).

The companies' annual data in revenue and employment illustrate their exponential development paths during the first three stages and stabilized growth at the globalization stage (Figures 8.3 and 8.4).

[104] ING Barings. 2000. "China Research, Legend Holdings." Analyst Report. September 2000.

Table 8.5 Legend, Founder, and Great Wall, Major Statistics

Company Name	Date of Establishment	Employ-ment	8.2.2.1.1 Sales Revenue (in US$ billion)	Profit (in US $ million)
Legend Computer Group Corporation 联想控股有限公司	1984	12,000	3.9	169.3
Peking University Founder Group Co. 北京北大方正集团公司	1985	6,000	1.4	29.5
China Great Wall Computer Corporation 中国长城计算机集团公司	1986	n.a.	2	n.a.

Source: Company's websites and MII, 2003.

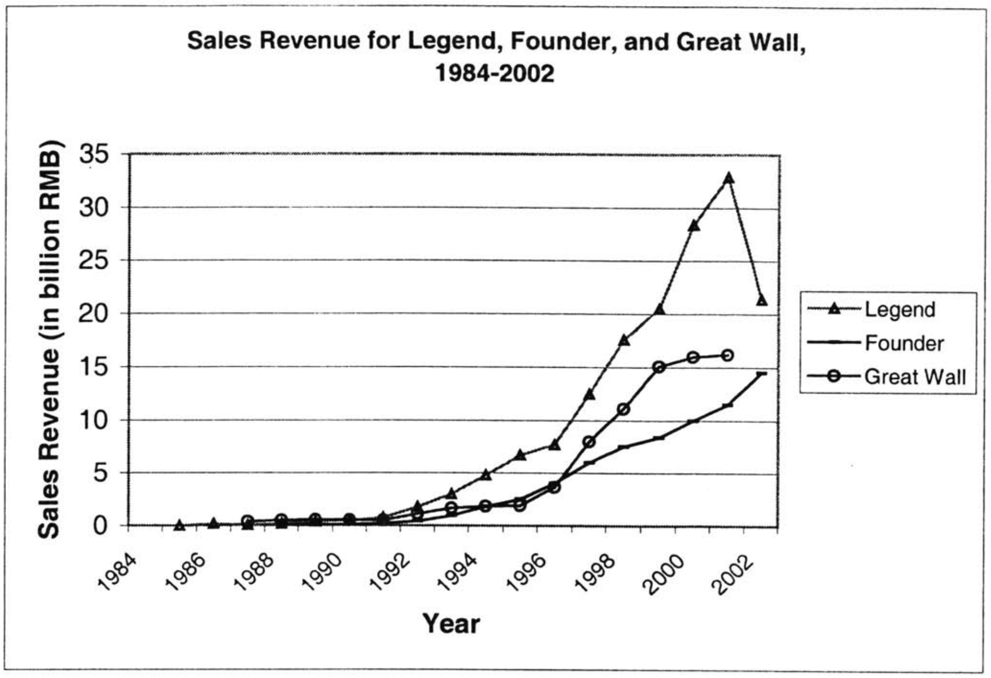
Note: Great Wall's Revenue is RMB 16.2 billion, about $1.96 billion, Eastcom's renenue is RMB 10.5 billion, about $1.27 billion, both are 2001's data.

Table 8.6 Legend, Founder, and Great Wall, Founding Organization and Major Products

Company Name	Founding Organization	Major Products/Services
Legend Computer Group Corporation 联想控股有限公司	China Academy of Science	agent sale (1984-); Chinese language add-on cards (85-88); mother boards (1987-); PC (1990-); system integration (1994-); network products (1996-); internet portal (1999-); wireless data technical development (2000-)
Peking University Founder Group Co. 北京北大方正集团公司	Peking University	electronic publishing and multi-media system (1985-); Chinese language add-on cards (88-95); distribution (1993-); Pcs (1995); system integration (1995-); internet software (1999-); on-line bookstore (2000-)
China Great Wall Computer Corporation 中国长城计算机集团公司	Ministry of Electronic Industry	PCs (1984-); PC Monitors (1995-); other PC components, distribution (1995-); magnetic heads and hard disks (1995/12-); system integration (1996-);network products (1999-)

Source: Xu (2002, p. 46-47).

Figure 8.3 Sales Revenue for Legend, Founder, and Great Wall, 1984-2002



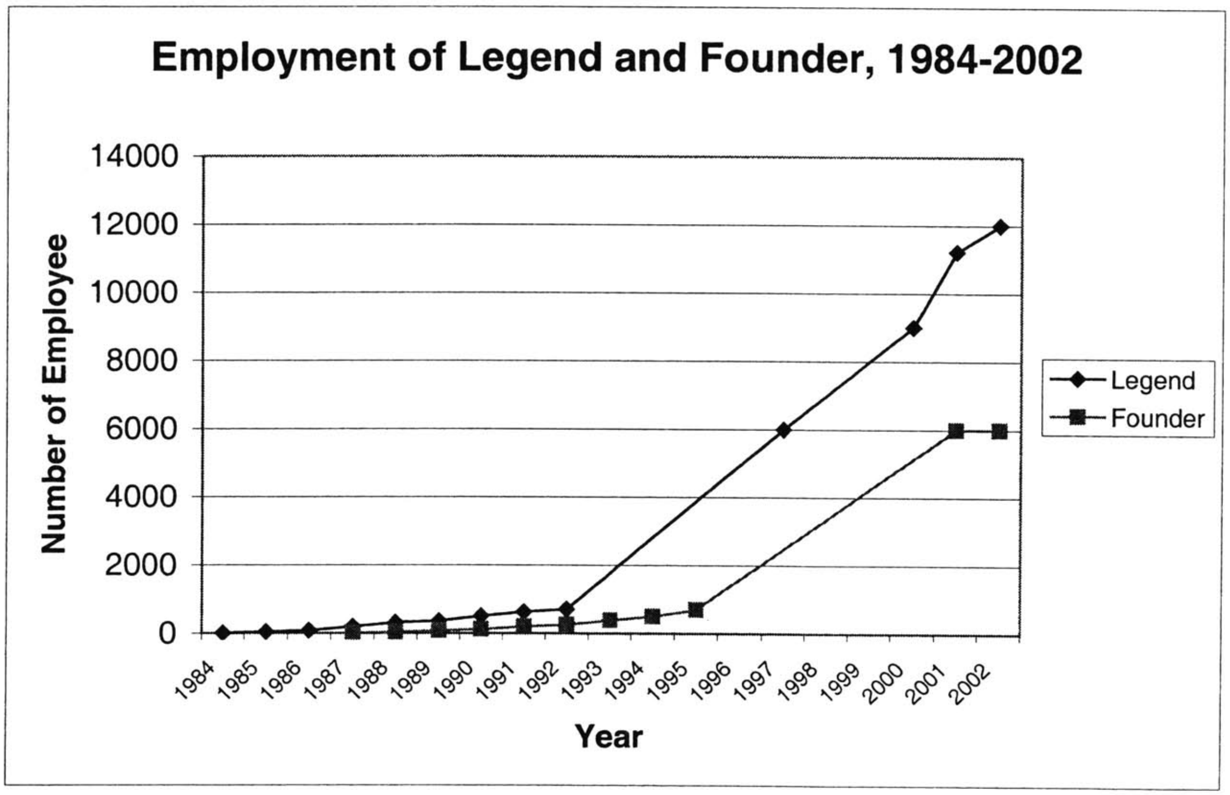


Figure 8.4 Sales Revenue for Legend, Founder, and Great Wall, 1984-2002

Legend Computer Group Corporation (Legend, 联想控股有限公司) is the leading PC manufacturer for both China's domestic market and the Asia-Pacific region, excluding Japan. The company became the captain for the domestic market in 1996 and has kept its leading position since then. Legend has two public companies: Legend Holdings Ltd., and Digital China Group, on the Hong Kong Stock Exchange. Legend Holdings went to Initial Public Offering (IPO) in April 1994, while Digital China Group was spun off and went public in June 2001. Legend's business covers PCs and other access devices, motherboards, foreign-brand distribution, and Internet services. PC manufacturing and agent sales of foreign-brand computer products are the two main sources of revenue. Legend Holdings' core business includes system integration and manufacturing Legend Brand PC peripherals, PCs, and motherboards. Almost 90% of its operating profit is from Legend Brand PC peripherals and PCs. Legend started with only eleven employees in 1984 and grew to 12,000 employees and sales revenue of RMB 21.4 billion ($3.9 billion) in 2002. Corresponding to the exponential growth of its workforce, the company has enjoyed an average annual growth rate of 40% (Figure 8.3).

Founded in 1985, Peking University Founder Group Corporation (Founder, 北京北大方正集团公司) is the second largest PC manufacturer in the Chinese domestic market and one of the ten largest PC manufacturers in the Asia-Pacific market, with total assets of RMB 6 billion and sales revenue of RMB 14.5 billion ($1.4 billion) in 2002. However, PC manufacturing is only one of the main businesses of Founder in which it takes pride. With 6,000 employees, Founder has three main businesses in IT: software development, systems integration, and hardware manufacturing.[105] It provides information-systems integration to the media industry (newspaper, preprinting, and TV and broadcasting). Founder is the world leader in pictographic-language, electronic-publishing-systems technology. For instance, Founder's Chinese electronic-publishing system has an 80% share of the world market. Furthermore, it provides large-scale information systems for the banking, insurance, taxation, and security industries in China. Founder also leads the industry in systems integration in the media and financial sectors. In 2000, Founder entered other businesses, including an Internet retailing business (an on-line bookstore), broadband, mobile communications, etc. (Founder, 2002)

Founded in 1986, China Great Wall Computer Corporation (Great Wall, 中国长城计算机集团公司) was the first domestic PC manufacturer, and it is the largest computer-component manufacturer and OEM supplier in China. With a sales revenue of RMB 16.2 billion ($2 billion) in 2001, Great Wall has two core businesses: Internet value-added service and IT equipment manufacturing (including PCs and their components, such as power supplies, monitors, boards, magnetic heads, software, etc.). Great Wall currently has four listed public companies, three on the Shenzhen Stock Exchange and one on the Hong Kong Stock Exchange. It has 14 wholly owned companies, majority-stake in 11 companies, and 12 holding companies. (Great Wall, 2002)

[105] Founder has also started to explore the fields of mobile communication, broadband, and rare earth and neo-materials. Founder owns four publicly listed companies: (1) Founder Holdings, Limited, (2) EC-Founder Co., Ltd, (3) Shanghai Founder Yanzhong Science & Technology Group Co., Ltd, and (4) PUC Founder (Malaysia), along with17 wholly owned subsidiaries and joint ventures. (Founder, 2002)

8.2.3 Major Domestic Companies' Development during the stages

Legend in Stages

I examine how Legend has developed itself through the stages by dividing Legend's development into four periods: 1984-1987, 1988-1993, 1994-1997, and 1997-present, which correspond to the four development stages of China's PC industry described earlier.

The early 1980s to the late 1980s was the "**preparation stage**" of China's computer industry; during this period, hundreds of companies were established in the ZhongGuanCun Area, including Legend. In November 1984, Legend was founded as a "New Technology Development Corporation of the Institute of Computing", an entity of the Institute of Computing Technologies (ICT), Chinese Academy of Sciences (CAS), with an investment of RMB 200,000. Legend started by providing computer services to customers, including testing, installation, and maintenance of PCs. It then took the opportunity to develop the Legend Chinese language add-on card, the first product of the company and one of the most successful Chinese language add-on cards at the time. The reputation and market success of the Legend add-on card attracted the attention of some international PC manufacturers, such as AST,[106] who decided to choose Legend as their distributor and partner to customize and distribute their PCs for the Chinese market (Xu, 2002).

Legend's development from 1988 to 1993 corresponded to the "**growth stage**" of the industry as it focused on expanding its manufacturing capacity to produce its own brand name PCs. In the late 1980s, there were no technologically advanced PCs that suited the Chinese market, so Legend, in cooperation with AST, focused on customizing PCs for the Chinese market. Legend intended to expand its manufacturing capacity, however, it was not able to obtain a PC manufacturing license at the time from the government, because the industry was strictly regulated and it was very difficult to obtain a PC manufacturing license. Thus, Legend established a joint venture in Hong Kong with two other partners-Daw Inc., a small computer-related trading firm in Hong Kong, and China Technology Corporation, a state-owned corporation in China. Later, it acquired Quantum Design Inc. (QDI), a small Hong Kong-based PC motherboard manufacturer. With market know-how from Daw, financial capital from China Technology, and manufacturing capacity from QDI, Legend was able to increase its sales revenue quickly through production of motherboards and Legend's PCs. In 1989, Legend submitted its brand of PCs for the technical test administered by the Torch Program[107] and thus gained permission to manufacture in Mainland China. (Zhu, 2000)

In the third period of its development (1994-1997), corresponding to the **filtration stage**, Legend focused on marketing its own brand PC. During the early- and mid-1990s, with an exploding domestic demand for PCs, international PC products, capital, and services all entered the Chinese market. Furthermore, the PC technology of China's market

[106] The cooperation between Legend and AST ended in 1995 when Samsung acquired AST.
[107] This is an important program sponsored by the National Science and Technology Committee, see detail in Chapter 7.

lagged behind the U.S. market by only one or two months, significantly shorter than before the 1990s when it was as much as ten months behind. With capital accumulated over the past decade, a strong presence in the international motherboard market, and experience in distribution networks and after-sale services, Legend quickly established itself as the number one producer in the domestic market and has maintained leadership since 1996 (Zhu, 2000).

During Legend's fourth development period (1997-present), China's PC industry entered the **globalization stage**; Legend advanced itself to become the leading manufacturer in the Asia-Pacific market. Meanwhile, Legend went through a progression of organizational and operational restructuring to upgrade itself to a modern enterprise. For instance, it established a stock-option program for the founders, a rare practice at the time for domestic companies. Further, Legend introduced younger managers, who later became the central force of the company. Most outstanding, in September 1998 Legend took over its parent–Institute of Computer Technology–and reformed it as Legend's central research institute. (Lu, 2000; Zhu, 2000; Xu, 2002)

Similar to Legend, Founder and Great Wall developed their firms through the four stages. The following sections review their early histories in the preparation stage in order to examine how they gained momentum through development of their own technologies that distinguished them from their many competitors at the time.

Founder at the Preparation Stage

Founder was established at Peking University[108] with an investment of RMB 400,000 in the summer of 1985 as an enterprise affiliated with the university.[109] The company was named "Peking Like New Technology Company" (Like) and was led by one professor from Peking University–Lou Binglong. Its first product was the Huaguang Electronic-Publishing System, a commercialized version of the Chinese-language electronic-publishing system invented by Professor Wang Xuan. (Lu 2000; Xu, 2000; Xu 2002)

In May 1987, with an investment of RMB 1.2 million from a "peasant entrepreneur,"[110] another university-affiliated company–Beida New Technology Service Company (Beida) was established to trade PCs. Because of the high profit, more funding soon became available to enable Beida to trade PCs, including Jingshan-brand Super PCs, on a larger scale. In 1988, Like and Beida were merged into the Beida New Technology Company (New Tech) and renamed in 1993 to the Peking University Founder Group Company. New Tech began distributing a Chinese-language add-on card (Beida Super Card). It became one of the four best-known Chinese-language add-on cards[111] and generated profits for Founder of more than RMB 100 million from 1988 to 1995. (Lu 2000; Xu, 2000; Xu 2002)

[108] Peking University is also called Beijing University.
[109] In March 1984, seven professors at Peking University proposed that the university establish an enterprise.
[110] Fu Hongjiang of Yuyuantan Village, a Beijing suburban government.
[111] The other three best-known Chinese-language add-on cards are Juren, Wangma, and Legend.

Founder PC

Before Founder started manufacturing its own PCs in 1995, Founder had acted as a sales agent for several foreign-brand PCs since 1992 and became the main distributor of Digital Equipment Corporation (DEC) brand PCs in 1993. Utilizing its skills in PC marketing, sales-network development, and after-sale services that were built through agent sales, Founder started to design, manufacture, and market its own brand PCs and monitors in December 1995. From second quarter 1999, Founder has been listed as one of the ten largest PC manufacturers in the Asia-Pacific region, and the second-largest PC manufacturer in China's market.

Currently, the PC division of Founder has about 1500 employees. Founder's PC sales have grown tremendously within the seven short years since Founder entered the market. Reviewing Founder's PCs, three products distinguish themselves. Founder's *ZhuoYue 98* computer was the first domestic PC that "bundled with the Internet", i.e., this kind of PC has Internet services set up at the time the consumer purchases it. After *ZhuoYue 98*, several companies learned from Founder and designed internet-bundled PCs. When Founder's *ZhuoYue 3000* computer entered the market in 1999, its keyboard had added several function keys. *ZhuoYue A+* entered the market in June 2002 and attracted consumers with its black-color design motif. In addition, because CD-ROM drives break easily, customers find it useful that this product's CD-ROM drive can be easily added on or taken off. (Interviewee # 25, 2003)

Great Wall at the Preparation Stage

Great Wall, a state-owned and state-run company, was founded in December 1986 to commercialize GW 0520 CH, a domestically designed and manufactured IBM-compatible PC. As early as 1983, the Ministry of Electronic Industry (MEI) organized an annual nationwide conference on PC development. At this conference, the country's computer experts agreed to adopt the IBM standard in China and identified that the biggest hurdle to domestic PC development was to build a Chinese-language processing system. Yan Yuanchao, a technician who worked for the Sixth Research Institute of MEI, participated in the project and developed the Chinese Character Disk Operating System (CCDOS), software that could input and display Chinese characters. Yan further proposed a Chinese-language add-on card to save the memory required by the software. In 1984, the first Chinese-language add-on card, Great Wall (GW) 0140 card, was developed. (Lu, 2000; Xu, 2002)

In June 1985, Great Wall's 0520CH PC (GW 0520 CH), the first domestically designed and manufactured IBM-compatible PC, was exhibited. In addition to its better performance than IBM PCs or NEC PCs in areas of monitor technology and compatibility, the computer amazed the audience with its Chinese language processing capability provided by the GW 0140 card.[112] On December 12, 1986, with an investment

[112] Since the start of GW 0140 cards, several other companies entered the Chinese-language add-on card business, such as Legend, Founder, and Juren, who developed Legend cards, Super Card, and Juren Cards, respectively.

of RMB 3 million from the MEI, China Computer Development Company (CCDC), the predecessor of Great Wall, was founded to commercialize the technology of GW 0520 CH. Wang Zhi, the deputy chief of the Computer Industry Administration Bureau of MEI, was named general manager of the company. Great Wall thus started to commercialize the PC initially developed inside the MEI's research institute. (Lu, 2000)

8.3 The Role of the Government

The Ministry of Information Industry (MII) has been the chief government party that set policies for the computer industry. MII plans China's information infrastructure, develops its national computer policies, and licenses government supported companies. In addition to the computer industry, MII also supervise China's telecom-equipment industry. Because the convergence of computer and telecommunications in the last two decades, the State Council combined the Ministry of Electronic Industry (MEI) and the Ministry of Posts and Telecommunications (MPT) into MII to avoid conflicts between the two ministries on a number of issues (Caroll, 1998). Dedrick and Kraemer (1998) pointed out that this change eliminated bureaucratic competition that could paralyze the policies, as seen in Japan and Korea.

