Technological Capability Generation in China’s High-tech Industries: Experiences from China’s Mobile Phone Industry

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Jun Jin
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Approved on the application of

Prof. Dr. Li Choy Chong
and
Prof. Dr. Maximilian von Zedtwitz

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The President:

Prof. Ernst Mohr, PhD
Technological Capability Generation in Chinese High-tech Industries: Experiences from China’s Mobile Phone Industry

Summary

The development of technological capabilities (TC) is critical for companies in emerging countries to survive and succeed in competitive business worldwide. Technology transfer (TT) is important in the process of technological capability development. Technological capability development and technology transfer have attracted extensive attention not only from academics, but also from business managers and government officials. However, the research on the TC development process in high-tech industries and such research on Chinese manufacturers are not adequate. In addition, practical evidence does not fully support previous research results, such as Kim’s three-stage model and the determinants of TC development.

The purpose of this dissertation is to explore the process of technological capability development in Chinese high-tech industries and to identify the key factors in this process. The dissertation selected four Chinese mobile phone manufacturers for in-depth analyses on the TC development process in Chinese high-tech industries.

This research reveals that the TC development process in Chinese high-tech industries is a process of acquiring technology in an established external alliance network and diffusing acquired technology internally with intensive efforts. With the development of technology and industry, technology transfer has taken place in alliance networks. Effective intra-firm technology diffusion under extensive internal efforts has a positive effect on the technological capability improvement of a company.

Additionally, my research results indicate that the process of TC development is influenced by the nature of technology (which contains the complexity, uncertainty and monopoly of technology), the industry value network, the diffusion of ICT, and the absorptive capacity. Furthermore, Kim’s three-stage TC development model is extended to a four-stage TC development model with a complementary stage of recessive technology.
Moreover, a technological capability development routine model based on the R&D capability and marketing capability is formulated in this dissertation.

This research contributes to the deep understanding of the process of technological capability development in Chinese high-tech industries and the determinants in this process. This will help companies in other countries, particularly companies in high-tech industries, to develop the proper strategy for the Chinese market.

Additionally, this dissertation provides new insights into the theories of technological capability development and technology management. The new findings suggest that managers and government officers should modify others’ experience with their indigenous characteristics when they develop the technology development strategies. The research results concerning FDI suggest that the Chinese government and other emerging countries should strike a balance between the national acquisition of foreign capital and the company’s acquisition of more supports to develop indigenous technological capability.

The four-stage TC development model suggests that technology managers should use different methods to manage different phases of technologies. This four-stage model also indicates that companies in China in particular, in emerging countries in general, would have more opportunities in growing and emerging technologies to develop technological capability and compete with MNCs in the world.

The research results suggest that MNCs as the dominant part of suppliers should rethink the role of recipients in technology transfer to find a balance between the benefits of technology transfer and protection of intellectual property rights. Furthermore, this research reveals that companies in developed countries need to consider cooperation with companies in emerging countries to develop the emerging technology.
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St. Gallen, July 04, 2005

Jun Jin
## Abbreviations

<table>
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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AC</td>
<td>Absorptive Capacity</td>
</tr>
<tr>
<td>B2B</td>
<td>Business to Business</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
</tr>
<tr>
<td>DOI</td>
<td>Diffusion of Innovation</td>
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<td>FDI</td>
<td>Foreign Direct Investment</td>
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<td>FTA</td>
<td>Federal Technology Authority</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>GSM</td>
<td>Global System for Mobile Communication</td>
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<tr>
<td>HCT</td>
<td>Heavy and Chemical Technology</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<tr>
<td>IP</td>
<td>Intellectual Property</td>
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<tr>
<td>IPRs</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>ITD</td>
<td>Internal Technology Diffusion</td>
</tr>
<tr>
<td>ITU</td>
<td>International Telecommunication Union</td>
</tr>
<tr>
<td>JV</td>
<td>Joint Venture</td>
</tr>
<tr>
<td>M&amp;A</td>
<td>Mergers and Acquisitions</td>
</tr>
<tr>
<td>MII</td>
<td>Ministry of Information Industry, China</td>
</tr>
<tr>
<td>MNC</td>
<td>Multinational Corporation</td>
</tr>
<tr>
<td>NIEs</td>
<td>Newly Industrializing Economies</td>
</tr>
<tr>
<td>OBM</td>
<td>Original Brand Manufacturer</td>
</tr>
<tr>
<td>ODM</td>
<td>Original Design Manufacturer</td>
</tr>
<tr>
<td>OECD</td>
<td>Organization for Economic Cooperation and Development</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>TACS</td>
<td>Total Access Communication System</td>
</tr>
<tr>
<td>TC</td>
<td>Technological Capability</td>
</tr>
<tr>
<td>TD-SCDMA</td>
<td>Time Division-Synchronous Code Division Multiple Access</td>
</tr>
<tr>
<td>TI</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>TT</td>
<td>Technology Transfer</td>
</tr>
<tr>
<td>TTM</td>
<td>Technology Transfer Mode</td>
</tr>
<tr>
<td>UNCTAD</td>
<td>United Nations Conference on Trade and Development</td>
</tr>
<tr>
<td>VC</td>
<td>Value Chain</td>
</tr>
<tr>
<td>WCDMA</td>
<td>Wideband Code Division Multiple Access</td>
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1. Introduction

1.1 Motivation of this Dissertation

1.1.1 Importance of technological capability

Technology is recognized as one of the most valuable resources that provide sustainable competitive advantages (Caloghirou et al., 2004). Technical advancement is a key driving force and an important source of economic and social development (Smith, 1776; Marx, 1867; Schumpeter, 1911; Nelson, 1987). In addition, technology has become the center of competition in the world market. The diffusion, assimilation and further improvement of new technology determine the patterns of competition, growth and trade around the world at large (Lall, 1990). The capability of accessing new technology thus affects the ability of companies in emerging countries to build indigenous technological capabilities and compete in world markets (Lall, 1990). Accordingly, technological capability (TC) has become the focus of attention not only among academics, but also among business managers and government officials (Lall, 1990; Miyazaki, 1995; Kim, 1997).

Industrial development is recognized as a process of acquiring technological capabilities and transforming them into product and process innovations in the course of continuous technological change (Kim et al., 2000). In other words, the process of industrial development, in fact, is the process of generating technological capabilities. Therefore, technological capabilities play a strategic role in affecting the competitive advantage of a company, an industry, and even a country. Technological capability has become a pervasive factor of production in the future (Lall, 1990). Thus, the development of technological capabilities is critical for companies, especially those manufacturing companies in the countries which are in a catch-up phase of industrialization.

Though the development of technological capability has been studied in a large body of literature (e.g. Lall, 1990, 1996, 2000; Nelson, 1996; Kim, 1997; Seibert, 1997), the current understanding of TC development is still inadequate, in part due to the fast-changing nature of technology and globalizing cooperation. It is necessary to study the development of technological capabilities in emerging countries in a global hypercompetitive environment.
Technological capability could be divided into two different levels – the company and the country (Lall, 1990). In the final analysis, the technological capability of countries depends on the technological capability of companies. Thus, the dissertation research concentrates on the development of technological capabilities at the corporate level.

1.1.2 Research gaps

The development of technological capabilities has attracted extensive attention both from the theoretical and empirical viewpoint. In addition, extensive research on the development of technological capabilities is carried out not only in emerging countries (e.g. Kim, 1997; Lall, 2000) but also in advanced countries (e.g. Miyazaki, 1995). Most of such research in emerging countries is based on the development experiences of newly industrializing economies (NIEs) (e.g. Kim, 1997, 1999; Lee, 2001). Little is known about the process of building up technological capability in non-industrialized countries such as China, India and Indonesia.

Most research on the experiences of NIEs and emerging NIEs (e.g. Malaysia and Thailand) focuses on the heavy and chemical technology (HCT) industries, the labour-intensive industries or electronics industries (e.g. Lee et al., 1988; Kim, 1997; Kumar et al., 1999; Lall, 2000; Lee, 2001). New industries have emerged and developed fast, particularly around information and communication technology (ICT). These emerging industries have gradually played key roles in the development of national economies. The research on technological capability development in high-tech industries in emerging countries is neglected because of their low market position in high-tech industries in the world. The new technologies, especially ICT, affect a company’s technological capability development in emerging countries. There are special characteristics in high-tech industries, such as the fast development speed of technology and highly intangible elements of technology in these industries. It is thus necessary to study the developing process of technological capabilities in high-tech industries in China in order to contribute to the research on technological capabilities.