To develop China's PC industry, MII has two different sets of policies for foreign and domestic firms: for foreign firms, aiming at leveraging access to China's market in exchange for technology and investment; for domestic firms, stimulating their growth through regulation and subsidies (Kraemer and Dedrick, 2001). During the1980s and the early 1990s, several MNCs started to set up operations in China in response to China's invitation to help develop its PC industry (Tale 8.4). As a prerequisite for granting production licenses and market access, the Chinese government required MNCs to transfer technology and form alliances with domestic companies. Thus, MNCs such as HP, Toshiba, and Compaq formed joint ventures with local companies; IBM, for example, formed five joint ventures with Great Wall in order to market its own products and gain access to local distributional channels in China's rising computer market. (Lu, 2000)

The Chinese government took several steps to give domestic firms time to establish themselves: discouragement of import, encouragement of export, and obstacles to foreign firms (Kramer and Dedrick, 2001). The government imposed high tariffs and taxes to discourage direct import in the growth stage of development; for instance, the tariff was 82% in 1992. It encouraged exports by creating "export processing zones" where imported materials used in production would be free from duties and taxes when the resulting products were directly exported. Furthermore, it slowed the entry of foreign firms and increased their costs through a rigorous certification process encompassing quality, local content, and export limits. (Kraemer and Dedrick, 2001)

However, intervention from the government mostly occurred at the earlier stages of the industry. The government made China's PC market more open to foreign producers as the industry moved to the filtration stage--it reduced tariffs, from 82% in 1992 to 35% in 1993, and again to 15% in 2000 (Kraemer and Dedrick, 2001; Xu, 2002). Domestic firms by that time had gained the ability to compete with the MNCs.

Overall, the government's policy towards domestic computer companies was largely indirect. The industry was affected by government policies intended to reform state enterprises: separating politics from enterprise management, converting from military enterprises to civilian production companies, commercializing research results, and forming joint ventures with foreign firms. (Kraemer and Dedrick, 2001)

Even though there were few government interventions, leading PC manufacturers have benefited from the support of affiliated government institutes. The institutes initialized and facilitated domestic firms' growth by providing them with access to the technologies developed by state R&D institutions. Legend and Founder are closely affiliated with the Chinese Academy of Sciences and Peking University. Great Wall's initial PC was developed inside MEI research institutes. As a spin-off from MEI's research institute, it is evident that Great Wall has gained strong support from MEI for its growth and cooperation with IBM. These companies have had easy access to their parent institutes' resources-technical expertise, financial support, and the well-respected reputations of the institutes. However, these affiliations also had disadvantages. Little autonomy and too much intervention from the supporting institutes have hampered the ability of the companies to operate as modern enterprises and make rational business decisions in response to the market. Eventually, all three companies have realized such problems and started various degrees of restructuring to resolve the problem.

Of the three companies discussed in this chapter, Great Wall has gained the most government support since its establishment. With his family background[113] and his extensive government experience in the Computer Bureau, the company's first president, Wang Zhi, was able to access considerable government support. Other top managers of the company were also able to do so.[114] Great Wall enjoyed privileges provided by the government, such as access to institutional buyers[115] and loans from state-owned banks,[116] and connections with top multinational companies (Xu 2002). These privileges were not available to other companies, such as Legend and Founder. Because of Great Wall's associations with the government, many foreign corporations, such as IBM, Microsoft, and DEC, formed joint projects with the enterprise (Great Wall's website, 2002).

The close connection with the government brought privileges for Great Wall (GW) but also problems. Great Wall had to sacrifice some autonomy in exchange for these privileges; the firm was asked to maintain a certain level of local content in its PCs, sometimes from particular factories. In the late 1980s, GW-brand PCs were composed of roughly 50% locally produced components, most of which had serious quality

[113] Wang Zhi is the third son of Wang Zhen, one of the most powerful politicians in China in the 1980s.
[114] For instance, Lu Ming, who later became CEO of Great Wall, was the son of a well-known general in the People's Liberation Army (PLA).
[115] In the late 1980s and earlier 1990s, the government usually required the institutional buyers, who needed quotas from the government, to buy only GW 0520 CH PCs. (Xu, 2002).
[116] For instance, Great Wall obtained a loan of RMB 287 million to expand its Shenzhen operation in December 1992. This project is the only major project listed in the national Eighth Five-Year Plan for PC manufacturing.

problems. This poor quality hindered the development of the company. Great Wall tried to resolve the problems by seeking foreign cooperation and internalizing the production of components.

In addition, the nature of state-ownership and running of the firm brought a negative effect: ineffective management. The high-profit margin of its PC business at the time permitted the firm to ignore the issue. Compared with other companies, such as Legend and Founder, Great Wall had less marketing and after-sale services. (Xu, 2002)

8.4 Chapter Conclusion

I have examined the development of China's PC industry and explained that domestic firms have caught up with MNCs through a catching-up process that can be described by the four distinct stages of the staged catching-up theory: preparation stage (early 1980s to late 1980s), growth stage (late 1980s to early 1990s), filtration stage (early 1990s to middle/late 1990s), and globalization stage (middle/late 1990s to present, i.e., 2002). The evolution of China's market, domestic and foreign brand market shares, revenue, and employment data, and the individual development histories of Legend, Founder, and Great Wall, all have confirmed that China's PC manufacturing industry has gone through the preparation, growth, and filtration stages and is now at the beginning of the globalization stage.

Although there are no detailed data available to analyze how effective these policies were in slowing foreign producers' progress in China's PC market, the window of opportunity provided by the government certainly helped domestic firms to grow at the earlier stages. More importantly, it seems that the support from affiliated government institutes provided needed knowledge-based assets to fertilize the growth of leading domestic firms and thus pushed the industry transit from the preparation stage to the growth stage. I will study this in more detail in the next chapter.

The government's policies towards domestic computer companies were largely indirect and China's PC market has been quite open since the early 1990s. The openness of the market triggered China's PC industry to move from growth stage to the filtration stage. If Chinese domestic firms were incompetent at the time, they might have been wiped out from the market. In fact, that happened to many domestic firms at the time. However, several large domestic firms competed with the MNCs intensely, and they not only survived the battle but rose to become leaders afterwards. What has made these firms succeed in their competition with the MNCs? The next chapter studies the role the cause of leading domestic producers' competitiveness--innovation—has played in their development.

9 Innovation Capability of the Leading PC Manufacturers

Like with telecom-equipment manufacturers, innovation capability and self-developed technologies have allowed Chinese domestic firms to catch up with the MNCs in the PC industry. In this chapter, I analyze the role of innovation, channels to acquire it, and the role of the government during the catching-up, focusing on three leading firms, namely, Legend, Founder, and Great Wall.

I have organized the chapter as follows: I first investigate the role that innovation has played in the development of leading domestic firms in Section 9.1. In Section 9.2, I study two major channels for leading domestic firms to acquire innovation capability: in-house R&D development and external alliance, as well as technology transfer through the joint ventures of one particular company, Great Wall. In Section 9.3, I further explore the factors, such as the government involvement, network clustering, disintegration of the global value chain, and sub-sector linkages, that have enhanced the building of innovation capability of these firms. I present concluding remarks in Section 9.4.

9.1 The Role of Innovation Capability

Earlier, I have shown that China's PC industry has successfully gone through the preparation, growth, and filtration stages, and has entered the globalization stage. What has driven the industry to upgrade itself through the stages and especially what has made leading firms succeed in competition against the MNCs? My study has demonstrated that, for leading domestic PC manufacturers, innovation capability and self-developed technologies have been the key to catching up with the MNCs. This session presents the regression analyses of the top 10 PC producers in China and examples on how these companies have built their competitiveness through innovation capability.

9.1.1 Innovation Capability in Catching-up

Strength in innovation capability and self-developed technology has determined who the leading domestic firms are in the PC industry. Table 9.1 illustrates a close relationship between industrial leadership ranking and the innovation capability ranking of domestic PC producers.[117] Corresponding to the dominant position of domestic producers in terms of market share, eight of the top ten PC producers in China are domestic (Table 9.1).

[117] I rank company's leadership in PC industry by their sales revenue in PC products. I build my own innovation capability ranking in the following way: Similar to the telecom-equipment industry, I asked my interviewees to rank top domestic PC firms in terms of their innovation capability. Based on the ranking, I built an aggregate rank index for innovation capability, taking R&D input and R&D output of these companies into account. The R&D input mainly refers to firms' R&D spending as a percentage of revenue. The R&D output includes indicators such as the number of patents held by the company, participation in the national S&T program, and evaluation by their peers.

Meanwhile, Legend, Founder, and Tongfang lead in both industry and innovation capability.

The computer hardware industry is less R&D intensive than the telecom-equipment industry. In general, computer manufacturers spend significantly less than telecom equipment manufacturers. For instance, in 2002, global computer giants such as IBM, HP, and Apple each spent between 6.2% and 8.2% of their revenue in R&D, while telecom-equipment manufacturers generally spent 10%-20% of their revenue in R&D.

Nevertheless, my study shows that the stronger the innovation capability a domestic PC producer has, the stronger its leading position in the industry. The only exception is Great Wall. Great Wall, even though listed as the third place in terms of production, ranks low in its innovation capacity. Great Wall spent only 0.4% of its revenue in R&D, significantly lower than any other domestic PC producers. The fact that Great Wall's profit was quoted as 1.5%, significantly lower than Legend (3.6%) and Founder (4%) in 2001, indicates that Great Wall is not as competitive as its sales revenue implies. Therefore, if industrial leadership also means competitiveness rather than the size of the sales, Great Wall's industrial leadership should be discounted.

Table 9.1 Top Ten Producers in PC Industry: Leadership and Innovation Capacity

Company Name 单位名称	Ownership	Rank in PC Industry	Rank in Electronic Industry	Rank in Innovation Capacity
Legend Computer Group Corporation 联想控股有限公司	Domestic	1	3	3
Peking University Founder Group Corporation 北京北大方正集团公司	Domestic	2	10	1
China Great Wall Computer Corporation 中国长城计算机集团公司	Joint Venture (IBM)	3	7	8
Dell Computer (China) Co., Ltd. 戴尔计算机（中国）有限公司	MNC (Dell)	4	n.a.	n.a.
Trigem Computer (Shenyang) Co., Ltd. 三宝电脑（沈阳）有限公司	MNC (Trigem)	5	n.a.	n.a.
Tsinghua Tongfang Co., Ltd. 清华同方股份有限公司	Domestic	6	19	2
Langchao Electronic Information Industrial Group Corp. 浪潮集团有限公司	Domestic	7	20	4
TCL Holding Co., Ltd. TCL 集团有限公司	Domestic	8	6	6
Guangzhou Qixi Computer Holding Co., Ltd. 广州七喜电脑股份有限公司	Domestic	9	50	7
Hisense Group Co. 海信集团有限公司	Domestic	10	8	5

Note:
1. Great Wall established five joint ventures with IBM from 1995 to 2000 to produce a wide range of computer components and provide computer services. By 2000, Great Wall had received $100 million in investment from IBM.
2. Dell Computer established its China Customer Center in 1998 in Xiamen, Fujian Province in P. R. China. Dell is well known for its low R&D Spending. It spends around 1.5% of revenue in R&D in 2000. (CAHNERS RESEARCH; EUROPEAN ELECTRONICS MARKETS FORECASTS -- Electronic Business, 8/1/2001).
3. Trigem Computer (Shenyang) Co., Ltd was established in 1999 in Shenyang by Trigem Computer Co., Ltd as a wholly owned subsidiary.
4. Unlike other PC manufacturers listed here, TCL and Hisense have a diverse range of electronic products. PC only occupies a small portion of their revenue, as shown by their leading ranking in electronic industry.
5. Evaluation for Great Wall is based on 2001's data.
6. Hisense's R&D as % of revenue is based on 2001 data.
7. For detailed information see Table 9.4 in Appendix.
Source:

Gao Sumei (MII). 2003. "2002 China PC Production and Sale Analysis." Website: http://www.mii.gov.cn.
MII. April 2002. "2002 Top 100 Chinese Electronic Companies" Website: http://www.mii.gov.cn.
MII. April 2001. "2001 Top 100 Chinese Electronic Companies" Website: http://www.mii.gov.cn.
Great Wall website, www.greatwall.com.cn; Dell China Website, www.dell.com.cn; Trigem (Shenyang) website, www.tg-sy.com; Qixi website: www.hedy.com.cn.
State Intellectual Property Office of P.R. China, website: www.sipo.gov.cn.

9.1.2 Regression Results on Innovation Capability

In the appendix of this chapter, I adopt the linear regression model to investigate the relationship between "Leadership in the PC Industry" (dependent variable, Y) and "Rank in Innovation Capability" (independent variable, X). Appendix 9.1 displays more detailed information on innovation capability of the top 10 PC producers. Appendix 9.2 illustrates the regression analysis results using the data of the leading domestic PC producers, excluding Great Wall for the reason noted above. The model is significant, with an R^2 value at 0.76 and the actual rank in the PC industry of each data point is quite close to the predict rank by the model (Figure 9.1), which indicates a strong explanatory power of innovation capability to leadership in the PC industry.

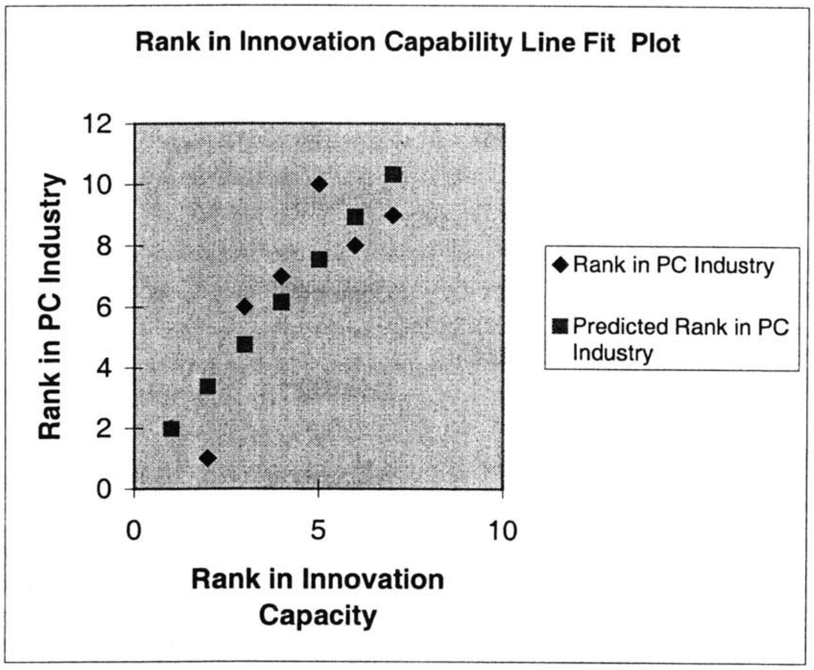


Figure 9.1 Rank in PC Industry vs. Rank in Innovation Capability Line Fit Plot

I further investigate the relationship between "Rank in Innovation Capability" and "R&D Spending" in Appendix 9.3. With an R^2 value at 0.46 and the line plot illustrated by Figure 9.2, it confirms that "R&D Spending" is quite relevant in explaining ranks in innovation capability.

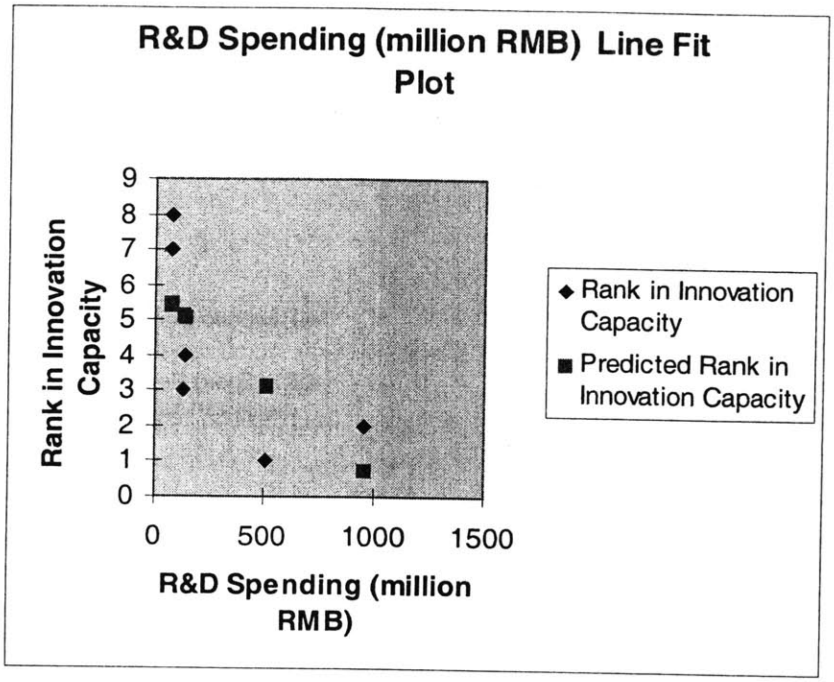


Figure 9.2 Rank in Innovation Capability vs. R&D Spending Line Fit Plot

In Appendix 9.4, I examine the relationship between "Revenue" and "R&D Spending" of domestic PC producers. The result shows that the model is significant with a high R^2 value at 0.82 and a very nice line plot (Figure 9.3). Analysis in Appendix 9.3 and 9.4 demonstrate that "R&D Spending" plays a significant role in explaining the innovation capability and leadership of the domestic firms in the industry.

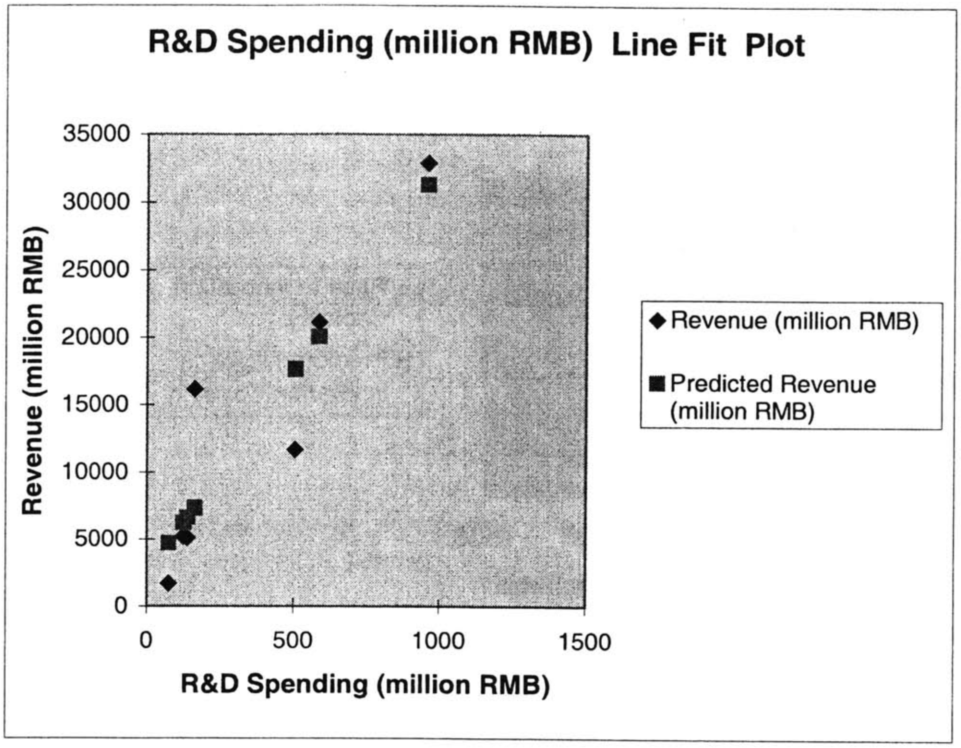


Figure 9.3 Revenue vs. R&D Spending Line Fit Plot

The development histories of the leading PC companies and their key products is perhaps more intuitive than the numbers in revealing the causal relationship of innovation capability to industrial leadership. Therefore, in addition to the above simple regression analysis, I give examples showing how innovation has positively affected the development of leading domestic firms (Legend and Founder) throughout their entire development history. I demonstrate that during the earlier years (late 1980s and early 1990s), innovation made Great Wall the industrial leader of domestic PC manufacturers. In Section 9.2, I explore Great Wall's declining innovation capability and competitiveness and its choice of forming a joint venture with IBM.

First, all three PC manufacturers of this research started their companies with innovation and self-developed technology. Legend's first product was a self-developed Chinese-language add-on card. Great Wall started with its GW0140 Chinese language add-on card and the first domestic PC, GW 0520 CH PC. Founder, on the other hand, started by commercializing its innovation of fourth generation digital publishing technology. There were many companies manufacturing Chinese language add-on cards at the time, but only a few finally won the market with their high quality products. This implies that technological innovation is the key for these companies to start gaining an advantage over other firms, since a company's technological innovation capability was reflected by the ability to make a high-quality Chinese language add-on card. Specifically, Founder, led by scientist Wang Xuan, directly leapfrogged to develop the most advanced generation (the fourth generation) of modern typesetting technology for electronic publishing systems while most of the world still worked with third-generation electronic publishing systems. Interestingly, each technological innovation involved some kind of Chinese characteristic that might discourage an MNC from making efforts to develop it. I consider the existence of such opportunities critical to create room for these companies to grow in the first place.

As an industry, PC manufacturing requires less R&D input than the telecom-equipment industry. Nevertheless, domestic PC producers have gained market share by making PCs with the most technologically advanced components rather than keeping one or two cycles behind to seek only a low-cost advantage. For instance, in the middle 1990s, Legend stirred a market war by advertising its most advanced PC with a reasonable price for Chinese customers. Through its continuing R&D effort, Founder had been able to keep its monopoly position for about a decade in electronic publishing and its other core business areas. The experience of these Chinese PC manufacturers indicates that innovation capability and self-developed technology have been key factors in catching-up.

9.1.3 Founder: Ji-Gong-Mao and Leapfrogging by Innovation

Founder has characterized its development as *Ji-Gong-Mao* (*Technology–Manufacturing–Trade*), i.e., develop a key technology first, build its manufacturing capacity, and then establish distribution channel(s) for it.[118] Innovation and self-developed technology have played vital roles throughout the history of Founder's development. When the company was just established, the innovative fourth-generation electronic- typesetting technology, based on Wang Xuan's Huaguang model, built a solid foundation for Founder as a leader in the electronic publishing industry. In August 1990, the company launched China's first long-distance satellite newspaper page transmission system (Founder, 2002). In 1993, the Founder-93 Color Electronic Publishing System was developed. The continuous innovation and development of electronic publishing systems enabled Founder to remain a leader in the PC business. Founder's later movement to Gong (manufacturing) and Mao (trade) was based on the commercialization of its Ji (R&D) results.

As mentioned earlier, Founder's leapfrogging by innovation can be best illustrated by its development of fourth-generation electronic- typesetting technology, which started as a government-funded project in the 1970s. At the time, while other industrialized countries developed computer technology rapidly, China was trapped in its "cultural revolution." China resumed its contact with the West after the visits of President Nixon and the Japanese president in 1972. The government realized that China was far behind in computer technology, and was urgently intent on developing the technologies that could input and output the complicated Chinese characters to overcome this hurdle to development. In August 1974, a project aimed at Chinese-language information

[118] The "Ji-Gong-Mao" characteristic is in direct contrast with Legend's "Mao-Gong-Ji," which will be discussed later.

processing technology and digital typesetting, *Project 748*, was initiated.[119] In addition to the most fundamental Chinese-language phototypesetting, the project included two other sub-projects: Chinese-language information database technology and long-distance Chinese-language information transmission technology. At the time, newspapers in China still used the traditional lead type method to typeset pages – manually organizing thousands of Chinese characters laboriously.

The key person on *Project 748* was Wang Xuan, a professor at Peking University.[120] After studying three generations of modern typesetting technologies,[121] Wang Xuan decided to leapfrog directly to the most advanced fourth-generation technology of modern typesetting. In 1976, Wang Xuan invented a mathematical system that could resolve the problem of storing Chinese characters. The system compresses the font information significantly, because it categorizes Chinese characters by breaking each character into several separate strokes. In October 1978, Peking University and Shandong Weifang Computer Corporation (Weifang) signed a contract to jointly develop an electronic publishing system based on Wang's method; Weifang would produce the hardware and be in charge of sales and after-sale services. (Lu, 2000)

From 1979 to 1987, Wang and the research team developed four improved systems of the fourth-generation modern typesetting technology and the series were named "Huaguang." In July 1979, Wang and his colleagues and engineers from Weifang completed a prototype of the fourth-generation Chinese typesetting system, Huaguang I.[122] In September 1983, Huaguang II, an improved system, was tested. In September 1986, Huaguang III, the first commercialized product, and one that uses an imported microcomputer and a new version of Raster Image Processing System (RIP), was completed and passed its test operation. In early 1987, Wang Xuan designed Huaguang IV, a smaller and faster system based on large-screen typesetting technology and the personal computer. (Lu, 2000)

The leapfrogging from second-generation to fourth-generation modern typesetting technology helped China to regain the market share for domestic electronic typesetting.

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119 Five agencies jointly proposed *Project 748*: the Fourth Ministry of Machine Industry, the First Ministry of Machine Industry, the Chinese Academy of Sciences, the Xinhua News Agency, and the State Bureau of Publishing Affairs Administration.

120 After learning of Project 748 through his wife, in 1975, Wang Xuan submitted a proposal, titled "Regular and Non-Regular Strokes, Shapes, and Parameters – Chinese-Language Compression Methods," to the University for participating in Project 748. Wang Xuan participated in building China's earliest mainframe computers and studied Chinese-character input methods.

121 The first-generation modern typesetting technology was based on manual phototypesetters and the second-generation uses phototypesetter machines to provide fonts of characters on filmstrips. Both generations of technology were invented by U.S. entrepreneurs in the 1940s and 1950s. The third-generation system was invented by Germans in 1965; representations of characters were formed by raster imaging on high-resolution cathode ray tubes (CRTs) (Account drawn from Brailsford, 1988).

122 Dissatisfied with Weifang's poor quality control and after-sale services, Peking University decide to let New Tech (Founder's predecessor) produce and sell a Founder series of the Huaguang system, Founder Electronic Publishing Systems (Founder EPS) at the end of 1988, while Weifang still produced and sold under the name of Huaguang.

Because of the advanced technology and lower unit price[123] of the Huaguang systems, foreign laser-typesetting companies had all exited China's market by the end of 1989. In 1999, Founder EPS enjoyed an 80% share of China's publishing market. (Lu, 2000)

9.1.4 Legend: Mao-Gong-Ji and Technology Failure?

Many analysts have used *Mao-Gong-Ji* (*Marketing–Manufacturing–Technology*, i.e., first focusing on marketing, then manufacturing, then technology development) to describe Legend's growth (Xu, 2002). Legend started as a sales agent to accumulate experience in distribution and management. Afterwards, Legend built its manufacturing capacity and its brand-name products.

Although I agree that marketing and manufacturing capabilities were crucial, I disagree that Legend has placed them first, while ignoring the importance of technology development in its history. From the very beginning, Legend distinguished itself from many other PC companies at the time by its first product–the Legend Chinese add-on card, which was developed by ICT scientists. It was this product that attracted the attention of international PC manufacturers, who later asked Legend to be their distributor. Furthermore, Legend accumulated its capital at the initial stages through services provided by Legend's employees, who were mostly ICT scientists and research staff. It was the knowledge of these people that served customers and built the good reputation of Legend. In this sense, the technology brought the opportunity for Legend's development of other capabilities. Legend had the advantage of technological capability over other computer companies at the time; it seemed more determined to develop other capabilities that were needed by the company, such as sensitivity to the market.

Some have argued that technology has sometimes encumbered, rather than facilitated, the company's development (Xu, 2002). For instance, even Liu Chuanzhi, the company's founder and number one person, once said, "technology has failed sometimes"(Xu, 2002). The minimization of the role of technology development comes from the conflict between company management and R&D forces when the R&D direction does not reflect the market need. Is this a technology failure or a management disappointment?

In my opinion, market-led technology development is the primary reason for Legend's success. From the first product, Legend's Chinese add-on card, to the Legend-brand PC, to Internet-bundled PCs, Legend was creative and swift to follow the market's lead. Using advanced technology rather than imitating others was their key strategy to gaining industrial leadership. Therefore, it is unfair to say that technology sometimes fails the company. The right choice of technology and the right direction of technology development matter most. The management team of Legend has a deep understanding of the market as well as of the technology. This gives them the advantage in making the smart choice as the market develops.

[123] For instance, Huaguang III was sold at RMB 1.8 million (approximately $0.22 million), while a Chinese-language electronic publishing system made by HTS Corporation of the U.S. sold at $ 4.3 million.

9.1.5 Great Wall: First Domestic PC and the Great Wall Model

The early success of Great Wall was closely associated with the first domestically designed IBM-compatible PC "GW 0520 CH" and with the pioneering vision of Wang Zhi, known as "the Great Wall Model." As described earlier, Great Wall was established in 1986 to commercialize the "GW 0520 CH" computer. Without the innovation and self-developed technology--"GW 0520 CH" -- it would have been impossible for the company to establish and get a head start. Wang Zhi, on the other hand, played an essential role in making the company grow in its own way. As the deputy director and an engineer, Wang Zhi considered building China's domestic PC sector as early as 1983. During his participation in negotiations with multinational companies, such as IBM and Microsoft, he realized that market-oriented operation is critical for a company's development.

Wang Zhi has exercised three innovative methods, which became well known as the "Great Wall Model." First, to obtain better quality, Wang Zhi employed a bidding method in manufacturing "GW 0520 CH" PCs. Second, to establish a distribution network, Wang Zhi adopted IBM's "dealer distribution" model, which was drastically different from the "integrated buy-and-sell" model used by state-owned enterprises at the time. In the 1990s Great Wall improved its distribution networks by creating a chain of principal distributors who provided products to secondary distributors, who in turn sell those PCs to end-users. This distribution system helped to bring about Great Wall's market success and prompted IBM to withdraw its IBM 5550 PCs from the local market. Third, to differentiate Great Wall products from clone PCs, the company set up specialty shops. With all these efforts, Great Wall became one of the best-known brand names in the domestic market only one year after its birth. From 1986 to 1994, Great Wall remained the largest domestic PC producer in China. (Xu, 2002)

9.2 Channels for Acquiring Innovation capability

Computer manufacturer leadership is closely related to innovation capability. For instance, two PC industrial leaders, Founder and Legend, are listed as first and second in terms of innovation capability; especially Founder, who has been listed by the government as one of the first six national level pioneer enterprises engaged in innovative technologies. How have they achieved their innovation capability? Why has Great Wall not achieved a similar level of innovation capability in later stages? I investigate the two main channels through which firms build their innovation capability: in-house R&D and external alliance. I also study why joint venture experience with IBM has been unsuccessful as a channel for Great Wall to build their innovation capability.

9.2.1 Internal Development

Though data for MNCs' R&D spending in China is not all available, it is most likely that MNCs will spend a very small portion of revenue on R&D, assuming their spending pattern is similar to the MNCs in the telecom-equipment industry in China. Among the ten top PC manufacturers, domestic firms generally spend a larger percentage of their revenue in R&D than MNCs or firms with joint ventures, such as Great Wall and Dell China (Table 9.4). For instance, Legend and Founder each spent 2.9% and 4.3% of revenue in R&D in 2002, while Great Wall spent only 0.4%. This level of R&D spending is slightly lower than most of the global leaders, such as IBM, HP, and Apple, which spent 6.2%, 6.5%, and 8.2% of their revenue, respectively, in R&D in 2002. But it is higher than Dell, who spent only 1.5% of revenue in R&D in 2002.

In addition to their R&D spending, Legend and Founder also set up R&D centers engaged in technology advancement. For instance, Legend set up Legend R&D Institute in 1999 and later developed a two-tier R&D system, which includes 47 R&D labs. Legend had over one thousand R&D staff and started to construct Legend Beijing R&D Mansion in 2002.

Table 9.2 Founder's Corporation Technology Centers

Institute	Main Activities
Founder R&D Center	the most important R&D base for Founder, mainly responsible for Founder's general media-related R&D directions, new product development, and R&D resource accumulation; has two State-level Research Laboratories in Text Processing and Electronic Publishing System; the world's most distinctive R&D base for Chinese electronic publishing systems; one of the world's major research bases for multi-language electronic publishing systems; more than 400 researchers, half of whom have master's or doctoral degrees.
Founder Information Technology Institute	developed the soup-to-nuts computer and server products; more than 100 researchers, most of whom have master's or doctoral degrees
Founder Information Product Institute	DSP development and application, network products (modem, graphical terminal, workstation, WBT, router, hub, network card, etc.), display products (CRT monitor, LCD monitor), office automation and teaching equipment (projector, teaching PC), and other high-tech application products (Anti-Fake Tax Controller, Note Processor).
Founder Lanthanide Technology Institute	R&D in lanthanide technology; world leader in separation technology of lanthanide and functional materials

Source: Founder's website as in January 2003.

Founder, corresponding to its first position in innovation capability, evidently has a larger R&D department compared to other high-tech companies in China. As one of the first six national-level pioneer enterprises engaged in innovative technologies, Founder has established a Corporation Technology Center that consists of Founder R&D Center, Founder Fingerprint Technology Institute, Founder Information Technology Institute, Founder Information Products Institute, and Founder Lanthanide Technology Institute.

These R&D centers conduct R&D activities in media technology (electronic publishing), computer, network technology, and new material technology (see Table 9.2).

Founder has insisted on developing its own intellectual property for more than 10 years. Currently, Founder has 1000 software engineers devoted to software development. It leads the world in technologies such as Chinese word processing and fingerprint recognition. The Founder Software Base was included in the National Torch Project.

9.2.2 External Alliance

Though it is difficult to say whether or not the affiliated relationship is really external to the companies studied here, affiliations have been critical to support companies' innovative activities at their earlier stages. Legend, Founder, and Great Wall all have a technologically oriented entity as their founding organization; namely, the Institute of Computing Technology of Chinese Academy of Science, Peking University, and Ministry of Electronic Industry, respectively. These institutes provide rich soil for these companies to grow.

The technical expertise gained from the institutes has become part of the companies' initial innovative capabilities. For instance, because of the affiliated relationship, Peking University played a vital role in providing R&D resources to Founder, especially through its Institute of Computer Science and Technology. It provided technologies, such as Founder EPS in 1988 and the core technology[124] for Founder-93 Color EPS in 1993. It also helped in launching the long-distance satellite newspaper-page transmission system mentioned above, and also an integrated newspaper management network in 1994. In July 1995, Founder R&D Center was established as a result of merging the research institute and company, so that the R&D achievements of the institute would stay inside the company.

Furthermore, all the companies studied here have strategic alliances or R&D partners in various areas, domestically or internationally, especially in the areas of their core competence or where they intend to build their competence. This phenomenon indicates that strategic alliance seems to be an effective way to keep up with cutting-edge developments and to quickly ramp up companies' technological capabilities. For instance, as the market leader in the Chinese and Asia-Pacific PC industry, Legend has actively partnered with world-class leaders in various technology areas. It has strong working relationships with Intel and Microsoft. It has established joint ventures with Computer Associates and D-Link for software and networking products in China. Legend has established joint laboratories with National Semiconductor and Texas Instruments to use its partners' strengths to develop Internet appliances and other networking products. (Table 9.3)

[124] A dual-processor solution that increased the speed of character generation and improved the quality of color images relative to traditional electronic color separators.

Table 9.3 Legend's Technological Partnership

Partner	Nature of Relationship
Intel	Strong working relationship
Microsoft	Strong working relationship
Computer Associates	A joint venture by Legend and Computer Associates to develop software for the China Market
D-Link	Joint venture capitalized at $10m in which Legend holds 57% and the remainder is held by D-Link to design, manufacture, and distribute networking products for the China market
IBM	A strategic alliance with IBM to customize and distribute IBM software products to China
National Semiconductor	A jointly established laboratory by Legend and National Semiconductor to develop internet appliances, such as set top boxes and thin clients.
Texas Instruments	A jointly established Digital Signal Processing laboratory by Legend and Texas Instruments to develop products, such as the ADSL modem.

Source: Legend website, as of January, 2003.

9.2.3 Technology Transfer through Joint Ventures

Great Wall and IBM set up five joint ventures from 1994 to 2000. The joint ventures' products and services ranged from IBM and Great Wall PC manufacturing, to circuit-card assembling, magnetic-resistant head gimbal assembling (for IBM's hard disk drives and electronic components), to computer-leasing services. By 2000, Great Wall had received $100 million in investment from IBM. With the help of IBM's financial capital and manufacturing experience, Great Wall has transformed itself from a pure PC manufacturer to a leader in PC component manufacturing and an IT giant (in terms of revenue) with a wide range of businesses. (Xu, 2002)

Great Wall had very low internal investment in R&D; for instance, it invested RMB 71.34 million in 2001, only 0.4% of its sales revenue, much lower than Legend and Founder (3.0% and 4.5% respectively). It is not clear how much the joint ventures have contributed to the development of Great Wall's R&D capability. However, it seems that instead of being an independent domestic PC manufacturer in design and development, Great Wall became a low-value-added manufacturing site in IBM's global value chain.

9.3 Factors Affecting Improving Innovation Capability

Through my case studies, I have confirmed that government involvement in accumulating knowledge-based assets is crucial for the improvement of innovation capability of domestic PC manufacturing firms. It has helped to build a positive feedback system that rewards companies' efforts in building innovation capability and developing proprietary technologies. The positive feedback system for innovation capability is composed of network clustering of R&D functions, disintegration of the global value chain, and sub-sector linkage.

As discussed in Section 8.3, unlike the telecom-equipment industry, the government's policy towards domestic computer companies has been largely indirect. PC manufacturing was treated as part of the general enterprise reform. However, at the early stages of development, sustenance from their affiliated state-owned research institutes provided knowledge-based assets needed for the growth of Legend, Founder, and Great Wall. At later stages, national S&T programs such as the "Torch Program" and "863 Plan" (details of these programs can be found in Chapter 6) encouraged the improvement of R&D capabilities of domestic PC manufacturers.

Studies of this chapter confirm that Beijing, particularly the ZhongGuanCun area, is the favorite location for R&D functions; this is shown by the fact that Legend and Founder have both located their R&D headquarters in ZhongGuanCun, where CAS and Peking University, their affiliated state institutions, reside. At the same time, they have chosen various locations for their manufacturing. For instance, Legend has chosen Shanghai, Beijing, Huiyang (Guangdong Province), and Xiamen (Fujian Province) as its manufacturing base for PCs, various computer products, and cell phones. They have a well-developed sales network covering both domestic and overseas markets. Legend has a regional platform or sales office in most of China's provincial capital cities, as well as several overseas branches in the United States, United Kingdom, Holland, France, Germany, Spain, and Austria.

As discussed earlier, the computer industry is increasingly taking the form of configurational technologies because of modular design and the use of the open standards of the IBM PC architecture. The new industrial organization that was pioneered by the global PC industry is based on horizontal specialization rather than vertical integration. Therefore, firms compete by specializing in a horizontal industry segment, rather than by extending vertically. This trend towards disintegration of the global value chain has made innovation in specific areas possible for domestic PC manufacturers. The major Chinese PC manufacturers have been able to focus on building their strength in specific areas, such as sales, distribution, and customer relationships, as well as innovation capability, by using available configurational technologies and acquiring decreasing-cost components from international suppliers.

Moreover, I find that Legend, Founder, and Great Wall have diversified into various sub-sectors of the industry through linkages between those sub-sectors (Table 8.6). For instance, Legend started with agent sales and language add-on cards, diversified into motherboard production in 1987, PC manufacturing in 1990, system integration, network products, internet portal, and wireless data from the middle to the end of 1990s. Founder, on the other hand, embarked on the electronic publishing system in 1985, and then moved to Chinese language add-on cards and PC distribution in late 1980s and early 1990s. It began PC manufacturing, along with system integration and Internet software in 1995, and later on set up an on-line bookstore. Great Wall started with China's first domestic PC in 1984 and diversified itself to a broad range of business-PC monitors, other PC components, distribution, and magnetic heads and hard disks in 1995. It later entered into system integration and network products in 1999. It needs to stress that the linkages between different sub-sectors can make diversification easy only when one has developed its own proprietary technology in one of the sub-sectors.

9.4 Chapter Conclusion

This chapter reveals that innovation capability and self-developed technologies have been the key for leading domestic PC producers to catch up with the MNCs. Innovation capability is a strong factor in the current leadership position of Legend and Founder and the earlier leading position of Great Wall. All three firms started with some technological innovation after their establishment. This fact is contrary to the popular categorization of these PC manufacturers, which labels Legend and Founder as "Mao-Gong-Ji" and "Ji-Gong-Mao," respectively. There were many companies manufacturing Chinese language add-on cards at the time, but Great Wall and Legend and a few others finally won the market of Chinese language add-on cards with their high-quality products because of their strength in innovation capability. So did Founder, who leapfrogged to the fourth-generation technology of modern typesetting.