Companies currently compete in the environment with business and innovation globalization (e.g. Gassmann and von Zedtwitz, 1998, 1999) and the diffusion of information and communication technology (e.g. Roger, 1995, 1997; OECD, 2001a). However, the research on technological capability development in such a business environment is inadequate. This dissertation strives to close this research gap.
1.1.3 Call for practice

Kim’s TC theories are widely regarded as applicable to many emerging countries, China as well. Kim proposed that most emerging countries develop TC in the mature-phase technology through three stages: acquisition, assimilation and improvement. However, the Chinese telecommunication industry has not just ‘imported’ mature-phase technology from more advanced economies; it has also adopted and developed technology at a relatively emerging stage. It did not seem to follow Kim’s (1980) three-stage model of acquisition, assimilation, and improvement of technologies from mature to growing to emerging phases. It appears to have leapfrogged one or several technological stages despite the fact that the technological capability was still not well developed for the next stage. Kim’s model, however, stipulates separate stages and a linear transition through these. Thus, Kim’s model should be modified for companies in high-tech industries.

Technology transfer is recognized as one of the important methods for improving technological capability in emerging countries. Our observations in high-tech industries suggest that the externalized technology transfer mode, such as technological alliance or technological cooperation, has become one of the preferred technology transfer methods selected by companies. This did not seem to support the theories of Lall (1993; 2002) and other technology transfer experts (e.g. Lee, 2001) that the internalized technology transfer mode, such as FDI, increases with the diffusion of ICT. Therefore, it is necessary to study technology transfer in the process of technological capability development in high-tech industries in the ICT-intensive business environment.

As the largest emerging country, China is keen to develop indigenous technological capabilities in order to close the economic and technological gaps with advanced countries. Understanding China’s rise in technological capability is important for several reasons. First, China is one of the largest nations in the world. Second, China’s economic and technological development in less than three decades is a model for many emerging countries that have not yet been able to master modern technology and generate indigenous technological capability. Thus, it is extremely prominent to understand how China’s companies built up their technological capability.
1.2 Purpose of this Dissertation

1.2.1 Research questions

Due to research gaps existing in the previous studies of technological capability’s development and the fast change of the business environment, it is necessary to explore the process of technological capability generation in high-tech industries. This dissertation therefore pursues the following research questions. The dominant research question of this dissertation is:

- **Question 1:** How do manufacturers in Chinese high-tech industries develop their technological capabilities?

Kim’s theories on technological capability development in emerging countries are widely adopted by Chinese academics as well as Chinese government officials and business managers. Kim’s technological capability development model is formulated for companies in emerging countries in the industrial era. The diffusion of information and communication technology makes the business environment different from that in the industrial era. The aim of this effort is to formulate a complement model for technological capability development in the information era. Therefore, the research question is proposed:

- **Question 2:** What reformulation would be necessary in Kim’s model to fit the current requirement of technological capability development?

The research to pursue the above questions enables us to find answers for an additional sub-question:

- **Question 3:** What are the main factors that impact on the technological capability development of manufacturers in high-tech industries?

In sum, there are two perspectives of research questions. Question 1 and question 2 are the questions relative to the process of technological capability development, while question 3 is a question regarding the factors in this development process. This research is analyzed from these two aspects.
1.2.2 Research purpose

The goal of this dissertation is to explore the process of technological capability development for manufacturers in high-tech industries in order to close the research gaps mentioned above. During the analyses of the TC development process, the main determinants in this process are investigated from the perspective of Chinese manufacturers in high-tech industries. In short, the aim of this explorative research is to develop research models and provide propositions for further research and to make well-founded observations to facilitate future investigations in technological capability generation and technology management.

The greatest significance of such a study is that more and more multinational corporations (MNCs) compete in China and the competition between the MNCs and local companies in the Chinese market is becoming fiercer and fiercer because of China’s fast developing economy and its huge market. However, despite the rapid growth of international technology movement into China and the technological competitive capabilities of China’s local companies, little is known about the evolutionary process of accumulating technological capabilities in China’s high-tech industries. Knowing what happened during the development of technological capability in Chinese companies can contribute importantly to our broader understanding of technological capability creation in high-tech industries in the information era.

This dissertation makes contributions to technological capability growth and economic growth theory. In addition, this dissertation research contributes to the technology management and the alliance research in emerging countries. Moreover, it could help the managers and policy makers to improve management performance during technological capability development.

1.3 Objective of this Dissertation

This dissertation concentrates on the process of technological capabilities development from the aspect of the building up of alliances. Previous studies suggest that, in an effort to develop indigenous technological capabilities, the process of technological capabilities development in emerging countries includes two stages: (1) obtaining advanced technologies from outside of companies; and (2) absorbing and improving advanced technologies and then developing new technologies (e.g. Lall, 1990; Kim, 1997). In other words, the TC process is an integration of an external stage (technology transfer in alliances)
and an internal stage (intra-firm technology diffusion), as shown in Figure 1-1. The external and internal stages are the focuses of this dissertation.

![Figure 1-1: Two Stages of Technological Capability Development Process](image)

Note: TT = technology transfer; ITD = intra-firm technology diffusion

The dissertation research selected the Chinese mobile phone industry, particularly Chinese local manufacturers of mobile terminal products, as the research objective. This selection is based on the special features in the development of the Chinese mobile phone industry. The Chinese mobile phone industry has developed rapidly within decades and has become one of the pillar industries in China. In addition, Chinese local mobile phone manufacturers have gradually generated the technological capabilities to compete with the foreign invested manufacturers in the Chinese market in a short time. Though China’s telecommunication equipment manufacturers, particularly the success of HUAWEI, have attracted the attention of researchers, studies on the development of mobile telecommunication terminal producers (mobile phone manufacturers) have been neglected because of the open, hypercompetitive Chinese mobile phone market, short development time, and low market position of Chinese local manufacturers in the past. Recently, China’s local mobile phone manufacturers have held nearly 50 per cent of the domestic market. Therefore, the rapid development process of the Chinese mobile phone industry as the dynamic process of building up technological capability could provide complementing or contrasting insights into industry development in emerging countries. More specifically, the
possible differences between the new model and previous model and the reasons behind them would shed new light on the technological activities carried out by Chinese companies to develop indigenous technological capability in the rapidly changing competitive environment.

1.4 Research Process

This dissertation aims to explore the process of technological capability development and identify the key factors in this process for Chinese companies in high-tech industries. This research is explorative to construct new theories in technology management for companies in China’s high-tech industries in particular, for companies in other emerging countries in general.

As an explorative and empirically oriented research study, an in-depth multi-case study is conducted in this dissertation in order to investigate the phenomenon within its real-life context. It is possible that case study method is the most suitable research method for empirical and explorative studies. Four Chinese local mobile phone manufacturers, which represent the development of China’s mobile phone industry, were chosen as cases to elaborate the three research questions.

![Figure 1-2 Research Process of the Dissertation](image)

Moreover, as the research was driven by theoretical questions based on some unstructured empirical observations, four companies were investigated on the basis of literature review. According to data analyses and discussion, new findings were proposed and new theoretical constructs were formulated. The detailed research process is shown in Figure 1-2.
1.5 Key Findings

1.5.1 Key findings

Based on detailed analyses, this dissertation proposes and examines a research model – a general TC development process for the future research on technological capability (Figure 2-5). This research model suggests that:

- The technological capability development process of a company in high-tech industries in the information era is a process involving the building up its external technology alliance network and transferring technology in this network together with the intra-firm technology diffusion under intensive internal efforts.
- In this process,
  - Companies prefer to access outside technology sources through technology transfer in alliances in order to develop their own technological capabilities.
  - Effective improvement of technological capability depends on the intensive internal efforts to speed up the diffusion of technology internally.

In addition, this research suggests that:

- The higher monopoly nature the technology has, the more probably companies prefer the alliance mode to acquire monopolistic technology.
- The industry value network encourages companies to cooperate with others during the process of technological capability development.
- The diffusion of ICT has an impact on the alliance building and technological capability development.
- The higher absorptive capacity the company has, the more effectively the company assimilates and improves the technologies.

In addition, this research modifies Kim’s three-stage TC development model and proposes a four-stage TC development model, adding a complementary stage of recessive technology for companies in high-tech industries (See Figure 6-3 in Chapter 6). The four-stage TC development model indicates that, given the context of the information era, companies may undertake concurrent activities in acquisition, assimilation, and
improvement of mature, growing, and emerging technologies at the same time. According to the research analyses, I develop a model of companies’ detailed TC development routines based on marketing and R&D capabilities (See Figure 7-8 in Chapter 7). This TC development routine model suggests that with the different levels of marketing and R&D capabilities, companies follow different routines to develop their technological capabilities.

1.5.2 Concepts in findings

This dissertation suggests that monopoly is one of the important features of technology. The monopolistic nature of technology as well as intra-firm technology diffusion has an impact on technological capability development. Both the monopolistic (or public) nature of technology and the intra-firm technology diffusion are defined based on the research necessity. In addition, this dissertation proposes a concept of four-stage technology according to the research results.

Monopoly of technology

Monopoly is the form of market organization in which a single firm sells a product for which there are no close substitutes. Entry into the industry is very difficult or impossible. Monopolistic competition refers to the case where there are many sellers of a differentiated product and entry into or exit from the industry is rather easy in the long run (Salvatore, 2001).

In this research, monopoly is defined as one of the important features of technology. Based on the definitions of monopoly and monopolistic competition in economics, monopolistic technology refers to a technology which is controlled by one or two companies. In addition, the intangible entrance barrier of such technology, such as the high investment cost, long R&D duration and high R&D risk, makes it difficult or impossible for most companies to touch this technology.

Monopoly and public are recognized as two opposite features of technology. A technology is either monopolistic or public. Public technology is mastered by many companies and it is not difficult for companies to find and acquire public technology. Most of the time, products with public technology are standard products. In general, while growing to be mature, a technology sometimes changes from monopolistic to public.

Monopoly of technology affects the process of technological capability development, technology transfer, and technological alliance formation in emerging countries the same as
other features of technology, such as the uncertainty and complexity of technology. The higher the public nature, the more opportunities the recipients have to select technology suppliers and technology transfer modes. In addition, the higher the public nature, the more likely the recipients prefer the externalized TTM to access advanced technology and to develop their indigenous technological capability. On the other hand, the higher the monopoly nature of a technology, the fewer selections the recipients have. However, the recipients have to choose externalized TTM, buying the monopolistic technology from its owner or cooperating with the owner.

**Definition:** In this dissertation, the monopoly of technology is a nature of technology. A monopolistic technology is controlled by few companies, one or two. Entry into the R&D field of monopolistic technology is very difficult or impossible.

*Four stages of technology*

This dissertation expands three-stage technology into four stages of technology, adding a recessive stage. These four stages are recession, mature, growing, and emerging stages of technology.

This dissertation defines the recession stage as that in which the technology will soon vanish; the technology will be replaced by the other technology in a short time. The mature stage is the period in which the commercialization of the technology succeeds and a large part of the technology is public. The growing stage is the period when the technology is diffusing; there are technology standards in the world and commercialization proceeds smoothly, but the technology is still not public technology. The emerging stage is the period in which the technology is new and there is (are) no one/several standard(s) accepted by all countries.

In the mobile phone industry, TACS (Total Access Communication System, the first generation mobile phone technology) is the recession technology, which has vanished from the market. GSM (Global System for Mobile Communication, the second generation mobile phone technology) is the mature technology, most of which is public. GPRS (General Packet Radio Service) and CDMA (Code Division Multiple Access) (two kinds of the 2.5th generation mobile phone technology) are the growing technology. WCDMA (Wideband
Code Division Multiple Access), CDMA2000, and TD-SCDMA (Time Division-Synchronous Code Division Multiple Access) (three kinds of the third generation mobile phone technology) are the emerging technology.

**Definition**: In this dissertation, technology develops following four stages: emerging, growing, mature and recessive stages.

**Definition**: The recessive stage is a stage where a technology will soon vanish. The technology at the recessive stage will be replaced by the other technology in a short time.

*Intra-firm technology diffusion*

Roger (1995) defines diffusion of innovation as a process in which innovation spreads in the economy and organizations or individuals adopting the innovation. In this definition, diffusion is an activity happening among different organizations or economies. In other words, according to Roger’s definition, diffusion of innovation is an inter-firm activity. In this dissertation, diffusion of ICT is a process in which ICT moves from one organization to other organizations. Like diffusion of innovation, it is an inter-firm ICT movement. On the other hand, this dissertation defines another concept as ‘intra-firm technology diffusion’. In this concept, diffusion is an activity within an organization. Therefore, intra-firm technology diffusion is a process in which the technology spreads within an organization and is improved through combining with existing technology in the organization.

**Definition**: In this dissertation, intra-firm technology diffusion is a process in which the technology spreads within an organization.

1.6 Definitions

1.6.1 High-tech industries

The definitions of the term “high-tech industries” in literature are various. In general, high-tech industries are defined according to technology intensity, which is measured by the
R&D expenditures (OECD, 1997). Technology intensity concerns the degree to which technology is produced and used within different industries. Industries with relatively high measures of technology intensity are grouped as high-tech industries (OECD, 1997). The OECD (2001b) defines the threshold between low technology and high technology as 3.5 per cent of R&D expenditure related to turnover. Table 1-1 shows different aspects of the OECD (2001b) classification and typical popular definitions based on Savioz (2004). Generally, the industries with new and emerging technology, such as information and communication technology, biotechnology, new materials and energy technologies, are regarded as high-tech industries. The basic characteristics of these new technologies are that they are knowledge and research-intensive and tend to be closely interrelated (UNCTC, 1990).

**Definition:** A high-tech industry refers to an industry with high technology intensity (R&D expenditure higher than 3.5 per cent of revenues).

### 1.6.2 Technology

Technology refers to the application of theoretical and practical knowledge, skills and artifacts to the establishment, operation, improvement, and expansion of facilities for such transformation and to the designing and improving of outputs therefrom (Merrill, 1968; Westphal et al., 1985; Burgelman et al., 1996; Kim, 1997; UNCTAD, 2001). Technology is a necessary tool of an advanced manufacturing system. It has provided a new opportunity to achieve new heights of performance in respect to simultaneously high levels of flexibility and efficiency (Harrison and Samson, 2002).

According to Polanyi (1966), technology has two primary dimensions: explicit and tacit or implicit. The explicit type of technology could be codified in formal and systematic language (encoded knowledge). Tacit technology is hard to codify and communicate. In addition, tacit knowledge is embedded in different aspects of human and organizational activities. It is therefore more complex and difficult to be transferred than explicit knowledge (Marcotte and Niosi, 2000; Ernst and Kim, 2002). Key elements of technology may be tacit, only embodied in people, materials, cognitive and physical process, plant, equipment and tools (e.g., trade secrets based on know-how) (Burgelman et al., 1996).
Table 1-1 Examples of High-tech and Low-tech Industries