Legend and Founder have built their innovation capability mainly through in-house R&D, supplemented with external alliances. Moreover, my research reveals that reliance on joint ventures, as a means to build innovation capabilities, seems to have been ineffective for Great Wall.

This chapter also demonstrates that, even though government involvement is mostly indirect for PC manufacturers, sustenance from their affiliated state-owned research institutes at the early stages of development, along with other national S&T programs, played a vital role in the growth of Legend, Founder, and Great Wall. The Chinese government's involvement helped these companies to build their innovation capability and develop proprietary technologies through a positive feedback system composed of network clustering of companies' R&D functions, the trend of disintegration of the global value chain of the computer industry, and sub-sector linkages shown by the companies' fast diversification into other sub-sectors.

Chapter 9 Appendix - Regression Analysis

A 9.1 Top Ten PC Producers in China, Innovation Capability

Table 9.4 Top Ten Producers in PC Industry: Innovation Capability Analysis

Company Name 单位名称	Ownership	Rank in PC Industry	Rank in Electronic Industry	Rank in Innovation Capability	Revenue (million RMB)	R&D Spending (million RMB)	R&D Spending (% of Revenue)	Patent
Legend Computer Group Corporation 联想控股有限公司	Domestic	1	3	3	32876.58	961.46	2.9%	112
Peking University Founder Group Corporation 北京北大方正集团公司	Domestic	2	10	1	11662.97	505.59	4.3%	7
China Great Wall Computer Corporation 中国长城计算机集团公司	Joint Venture (IBM)	3	7	8	16228.03	71.34	0.4%	5
Dell Computer (China) Co., Ltd. 戴尔计算机（中国）有限公司	MNC (Dell)	4	n.a.	n.a.	n.a.	n.a.	<1.5%	n.a.
Trigem Computer (Shenyang) Co., Ltd. 三宝电脑（沈阳）有限公司	MNC (Trigem)	5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tsinghua Tongfang Co., Ltd. 清华同方股份有限公司	Domestic	6	19	2	5228.35	125.89	2.4%	37
Langchao Electronic Information Industrial Group Corp. 浪潮集团有限公司	Domestic	7	20	4	5103.27	139.12	2.7%	8
TCL Holding Co., Ltd. TCL 集团有限公司	Domestic	8	6	6	21111.96	586.00	2.8%	40
Guangzhou Qixi Computer Holding Co., Ltd. 广州七喜电脑股份有限公司	Domestic	9	50	7	1711.60	75.00	4.4%	n.a.
Hisense Group Co. 海信集团有限公司	Domestic	10	8	5	16157.33	163.53	2.1%	54

Note:
1. Great Wall established five joint ventures with IBM from 1995 to 2000 to produce a wide range of computer components and provide computer services. By 2000, Great Wall had received $100 million in investment from IBM.
2. Dell Computer established it China Customer Center in 1998 in Xiamen, Fujian Province in P. R. China. Dell is well known for its low R&D spending. It spent around 1.5% of revenue in R&D in 2000. (CAHNERS RESEARCH; EUROPEAN ELECTRONICS MARKETS FORECASTS -- Electronic Business, 8/1/2001).
3. Trigem Computer (Shenyang) Co., Ltd was established in 1999 in Shenyang by Trigem Computer Co., Ltd as a wholly-owned subsidiary.
4. Unlike other PC manufacturers listed here, TCL and Hisense have a diverse range of electronic products. PC only occupies a small portion of their revenue, as shown by their leading ranking in the electronic industry.
5. Evaluation for Great Wall is based on 2001's data.
6. Hisense's R&D as % of revenue is based on 2001 data.

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MII. April 2001. "2001 Top 100 Chinese Electronic Companies" Website: http://www.mii.gov.cn.
Great Wall website, www.greatwall.com.cn; Dell China Website, www.dell.com.cn; Trigem (Shenyang) website, www.tg-sy.com; Qixi website: www.hedy.com.cn.
State Intellectual Property Office of P.R. China, website: www.sipo.gov.cn.

A 9.2 Regression Results, Leadership and Innovation Capability

Companies	**Rank in PC Industry**	**Rank in Innovation Capability**
Legend	1	2
Founder	2	1
Tongfang	6	3
Langchao	7	4
TCL	8	6
Qi Xi	9	7
Hisense	10	5

Regression Statistics	
Multiple R	0.8755758
R Square	0.7666331
Adjusted R Square	0.7199597
Standard Error	1.8185552
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	54.321429	54.321429	16.425486	0.009798
Residual	5	16.535714	3.3071429		
Total	6	70.857143			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.5714286	1.5369596	0.3717915	0.7252838	-3.3794455	4.5223026	-3.3794455	4.5223026
Rank in Innovation Capacity	1.3928571	0.3436746	4.0528368	0.009798	0.5094148	2.2762994	0.5094148	2.2762994

A 9.3 Regression Results, Innovation Capability and R&D Spending

Companies	**Rank in Innovation Capacity**	**R&D Spending (million RMB)**
Legend	2	961.46
Founder	1	505.59
Tongfang	3	125.89
Langchao	4	139.12
Qi Xi	7	75
Great Wall	8	71.34

Regression Statistics	
Multiple R	0.6767644
R Square	0.45801
Adjusted R Square	0.3225125
Standard Error	2.2938656
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	17.786055	17.786055	3.3802101	0.1398359
Residual	4	21.047278	5.2618195		
Total	5	38.833333			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.8197983	1.2982501	4.482802	0.0109662	2.2152706	9.4243259	2.2152706	9.4243259
R&D Spending (million RMB)	-0.0052804	0.0028721	-1.8385348	0.1398359	-0.0132547	0.0026938	-0.0132547	0.0026938

A 9.4 Regression Results, Revenue and R&D Spending

(1) Not including Great Wall

Companies	**Revenue (million RMB)**	**R&D Spending (million RMB)**
Legend	32876.58	961.46
Founder	11662.97	505.59
Tongfang	5228.35	125.89
Langchao	5103.27	139.12
TCL	21111.96	586
Qi Xi	1711.6	75
Hisense	16157.33	163.53
Great Wall	16228.03	71.34

Regression Statistics	
Multiple R	0.9063502
R Square	0.8214707
Adjusted R Square	0.7857648
Standard Error	5076.1746
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	592823796	592823796	23.006605	0.0048987
Residual	5	128837741	25767548		
Total	6	721661537			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2438.6528	2985.0679	0.8169505	0.4511123	-5234.6959	10112.001	-5234.6959	10112.001
R&D Spending (million RMB)	30.032774	6.2613674	4.7965201	0.0048987	13.937443	46.128105	13.937443	46.128105

(2) Including Great Wall

Regression Statistics	
Multiple R	0.8228459
R Square	0.6770754
Adjusted R Square	0.6232546
Standard Error	6262.1913
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	493332571	493332571	12.580188	0.012118
Residual	6	235290242	39215040		
Total	7	728622813			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5237.0175	3267.4381	1.6027901	0.1601014	-2758.1214	13232.156	-2758.1214	13232.156
R&D Spending (million RMB)	25.945878	7.3151764	3.546856	0.012118	8.0462727	43.845483	8.0462727	43.845483

10 Case Analysis for Cell-Phone Manufacturers

Gaining from near zero percent to 30% of domestic market share, Chinese domestic cell-phone manufacturers have grown rapidly during the last three to four years. Instead of a detailed analysis as for the telecom-equipment and PC manufacturers, in this chapter, I focus on using the staged catching-up theory to analyze the development of main domestic cell-phone manufacturers in the growth stage and their future in the filtration stage. Domestic cell-phone producers have gone through the preparation and growth stage, and just entered the filtration stage at the end of 2002.

Before starting the case analyses of the five selected domestic cell phone manufacturers in China, I introduce both the global and China's domestic cell-phone markets in Sections 10.1 and 10.2. From Section 10.3 to 10.7, I present the brief history of these five cell-phone manufacturers, namely, TCL, Haier, Hisense, Eastcom, and Panda Electronics, review their entry to the cell phone market, compare their competition strategies, and analyze the relationship between innovation capability, growth and the long-term sustainability of these firm. I present concluding remarks in Section 10.8.

10.1 Global Cell-Phone Market

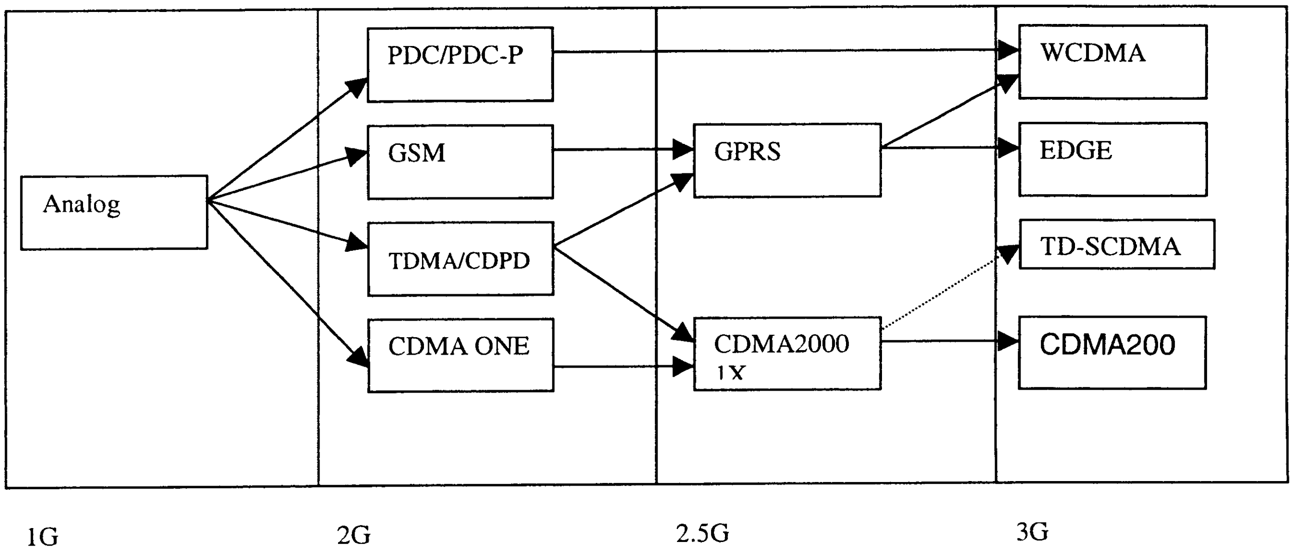
In order to understand the global cell-phone market, it is important to comprehend the evolution of mobile systems. Therefore, I start this section by introducing three generations of mobile systems. Then I examine the demand and supply of the global and China's cell-phone markets. At the end of this section, I will focus on analyzing the third generation mobile communications systems (3G) market.

Evolution of Mobile Systems

Since the start of mobile communications, mobile systems have experienced evolution through three generations, as shown in Figure 10.1. The first generation (1G) is analog mobile systems. The second-generation (2G) uses digital technology and includes four different standards. Three of the 2G standards have developed into two systems: General Packet Radio Service (GPRS) and Code Division Multiple Access (CDMA) 2000 1X, which we call 2.5G, a generation in between 2G and third-generation mobile systems (3G). Currently, Global System for Mobile Communications (GSM, 2G standard) and GPRS are used in most European countries, while CDMA One (2G standard) and CDMA 2000 1X are used in North America. Three dominant 3G standards are: Wideband CDMA (WCDMA), CDMA 2000 1XEV, and Time Division Synchronous Code Division Multiple Access (TD-SCDMA), a new standard that was developed jointly by the Chinese Academy of Telecommunications Technology (DTT) and Siemens. (For details of TD-SCDMA, please refer to Chapter 7.)

Each standard segment of a mobile system includes base transceiver stations (BTS), base station controllers (BSC), and mobile switching centers (MSC) as equipment for service providers. In addition to this equipment, each standard has a corresponding mobile handset for end users.

Figure 10.1 The Evolution of Mobile Systems



Source: adapted from Ericsson[125]*, 2001.*
Note: I added TD-SCDMA to the source figure.
G= generation.

Demand for Mobile Communications Systems

In 2002, mobile-handset subscribers world-wide totaled about one billion in number, including 650 million GSM and 120 million CDMA users, with China and the United States as the leading markets, followed by Japan, Germany, Italy, the United Kingdom, France, South Korea, Spain, and Brazil, as the 3rd to the 10th largest markets, respectively. China was the largest cellular market with about 170 million mobile subscribers.[126] With a population of 1.3 billion, China's cell phone market was far from saturation, compared with other large markets, especially the other leading cell phone markets, for instance, the United States, which was the second largest. With 137 million subscribers and a population of 280 million, the U.S. subscription rate is already close to 50% (Table 10.1).

[125] http://www.ericsson.com/annual_report/2001/eng/br/leading.shtml as of Oct. 28, 2002.
[126] The latest statistics shows that there was 1.3 billion global mobile phone users at the end of June 2003. China had 200 million and US had 140 million. (http://www.cellular.co.za/stats/stats-main.htm, as of July 2003)

Table 10.1World's Largest Mobile Markets

Country	Subscribers (millions)
China	170
United States	137
Japan	70.2
Germany	64.4
Italy	47
United Kingdom	45
France	34
South Korea	32
Spain	28
Brazil	27

Source: Summarized from various sources (www.umtsworld.com/industry/marketshare.htm as of Oct. 28,2002

Supply of Mobil Communications Systems

In the market for mobile handsets, Nokia has maintained a large lead (around 35% of market share), primarily because GSM subscribers are the majority of the customers in the mobile handset market (Table 10.2.) Motorola follows with a 15% market share, less than half of Nokia's. Following Nokia and Motorola, Samsung, Siemens, and Sony/Ericsson round out the top five in the worldwide market.

Moving away from the traditional integration of production, R&D, and marketing by cell-phone manufacturers, the cell-phone industry is heading towards a high division of these functions among different companies. Experts have described the global value chain of the cell phone as "chip design in Europe, whole cell-phone design in Korea, and production in China." For instance, Ericsson announced in January 2001 that from April 1st, 2001, Ericsson will subcontract production and sales to Flextronics and will concentrate on technology development, design, brand expansion, marketing, and after-sale services.

Table 10.2 Global Markets for Mobile Handset, 2001, Q1& Q2 of 2002

Company	2001	Q1 2002	Q2 2002
Nokia	35.6%	34.7%	35.6%
Motorola	10.0%	15.5%	15.7%
Samsung	7.5%	9.6%	9.5%
Siemens	7.4%	8.8%	8.4%
Sony/Ericsson	7.3%	6.4%	5.3%
Others	32.2%	25.0%	25.5%
Total (in million units)	399.5	93.8	98.7

Source: Gartener Dataquest.
summarized from http://www.umtsworld.com/industry/marketshare.htm as of Oct.29, 2002.

Third-Generation, Mobile-Communications Standard (3G)

WCDMA, CDMA 2000, and TD-SCDMA are the three main competing standards of third-generation systems. The WCDMA standard was developed in Europe; the CDMA 2000 standard was developed by Qualcomm of the United States; and the TD-SCDMA was developed by Datang Telecommunications of China. To support their own companies and decrease the cost of transition , countries choose a 3G standard mostly corresponding to the 2G standard that they are currently using. For instance, 15 countries in the European Union, Japan, and other countries using GSM generally support WCDMA, while the USA, South Korea, and other countries with the CDMA standard generally support CDMA 2000.

As Table 7.4 of Chapter 7 indicates, WCDMA leads CDMA 2000 and TD-SCDMA in terms of R&D staff, R&D investment, and number of supporting firms. Even though Nippon Telegraph and Telephone Corporation (NTT) DoCoMo[127] had the only 3G WCDMA commercial network by the end of 2002, the market for WCDMA mobile equipment has already been contested (see Table 10.3). Ericsson and Nokia are two distinct leaders in terms of market share. Siemens has claimed that it would become the second largest 3G vendor, even though currently it has only 15% of the market share. Siemens has focused in Asia by cooperating with NEC and by conducting R&D with Chinese companies, for instance, Datang. Meanwhile, Lucent has sold WCDMA to Japan and Germany.

Table 10.3 WCDMA equipment sale volume market share (late 2001)

Company	Share
Ericsson	33%
Nokia	32%
Siemens (NEC)	15%
Nortel	8%
NEC (Siemens)	4%
Alcatel	4%
Lucent	3%
Motorola	1%

Source: Gartener Dataquest.
summarized from http://www.umtsworld.com/industry/marketshare.htm as of Oct.29, 2002.

At the end of 2002, six countries and fifteen telecommunications service providers have begun using CDMA networks. Motorola has been the most successful manufacturer in the CDMA 2000 market. In Japan and South Korea, many CDMA cell phones have

[127] NTT DoCoMo is the world's leading mobile communications company with more than 44 million subscribers, as of October 2002, and sales of 5.1 trillion yen (consolidated, Japanese GAAP) in fiscal year 2001 (ended March 31, 2002). DoCoMo was formed in July 1992 to take over the mobile communications operations and sales of Nippon Telegraph and Telephone Corporation (NTT DoComo, 2003).

appeared in the market as a result of support from cell-phone producers. Services on 3G networks have been accepted by users. For instance, KDDI of Japan started a CDMA 2000 1X network on April 1st, 2002, and obtained over one million subscribers by June 2002, quickly surpassing the number of subscribers of NTT DoCoMo, which had started its WCDMA network 8 months before KDDI (CEN, 2002a). New services, such as instant pictures and geographic positioning (using GPS), have attracted users. In South Korea, over 7 million people subscribed to CDMA 2000 1X in 2002. The combination of support from the government and a strong industrial alliance of SK Telecommunications as a service provider and Samsung and LG as CDMA equipment manufacturers has put South Korea ahead of other countries in mobile communications (CEN. 2002a).

In May 2000, IEEE announced acceptance of TD-SCDMA, submitted by Datang, as one of the third-generation mobile communications standards. This Chinese 3G standard has been at the center of attention since then. I provide details of TD-SCDMA and its developer, Datang, in Chapter 7.

China's 3G market has an estimated value of RMB 1000 billion. Commercializing WCDMA or CDMA 2000 in China would mean more patent fees would be paid by China. In 2002, China operated both GSM/GPRS and CDMA networks and the government was testing the three main 3G standards, i.e., WCDMA, CDMA 20001X, and TD-SCDMA. Whether or not TD-SCDMA will be accepted by service providers is still unclear. [128] Equipment manufacturers are currently developing their equipment for multiple standards to increase their chance of market success in the future (Communication World, 2002).

10.2 China's Cell Phone Market

Before 1999, China's domestic cell phone production appeared in only MNCs' subsidiaries and a few domestic firms, such as Motorola, Nokia, Eastcom, and Panda Electronics. I call this period the "preparation stage" of China's cell-phone industry. The Chinese government announced "State Council Document No. 5" in 1999 as a means to control foreign production and to stimulate domestic cell-phone production. Within only four years (1999-2002), domestic firms expanded their market share from 3% to close to 30%. I call these four years the growth stage of China's cell phone industry, since it has the main characteristics of the growth stage described by the staged catching-up theory: increasing demand and supply of the market, high profit for producers, the growth of domestic producers in different market segments of the industry, etc. At the end of 2002, over 30 cell-phone producers existed in China. As domestic firms' market share expanded, production capacity has been increasing faster than demand; domestic firms are starting to compete more directly with the MNCs in the local market. I view this as a sign of entering the filtration stage when the market starts to saturate, fierce competition happens, and some incompetent producers are forced out of the market.

[128] China Mobile and China Unicom, two mobile service providers who have 3G licenses, will most likely use WCDMA and CDMA 2000. It is estimated that the government will require China Telecom to use TD-SCDMA in exchange for its 3G license (www.Chinanex.com, June 2003).

Document No. 5

The Chinese government's role in the development of China's cell-phone industry could be best reflected by "Document No. 5", an official statement from the government for supporting the domestic cell-phone industry in 1999.

Before 1999, the Chinese government put few constraints on the field of R&D, manufacturing, and marketing of cell phones. Lou PeiDe, an official of MII, said, "with such a high-tech product, we would encourage anyone who would like to try"(Financial Biweekly, 2002a, p. 82). At the time, cell phones were luxury goods for only a few rich people. The R&D- and capital-intensive nature of the cell phone had made it the domain of only a few MNCs, such as Motorola, Nokia, and Ericsson, and had kept domestic producers away. However, as the economy developed quickly in the 1990s, more people, especially those in business, were eager to own a cell phone for its convenience. Further, because of the long wait to get their land-based phone connected, many customers would rather choose a cell phone as their communication tool. From 1992 to 1997, the number of cell-phone subscribers in China increased from 179,000 to 13.23 million. Foreign cell-phone producers dominated this large market. The government was surprised at the rapid growth of the market and started to think about "how to support domestic producers, constrain foreign producers, and let the domestic producer grow" (Finance, 2002, p. 82). In this context, in 1999, the State Council announced "Comments on facilitating development of China's mobile communications industry," also called State Council Document No. 5. One of the drafters explained that the document was intended to constrain foreign producers in China's cell-phone market. (Finance, 2002a)

Document No. 5 indicated that the government would financially support the domestic development of mobile communications. The government would use 5% of the fixed-line phone installation fee for R&D and production of domestic mobile systems and cell phones. This is partially a special fund established by MII for supporting industrial R&D in the telecom-equipment industry, which is about 3 billion RMB per year. 40% will go to supporting R&D within the mobile communications industry (Smith-Gillespie, 2001). In addition, it would allocate RMB 1.4 billion of the national debt to developing domestic cell phones. Meanwhile, to constrain foreign manufacturers' production, foreign producers would need to meet three requirements: (1) they must establish an R&D center in China; (2) the ratio of products for the domestic market to products for export should be less than 4:6, i.e., foreign producers in China should export at least 60% of their cell phones; (3) localization, i.e., foreign producers would be required to use local suppliers' products for certain components.

The most important element of the document is the license distribution. The document announced that the setting-up of wholly owned subsidiaries and joint ventures would be controlled by the central government. Anyone (foreign or domestic producers) involved in production of cell phones, or importing of equipment and components would need to get a permit from the central government. Cell-phone production is listed as a controlled category in the "Foreign Investment Industry Catalog." At the end of 1999, MII designated 8 joint ventures and 9 domestic producers[129] as the first group of cell-phone producers, measured by criteria such as capacities in R&D and manufacturing.

Domestic Producers

Domestic producers started manufacturing mobile handsets much later than the MNCs and were far behind the foreign producers led by Motorola, Nokia, and Ericsson. However, their progress has been astonishing. From holding 3% of the domestic market share in 1999 to nearly 30% at the end of 2002, domestic firms have progressed dramatically within four short years (Tables 10.4). In 2002, Nokia, Motorola, and TCL are the three leading cell-phone producers in China's market. In the appendix of this chapter, Tables A10.1 and A10.2 give a detail account of leaders in sales (measured by units) in 2001. Though Nokia and Motorola still kept their first and second positions in terms of sales in 2002, the other leaders in 2001, such as Siemens, Ericsson, and Panda Electronics, were surpassed by TCL in 2002, and domestic producers' market share doubled from 15% in 2001 to 30% in 2002.[130]

Table 10.4 Market Share of Chinese Domestic Cell-Phone Producer

Year	1997	1998	1999	2000	2001	H1 20002	Q3 20002	2002
Domestic share	n.a	0%	3%	10%	15%	18%	26%	30%
Total (million units)	n.a	n.a	n.a	n.a	79.23	n.a	n.a	n.a
Total subscribers (million	13.23	n.a	43.23	n.a	n.a	n.a	n.a.	170

Source: various.

In the following sections, I will examine five of these firms, namely TCL, Haier, Hisense, Eastcom, and Panda Electronics (see Table 10.5). I have chosen these five companies as my cases according to the criteria that I set in the methodology section (Chapter 5), i.e., if they are the major players in the industry and have had great impact in the industry. Table 10.5 summarizes the main characteristics of these five companies in terms of cell-phone production. I devote the rest of the chapter to revealing the relationship between innovation capability, growth, and a firm's long-term sustainability by analyzing how leading cell-phone producers, such as TCL, Haier, and Hisense, have built up their innovation capability during the process of growth, and how other former leaders, such as Eastcom and PEG, were discouraged to do so because of their cooperation with MNCs. In the appendix, Table 10.8 gives a brief introduction of the products and services of these five companies, since most of them devote only a small portion of their business to cell-phone production.

[129] The nine domestic producers are: Xiahua Electronics, Eastcom, ZTE, Konka, Haier, Southern High-tech, Bird, China Kejian, and TCL.

[130] The following additional facts also illustrate that domestic handsets are on their way to gaining market share: (1) Shengzhen Guowei's cellular phone HB97's outlook and quality have reached international standards and are being exported to European countries; (2) ZTE has developed a domestic dual-frequency cellular phone; (3) Eastcom's EC528 has obtained domestic and foreign certification and licenses.

Table 10.5 Major Domestic Cell-Phone Manufacturers Characteristics

Cell-phone Manufacturers	Cell-production Characteristics
TCL Holding Co., Ltd. TCL集团有限公司	Largest domestic cell-phone producer in 2002, "partial technological innovation with Chinese characteristics", innovative concept of using cell-phone as a decorative good rather than just a communication tool
Haier Group Co. 海尔集团公司	2nd largest electronics company in China, leading in innovation by satisfying customers' need first (developing low radiation phone, phone with firewall function, etc), very distinguished 24-hour continuous development model that uses its &D resources in China, US, and Europe, expanding in global market
Hisense Group Co. 海信集团有限公司	Well-known for its heavy R&D investment, started cell phone production in 2001, but progressed fast, introduced the first color screen CDMA phone in China
Eastern Communications Group Co. Ltd. 东方通信有限公司	Started production in 1990, cell-phone production as its main business, joint venture with Motorola since 1994, problem of creating its own brand-name phone
Panda Electronics Group Co., Ltd 熊猫电子集团有限公司	Pioneer in Cell-phone production, joint venture with Ericsson started producing analog cell phone in 1994, lack of motivation for innovation and developing its own brand-name

Source: The author, summarized from 10.3 to 10.7.

10.3 TCL Holding Co., Ltd (TCL)

Established in 1981 with only RMB 5,000 in Huiyang, Guangdong, TCL is now a large-scale state-owned enterprise whose business covers four categories: consumer electronics, telecommunications, information appliances, and electrical components. TCL has experienced substantial growth since its founding date and has maintained a 50% annual growth rate during the past 10 years. In 2001, TCL generated sales revenue of RMB 21.1 billion, with a profit of RMB 715 million.[131] (TCL, 2002)

TCL Mobile

[131] TCL brand value (the total sales value for the products with "TCL" brand name) was RMB 14.4 billion, listed as No. 5 domestically.

The Chinese people first started to recognize the TCL brand name through its telephones. It has been called the "King of the Telephone" because its market share in the land-based phone market has stayed No. 1 since 1988. TCL entered the cell-phone market because of the large profit margin of the cell phone in the late 1990s as the company was looking for new growth opportunity in electronics (Interview #3, 2003). TCL started to enter mobile communications in March 1999 by setting up TCL Mobile Communications Co., Ltd. (TCL Mobile), after TCL obtained a license from MII for producing cell phones. (TCL, 2002)

In 2002, TCL produced over 6 million TCL brand cell phones and was the champion among domestic producers, trailing only Motorola and Nokia. Cell-phone production brought TCL Mobile US $1 billion sales revenue, which accounts for one-fourth of the sales revenue of the total TCL Group and two-thirds of its profit. Of its 2500 employees, TCL Mobile has about 2100 marketing staff, 300 R&D staff, and 100 management staff. In addition, the company has 4000 manufacturing workers. (Interviewee #3, 2003)

What was the secret of TCL Mobile to champion domestic producers in 2002? I would argue that TCL has distinguished itself from other domestic producers by successfully applying the principle of "partial technological innovation with Chinese characteristics" in developing its cell-phone products. Their innovative conceptualization of the cell phone as a decorative good rather than a simple communications tool is such an example. The history of TCL mobile also indicates that the nature of the cell phone as a consumer product means that marketing and appearance of the product play a much more important role than for telecom equipment.

R&D

TCL Mobile has followed the principle of "partial technological innovation with Chinese characteristics" to gain a technological advantage, i.e., TCL has tried to lead only certain aspects of technology and develop products that suit the Chinese consumer. For instance, out of a dozen patents of TCL Mobile, most of them are for design of appearance. In regard to key technologies, TCL realizes that the cell-phone chip is very standardized nowadays, and is not something TCL can become proficient at in a short time. TCL regards systems integration, i.e., how to add application software to the chip, as proprietary technology, and sometimes does its own systems integration, while at other times cooperating with others, for instance, Ericsson. (Interviewee #3, 2003)

TCL understands that the cell phone business requires much more R&D input than its other business segments. Every year, TCL Mobile devotes 5% of its revenue to R&D, higher than the 3% R&D spending of revenue of the TCL Group in general (CEN, 2002b). The company has a TCL Mobile Communication Research Institute, which is composed of over a dozen Ph.D.'s and Master's degree holders. It has an overseas R&D center in Silicon Valley in the United States. In 1998 TCL established a technology center that was honored as a state-class R&D center in January 2000.

The Cell Phone as Jewelry

TCL's success is closely associated with its innovative concept of cell phones as decorative goods rather than just communication tools. The first popular TCL cell phone, TCL 999D, was a diamond cell phone and attracted great attention when it came on the market in 2000. The uniqueness of the cell phone was that its cover was decorated with diamonds. The CEO of TCL Mobile, Dr. Wan Mingjian, observed that some people like to buy expensive watches, such as Rolex, not just for the function of a watch but also for its appearance. As the company was exploring ways of defining TCL cell-phone products, the phenomenon stimulated his imagination: the cell phone could attract customers by its appearance, just like those watches. Wan discussed the idea with other managers and they agreed that this concept would appeal to Chinese consumers, especially those who would like to demonstrate their financial success. (Interviewee #3, 2003)

10.4 Haier Group (Haier)

Haier Group was incorporated in 1984 as the Qingdao Refrigerator Factory.[132] With 30,000 employees, this large state-owned enterprise produces a wide range of household electrical appliances in 86 categories and with 13,000 specifications. The domestic market share of Haier refrigerators, freezers, air conditioners, and washing machines is 30%. Haier operates 18 design institutes, along with 10 industrial complexes (including one in the United States and one in Pakistan).[133] In 2001 its sales revenue reached RMB 60.2 billion. Haier products also have a significant presence in the international market: Haier ranks as the world's fifth largest manufacturer of white electronic goods, and it has the largest global market share in refrigerators. (Haier, 2002)

Cell Phones

Haier entered the cell-phone market in 1999 by establishing Qingdao Haier Mobile Communications Co., Ltd. It obtained licenses for producing both GSM and CDMA cell phones. The following describes the major milestones that Haier has achieved in its cell-phone development. (Haier, 2002)

- May 2000, Haier became the first producer whose cell phones passed the radiation test in China.
- July 2001, Haier developed the lightest GSM cell phone in the world, which weighed only 69g. In the same month, Haier's PDA and chord ringing cell phone came onto the market.

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[132] In 1984, with RMB 1.47 million debt, Haier had only 800 employees, and produced only one product–refrigerators. Haier's development can be divided into three stages: (1) brand-name stage (1984-1991): building its brand through refrigerators and establishing a comprehensive quality-management system; (2) diversification stage (1992- 1998): diversifing products, expanding market; (3) globalization stage (1998-present): bringing the Haier brand to the international market and expanding both markets and production sites internationally.

[133] The other eight complexes' locations are: 5 in Qingdao, 1 in Hefei, 1 in Dalian, and 1 in Wuhan

- August 2001, Haier announced its "5A Diamond Service Plan", targeting the after-sale service market.
- October 2001, Haier's CDMA cell phone passed the network test of China Unicom.
- May 2002, Haier became the first company to be certified as a 3C enterprise (Consumer Electronics, Communications, Computers) by the government.

The list of the events above implies Haier has led in innovation capability by putting themselves in consumers' shoes-developing products that quench the need of the customers. The first low radiation cell phones, cell phones with the lightest weight in China, and the first cell phones with a fire wall function in China are all such examples. The following illustrates the development of Haier's Tianzhi Star T6000 cell phone, the first cell phone in China with the firewall function.

Tianzhi Star T 6000

In June 2002, Haier developed the first cell phone that has a firewall function for incoming calls, named Tianzhi Star T6000. The user can block calls from ten phone numbers. The firewall function can also be used in reverse: the user can block calls from all other phone numbers except the ten preset phone numbers. In addition to the firewall function, the cell phone has two other new functions: FM radio and mobile QQ (instant messaging for mobile phones). The new functions of the cell phone attracted much customer attention and achieved great market success. (Haier, 2002)

How Haier developed Taizhi Star T6000 is an interesting story. It started with a letter to Haier Information Center from a customer in February 2002. He was bothered by unwanted phone calls at night, but he could not turn off his cell phone because he was on call for his job. He had written to several companies and asked if they could develop a cell phone with a firewall function to filter out unwanted calls, similar to those in computer networks. However, most companies were reluctant to say yes, mainly because of the difficulty involved in developing such a function, the long-development process, and huge investment. After he heard of Haier's development of a washing machine for washing melons, he then wrote to Haier with the same request.

Haier started market research immediately and found that 80% of customers reported being bothered to varying degrees by unwanted calls. This convinced Haier to develop cell phones with this function. Usually it takes two years to develop a new cell-phone product, but Haier decided to develop this product within the shortest possible time and made a 180-day plan. How could Haier achieve such an ambitious, seemingly impossible goal? The secret weapon lay in its 24-hour continuous development model, which had already succeeded in its development of "Network Blue-Tooth Home Electronics." Haier used time differences to combine its R&D resources in Asia, Europe, and the U.S. For instance, the first development team in Asia would pass its results of the day to the second team in Europe through the Internet; then, the second team would continue the development and pass its result of the day to the third team in the United States. The third team would pass the results back to the first team. This way, Haier could achieve 24-hour continuous development. While the whole world was watching the world cup football game, Haier's engineers worked continuously and finally finished development of phones with firewall functions on June 15, 2002.

The development process of T6000 caught the attention of others. One Silicon Valley company heard about Haier's development and realized the market potential of this function. It proposed to add its own new technology-the mobile QQ–to the phone. Similarly, another U.S. company added its FM radio module to T6000. Domestic producers' cell-phone software development mostly depends on foreign technologies. However, a firewall for incoming messages, a technological innovation by Haier, leapt ahead of foreign producers. (Haier, 2002)

Export

In 2001, Haier obtained a license from the British Approvals Board for Telecommunications (BABT) in the United Kingdom and exported 300,000 cell phones to the United Kingdom, leading all other Chinese domestic producers. Haier's unique strategy is called *first difficult, then easy* (*Xian Nan Hou Yi*), which means, enter the market of developed countries first, build one's brand name, then enter the developing countries from a higher position with experience accumulated in the advanced markets. (Interview# 28, 2003) The fact that Haier started to globalize its cell-phone products even though the industry just entered into the filtration stage is related to Haier's global networks for its other businesses, such as refrigerator, microwave, and air conditioning. With the networks built by these businesses, it is easy for Haier to tap into the same foreign markets. Nevertheless, the domestic market still remains the main destination for Haier's cell phones. Thus, for China's cell-phone industry, it seems that there is a blurry boundary between the filtration stage and the globalization stage, as some domestic cell phone producers, such as Haier, already start to export to the international market.

10.5 Hisense Group Corporation (Hisense)

Founded in 1969, Hisense Group Corporation (Hisense) is a large state-owned company located in Qingdao, Shandong Province. With ten thousand employees, this high-tech company specializes in consumer electronics, household appliances, and information technology. With sales revenue of RMB16.1 billion in 2001, Hisense was ranked as one of the "Top 10 Chinese Electronics Manufacturers" in 2000. Hisense's main products include: televisions, air conditioners, refrigerators, computers, DVDs, CDMA mobile phones, software, and network apparatuses. (Hisense, 2003)

Brief History

In December 1969, with only thirty people and a fixed asset worth only RMB 170,000, "Number Two Radio Factory of Qingdao," Hisense's predecessor, was founded to manufacture "Red Lantern" brand radios. Immediately after its establishment, the factory was chosen by the Qingdao city government to develop a black-and-white television. A group of technicians from the company were sent to Tianjin 712 Factory for training, and they developed the first vacuum-tube television with a 14-inch screen in China three months later. Afterwards, through continued efforts of technical innovation, the company replaced the manual mode of production by a mechanical one and developed transistor TV receivers. (Hisense, 2003)

Joined by three other companies, "Number Two Radio Factory of Qingdao" was renamed in February 1979 as "Qingdao Television Factory" to produce televisions. The first take-off of the company occurred in 1985, right after the company imported the technology and equipment for producing color TVs in 1984 from Matsushita of Japan. With RMB 37.48 million, the main economic indicators of the factory took first place among the electronic enterprises of the Province and the TV industry of the country. The second peak of its development came in 1989, when its output capacity surpassed 0.4 million, and it won three successive "domestic firsts" and two international gold awards for its televisions. The factory became one of the 500 largest enterprises and 100 top electronics enterprises in China. (Hisense, 2003)

At the time Zhou Houjian was appointed as the leader of the company in 1992, television was still its dominant product. Under Zhou's strategy of "developing without solely relying on television, and engaging in but not being confined by electronics," the company has carried out a series of radical reforms and expanded quickly in various areas of business since 1993, when the company adopted "Hisense" as its official corporate and brand name. Hisense set up several joint ventures to produce electronic components, cash registers, and other IT and telecommunications products, including Lucent (Qingdao) Technologies Co., Ltd. Worthy of mention is Hisense's principle during the color TV price war that broke out among China's domestic TV manufacturers in October 1996: Zhou announced that Hisense would not reduce its prices to unreasonably low levels, but rather maintain its market share by its high technology, fine quality, and excellent service to its customers. (Hisense, 2003)

R&D

Hisense is well known for its strength in R&D and heavy R&D investment. Hisense's president, Zhou Houjian, once commented that "Haier has advantages in marketing and advertising, while Hisense has advantages in R&D and human resources."[134] Hisense spent 4.7% of sales revenue in 2001 in R&D, while other companies in the electronics industry spent only 3% or less (MII, 2002). [135] Newly developed products account for 30% of the company's turnover. A new product comes out on average every 2.5 days. Of the 10,000 employees in Hisense, 42 hold doctor's degrees, 380 hold master's degrees, and over 4000 hold bachelor's degrees, and many of these are active in various subsidiary-level and central-level R & D areas. In addition to its in-house investment in R&D, Hisense has long-term, technological, cooperative relations with the Chinese Academy of Sciences, prestigious universities (such as Tsinghua University, Beijing University, Beijing Aeronautical Engineering University, Xi'an University of Communications, Shandong University, Qingdao Oceanography University, and Qingdao

[134] *Talk with 100 CEOs (3)*, Gongshang Publish House, 1999, p. 12.
[135] Haier spent 3.8%; Legend 3%, Founder 4.5%, Great Wall 0.4%, Panda 0.5%, TCL 2.5%, etc.