<table>
<thead>
<tr>
<th>OECD (2001) definitions</th>
<th>Typical popular definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-tech industries:</strong></td>
<td><strong>High-tech industries:</strong></td>
</tr>
<tr>
<td>• Aircraft</td>
<td>• Aerospace</td>
</tr>
<tr>
<td>• Office &amp; computing equipment</td>
<td>• Biotechnology</td>
</tr>
<tr>
<td>• Drugs &amp; medicines</td>
<td>• Chemicals</td>
</tr>
<tr>
<td>• Radio, TV &amp; communication equipment</td>
<td>• Electrical equipment</td>
</tr>
<tr>
<td></td>
<td>• Medical technology</td>
</tr>
<tr>
<td></td>
<td>• Pharmaceuticals</td>
</tr>
<tr>
<td></td>
<td>• Semiconductors</td>
</tr>
<tr>
<td></td>
<td>• …</td>
</tr>
<tr>
<td><strong>Medium-high-tech industries:</strong></td>
<td><strong>Low-tech industries:</strong></td>
</tr>
<tr>
<td>• Motor vehicles and transport</td>
<td>• Construction &amp; real estate</td>
</tr>
<tr>
<td>• Electrical machines</td>
<td>• Food, beverage &amp; tobacco</td>
</tr>
<tr>
<td>• Chemicals excl. drugs</td>
<td>• Footwear &amp; textiles</td>
</tr>
<tr>
<td>• Non-electrical machinery</td>
<td>• Metals &amp; minerals</td>
</tr>
<tr>
<td></td>
<td>• Transportation</td>
</tr>
<tr>
<td></td>
<td>• …</td>
</tr>
<tr>
<td><strong>Medium-low-tech industries:</strong></td>
<td><strong>…</strong></td>
</tr>
<tr>
<td>• Rubber &amp; plastic products</td>
<td>• Banks, insurance</td>
</tr>
<tr>
<td>• Metal products</td>
<td>• Retails</td>
</tr>
<tr>
<td>• Petroleum refineries &amp; products</td>
<td>• Services</td>
</tr>
<tr>
<td></td>
<td>• …</td>
</tr>
<tr>
<td><strong>Low-tech industries:</strong></td>
<td></td>
</tr>
<tr>
<td>• Paper products &amp; printing</td>
<td></td>
</tr>
<tr>
<td>• Textiles, apparels &amp; leather</td>
<td></td>
</tr>
<tr>
<td>• Food, beverage &amp; tobacco</td>
<td></td>
</tr>
<tr>
<td>• Wood products &amp; furniture</td>
<td></td>
</tr>
</tbody>
</table>

In most research (such as the research on technology transfer and technology alliance), the nature of technology refers to the complexity of technology, the uncertainty of technology, and so on. The technology with a higher tacit element is more complex and uncertain. As mentioned above, the nature of technology has an impact on technology transfer, technology alliances, and technological capability development. This dissertation defines monopoly as one important nature of technology. The nature of technology in this dissertation thus focuses on the complexity, the uncertainty, and the monopoly of technology.

**Definition**: In this dissertation, technology refers to the application of theoretical and practical knowledge, skills and artefacts to the establishment, operation, improvement, and expansion of facilities for such transformation and to the designing and improving of outputs therefrom.

### 1.6.3 Technological capability

The definition of technological capability varies in perspective, depending on the aims of the researchers. Lall (1990: 17) defines technological capability broadly as “the entire complex of human skills (entrepreneurial, managerial and technical) needed to set up and operate industries efficiently over time”. He defines TC in a narrow sense as the capability to execute all the technical functions entailed in operating, improving and modernizing the company’s production facilities. Westphal et al. (1985) and Kim (1997) define the term ‘technological capability’ from the aspect of corporate development. Technological capability refers to the ability to make effective use of technological knowledge to assimilate, use, adapt, and change existing technologies. It also enables one to create new technologies and to develop new products and processes in response to a changing economic environment (Westphal et al., 1985; Kim, 1997).

There are many different categorizations of technological capability depending on the research purpose (Lall, 1990). Kim (1997) distinguishes technological capability into three elements: production, investment, including duplication and expansion, and innovation. Lall (1990) categorizes technological capability into investment technological capability, production technological capability, and linkage technological capability according to the functions. Kim (1997: 4) points out that in emerging countries ‘technological capability’
can be used interchangeably with ‘absorptive capacity’ (Cohen and Levinthal 1990): absorbing existing knowledge, assimilating it, and in turn generating new knowledge.

In this paper, we use technological capability as the capability to make effective use of technical knowledge and skills, not only in an effort to improve and develop the products and processes, but also to improve the existing technology and to generate new knowledge and skills in response to the competitive business environment. In addition, the technological capabilities in this dissertation cover production capability, investment capability, marketing capability, and R&D capability.

**Definition**: Technological capability refers to the capability to make effective use of technical knowledge and skills, not only in an effort to improve and develop the products and processes, but also to improve the existing technology and to generate new knowledge and skills in response to the competitive business environment. R&D capability and marketing capability are two important types of technological capability.

### 1.6.4 Industry value network

In the early 1980s, Michael Porter (1980, 1985) proposed a value chain model to identify competitive advantage. The value chain (VC) is a business model that enables the organizing of operations around the value creating activities that result in a better service or product (Porter, 1985). Since Porter proposed the VC model in 1985, value chain analyses have gained popularity. The concept has been broadened and used from a company to an industry level. The industry-level value chain considers the interdependence of companies in an industry and engagement of companies in the value creating activities (e.g. Kothandaraman and Wilson, 2001; Maitland et al., 2002). In other words, with the changing technology, the value chain has expanded into the value network (Kothandaraman and Wilson, 2001).

The research on the telecommunications industry certifies that at an industry level, the value chains are rapidly involving into value networks, with multiple entry and exit points, creating enormous complexity for all the players involved (e.g. Gulati et al., 2000; Li and Whalley, 2002). Whilst value networks are a phenomenon occurring across the entire telecommunications industry, the way in which they are constructed by companies differs
depending on which part of the industry they are located in (Li and Whalley, 2002). Therefore, the concept of the industry value network is used in this dissertation. The value networks in industry affect the strategy and development of companies in this industry.

In this dissertation, the industry value network means that all companies in one industry operate together as a network to create value that results in better products and services. Some companies produce the accessories, some companies design, some companies provide the key technology, and some companies assemble and produce the terminal products.

In an industry with a high level of industry value network, a company must cooperate with others to finish things, particularly to innovate complex technology. In addition, in such an industry, an innovation is the consequence of the cooperation of many companies. In other words, a company in such an industry conducts R&D with its suppliers, its customers, its competitors, and others. Most importantly, all companies in an industry are involved in the industry value network. No one can survive and succeed alone without this industry value network. Therefore, the higher level of the value network an industry has, the more likely companies in this industry prefer technology cooperation.

**Definition**: In this dissertation, the industry value network refers to the case where all companies in an industry engage together to create value that results in better products and services. Companies in an industry run interdependently.

### 1.7 Structure of this Dissertation

The rest of this dissertation will proceed as following. There are another seven chapters, divided into three parts.

The first part includes chapter two and chapter three. These two chapters are the basis of this dissertation, including literature review and research methodology. The second chapter is the literature review, covering the previous theoretical and practical research on the technological capability generation, for instance, the theories of technological capability, technology transfer, technology alliances, diffusion of innovation, and other relative theories. Based on the literature review, the research gaps in studies of technological capability development are concluded. The research framework and research focus of this dissertation
are proposed at the end of chapter two. The research methodologies conducted in this dissertation are presented in the third chapter. These two chapters are the theoretical bases of analyses in this dissertation.

The second part is the main theme of this dissertation. It contains four chapters, from chapter four to chapter seven. I analyze four cases in-depth in this part. Chapter four introduces the general TC development of the Chinese mobile phone industry. Chapter five expands the general information regarding the TC development process of China’s mobile phone manufacturers. According to the research framework, the industry and four cases in these two chapters are analyzed from two aspects: the process of technological capability generation and the factors in this generation process. In addition, the process of technological capability development is explained following the development history of different generations of mobile phone technologies. Chapter four and chapter five are the practical bases of analyses in this dissertation.

Afterwards, I analyze and discuss the research results in the following chapter six and chapter seven in order to resolve three research questions of this dissertation. These two chapters are analyzed according to the research models. The sixth chapter addresses the process of technological capability development in the Chinese mobile phone industry and the factors in this process. Chapter six answers three research questions. In addition, four research findings based on research analyses results are proposed in this chapter for the future research. In addition, in chapter six, Kim’s model on the process of technological capability development is modified and remedied. A new complementary model is formulated.

Then the construction of new theories is developed in chapter seven. The detail TC development routines regarding R&D and marketing capabilities are discussed in this chapter based on the development routine model proposed in chapter two. In chapter seven, a final model regarding the influence of the existing R&D and marketing capability on the TC development process is developed.

The third part of this dissertation is the summary of research results. In chapter eight, I present some general conclusions of this whole research, theoretical constructions, implication and limitation of research results, and approaches for the further research.