University) and MNCs, such as AT&T, Intel, IBM, Panasonic, Toshiba, Sanyo, HP, and Siemens. (Hisense, 2003)

Hisense has committed itself to a strategy of "developing high technology, producing quality products, providing top-level service, and creating a world-famous brand," which it has implemented by technological innovation, product-line optimization, and capital investments. As an industrial base for the state's "863 Plan," every year Hisense undertakes more than 10 state-level research projects. Hisense has a nationally certified technology center and a national post-doctoral scientific research station. It has also been designated as a National Experimental Unit for Intellectual Property Protection and a National Technology Innovation Base. (Hisense, 2003)

Cell Phones

After entering the cell phone market in 2001, Hisense instantly rose to become the domestic leader in the CDMA market in 2002. The quick ascent of Hisense is associated with Hisense's long tradition as an R&D-focused company. Hisense set up a telecommunications research institute as early as 1993. In 1996 and 1998, Hisense developed its own analog and digital wireless phones. In 1999, assembling about 100 R&D people, Hisense established its Mobile Communications Research Institute and started its R&D on CDMA cell phones. Hisense spent nearly one- fifth of the asset value of its Mobile Communications Corporation on cell-phone R&D. Hisense also obtained financial support from the State Economics and Trade Commission for the CDMA 1X cell phone's development. On August 29, 2001, the government announced that 19 manufacturers (including Hisense) had been assigned CDMA licenses. That same afternoon, Hisense announced the first color screen CDMA cell phone in China. To Hisense, several MNCs have already dominated China's GSM market. However, in the CDMA market, domestic producers are at the same starting point with the MNCs because of the newness of CDMA technology. To some extent, domestic producers may even have some advantages over the MNCs, such as license privilege, close relationship to customers, etc. (Interviewee # 29, 2003)

According to Hisense, in addition to the advantages of knowing local culture and lower production costs, the most crucial thing for a domestic producer is to possess its own cell-phone technology. Based on the principle of technological innovation and developing proprietary technology, Hisense unveiled several CDMA cell phones, such as the C2101 (the first color screen cell phone in China), C628, C520, and C2198, all of them self-developed (Interviewee # 29, 2003). Even though Hisense only entered the cell-phone market in August 2001, with the inauguration of China Unicom's CDMA network, Hisense sold 100,000 units per month in 2002, making it the leader in the CDMA cell-phone market. (Hisense. 2003)

10.6 Eastern Communications Group Co. Ltd. (Eastcom Group)

Eastern Communications Group Co. Ltd. (Eastcom Group) grew out of Hangzhou Communications Equipment Factory, one of the largest mobile communications equipment manufacturers held by the Ministry of Posts and Communications (MPT). By the end of 2001, Eastcom had 2,200 employees and annual sales revenue of RMB 10.5 billion. Eastcom mainly provides products and services related to systems and terminal equipment for mobile communications networks. It has been listed as one of the top 500 industrial companies for the past six years. (Eastcom, 2003)

The company's main revenue (more than 98%) comes from its GSM and CDMA cell-phone production. In addition, the company produces the integrated circuit (IC) calling card, ATM switch, transmission systems and power supplies, etc. Eastcom was the earliest domestic cell phone producer. With more than a decade of experience of cooperation with Motorola, Eastcom is also the largest OEM handset supplier of Motorola brands, accounting for some 15% of Motorola's cell phone output in China.

Early History

In 1958, the predecessor of Eastcom Group, Zhejiang Communications Equipment Factory, was established with only 13 persons. In its earlier days (1960s and 1970s), it had several significant achievements in the communications area and was one of the largest communications equipment factories held by MPT.

In 1988, Shi Juxing became the head of the factory. After extensive market research, the leadership decided to move in a new direction by importing mobile-phone production technology from Motorola. The total number of cell-phone subscribers was estimated by some state bureau to grow to at most 200,000 by the end of the century in China. Although it had a total asset value of only RMB 20 million, the factory would need to invest RMB 40 million for their new market venture. The large investment requirement and the uncertainty of the future made the new direction look very risky. (Eastcom, 2003)

In December 1990 Eastcom signed the first contract with Motorola to import its cell-phone technology. The cell-phone production line was sited in Hangzhou. In July 1991, Eastcom signed a second contract with Motorola to import mobile-phone system-equipment technology, so that they could take advantage of combining the sales of base stations and cell phones. Eastcom achieved sales revenue of RMB 400 million in 1992, ten times its initial investment. (Eastcom, 2003)

Investment Capital and Cooperation with MNCs

Eastcom had a long history of cooperation with Motorola, starting from the early 1990s, both in terms of importing technologies and setting up joint ventures for cell phone related production. In line with the industrial policies of the government, Eastcom borrowed RMB 80 million for importing technologies from Motorola in 1990 and 1991. In 1994, Motorola established joint ventures with Eastcom. In 1995, Eastern Communications Co. Ltd. was established, and the next year the company went public to obtain more investment capital from the market. Going public has transformed the company in many ways. In addition to obtaining investment capital, the company has become more transparent in terms of management and has responded to market needs better. (Eastcom, 2003)

R&D

Eastcom was aware that although it imported the production technology, it was still not controlling the key technologies for cell phone. Therefore, the company needs to develop its own key technology. Since 1990, Eastcom managers have hired over one thousand professionals who have bachelors or higher degrees. Of the total workforce, 70% are professional technicians. Eastcom has several R&D bodies, such as the national-level technology center, Beijing Eastcom S&T Development Company (set up in 1996), a U.S. company, a cell-phone research institute, post-doctoral stations, etc. In 1997, Eastcom set up a cell-phone research institute in Silicon Valley, in the United States. In 1999, Eastcom developed China's first domestic cell phone that had proprietary technology (EC528). By September 2000, Eastcom had sold around 7% of the 65 million cell phones sold in the domestic market up until that time. (Eastcom, 2003)

However, most of Eastcom's cell-phone sales still come from the joint venture set up with Motorola. Eastcom has not established its own brand name in the market. For instance, in 2001, Eastcom produced 5,178,000 units for Motorola, but only 365,700 units under its own brand name, less than 8% of what it produced for Motorola. (See Table 9.5 and 9.6.)

10.7 Panda Electronics Group (PEG)

Founded in 1936, Panda Electronics Group Co., Ltd (PEG) is called the cradle of China's electronics industry (PEG website, 2002). It is the largest electronics backbone enterprise in China.[136] "Panda" brand was the first Chinese electronics product to enter the international market and also the first "well-known brand" of the Chinese electronics industry. With sales revenue of RMB 20.6 billion (profit RMB 950 million), it was ranked by MII as No. 6 among the 100 largest electronics enterprises in China in 2001.[137] PEG was a company directly supervised by MII. (PEG, 2003)

PEG has five national engineering research centers[138] and a postdoctoral scientific research station. It cooperates with 12 large international companies that are among the 500 largest companies in the world and with more than ten prestigious domestic universities and research institutes to jointly develop new products. Every year, Panda's

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[136] PEG is one of the 120 pilot enterprise groups, 512 key enterprises, and six largest groups of electronics industries in China.

[137] PEG's major products cover High Frequency (HF) communication, satellite-communication systems, mobile-communication systems, mecha-electronics production equipment, base stations, program-control exchangers, mobile phones, TV sets, washing machines, DVD players, computers, monitors, system integration, network, software, and radio receivers.

[138] The five centers are: engineering research center for A/V digital products, national technology development center, mass production technology center, micro-electronics technology design center, and engineering research center for mobile satellite communication technology.

revenue from new products is about 80% of the total revenue. Invention patents make up 48% of its total patent applications. (PEG, 2003)

Cell-Phone Production

Panda Communications Industry Group is one of the six largest industry groups of PEG.[139] The group[140] first introduced domestic-brand mobile telephones, pagers, stock pagers, and green mobile phones, all of which were honored as "First Chinese Goods" and "Famous Brand Products China '97."

PEG has a long history of cell phone production and is one of the few who started cell phone production in the early and middle 1990s. This long history, like that of Eastcom, was closely related with its cooperation with Ericsson. PEG entered the area of cell phones in 1990. In 1992 PEG set up a joint venture– Nanjing Ericsson Panda Communications Co., Ltd. [141]–with Ericsson to produce 900GHz analog base station switches. In 1994 this joint venture produced 30,000 analog cell phones. Although earlier than most other domestic producers in terms of entering the analog cell-phone market, PEG was late in digital cell phones–it was not until 1998 that the second joint venture between PEG and Ericsson, Nanjing Ericsson Panda Mobile Terminal Co., Ltd.,[142] was set up to produce two brands of cell phone, Ericsson and Panda. In October 1999 PEG introduced its first digital Panda cell phone to the market. Since then, even though PEG had produced the first Chinese analog cell phone, it has relied on cloning Ericsson cell phones almost completely (Gu, 2002).

The license

Even though PEG was the leader in analog (1G) cell phones, it was not one of the first ten domestic companies who were assigned licenses to produce digital cell phones. PEG was hurt hard in the color TV price war of 1998-99. Because too many suppliers at the time competed in the market, the price of a color TV dropped to below its production cost. TV at the time was one of the major products of PEG; it thus suffered great revenue loss. Over a dozen senior officials of the Ministry of Electronics Industry (MEI) petitioned the central government to help PEG. They requested transformation of PEG's RMB 0.9 billion bad debts to equity, and permission for the company to produce cell phones and other high return products. Panda obtained a cell-phone license and started to produce

[139] PEG has six industrial groups: Household Appliance Industry Group, Military Communication Industry Group, Mechatronics Industry Group, Panda Communication Industry Group, Information Industry Group, New Industry Group.

[140] The group consists of four companies and two R&D centers. Panda International Communication System Co., Ltd is the main body of the group.

[141] The joint venture is to manufacture communication system products including the design, production, sales, and installation of GSM/CDMA digital mobile communication system and switches. The company was incorporated in 1992 and has been authorized by the Ministry of Information as the first Sino-foreign joint venture licensed for access to digital mobile communication system. In 2000 it was honored to be one of the "top 500 foreign invested enterprises" as well as one of the "top 100 high technology enterprises " in China. For the time being it has grown into the supply center of Ericsson in Asia-Pacific Region.

[142] Business scope covers design, production and sales of digital mobile phones and accessories.

cell phones (Finance, 2002a). Cell-phone production turned out to be the new-growth opportunity the company needed as it quickly brought PEG great revenue.

Cooperation with Ericsson and Microcell

The type of cooperation represented by the joint venture of PEG and Ericsson is not rare in the Chinese cell-phone market; other marriages of this sort include Eastcom with Motorola and Shouxin with Nokia. Joint R&D and production, but different brands and marketing are their common characteristics. To avoid competition from their Chinese brands, the foreign partners will delay the products of the domestic brand, leading to shortcomings of the domestic brand, such as weak brand name, fewer types, and longer cycle for new products (Yang, 2002). At the same time, PEG was seen as a production floor for Ericsson cell phones. For instance, in 2001, PEG produced 3.3 million cell phones, but only 0.5 million were under the Panda brand name. The profit from the cell-phone business was mainly from the processing fee of Ericsson cell phones. Consequently, this stable profit source discouraged the company's efforts to develop its own brand name. (Yang, 2002)

Selling 3.47 million mobile phones in 2001, PEG was the first among the domestic producers (see Table 10.7) in terms of quantity.[143] However, in 2002 the pioneer of the analog cell phone fell to seventh. It was companies such as TCL, Bodao, and Xiaxin that have gained large shares.

PEG's easy and stable marriage with Ericsson ended in April 2002, when Ericsson decided to implement its global "efficiency plan" and terminated its cell phone co-production with PEG. Ericsson handed its 65% share of the joint cell phone company to Microcell, a Finnish cell phone designer. Although it was just established in 1997, Microcell is one of the main mobile platform designers in Europe, whose main task is to design cell phones for Nokia and Ericsson, as well as other European cell-phone companies. Microcell does not have its own brand or production base. (Yang, 2002)

The restructuring of Panda Mobile has been described as an upgrade for PEG. The newly established Microcell Panda Mobile Equipment Co. has first-class design technology from Microcell, PEG's low-cost production, and the distribution network of Tianchuang.[144] Their cooperation has formed a complete and potentially strong supply chain from design, to production, to marketing. In 2002, the company's sales reached 1 million units.[145] (Gu, 2002)

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[143] It was No. 5 in the domestic market.

[144] Right before that, Tianchuang[144], the largest cell phone distributor in Jiangsu province joined Panda to establish Panda Mobile Equipment Co..

[145] In addition, to increase market share, Panda has cooperated with Yimei Telecom cooperation so that Yimei will produce a double brand cell phone (Yimei plus Panda)[145]. The new company will invest 0.15 billion in R&D, 0.2 billion RMB in sales and market expansion, and RMB 0.1 billion in production technology and equipment upgrading. At the same time, Microcell will support the company by providing a large amount of capital. (Gu, 2002).

10.8 Chapter Conclusion

According to a market research report on *China Electronic News*, consumers consider domestic cell phones to be similar to the foreign ones in terms of their functions and appearance, except that foreign cell phones probably have advantages in brand recognition (CEN, 2003). Still, the rapid growth of domestic cell phone producers in 2002 went beyond most people's expectations. For instance, an officer from the MII said that he had never expected that domestic cell phones would grow so fast in 2002 (Southern Weekend, 2003). What has enabled Chinese domestic cell phone producers to achieve such a significant market share within a short period of only three years? Will the growth be sustainable? What is the future of these domestic producers? This section will summarize some findings from the previous case analyses.

Reasons for Growth

Apparently, domestic firms have just gone through the preparation and growth stage and now entered the filtration stage. Several factors have directly contributed to the rise of domestic cell-phone producers in the growth stage: on the demand side, there was an explosive increase from Chinese consumers; on the supply side, domestic producers have advantages in their distributional channels and connecting with the customers through a "zero" distance relationship. They have worked hard to improve their innovation capability, via innovative redefinition of, and adding new functions to, the product.

China's cell-phone market of the past four years has distinct characteristics of the growth stage, the rising demand and supply. I view the current market for cell phones to be similar to that of the color TV in 1996–whoever was in the market could make huge profits because of the rapid growth of the demand. By October 2002, more than 90 million cell phones had been produced and sold in the Chinese market. As I have shown before, China now is the country with the largest number of cell-phone subscribers. As the standard-of-living is raised in the economy, more and more people have started to accept the cell phone as a necessity rather than a luxury good, which has directly contributed to the rising demand. In addition, the intense competition between two service providers, China Unicom and China Mobile, and their efforts in providing various new services to customers such as short messages, have facilitated the growth of the demand.

On the supply side, first, it is clear that domestic producers have advantageous distribution channels. Domestic producers sell their cell phones directly, while the MNCs choose agents to sell their cell phones.[146] Because it is difficult to lower the manufacturing costs, it is critical to decrease sales costs. The direct sales model has benefited domestic producers in various aspects. For instance, direct sales can get better and quicker feedback from the customers, while through the sales agents, there are too many intermediate steps, and after-sales services usually lag behind. Sales agents enjoy

[146] MNCs usually use the model of chief sale agent, then distribute to a sales agent at various location. Even though they have large-scale production, they are not very effective in logistics and serving end-users.

selling products, but usually they are not excited about dealing with the after-sale services. Domestic producers have chosen to sell directly, probably because of their lower costs for sales personnel. Most domestic companies have sales staff as the largest portion of their employment. In addition, quite a few, especially those consumer electronics producers such as TCL, Haier, Hisense, Xiaxin, and Konka, had already gained experience in building sales networks for consumer electronics goods before they entered the cell phone market. They are very experienced in building sales networks, especially in second- and third-tiered cities. For instance, in most second and third tier cities, many stores have domestic cell phones sales over 50% (Southern Weekend, 2003). It is worth mentioning that these distribution channels also have a regional effect, i.e., the companies have much better sales at locations close to their headquarters.[147]

Second, keeping "zero distance" with the customers has become one of the primary goals of domestic cell phone producers. In the Chinese market, the phrase "zero distance" was created to describe the close relationship between customers and producers (CEN, 2003). I consider that because of the direct-sales model, domestic producers maintain better after-sale services for customers and get much quicker feedback from their customers to their manufacturing functions, thus keeping closer relationships with the customers than the MNCs.

Third, domestic producers have worked hard on improving their innovation capability by redefining the concept and functions of cell phones, which has helped them to introduce their products to the market. For instance, the first popular TCL cell phone, TCL999D, which was designed with diamonds as decoration, suited the demand for certain Chinese consumers at the time. Haier's Taizhi Star T6000 was a result of responding to a consumer's letter requesting a firewall function and innovatively used their global R&D network, a rare practice for other cell phone producers. Further, domestic producers have an advantage in terms of designing the cell phone with an appearance that pleases Chinese consumers. (CEN, 2003)

Further, domestic firms have generally invested large amounts of money in advertising. For instance, PEG invested 60% of its yearly advertising budget (RMB 0.1 billion) for their advertisement during CCTV's[148] prime time for 2003. Domestic producers' choices of popular singers or movie stars as spokespeople are very effective in the large market segment that is oriented to young people. For instance, TCL chose the best-known Korean actress Kim Hesing, who has many fans in China, to advertise TCL cell phones.

Future

In the next two years, competition in the cell-phone market will intensify as production capacity matches or even surpasses demand. This is what I call the filtration stage of the cell phone industry. Currently, China has a production capacity of 80 million units, half

[147] For instance, in Guangdong Province, local brands, such as Southern High Tech, Kejian, dominate the market; while in Zhejiang Province, local brands, such as Bird and Eastcom, have surpassed the sales of Motorola and Nokia. (Southern Weekend, 2003).
[148] CCTV stands for Central China Television, the national TV station in China.

of the global capacity. In 2002, there were about 36 domestic cell phone producers in China,[149] while for most countries in the world, there were at most only several producers. The intense competition will lead to substantial industrial restructuring and leave only several strong producers in the market, as predicted by the staged catching-up theory. Hou (2003) expected that the cell phone market might follow the path of the color TV market of 1996. The color TV companies competed with each other on innovative concepts, distribution channels, and economies of scale. China's color TV market burst into a price war as the production capacity far surpassed the demand. The whole industry suffered from the price war unanimously, though not for long. The domestic firms in the color TV industry successfully revitalized themselves by deploying two strategies: R&D and exporting (Hou, 2003). Domestic cell-phone producers should foresee the intensified competition and consult the experience of color TV producers in deploying these two strategies.

Currently, there are three distinct groups of domestic cell-phone producers: (1) producers of consumer electronics (TCL, Konka, Haier, Hisense, Xiaxin, Xiahua; (2) telecommunications equipment companies (Eastcom, ZTE, Bird, Shouxin, Southern HighTech, CECT); and (3) IT companies (Legend, Topid). Other companies are still striving to enter the market (CEN, 2003). Economies of scale, distribution channels, and most importantly the technological capabilities, will determine who will survive the competition. Most profit from cell phones comes from superior R&D and sales performance. Therefore, even though domestic firms have better sales networks, the improvement of R&D is critical. The case analysis from this chapter has confirmed this point. The ascent of TCL, Haier, and Hisense are highly associated with their unique styles in building their innovation capability; on the other hand, the fall of former leaders of the industry, Eastcom and PEG, has to do with their lack of motivation for developing their own brand-names because of joint production with the MNCs.

Cell phone technology has three levels: the low level, consisting of a chip, the intermediate level, consisting of systems integration, and the high level, consisting the outer shell. Almost all domestic firms lack chip-level core technology. Only a few have developed their own systems integration. Most just add a shell to foreign cell phones or simply imprint their brand names. Chinese domestic firms currently use three different strategies for R&D: OEM, self-development, and subcontracting R&D. Currently only a few domestic companies are developing their own technologies, such as those telecommunications equipment producers who entered the 3G market (Huawei, ZTE, Datang) and Hisense, a traditional R&D-focused enterprise. Chinese companies may also explore a new way to quickly strengthen their R&D capacity through acquiring "helper companies" in Japan, who provide technology to large manufacturers.[150]

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[149] 12 companies produced both GSM and CDMA cell phones, 17 companies produce only GSM ones, and 7 companies produce only CDMA cell phones. (Hou, 2003)

[150] Those "help companies" have contributed to the strong "R&D" capacity but small R&D staff of Japanese companies. The large Japanese cell phone producers have the newest development technology for cell phones - they collect the product information from the market, then define production process, and hire/organize "help companies" to do R&D. Therefore, these are not passive subcontractors, but very proactive ones. (*Chen, 2003*).

As the industry moves toward more disintegration of the global value chain, fewer companies globally will cover every aspect of the value chain. Rather, more companies will focus on their specialization to enhance their core competencies. Specialization and the recent movement towards specialization of global cell phone leaders implies this trend. For instance, Nokia itself doesn't produce chips, Motorola contracts out manufacturing of cell phones, and Ericsson focuses on being a cell phone technology provider. This indicates that specialization may be a practical way for increasing core competencies for Chinese producers as well.