The end of this dissertation is references and appendixes. Appendix I provide the general introduction of the four cases. Appendix II covers the questions conducted in interviews.
1.8 Summary of Introduction

In this first chapter, an overview of the topic, the research purposes and the research questions are given. The most important facets above all are the technological change, the globalizing competitive environment, the diffusion of ICT, the rapid development of emerging high-tech industries and the call for practical research. Then, the research process is designed in an effort to approach research gaps, to find a way to close them, and to find the answers for research questions. This dissertation proposes a general TC development model, a complementary four-stage TC development process, and a detailed TC development routine model based on marketing and R&D capabilities. In addition, the main terms of this dissertation, such as the monopoly nature of technology, industry value networks, high-tech industries, technology, and the technological capability, are defined and explained. At the end of this chapter, the structure of this dissertation is described.
2. Literature Review

In this chapter, I examine the existing literature concerning the technological capability development of companies in emerging countries. This chapter will provide the theoretical background knowledge of this dissertation. I focus on the following five streams of literature: 1) the development of technological capability, including previous studies on the process of technological capability development; 2) technological alliance; 3) technology transfer; 4) diffusion of innovation; and 5) absorptive capacity. At the end of this chapter, I state the necessity to modify the current research regarding the process of technological capability development and propose the research framework.

2.1 Development of Technological Capability

Technological capability can be categorized into two levels: the corporate level and the national level (Lall, 1993). This dissertation concentrates on the corporate level of technological capability. At the corporate level, the technological capability development is the outcome of company-level efforts to build up new organizational and technical skills, its ability to generate and tap information, the development of an appropriate specialization vis-à-vis other companies, and the formation of linkages with suppliers, buyers and institutions (Lall, 1993). Furthermore, the social benefits of corporate efforts to build and develop technological capabilities may far exceed the individual benefit of companies themselves because of technological diffusion – the widespread externalities of skills and technologies (Lall, 1993).

2.1.1. Exploring technological trajectories

Most studies of newly industrialized economies and advanced countries alike suggest that the development of technological capability is path-dependent, which means that it develops along the technology trajectory (e.g. Utterback and Abernathy, 1975; Nelson and Winter, 1977; Dosi, 1982; Penrose, 1995; Kim, 1997; Teece, Pisano, and Shuen, 1997; Patel and Pavitt, 1998, 2000).

This dissertation deals with not merely one technology, but with several, each with its pattern of development and skill requirements, though these technologies are the same type
of telecommunication technologies. It is therefore imperative and challenging to clarify the trajectories of correlated evolving technologies. There are five major technological trajectories, each with a distinct nature and sources of innovation, and with distinct implications for technology strategy and innovation management (Tidd et al., 2001). Based on Table 2-1 and the characteristics of mobile phone technologies, the mobile phone industry is an industry with two technological trajectories: scale-intensive and information-intensive technological trajectories. Thus, the production technological capability and process technological capability are important in the mobile phone industry. In addition, information and communication technology has an impact on a company’s R&D activities in this industry.

Utterback and Abernathy (1975) postulate that the technology in advanced countries develops following three stages: fluid, transition and specific (upper part of Figure 2-1). The stages of the technology trajectory in developed countries are different from those in emerging countries. Kim (1980) developed a three-stage model for the technology trajectory in emerging countries – acquisition, assimilation and improvement – to extend Utterback’s model (lower part of Figure 2-1).

### 2.1.2. The process of technological capability development

The study of the process of technological capability development is extensive and empirically oriented. Most research focuses on the TC development process in NIEs. Based on a wide range of research (Westphal et al., 1985; Lee et al., 1988; Lall 1990, 1993; OECD, 1994; Kim, 1980, 1997, 1999; Kumar et al., 1999; Kim and Nelson, 2000; Lee, 2001), the TC development process in NIEs follows three steps.

1. Domestic companies in NIEs transfer mature technology from MNCs;
2. Then they absorb the transferred technology and diffuse the technology in companies and in the industry, even in the whole economy;
3. Eventually, these companies then develop their own new technology.
<table>
<thead>
<tr>
<th>Table 2-1 Five Major Technological Trajectories</th>
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<tbody>
<tr>
<td><strong>Supplier-dominated</strong></td>
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<tr>
<td>Main sources of technology</td>
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<tr>
<td>• Suppliers</td>
</tr>
<tr>
<td>• Production learning</td>
</tr>
<tr>
<td>• Suppliers</td>
</tr>
<tr>
<td>• Design offices</td>
</tr>
</tbody>
</table>
Figure 2-1 Integration of Two Technological Trajectories

Kim (1997) integrates Utterback’s three-stage model (1975) with his three-stage model (1980) to analyze the process of building technological capability (Figure 2-1) and to describe the TC development process in emerging countries.

According to Kim’s theory, during the early stage of the TC development, companies in emerging countries acquire mature (specific-state) foreign technology from MNCs since they lack adequate local production and innovation capabilities. Local companies develop their production processes through the acquisition of these ‘packaged’ foreign technologies. Companies merely assemble foreign inputs to produce standardized, undifferentiated goods. However, once companies have acquired the transferred technology, they make efforts to assimilate the transferred technology to manufacture more advanced and differentiated products. Companies repeat the process with higher-level technologies in the intermediate technology stage (growing technology). If they are successful in growing technology, companies may eventually accumulate indigenous TC to develop and generate the emerging technologies on their own and compete on leading-edge innovation with companies in advanced countries (Kim, 1997). Only few companies in emerging countries reach the third stage. For instance, in the early 1900s the origins of NEC were laid through a joint venture with Western Electric, an American telephone company, to transfer technology for exploitation in Japan. After the Second World War, NEC started to export indigenous technology to emerging countries in the Asia-Pacific region. With substantial R&D efforts, NEC gained a leading technology position by the 1970s and started to export technology to the US, the source of its initial technology provision. By the mid-1980s, NEC was eventually acclaimed a worldwide leader in its field of top-end mainframe and general-purpose computers.

The nature of R&D changes through the progress in these three stages. Technological activities in the acquisition stage emphasize duplicative imitation, producing knockoffs and clones of the mature technology, normally without improvement of the technology. In the assimilation stage, the technological emphasis is creative imitation, producing facsimile products but with new features. In the third stage, indigenous innovation is essential (Kim, 1999). Most research in emerging countries supports Kim’s idea that companies make efforts to master the transferred mature technologies and practice them efficiently, but companies make no or only little improvement (Dahlan et al., 1987; Lall, 1987, 1990). Moreover, the TC development of companies generally follows this three-stage model, moving from acquisition to assimilation and finally to improvement (or innovation). Some researchers examined companies in Korea, such as Samsung, to provide further evidence for this model of the TC development process (e.g. Kim, 1997, 1999; Lee, 2001).
To summarize, Kim’s theory of the TC development process is:

- In emerging countries, the state of technological capability develops from mature to growing and to emerging technology.
- Most companies in these countries are at the stage of mature technology; few reach the stage of emerging technology.
- There are clear and discernible boundaries between these three different stages.
- Technological capability must develop from one stage to the next, step by step.
- The main R&D activities of companies in emerging countries are acquisition and assimilation of the transferred mature technologies, not development of the mature technology.

Cyhn (2002) argues that original equipment manufacture (OEM) is very effective in helping companies in emerging countries to change from one stage to another stage. OEM is more effective than other ways of technological learning (such as reverse engineering and licensing technology), in offering the opportunity for companies in emerging countries to have intimate interaction with companies in developed countries (Cyhn, 2002).

In recent research, however, Gao (2003) found that telecommunication equipment-manufacturing companies in China do not follow this model, as companies did research and improved the mature technology. Gao’s study results (2003) suggest that some companies deviate from the ‘normal’ way of the TC development (acquisition, assimilation, and development) and have made impressive progress. Companies starting early to develop proprietary technology generate TC more effectively than those companies following the traditional paradigm. In addition, Gao’s research (2003) indicates that reinvesting in “mature technology” is effective for companies in emerging countries to develop TC. Therefore, we conclude that it is essential to examine Kim’s three-stage model in an emerging industry in China.

### 2.2 Technological Alliances

Alliances have different objectives, depending on the aspect which researchers and managers deal with. This dissertation focuses on the narrow area of technology alliances to undertake R&D activity. An R&D alliance is an arrangement – formal or informal – intentionally, culturally, or by accident – for the purpose of facilitating knowledge flow (Link, 2002), acquiring technical knowledge, generating innovations (Hagedoorn, 1993;
Nalura, 2003), and improving technological capabilities. Generally, an alliance is a bond or connection between two or more individuals or organizations (c.f. Chen and Chen, 2002). In this dissertation, an R&D alliance is seen as a set of selected and explicit linkages with preferential partners to reduce static and dynamic uncertainty and cost in R&D activities. Extensive research already exists on the motivation, formation and other issues of strategic technological alliances.

### 2.2.1. Motivation of alliances

Companies collaborate for a number of motives (c.f. Tidd et al., 2001):

- To reduce the cost of technological development or market entry;
- To reduce the risk of development or market entry;
- To achieve scale economies in production; and
- To reduce the time taken to develop and commercialize new products

In general, a company is likely to have multiple motivations for an alliance (Tidd et al., 2001). For instance, the alliance between Philips and Sony had many motivations, including access to complementary technologies, economies of scale in production, establishment of international standards and access to the international market.

In short, the major motivations for R&D alliances are to pursue dynamic value (Gerybadze and Reger, 1999), improve response to technology changes, reduce risk and costs of R&D (Littler, 1993), and produce economies from synergies of partners (Iyer, 2003). A particular resource which is lacking in a company, such as funds, technology or market power, could be acquired through the formation of an alliance with another company. One of the main purposes of an R&D alliance is competence enhancement (Iyer, 2003). To be a successful alliance, the motivations of the respective partners should be complementary, rather than competitive (Tidd et al., 2001; Iyer, 2003). Companies should consider alliance partners with complementary technology, products or markets (Bleeke and Ernst, 1993).

### 2.2.2. Forms of alliances

Alliances can be viewed in terms of their strategic significance or duration (Table 2-2). In these aspects, contracting and licensing are tactical, whereas strategic alliances, formal joint ventures and innovative networks are strategic and more appropriate ways for learning
(c.f. Tidd et al., 2001). In high-tech industries, companies often prefer alliances with the following forms (Yasuda, 2004):

(a) Technology license;
(b) Joint R&D;
(c) Agreement with suppliers; and
(d) Joint venture.

Table 2-2 Forms of Alliances

<table>
<thead>
<tr>
<th>Types of Alliances</th>
<th>Typical duration</th>
<th>Advantages (rationale)</th>
<th>Disadvantages (transaction costs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subcontract/supplier relations</td>
<td>Short term</td>
<td>Cost and risk reduction</td>
<td>Search costs, product performance and quality</td>
</tr>
<tr>
<td>Licensing</td>
<td>Fixed term</td>
<td>Technology acquisition</td>
<td>Contract cost and constraints</td>
</tr>
<tr>
<td>Consortia</td>
<td>Medium term</td>
<td>Expertise, standards, share funding</td>
<td>Knowledge leakage</td>
</tr>
<tr>
<td>Strategic alliance</td>
<td>Flexible</td>
<td>Low commitment, Market access</td>
<td>Potential lock-in, Knowledge leakage</td>
</tr>
<tr>
<td>Joint venture</td>
<td>Long term</td>
<td>Complementary knowledge, Dedicated management</td>
<td>Strategic drift, Cultural mismatch</td>
</tr>
<tr>
<td>Network</td>
<td>Long term</td>
<td>Dynamic, learning potential</td>
<td>Static inefficiencies</td>
</tr>
</tbody>
</table>


Indeed, alliance formation has been classified in terms of equity joint venture and non-equity contractual agreement (Chen and Chen, 2002; Colombo, 2003). Equity-type
wholly- or majority-owned subsidiaries are preferred by companies in mature, stable industries where the technology is tangible and codifiable (Nalura, 2003). Non-equity contractual alliances are said to be widely used by established companies in the early stages of the life cycle of the telecommunications industry as a means for exploring untapped technological opportunities (Colombo and Garrone, 1998). Hagedoorn and Narula (1996) also show that the equity mode of alliances is preferred in relatively mature industries, while the non-equity mode of alliances is utilized in high-tech industries – the industries with the core technologies, such as biotechnology, new materials and information and communication technology. In addition, the equity mode of alliances represents a higher level of internalization and inter-organizational interdependence than the non-equity mode of alliances (Narula and Hagedoorn, 1999). The use of non-equity mode of alliances seems to enjoy an across-the-board increase, except in Latin America, during the period of 1980-1994 especially (Freeman and Hagedoorn, 1994; Nalura, 2003).

No single form of alliance is optimal in any generic sense (Tidd et al., 2001). Extensive research suggests: the tacit element of knowledge, the complexity of technology, the prior experience, and the absorptive capacity have an impact on the formation and performance of alliances (e.g. Simonin, 1999; Colombo, 2003; Chen, 2004). According to Tsang’s research (1998), the high proportion of tacit knowledge and the high cost and uncertainty of an R&D investment drive a company to form a strategic technological alliance with others to pool their resources together. Osborn and Baughn (1990) and Hagedoorn and Narula (1996) have illustrated that differences in the form of alliance derive from the rate and uncertainty of innovatory activity, as well as the technological intensity of industries. Thus, non-equity forms of alliances are more efficient for research-intensive industries than equity forms of alliances (Nalura, 2003).

Companies could improve their technological capabilities through learning from alliance partners (Dussauge et al., 2000; Bougrain and Haudeville, 2002). Therefore, an R&D alliance is recognized as an effective knowledge transfer method to access required technology or other resources from partners (e.g. Chen, 2004; Simonin, 1999; Chen and Sun, 2000; Lambe and Speckman, 1997).

2.2.3. Technological alliances in emerging countries

Technological alliances are convenient for companies to enhance their competitive advantages in international markets with limited resources (Nalura, 2003). Like companies from developed countries, companies from emerging countries have also engaged in
alliances (Nalura, 2003). The work of Freeman and Hagedoorn (1994) indicates that companies from emerging countries contribute only insignificantly to strategic alliance formation. However, the increasing homogeneity of technologies across countries and companies as well as the diffusion of information and communication technology has enabled companies in emerging countries to use strategic technological alliances as a means not only to generate technological competences and capabilities but also to close technology gaps between themselves and market leaders (Nalura, 2003).

The economic success of Asian newly industrialized economies such as Korea and Taiwan has prompted imitators throughout emerging countries (Lall, 1993, 2002; Kim, 1997, 1999; Kim and Nelson, 2000; Nalura, 2003). Nonetheless, it is clear that the growing use of strategic technological alliances is an increasingly important tool in the process of technological capability upgrading in these countries (Nalura, 2003). The work on the distribution of the strategic technological alliance illustrates that in Asian NIEs, technological alliance activities in high-tech industries increase, while the importance of technological alliance activities in medium- and low-tech industries gradually declines (Nalura, 2003).

Like companies in advanced countries, companies in technology-intensive, Schumpeterian-type industries (mostly high-tech industries) in emerging countries prefer strategic technological alliances due to the high costs of R&D and the high uncertainty in these industries (Ozawa, 1995; Nalura, 2003).

2.2.4. R&D alliances in China

Given China’s huge size and economic potential, the globalization of R&D activities today (Iyer, 2003), and the high quality of Chinese scientists and engineers (von Zedtwitz, 2004), more and more MNCs are setting up R&D activities in China including wholly-owned institutes, joint R&D centers, and contractual cooperation (von Zedtwitz, 2004; Li and Zhong, 2003). The statistics compiled by the Chinese Department of Science and Technology indicates that 65 MNCs had set up more than 80 R&D institutes in China by the end of August, 2002 (STS, 2003). There is a greater preference among MNCs for non-equity R&D cooperative agreements compared to equity R&D joint ventures (Li and Zhong, 2003). Li and Zhong’s finding (2003) suggests that the location; the number of partners, the nature of local partners, and the national origin of foreign partners are significantly related to the formation of R&D alliances in China.
However, research on R&D alliances from the Chinese local firms’ perspective has gone largely unnoticed, due to the difficulties in doing adequate research in China and the limited impact of Chinese local firms’ R&D in the world (Liu and White, 2001; von Zedtwitz, 2004). There is very little systematic research on international R&D alliances of Chinese companies.