The deployment of 3G will offer opportunities for domestic producers to catch up with or even surpass the MNCs. Currently, Huawei, the largest telecommunications equipment producer in China, has led the development of WCDMA in China, while ZTE, the second largest in the same category, has led CDMA 2000 among domestic producers. The most exciting opportunity exists in the area of TD-SCDMA, where China might lead the world. Currently, the TD-SCDMA developer Datang has been assigned the most frequency resources (155 MHZ) by the Chinese government, and it is estimated that the government will give out 3G licenses by the end of 2003. It seems highly possible that one or even two service providers will be given licenses to deploy TD-SCDMA. TD-SCDMA will bring domestic producers the chance to build a complete supply chain which covers all three levels of cell phone technology as well as technologies for mobile equipment, e.g., from base station, to switches, chips, design technology, components, and software.

Appendix

Table 10.6 Sales Ranking of Cell Phone Producers in China's market, 2001

Ranking	Company	Sales (10 thousand units)
1	Motorola (China, in Tianjin)	1645.3
2	Nokia (Beijing)	1616.8
3	Nokia (DongWan, Guangdong)	1163.7
4	Siemens (Shanghai)	980.6
5	Motorola (Hangzhou)	517.8
6	Ericsson	416.1
7	Panda Electronics	347.7
8	Samsung	313.4
9	Ninbo Bodao	277.0
10	Phillipe Sangda	253.7
11	Alcatel (Suzhou)	184.2
12	Xiamen Zhongqiao	166.6
13	Haier	132.0
14	Kejian	130.0
15	TCL	128.3
16	Beijing Toshiba	112.4
17	ZTE	95.0
18	Xiamen Huaqiao	68.4
19	Beijing San lin?	62.2

Source: Finance Biweek (Chinese), No. 24, 2002

Table 10.7 Sales Ranking of Domestic Cell Phone Producers in China's market, 2001

Ranking	Company	Sales (10 thousand units)
1	Panda Electronics	347.7
2	Samsung	313.4
3	Ninbo Bodao	277.0
4	Xiamen Zhongqiao	166.6
5	Haier	132.0
6	Kejian	130.0
7	TCL	128.3
8	ZTE	95.0
9	Xiamen Huaqiao	68.4
10	Eastcom	36.6
11	Southern Gaoke	30.1
12	Tianshida (Shenzhen)	26.6
13	Shouxin	21.6
14	Xiaxin Electronics	20.3
15	Zhongdian Telecom	5.1
16	Guowei (Shenzhen)	1.9

Source: Finance Biweek (Chinese), No. 24, 2002

Table 10.8 Major Domestic Cell-Phone Manufacturers, Headquarter Location, Major Products and Services

Company Name	Headquarter Location	Major Products/Services
TCL Holding Co., Ltd. TCL集团有限公司	Huiyang, Guangdong	Household Electronic Appliance: Refrigerator, [VCD & DVD, Player Video Wall, Washing Machine, Consumer Information Appliance, Family Cinema System, Air Conditioner, Color TV, Internet TV; Information Technology: Cable TV, Scramble and descramble System, Internet Product Computer; Telecommunication: Mobile, Phone, Pager, Telephone, Hyper-power Battery; Electrical Components: Switch, Green Lightening Products
Haier Group Co. 海尔集团公司	Qingdao, Shangdong	produces a wide range of household electrical appliances in 86 categories and 13,000 specifications; Domestic market share of Haier refrigerators, freezers, air-conditioners and washing machines is 30%.
Hisense Group Co. 海信集团有限公司	Qingdao, Shangdong	specializes in consumer electronics, household appliance, and information technology; main products include: televisions, air conditioners, refrigerators, computers, DVDs, CDMA mobile phones, software and network apparatuses
Eastern Communications Group Co. Ltd. 东方通信有限公司	Hangzhou, Zejiang	Cell-phone handsets for GSM and CDMA (>=98% of company's revenue); IC calling card, ATM switch, transmission systems and power supply.
Panda Electronics Group Co., Ltd 熊猫电子集团有限公司	Nanjing, Jiangsu	HF communication, satellite communication system, mobile communication system, mechatronics production equipment, base station, program control exchangers, mobile phones, TV sets, washing machines, DVD players, computers, monitors, system integration, network, software and radio receivers

11 Conclusion

This research uses a multi-case analysis approach, along with simple regression analyses, to study China's catching-up as a late-industrialized economy in the information and communications technology (ICT) industry. The significant contributions of this study are: the staged catching-up theory framework, the findings from the cases, and the policy implications.

This study contributes to the late-industrialization literature by filling its theoretical gap– how domestic firms can catch up when there is strong MNC presence and what is the role of innovation capability. The experiences of Chinese domestic manufacturers catching-up in the ICT industry vis-à-vis the multinational corporations (MNCs) are unique but not well studied. Few latecomers were successful in catching up when there was a strong MNC presence. Many researches have studied the successful catching up of Japan and Korea, who did not face a strong MNC presence in their domestic market at the time. Few, however, have studied China's recent experience, and fewer still attribute innovation capability as a possible cause of catching-up with the MNCs. My research contributes to the literature by filling this gap.

In this study, I develop a staged catching-up theory that can be used as a framework to analyze the successful catching-up process of domestic firms in a late industrialized economy while facing strong MNC presence (Chapter 3). The theory describes the behavior of domestic firms, the behavior of the MNCs, and the role of the government, as well as the spatial behavior at each stage.

The case studies (Chapter 6-10) confirm that Chinese domestic firms in the information industries have followed a path of catching-up that can be described by the staged catching-up theory, and innovation capability and self-developed technologies were the ultimate driving force that has enabled leading domestic firms to catch up with the MNCs in the telecom-equipment and PC manufacturing industries. These findings have significant implications for policy makers, domestic firms and MNCs in the host countries.

I organize this conclusion chapter as follows: Section 11.1 compares other major literatures that explain the catching-up of the domestic producers and reveals why they are inadequate. Section 11.2 summarizes important findings from the case analysis. Section 11.3 offers policy implications and Section 11.4 presents directions for future research.

11.1 Possible Explanations

Various analysts attempt to explain why domestic telecom equipment and PC manufacturers have achieved high domestic market shares and why cell-phone producers have progressed so quickly. I focus on analyzing the following four dominant perspectives and reveal why they are inadequate.

Guanxi and Corruption

Some analysts, such as Yeung (1997) and Hsing (1996), emphasize the role of *guanxi* or personal relationships in social or business networks in China's economic development. Schleifer and Vishney (1998) discuss the reasons for corruption and view corruption as a mechanism to transform power into income for politicians. These analysts imply that it is the sales and distribution channels of both industries, which favor the domestic producers, that are responsible for the significant market share of domestic firms.

Corruption and *guanxi* exist in the system, because the customers for telecom equipment products are mostly service providers owned by the government and customers for PCs may largely come from the public sectors. There are chances for corruption because government-run enterprises do not seek profit maximization, and individuals may use their power to gain personal benefits. Because most customers for computer products are from the business and public sectors (companies, education institutes, and governments), there is ample opportunity for corruption and *guanxi* to favor domestic producers.

To support this explanation, I need evidence that, even though foreign products should have been purchased because of a better function/price ratio than that of domestic products, public-sector customers still purchased domestic products in the telecom-equipment sector. Furthermore, individual customers should have drastically different PC purchase patterns from public or business customers.

Even though it is hard to determine how much privileged access the government gave to the domestic producers via *guanxi* and corruption, the following evidence is not consistent with the above explanations. First, under the goal to maximize profit in a very competitive market, telecom-service providers would not favor domestic firms just because of *guanxi* and corruption. The Ministry of Information Industry (MII) divided China Telecom into several different firms, and new service providers have entered the market. The competition in China's telecom service market has been very intense among the service providers, who are the main customers for telecom-equipment products. If they do not make rational choices by purchasing the best bargains on the market, they will fail to maximize their profit and go out of business. There is little motivation for them to accept *guanxi* or corruption just to support domestic products, either as companies or as individuals whose career paths depend on the companies' performances. Furthermore, since the early 1980s, foreign telecom-equipment companies have learned how to do business in China. Most foreign telecom-equipment companies have local people working in sales and distribution. It is likely that these individuals may also use *guanxi* or even bribery if they seem to work well.

Second, individual customers have similar purchase patterns as the business and public sectors. The revenue from individual PC buyers constitutes a significant percentage of the total.[151] It is reasonable to assume that individual customers make rational choices, i.e., generally choose products with optimal function/price ratios. Therefore, the similar purchase pattern of individual buyers to that of the business and public sectors implies that the business and public sectors have made sound purchases. Cell-phone users are individuals primarily purchasing for private use. Therefore, we can safely assume that most cell phone users made rational purchases.

However, it remains unclear how much the domestic firms might have benefited from *guanxi* and corruption, especially in the earlier stages of development, when China Telecom was the sole service provider. Although I agree that this might be a valid partial explanation, I do not focus on this perspective, in part due to the difficulties in obtaining adequate evidence. Moreover, such an explanation could never be entirely adequate in a context of customer choice. Instead, I argue that the innovation and self-developed technologies of the domestic producers is more important. Without them, in the competitive telecom equipment and PC markets in China, the *guanxi* and corruption mechanism would not work because domestic firms could not make the products with a reasonable profit margin and would be wiped out by the MNCs, and customers would have no alternative to buying foreign products. In fact, during the filtration stage, many uncompetitive Chinese domestic telecom equipment and PC producers were wiped out because they did not possess their own technology.

Protected Market and Privileged Access

Some (Fransman, 1995) claim that controlled competition could be an effective route for the development of domestic firms, as observed by Fransman in the case of Japan. This suggests that the Chinese market for telecom equipment and PCs may have been a highly protected market, and that Chinese domestic firms may have been able to achieve high domestic market shares because of a lack of competition from foreign producers. Similarly, one might contend that the domestic producers usually enjoy privileged access provided through the government, especially when they sell to large nationally owned service providers.

However, data show that China has not charged unreasonably high tariffs on imported products in these fields. For instance, the tariffs for PCs and components range between 9 % and 15%.[152] Further, foreign producers (both wholly owned and joint ventures) have coexisted with domestic producers in China for at least a decade. In fact, domestic producers in the PC industry started to grow after multinational corporations (MNCs) came to China in the 1980s. Similarly, domestic producers in the telecom-equipment industry have competed with MNCs from the very start of their existence. In the telecom-equipment and PC markets, both foreign and domestic products are widely available. People from Motorola, Nokia, and ZTE that I interviewed have acknowledged that the Chinese market for telecom equipment, PCs, and cell phones is one of the most competitive in the world.

[151] Merrill Lynch, September 2000. *China PC Industry: Fallacies and Facts.*
[152] ING BARINGS, Legend Holdings Limited, November 2000.

Nevertheless, this research finds that privileged access can play a role only when the domestic firms have already achieved a certain level of technological capability. Privileged access to the government was important to the development of a few domestic firms, such as GDT and Great Wall, at their earlier stage. But both GDT and Great Wall had developed their own proprietary technologies—the first domestic public digital switch system HJD04 and the first domestic PC—before they were provided with privileged access to government support. The resources of government research institutes and state promotion of R&D and its commercialization through national science and technology programs ("Torch Program" and "863 Plan") have a general positive effect on leading firms' effort in building innovation capability. Therefore, it is the state promotion of research and development (R&D), rather than privileged access, which matters most.

Privatization

Some analysts of economic reform and economic transition emphasize the role that the market has played (Shleifer, 1994, 1998; Wu, 2001). Shleifer (1998) argues that privatization should be advocated, because it encourages innovation and non-private ownership is often in conflict with social welfare.[153] These analysts imply that private ownership and deregulation of the Chinese business environment ("free competition") are the main reasons for the rapid growth of domestic firms.

Although I agree that the deregulated environment of the Chinese market provides a healthy and competitive market for economic development in general, I argue that observation of domestic firms in the information industry suggests that privatization is not necessarily the sole impetus for development. First, most companies in the rapidly growing telecom equipment and PC sectors have non-private ownership. For instance, three out of the four leading domestic telecom equipment companies (ZTE, DDT, GDT) are state-owned enterprises. In the PC sector, Legend and Founder, the two largest PC manufacturers, are state-owned enterprises.

Perhaps, however, the public/private distinction needs refinement. My study shows that it is not the ownership of a firm, but the way the firm is operated, that matters. Most of these state-owned companies could be viewed as part of a new generation of Chinese enterprises characterized by a unique form of enterprise governance: "state-owned, non-government-run" (*guoyou minying*). They are owned by the state, but have operational autonomy, like non-state-owned companies. The experience of enterprise restructuring for most leading firms studied in this research supports Lu's (2000) argument that technological capabilities and enterprise governance *together* have made possible the rise of these Chinese firms.

Industrialization without Proprietary Innovation

[153] The cost of innovation is high. Therefore, private ownership is needed for investors to reap satisfactory returns on their investment. Furthermore, privatization disconnects the channel of control from politicians who pursue their own selfish objectives, which usually oppose to social welfare. (Shleifer, 1998).

The literature on late industrialization suggests that backward countries can catch up in industries requiring large amounts of technological capabilities, even without proprietary innovations (Amsden, 2001). If so, the implication is that Chinese domestic firms depend on other countries' commercialized technology to establish modern industries, rather than on developing their own proprietary technologies.

Although domestic products are cheaper than those of their competitors in China in the information industry,[154] completely dismissing the possibility that the Chinese companies possess their own proprietary technologies seems untenable. Chapters 7 and 9 demonstrate that innovation capability and self-developed technologies have strong explanatory power for leading firms' high revenue and profit in the telecom-equipment and PC manufacturing industries. The case analysis confirms that the leading domestic firms have developed strong innovation capabilities (the skills necessary to design entirely new products and processes) and that has mattered most for their rapid growth.

The above-mentioned prevailing explanations are not sufficient to explain why Chinese domestic producers in the information industry have grown so rapidly in the last two decades. However, they do provide some valuable points of reference for the present research. Further, the variety of explanations shows the high interest of people from different fields in understanding the phenomenon.

11.2 Summary of Findings

This section summarizes findings from the case analyses (Chapters 6-10): (1) the staged catching up of the three industries, (2) the catching-up's spatial manifestation, (3) the role of the government, and (4) the role of innovation capability in leading firms' catching up.

The Staged Catching-up

The development of China's telecom-equipment industry and PC industry from the 1980s to 2002 indicates that domestic firms have caught up with the MNCs by the stages described by the staged catching-up theory: the preparation, growth, and filtration stages, and are now at the globalization stage, with the PC industry's stage development being slightly ahead of the telecom-equipment industry (chapters 6 and 8).

In the early and middle 1980s, many domestic producers in the telecommunications equipment and PC sectors acted as sales agents for foreign firms; which is precisely described by the staged catching-up theory as what happens in the preparation stage. For example, Huawei initially sold small-scale telephone switches for a Hong Kong firm; similarly, Legend acted as the sales agent for several foreign companies; Founder sold several foreign-brand PCs starting in 1992 before it began manufacturing its own PCs, and it became the main distributor of Digital Equipment Corporation's (DEC) PCs in the following year.

[154] ZTE company data and ING BARINGS, China Research, Legend Holdings Limited, Nov. 2000.

In the early 1990s, domestic firms in these two sectors entered the growth stages, i.e., they started manufacturing products in different market segments from the MNCs. Originally acting as foreign-brand sales agents of MNCs in the late 1980s, many domestic computer firms transformed themselves into PC manufacturers by first exploring the specialized market of Chinese-language add-on cards. Likewise, in the late 1980s and early 1990s, telecom-equipment firms produced and sold the small-scale telephone switches that rural telephone bureaus most needed.

In the middle and late1990s, the filtration stage of the industries, domestic PC manufacturers upgraded themselves to broader areas of production, and domestic telecom-equipment manufacturers started to produce large-scale digital telephone switches. Consequently, both of them faced strong competition from the MNCs. Those firms that were not competitive enough were forced to exit the market and only the strongest ones survived. For instance, of the major telephone-equipment producers that have survived, all had strong R&D capacities. Among the PC manufacturers, Legend and Founder both survived by virtue of their superb marketing and management skills or R&D capabilities. The rest of the firms, including Great Wall, either exited the market or chose to cooperate with other foreign companies.

Having passed through the growth and filtration stages by first building their own manufacturing and R&D capabilities, then competing with the MNCs, the leading domestic firms in the telecommunication-equipment and PC manufacturing sectors currently have globalization on their agendas, thus signaling that the industries are entering the globalization stage described by the theory. Except for Datang, the firms I studied in this research in these two sectors, namely Huawei, ZTE, Great Dragon, Legend, Founder, and Great Wall, have all exported to the international market. Many also have R&D centers abroad. The globalization stage turns out to be challenging for these domestic firms, especially when the export target is a developed country, whose markets require the best, most advanced products. In addition, a business environment different from what they have been familiar with can make operations more difficult.

Less mature than the firms in telecom-equipment and PC manufacturing, domestic cell-phone producers have gone through the preparation stage and are currently at the end of the growth stage and the beginning of the filtration stage. It was not until 1999 that many domestic producers started to enter the cell-phone market. Document No. 5 from the State Council about cell-phone-production licenses served as a constraint for MNCs and a control of domestic firms' growth. The expanding market and high profit margin quickly lured many producers to this sector. Some were fresh start-ups focusing only on cell-phone production; many others were from the consumer-electronics sector. Currently, China has about thirty-six domestic cell-phone producers, the largest number of any country in the world. As the sector enters the filtration stage, many will have to exit the market.

For domestic electronics giants such as TCL, Haier, and Legend, even though they have already entered the globalization stage in their original consumer electronics and PC businesses, their cell-phone production is still in the growth stage.

It is worth emphasizing that during the process of catching up, all these firms face great organizational challenges. Domestic firms will need to learn organizational structure and functions from the West (but tailored to fit the Chinese environment), or to restructure themselves to facilitate growth (such as by mergers and acquisitions), or to solve problems associated with their rapid growth (such as unclear ownership and organizational and managerial failures). Further, firms will need to explore new ways of obtaining investment, for instance, by selling non-core competency branches or by going public.

Almost all companies have been moving themselves toward modern enterprises with Chinese characteristics through resolving ownership issues and restructuring their corporations. Some have been quite effective, such as ZTE, Legend, and Founder; some are still striving to find a way, like Great Dragon.[155] Others, such as Huawei and Datang, are reluctant to respond to this urgent need. But all have felt the necessity of restructuring into a modern, efficient organizational structure. This situation may be especially Chinese, because China is in transition from a central planning economy towards a market economy.

Spatial Manifestation

Preparation Stage (Concentration)

At initial stages, domestic firms preferred locations where there was a good business environment or innovation. Among the twelve companies, three started in Shenzhen (Huawei, ZTE, and Great Wall), three started in Beijing (Datang, Legend, and Founder), two in Qingdao (Haier and Hisense), and one each in Zhenzhou (Great Dragon), Huizhou (TCL), Hangzhou (Eastcom), and Nanjing (Panda Electronic). The variety of the locations indicates that, to get started, high-tech companies need places with either a good business environment or with innovation.

This view is similarly shared by many analysts and reflected in policies implemented by different governments in the world. For instance, Silicon Valley has been favored by many entrepreneurs because it is the place where many innovations happen, and it has a friendly business environment (such as financial opportunities provided by venture capitalists) for small start-ups.

Support from the local government, especially in the preparation and the growth stages, can be a determining factor for both domestic firms' and MNCs' location decisions. For instance, the local government of Shenzhen, the first special economic zone in China, has been well known for its encouragement of entrepreneurship and creation of a friendly environment for entrepreneurs. It is in Shenzhen that Huawei and ZTE, two leading

[155] Great Dragon has experienced three serious organizational restructurings. The first and second ones turned out to fail. It still remains a question as to how effective is its third restructuring. (*Ren Min You Dian*, Nov. 11, 2002)

domestic telecom-equipment producers, started as trading companies, but later transformed to become manufacturers.