2.3 Technology Transfer

2.3.1. Technology transfer

Technology transfer is widely recognized as a crucial method for companies in emerging countries to obtain advanced technologies and to generate indigenous technological capabilities (e.g. Lall, 1993, 2002; Kim, 1994; and UNCTAD, 2001). Three main components exist in a process of technology transfer: the technology supplier, the technology recipient, and the technology transfer mode selected by the technology supplier and technology recipient, as shown in Figure 2-2 (e.g. Al-Obaidi, 1993; Lall, 1993).

2.3.2. Technology transfer mode

The Figure 2-2 indicates that technology transfer mode (TTM) is a bridge between a technology supplier and a technology recipient. In other words, a TTM is a business channel or an institutional arrangement, through which the transfer of technology from the supplier to the recipient takes place (Al-Obaidi, 1993).

There exist various modes of technology transfer according to the nature of technology, and the relationships between technology suppliers and technology recipients (Lall, 1993). Foreign direct investment (FDI) has traditionally been the dominant form of technology transfer. Minority joint ventures (JV) (under the control of companies in the host country), licensing, merger and acquisition (M&A)\(^1\), turnkey plants and/or capital goods imports, subcontracting, and technology cooperation in a project, have grown in importance (Dunning, 1981; Lall, 1993; Al-Obaidi, 1993; UNCTAD, 2001). In addition, these TTMs could be called non-FDI mode (Lall, 1993).

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\(^1\) In this paper, we regard FDI as the method that companies acquire and absorb the transferred technology through foreign wholly - owned subsidiaries or joint ventures (controlled by MNCs). M&A is the method to acquire transferred technology through merging or acquiring other organizations.
Figure 2-2: Technology Transfer Mode

According to the control power of technology supplier in a technology transfer process, these technology transfer modes could be categorized as internalized TTM and externalized TTM (Lall, 1993; UNCTAD, 2001). Internalized method refers to the technology transfer where control resides with the technology supplier (generally, but not necessarily, associated with the majority or full equity ownership), normally associated with FDI; while externalized method refers to the technology transfer where the technology supplier transfers the technology to other organizations (Lall, 1993; UNCTAD, 2001). Therefore, FDI and majority joint venture (under the control of the technology supplier) are internalized TTMs. The other TTMs are not under the supplier’s control, belonging to externalized TTMs (Lall, 1993; UNCTAD, 2001).

In general, internalized TTMs such as FDI may be the more efficient way of generating local know-how, but not effective for generating local know-why in the host economy (Lall, 2002). On the other hand, licensing, M&A and other externalized modes are more effective for generating local know-why in the host economy (Dunning, 1981; Lall, 2002).

The development of NIEs (except of Korea) suggests that FDI plays a great role in economic and social development (e.g. Kim, 1994, 2000; Lall, 1996). Additionally, FDI is still one of the dominant methods in most emerging countries, such as Indonesia, Brazil and Singapore (Lall, 1996; Kumar et al., 1999; UNCTAD, 2001). Nevertheless, the work of Nalura and Dunning on FDI (1999) suggests that, with the increasing reliance of less developed countries on FDI as a source of capital and technology, there is an increasing likelihood that there will be a widening gap between advanced countries and the bulk of emerging countries.

The development history of Korea and other newly industrialized economies indicate that the technology transfer mode changes because of the improvement of the host country’s economy and technology (e.g. Lee et al., 1988; Roger, 1995; Lall, 1996; Kim, 1997; Kim and Nelson, 2000).

2.3.3. **Determinants of technology transfer modes**

As shown in Figure 2-2, technology supplier and technology recipient as well as the environment within which they operate determine the selection of technology transfer mode. The important factors are the nature of technology, strategies of technology supplier, existing technological capabilities of technology recipient, and host country’s government policies (Lall, 1993; UNCTAD, 2001), as shown in Figure 2-2. As far as the nature of
In technology selection, TTM selection is determined by the complexity of the technology, technology’s changing speed, novelty, R&D concentration level, technology’s standardized level, technology’s diffusion speed, and whether the technology is product or process based (Lall, 1993). Generally, the higher the complexity, the faster the speed of change, and the higher novelty and value the technology has, the more a technology supplier will take such internalized TTM as FDI and majority joint venture (Lall, 1993). Tsang (1997) confirms the effect of the technology nature on the choices of TTM: the newer and the more complex the technology is, the more a technology supplier will prefer FDI as TTM.

In addition, the supplier’s strategy in the host country influences the transferring method and the value of the transferred technology. The supplier’s strategy is determined by the company’s size, product concentration, dependence on proprietary brand names, and so on (Lall, 1993; UNCTAD, 2001).

Moreover, the technological capabilities of technology recipients have a mixture of effects on the TTM’s selection (e.g. Lall, 1993; Tsang, 1997; UNCTAD, 2001). On the one hand, there is less need for a recipient with the higher capabilities to internalize the transfer. On the other hand, the recipient with the higher capabilities poses a greater potential threat to the supplier. Therefore, the supplier may prefer internalized TTM when the technology recipient has high technological capability (Lall, 1993).

In emerging countries, most governments seek to intervene in the technology transfer process in an effort to lower the costs and improve the business environment to attract more international technology transfer (e.g. Lall, 1993; Kim, 1994). In order to boost the development of domestic technological capability, some government policies have been adopted to increase externalized TTM, such as in Korea in the 1970s (Lall, 1993; Kim, 1994). However, FDI is still the leading and increasingly used method preferred by many governments (Lall, 2002).

### 2.3.4. Benefits of technology transfer

The benefits of technology transfer for the host country come not only from the acquisition and usage of the advanced foreign technology but also from the diffusion of the transferred technology throughout the whole economy. Because of the spill-over effect of information and skills, the technology diffusion is even more important (Kim, 1997; UNCTAD, 2001, Lall, 2002). The effective diffusion of transferred technologies and skills across companies within an industry and across industries within an economy maximizes the benefits of imported technology (Kim, 1997). Technology transfer provides suppliers with
more flexibility to utilize their technological strengths, to exploit their proprietary technologies in commercial technology markets for maximum gain, to extend their technologies’ life cycle, to exploit their dominant position in such markets and to enhance their international competitive advantage (Al-Obaidi, 1999; UNCTAD, 2001).

2.3.5. **Technology transfer versus technological capability development**

The ultimate purpose of technology transfer is to build up technological capability of technology importers; technology transfer therefore contributes to the development of technological capability for emerging countries (e.g. Lall, 1993, 2002; Kim, 1997; 1999; Wei, 1995). In addition, the relationship between the international technology transfer and the development of indigenous technological capability has long been the subject of academic, empirical and policy debates and concerns in less developed countries (Lall, 1993). Many researchers attempt to examine the relationship between technology transfer and technological capability (e.g. Lall, 1993; Kumar *et al.*, 1999). The theoretical study of Lall (1993) suggests that the relationship between technology transfer and indigenous technological development is not straightforward. There are several stages, such as assimilation, adaptation, and further improvement, between the import of technology and the development of local technological capabilities. Wei (1995) advances the study of Lall to study the costs of technology transfer, the assimilation of the imported technology, and the extent to which technology transfer contributes to the development of indigenous technological capabilities of the technology importing enterprise. Hence, it is a complex and evolutionary process to generate the technological capabilities through technology transfer (Lall, 1993). The technological and economic development successes of NIEs in East Asia certify that the technology transfer makes contribution to the development of technological capability of companies in host economies (e.g. Kim, 1997; Lee, 2001; Lall, 2002).