The city government of Qingdao, Shandong Province, is said to be very proactive and to have a long-term vision. Qingdao is the home for two companies in the present research--Haier and Hisense. The growth of these two giant electronics companies and Qingdao Beer, another famous brand in China, is closely associated with the Qingdao government's efforts. A similar relationship can be found between TCL and the local government of Huiyang Area and between Eastcom and the Hangzhou city government, especially in the growth stage of the industry.

Growth Stage (Expansion)

At the growth stage, the companies started to have several locations for their branches in addition to their original headquarters. Both Huawei and ZTE built their main R&D facilities somewhere other than at their headquarters in Shenzhen. At this stage, as the companies started to increase their investment in R&D, Beijing, Shanghai, Nanjing, and other cities in the mainland were more attractive to them, because these cities have highly concentrated, skilled R&D labor pools. Meanwhile, to expand its production capability, GDT built its manufacturing site in Changchun, one of the most famous manufacturing cities in Northeast China. The companies chose the locations to satisfy their needs for the resources they wanted to develop.

Filtration Stage (Consolidation)

In the filtration stage, as the telecom and PC industries started to consolidate, manufacturing took advantage of economies of scale and concentrated in only a few places. Sales, in contrast, were found to have a dispersal trend as the surviving firms formed national-sales networks. In addition, a few locations, such as Beijing and Shanghai, became the best sites for R&D for domestic firms as well as MNCs. The largest firms in China's PC industries are clustered in the ZhongGuanCun area in Beijing, with numerous other IT companies. A similar pattern was found with regard to the R&D facilities of the telecom-equipment firms when the industry entered the filtration stage. The co-existence of agglomerated economy and dispersal economy reflects the different spatial requirements of different functions.

Globalization

The spatial characteristic of the globalization stage is to internationalize different production functions, including R&D, marketing, and manufacturing, but especially the R&D functions. This characteristic is somewhat different from the globalization of the MNCs, who usually start by internationalizing sales and manufacturing functions. As telecom and PC domestic producers enter the globalization stage, Huawei, ZTE, and Great Dragon all export their products to Russia, Eastern Europe, Africa, South America, and even the United States. Leading the market share of the Asia Pacific region, Legend has been very aggressive in entering the international market. International cooperation has become common practice, for instance, Texas Instruments (TI) has joint laboratories with three of the producers--Huawei, ZTE, and Datang on digital-signal processing, in which TI is the best of the world. And the telecom-producers also have close cooperation with South Korean peers, especially in the 3G area.

Domestic producers also have built their R&D centers directly on the technology frontier, so that they can be as close as possible to the innovation centers of the world. For instance, Huawei has a total of five oversea R&D offices in the United States (Dallas and Silicon Valley), Sweden, India, and Russia. ZTE Korea FutureTel Co., Ltd., a holding company of ZTE, is engaged in development of a CDMA handset. Moreover, their sales offices have started to blossom in China's major cities, as well as abroad. Globalization is thus reflected in the location patterns of the companies. At this stage, the companies have favored locations with good R&D resources and easy market access both domestically and internationally.

Chinese domestic cell-phone producers currently are at the end of the growth stage and the beginning of the filtration stage. Yet those that diversified from consumer electronics have already accomplished globalization in these business areas. They are able to take advantage of their global resources for cell-phone development and marketing. For instance, the T6000 is an R&D result of Haier's global research teams in China, Europe, and the United States.

Government in the Catching-up Model

The role of the Chinese government is most conspicuous in the preparation and growth stages during the catching-up. In these stages, the government has exercised two types of control to create or maintain some room for domestic firms to grow: (1) the control of imports and (2) the control of setting up of manufacturing units by foreign firms. In the growth stage, the government imposed tariffs to discourage importation, for example when both domestic firms and joint ventures (JVs) started to produce switches. In terms of controlling the setting up of manufacturing units by foreign firms, the government allowed only JVs in the expectation that such ventures would bring some technology transfer. The government imposed local-content requirements on MNCs. MNCs henceforth used their percentage of local content to indicate their contribution to the Chinese economy.

The analysis of telecom-equipment manufacturers clearly shows the various patterns of government involvement. At the preparation stage, the government allowed the imports of foreign switching systems and, to some extent, supported the foreign imports because of China's urgent need to improve its outdated telecommunications infrastructure. However, the government (MPT) encouraged domestic development of switching systems starting from the early 1980s. The development history of HJD04 was clear evidence of MPT's intentions.

In the growth stage, the government controlled imports and implemented the strategy "exchange technology with the market" as they thought JVs were a good way to get foreign technology. As more and more domestically developed switches were certified and licensed, the government helped domestic producers in various ways: (1) financially, through financial aid for technology improvement in certain key products, and facilitating trust loans for customers who bought large quantities of telecom products from domestic producers, especially for companies within the MPT system; (2) market access: organizing two "Domestic Switches Customer Coordination Conferences" and helping in export; (3) resources: frequency spectrum allocation that favors TD-SCDMA, which definitely increased the bargaining power of domestic producers to lower patent fees for other 3G standards.

For PC manufacturers, even though few government interventions were available for Legend and Founder, their supporting institutes--the Chinese Academy of Sciences and Beijing University--compensated for the lack of government support. In addition, it is evident that the MEI and its strong support for Great Wall played a vital role in Great Wall's growth and its cooperation with IBM.

In the area of cell-phone manufacturing, the government has used Document No. 5 as a way of constraining foreign cell-phone manufacturers from setting up manufacturing units in China. Its main purpose is to encourage domestic development of mobile communications. The document has saved some room for domestic producers in the rapidly expanding cell-phone market.

Innovation capability and self-developed technology

This study has proved that innovation capability and self-developed technologies have been the key to Chinese domestic firms' catching-up with the MNCs and have determined who are the leading domestic firms in these industries. Table 11.1 summarizes major findings on this issue.

First, simple regression analysis confirms that strong innovation capability contributes to companies' leadership and heavy R&D spending accounts for leading companies' high revenue and profit in the telecom-equipment and PC manufacturing industries.

Second, the cases confirm that innovation capability and self-developed technology are crucial for starting and growing a high-tech company in China. The leading telecom-equipment manufacturers all developed small-scale digital switches and used them as a main source of income initially. The leading PC manufacturers all started their companies with self-developed technology--Chinese language add-on cards (Legend Chinese add-on card and GW 0520 card for Legend and Great Wall, respectively) and the fourth-generation electronic publishing systems for Founder.

Table 11.1 Major Findings on Innovation Capability

Findings	Evidence/ Examples
Importance of innovation capacity and self-developed technology (at entry point and at later stages)	Regression Results: Strong explanatory power of Innovation capability to Industrial Leadership, R&D Spending to Profit and Revenue At entry point (growth stage): GDT, Huawei, ZTE, and Datang (self-developed switches) Legend (Legend Chinese-language add-on cards), Founder (4th generation electronic publishing systems), Great Wall (GW0520 card and first Chinese PC) TCL (jewelry phone), Haier (firewall phone), Hisence (CDMA and color screen phone) At later stages (filtration and globalization stages): Huawei, ZTE, and Datang entered other subsectors through self-developed technologies Legend's market war for most advanced PCs Founder's monopoly position in electronic publishing through continuous innovation
Where does the innovation capability come from? (Channels for building capacities) -- Internal development	Large internal R&D investment Huawei, ZTE, Datang, GDT, Hisense, Founder's heavy R&D investment Specialization (investment a narrowly focused area) Huawei
-- External resources	Early stage: Initial resources of their attached entities Legend (CAS), Founder (Beijing University), Great Wall (MEI), Datang (CATT) Later stages: Alliance with both domestic and foreign institutes and companies Almost all companies have R&D partners
-- Being local	Understanding of consumers • Haier (Firewall), Legend (1+1 PC), Huawei (mobile intelligent network) Partial Innovation with Chinese Characteristics • TCL (Jewelry Cell Phone)
-- Technology transfer through JVs (seems unsuccessful)	Great Wall (JVs with IBM)—became lower value-added component maker of IBM's global value chain Eastcom—cooperation with Motorola failed to improve its technological capacity. Panda Electronic (with Ericsson)—no incentive for self-development and kept it steps behind Ericsson's cell- phone development
What has facilitated building	S&T projects (863 Plan, etc.) - direct

innovation capacity? -- Government involvement	Financial loan for technological improvement - direct Other financial loans, customer loans for supporting production in general- indirect Policies, regulations for controlling imports and FDI (tariff, control of JVs, Document No. 5) - indirect
-- Network clustering (Location concentration of R&D functions)	Domestic clustering: • Beijing: R&D centers of Legend, Founder, Huawei, ZTE, Datang, GDT, etc., most concentrated in Zhong Guan Cun Area; • Shanghai, Nanjing, etc. International clustering: • Huawei (R&D centers in Silicon Valley, Dallas, Sweden, Bangladore) • ZTE (South Korea for for its CDMA R&D center)
-- Disintegration of the global value chain	Telecom-equipment: a component-based architecture replaces a monolithic model PC: already has a disintegrated value chain (IBM Open architecture) Cell phone: companies move towards specialization Nokia does not produce chips Motorola contracts out manufacturing Ericsson focus on being a cell-phone technology provider
-- Subsector linkages	*Telecommunication equipment manufacturers:* shortened time to catch up with the MNCs' technology Cell-phone manufacturers: 1G-2G-3G: more and more self-developed technology
Innovation capacity does not guarantee success; it has to be matched with a good corporate and management system.	GDT: serious structural problem => from leading to lagging behind Datang: how to transform from a government research entity to a modern enterprise Huawei: pursuing better management (consultation with international experts) Founder and Great Wall: experience of failed management Legend: successful restructuring TCL: successful corporate reform Haier: superb management system as a national model

During the later stages, telecom-equipment manufacturers entered into other sub-sectors through self-developed technologies, such as access equipment, transmission equipment, routers, and switches. As shown in Chapter 9, domestic PC producers have caught up with the MNCs by making PCs with the most technologically advanced components rather than just seeking a low-cost advantage. Legend initiated a market war in the middle 1990s by advertising the most advanced PC in China at the time. Founder's one-decade monopoly position in electronic publishing was maintained by its continuing innovation.

In the domain of cell-phone production, TCL's jewelry phone (a totally innovative product concept), Haier's firewall phone, and Hisense's self-developed CDMA and color-screen phones all brought market success to these companies. Their successes only underscore the importance of self-developed technologies.

Channels for Building Innovation Capability

This study confirms that in-house R&D development, supplemented with external alliance, is the key channel for domestic companies to build innovation capability. Moreover, this study finds that joint ventures, as a means to build technological capabilities, are not effective for the firms studied here.

First, a large internal investment is critical to a firm's innovation capability, as the high R^2 value of the regression analysis between the R&D spending and the ranks of innovation capability indicates. Due to the R&D-intensive nature of the sector, all telecom-equipment manufacturers (Huawei, ZTE, Datang, and Great Dragon) invested heavily in R&D, achieving a level over 10% of their annual revenue. Consequently, these companies have self-developed most of their core technologies. Founder and Hisense, which devote the greatest percentage of revenue to R&D in their respective groups (PC manufacturers and electronics manufactures), are renowned R&D-oriented enterprises and lead in innovation capability. The research also finds that investment in a narrowly focused area can help a company to build innovation capability quickly; Huawei is well known for this strategy.

Second, external resources have been essential to support companies' innovative activities at the early stages. Legend, Founder, Great Wall, and Datang all have a technologically oriented entity as their founding organization, namely, ICT of CAS, Beijing University, MEI, and CATT. These institutes provide fertile soil for these companies to grow in and the technical expertise directly from the institutes has become part of the companies' initial innovative capability. Further, all the companies studied here have strategic alliances or R&D partners in various areas, domestically or internationally, especially in the areas of their core competencies or where they intend to build competencies. This phenomenon indicates that strategic alliance seems to be an effective way to keep up with cutting-edge developments and to quickly ramp up a company's innovation capability. Nevertheless, external alliance is conditional on the company's internal development; without the strong internal development of R&D, external alliance will not be effective.

This study also confirms that joint ventures, as a means to build innovation capability, are ineffectual for the firms studied, i.e., Great Wall, Eastcom, and Panda Electronics. Great Wall's cooperation with IBM, though preserving it from failure in the market, only made it a low-value-added component-maker of IBM's global value chain. Similarly, Eastcom's cooperation with Motorola has not helped it to improve its innovation capability. Further, Panda Electronic's marriage with Ericsson left it no incentive for a self-developed cell phone and has kept it always one or two steps behind Ericsson's phone development.

Government Involvement

My research suggests that the government can help companies to build knowledge-based assets directly through national science and technology (S&T) projects or through funding for technological improvement. Indirectly, it can help build critical assets by supporting domestic firms in general; I give the details of the Chinese government's indirect involvement in Chapters 6, 8, and 10.

The Chinese government has used national S&T programs such as "Torch Program" and "863 Plan" to encourage R&D activities and commercialization of R&D by companies. The companies with strength in the corresponding fields are funded for cutting-edge research. The funding and coordination of different entities provided by the government for the same research objective has proved to be a very efficient way to close the technological gap. National S&T projects have not imposed strict performance standards on those industries and companies that they aid, as was the case in South Korea (Amsden, 1989); however, they encourage and reward companies' efforts in improving technological innovation capabilities by merit-based selection.

Even though China started its R&D in telecom equipment very late, it has always had a very strong basic research base in the field of telecommunications and electrical engineering. In addition, because all the research institutes and universities involved in telecommunications are under the direct control of the MII (original MPT), those entities historically have had a very close interconnection with each other. When a group of Chinese telecom-equipment providers started to arise, it was these state-owned institutes and universities that provided most of the technical human resources needed by the companies, as well as being involved in many national science and technology projects. The existence and strong presence of these entities has ensured the technological prowess of the domestic producers, which is in line with the analysis by Freeman (1987), Nelson (1992), and Porter (1990) on national innovation systems (NIS). The findings from my research thus confirm that the government is needed to take responsibility for education and training, and for developing an infrastructure to support industrial development, as indicated by Friedrich List (Lundvall, 1992).

This research confirms that government involvement has rewarded companies' efforts to build innovation capability and develop proprietary technologies through a positive feedback system, which is composed of: network clustering, disintegration of the global value chain, and sub-sector linkage. Detailed discussion of the above three elements in the feedback system can be found in Chapters 7 and 9.

11.3 Policy Implication

This research has implications for how China can catch up, especially through developing domestic firms' innovation capabilities, in high-tech manufacturing areas despite the strong presence of MNCs. Also relevant is how other countries or regions, either late industrializing countries or less-developed regions in developed countries, can use the findings from this research to facilitate the development of their local firms in high tech industries.

The staged-catching up theory helps policy makers and domestic firms to understand the process of successful catching-up and the driving force underlining the process. With this understanding, domestic firms and governments can choose the most effective strategies according to the stage the industry is at and prepare for changes in the next stage.

Domestic firms are vital for building high-tech industries for late industrializing countries. This research emphasizes the importance of innovation capability, which is different from the existing literature. The research stresses that domestic firms should prioritize building innovation capability from the very beginning to ramp up their competitiveness and to survive in the filtration stage, even though its benefit may not be so distinguished in the growth stage. It also suggests domestic firms focus on in-house R&D development to build their innovation capability, supplemented with external alliances, since the latter's effectiveness is conditional on the strength of the former. Furthermore, while most literatures tend to emphasize the advantages of MNCs in the host country, this research points out that domestic firms have advantages over MNCs in the local market; domestic firms should use these advantages to develop innovative products that suit local demand. Finally, it reminds us that joint ventures tend to leave the domestic partners under the shadow of the MNCs and discourage them from developing their own proprietary technology and brand name. Further, firms need to have a matching corporate structure and good management system to ensure the sustainability of growth, especially at the filtration and globalization stages.

For governments in late-industrializing economies, their involvement in knowledge-based assets, which rewards firms' efforts in building innovation capabilities, is critical, as it helps to strengthen the positive feedback system for innovation capability building. Direct involvement such as financial support, market access, and resource provision are essential at the growth stage, but not so necessary once the industry enters the filtration stage. Merit-based selection of candidates for national S&T projects is effective in rewarding leading companies' efforts and encouraging innovation activity at the company level. Further, cooperation between universities, research institutes, and companies are essential for the progress of the entire industry at the technology frontier. Analysts believe China still has not caught up in the high-performance computer industry, even though one firm (Dawning) has caught up with the MNCs in innovation capability. This example confirms that group advancement, rather than one or two individual firms' super performance, is necessary in signifying the catching-up, which corresponds to an old Chinese saying "a single hand cannot clap."

The phenomena of geographic clustering of firms' R&D functions suggests that location does matter for companies' accumulation of innovation capability. Government effort in building high-technology zones could be effective, especially when such a location has already been a magnet for high-skilled labor. Further, specialization and diversification into rising sub-sectors are good strategies for firms to catch up in industries characterized by disintegration of the global value chain and strong sub-sector linkages, such as, but not confined to, telecom-equipment, PC, and cell-phone industries.

This research identifies innovation as the driving force for China's information industries' catching-up, which is in line with the argument of Yusuf (2003), who points out that innovation will be the driving force for East Asia's future growth in his new book

"Innovative East Asia: The Future of Growth." In addition to specific industry policies, a set of public and private initiatives could stimulate innovation (Yusuf, 2003), which includes strong education for a highly educated work force, R&D promotion, information technology to improve productivity, and continuing innovation of firms and networking among them through dynamic urban clusters. Domestic firms in the information industries seem to have benefited from most of the initiatives mentioned above.

As China has joined WTO, domestic firms have concerns about how they will adapt themselves to the new environment. In some sense, WTO will push every industry to enter the filtration and globalization stage much earlier than they expected. WTO will bring both benefits and disadvantages (Xu, 2001). One of the benefits is the reduced cost of production for domestic producers, resulting from the removal of tariffs on imported components, which will make domestic producers more competitive in the international market. In addition, the reduced barriers to exporting to WTO signatory economies will enhance the market-entry ability of the domestic firms. Therefore, WTO opens the door not only for foreign corporations, but also for Chinese producers. There may be some problems encountered by domestic producers when switching to the newly developed market. More professional help and support will be needed. It is also suggested that Hong Kong can act as China's globalization partner and professional middleman for bilateral transactions by using its expertise and talents in trading (for instance, the OFTA and UST's training programs for Chinese telecom regulatory and industry people) and its abundant investment capital (Xu, 2001).

11.4 Future Research

There are several directions that this research can carry on: (1) study more firms in the three industries; (2) study the catching-up process in other high-tech industries in China; and (3) study the catching-up process in the information industries of different late-industrializing economies.

First, I would take a more quantitative research approach by studying more domestic firms and MNCs in these three industries. I would select not only the domestic firms with strong innovation capability, as represented in this research, but also firms with comparatively low innovation capability and few self-developed technologies. Further, I would select multinational corporations in China to do comparison analyses. Few studies have addressed the innovation capability of MNCs in the host country versus domestic firms. Shen (1999) compares the development of PDSS of Shanghai Bell with GDT. I believe this plan will bring some fruitful policy recommendations for the government in how to guide MNCs in the process and what are the possible venues for MNCs to contribute to the growth of domestic firms. I would prepare my own survey forms, designing survey forms for detailed R&D information. With more firms, the result of regression analysis will be more convincing.

Second, I would use the staged catching-up theory developed in this study as a framework to analyze other industries' catching-up in China, such as the high-resolution

TV industry, the high-performance computer industry, the automobile industry, the chemical industry, etc. The different degrees of high-tech of these industries pose different requirements for domestic firms. It would be interesting to verify the generality of the staged catching-up theory and compare the variations.

Third, I realize that China has a very different institutional context from many other late-industrialized economies, such as a large domestic market and the transition from a socialist planning economy to a market economy. Therefore, I believe that doing a comparative study of China and other countries will be interesting; for instance, China and India, both of which are countries with a large population and with ample human resources in information industries. India's catching up in the software and biotechnology industries, which mainly service foreign markets, presents a drastically different path from China. Further, studies of China and other former communist-regime countries such as former USSR countries and Eastern-European countries will be appealing since, in addition to the similar transitioning economy, they all have strong bases of education, which are necessary for firms to accumulate innovation capability at the firm level.

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