However, when technological capabilities come from outside of the company as part of a corporate acquisition, different practices and cognitive structures may make their assimilation costly or impossible (Tidd *et al.*, 2001). It is because the tacit technical and organizational knowledge accumulated through experience are of central importance in generating technological capabilities and other corporate competencies (Mowery and Rosenberg, 1989).
2.3.6. **Summary**

In conclusion, the literature review on technology transfer suggests that:

- FDI is the preferred TTM of governments in many emerging countries. However, externalized TTM boosts the development of indigenous technological capability in emerging countries. Which is preferred by companies in China, FDI or externalized TTM?
- The TTM in a company, even in an industry and in a country changes with the improvement of technological capability. However, there is less research on the TTM changes in high-tech industries in China.
- The nature of technology, strategies of technology supplier, technological capabilities of technology recipient, as well as government policies have an impact on the TTM’s selection, as shown in Figure 2-2.
- The newer and the more complex the technology is, the more likely a technology supplier will prefer FDI as the TTM. However, the research on the preferred TTM of a recipient is largely neglected.
- With high technological capability, a technology recipient may have less need to internalize the transfer. Nevertheless, it is not clear whether a recipient may really prefer externalized TTM with high technological capabilities.

2.4 **Diffusion of Innovation**

One of the important benefits of TT to the TC development in emerging countries is the diffusion of imported technology in the whole economy. Most importantly, the diffusion of technology across companies and industries improves and speeds up the development of technological capabilities in companies and industries. This dissertation uses diffusion of innovation (DOI) theory because it is well established and widely used in research related to the influence from the diffusion of ICT (Prescott & Conger, 1995; Mustonen-Ollila and Lyytinen, 2003).

2.4.1. **Diffusion of innovation**

Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Roger, 1995). Diffusion is a
special type of communication concerned with the spread of messages that are perceived as new ideas. The four main elements in the diffusion of new ideas are (1) the innovation, (2) communication channels, (3) time, and (4) the social system (Roger, 1995). In this dissertation, the innovation is considered as the new technology recognized by companies in China.

In addition, the process of DOI could be recognized as the process by which the innovation spreads in the economy and organizations or individuals adopting the innovation. The characteristics of an innovation, the nature of potential adopters, and the process of communication affect the diffusion of innovation (Roger, 1995). The characteristics of an innovation determine its adoption rate – the speed of DOI. These characteristics are: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability (Roger, 1995; Roger and Scott, 1997). In theory, the greater the perceived advantage is, the faster innovations are adopted. In addition, the extent to which an innovation fits the existing skills, practices, equipment, procedures and value criteria of a potential adopter is important, and such innovation is relatively easy to access. The more complex an innovation is for potential users to understand, the more slowly the innovation will be adopted. In general, innovations which can be trialed will be adopted more rapidly than those which cannot. Moreover, the easier to see the benefits of an innovation, the more likely the innovation will be adopted (Roger, 1995). The skills, psychology, social context and infrastructure of adopters also affect the diffusion of innovation (Roger, 1995).

As the diffusion process develops, the experience of companies with new technology leads them to update initial estimates of both risk and returns and the usage’s level of new technology (Karshenas and Stoneman, 1995). Early adopters will influence the development of an innovation, but subsequent adopters may be more influenced by competitive and peer pressures (Roger, 1995; Tidd et al., 2001).

2.4.2. Diffusion of information and communication technology

Information and communication technology (ICT) is a new technology as well as a revolutionary technology (Nalura, 2003). ICT have affected numerous other industries (OECD, 2001a). The role of ICT is multiple (Santangelo, 2002). First, ICT has affected other products where the importance of data processing and communications was hitherto marginal or negligible. However, the role of ICT in the mobile phone industry where ICT is a core and central technology has been rarely mentioned. Second, ICT is a facilitating technology which reduces communication costs while improving reliability, efficiency and
coverage. The development of ICT has had a significant effect on the ability of companies to coordinate overseas activities, as well as better undertake outsourcing and alliances (Nalura, 2003).

The communication channel has an impact on DOI (Roger, 1995). New and developing information and communication technologies greatly influence the communication industry and DOI (Roger and Scott, 1997). Diffusion of ICT is not only the diffusion of itself – a new and developing technology, but also the incentive of successful diffusion of other new technology and innovations among organizations (Baskerville and Pries-Heje, 2001).

The diffusion of ICT allows companies to access information about both international and national markets more easily. Through the use of ICT, companies are more able to integrate the activities of their various affiliates and to respond more quickly to changing conditions in markets. In short, the diffusion of ICT has reduced both the costs of acquiring and disseminating information, the transaction and coordination costs associated with international activities and technological alliances, and led to the reduction of product life cycles (Narula, 2003).

Lee and Treacy (1988) argue that the notions of technology transfer seem to be restricted to the influence of information and communication technology from a practical standpoint. Nilakanta and Scamell (1990) argue that the scope and intensity of information sources and communication channels affect technology transfer as well. With respect to companies in emerging countries, the diffusion of ICT, by making more, better, cheaper and faster exchange of information possible globally, may have the effect of reducing the business risks associated with the development of new products and services (Rao, 2001). In addition, with significant competencies and rapidly developing ICT infrastructure, emerging countries like India and China have become serious players for companies from advanced countries in the current globalization wave (c.f. Rao, 2001).

2.5 Absorptive Capacity

2.5.1 Theories of absorptive capacity

Absorptive capacity (AC) is a company’s “ability to recognize the value of new, external information, assimilate it, and apply it to commercial ends” (Cohen and Levinthal,
The absorptive capacity of a company is a critical component of its innovative capabilities (Cohen and Levinthal, 1990).

Previous research proposes that a company’s absorptive capacity derives from the knowledge stock within the company (Cohen and Levinthal, 1990; Zahra and George, 2002). Cohen and Levinthal (1990: 131) emphasize that absorptive capacity ‘depends on the transfer of knowledge across and within subunits that might be quite removed from the original point of entry’.

According to theories of absorptive capacity, a company’s stock of prior related technology and knowledge determines the ability of a company to absorb new technology, knowledge and practices (Cohen and Levinthal, 1990). In other words, absorptive capacity can be divided into two important elements: the existing knowledge base (in the dissertation, we use ‘existing technological capability’ instead of ‘existing knowledge base’) and the internal effort for the distribution of new technology and knowledge in a company and problem solving (Cohen and Levinthal, 1990). In this dissertation, the distribution of new technology and knowledge in a company is thought of as the process of ‘intra-firm technology diffusion’.

Prior technology and knowledge influences the cost of discovering and acquiring new technology and knowledge as well as the degree to which one is likely to engage in a search for new practices (Lonex and King, 2004). In other words, the existing technological capability is an essential element in the process of technological advancement. The existing technological capability influences which type of new technology and knowledge is likely to be absorbed by a company. Existing knowledge enables companies to create tomorrow’s increased knowledge (Kim, 1997, 1999). Thus, the company needs absorptive capacity to recognize, assimilate, use and update new technology (Cohen and Levinthal, 1990; Burgelman et al., 1996; Kim, 1997, 1999).

The company’s ability to distribute technology internally is critical to absorptive capacity (Cohen and Levinthal, 1990). The intensity of effort refers to the amount of energy relinquished by organizational members to distribute technology internally and solve problems. It is insufficient merely to expose companies to the relevant external technology and knowledge. Without conscious effort to internalize such knowledge, the development of a company’s absorptive capacity and technological evolution in company cannot take place (Cohen and Levinthal, 1990; Kim, 1997, 1999). A company should commit effort to process the material for learning and store the technology and knowledge in memory (Cohen and Levinthal, 1990; Burgelman et al., 1996).
An organization’s absorptive capacity depends on the absorptive capacities of its individual members (Cohen and Levinthal, 1990; Burgelman et al., 1996; Kim, 1999). In this aspect, the development of a company’s absorptive capacity builds on the prior investment in its individuals’ absorptive capacities (Cohen and Levinthal, 1990; Burgelman et al., 1996). A company’s absorptive capacity is not, however, simply the sum of individuals’ absorptive capacities. Like individuals’ absorptive capacities, an organization’s absorptive capacity tends to develop completely and integrally (Cohen and Levinthal, 1990: 131).

The cumulativeness of absorptive capacity and the effect of absorptive capacity on expectation formation are two features of absorptive capacity. These two features imply that AC’s development is domain-specific and is path or history-dependent (Cohen and Levinthal, 1990: 136). In addition, these two features suggest that once a company ceases investing in its absorptive capacity in a rapidly moving field, the company may not assimilate and exploit new technology opportunities in that field, regardless of the value of those opportunities (Cohen and Levinthal, 1990). Moreover, a low initial investment in absorptive capacity diminishes the attractiveness of investing in subsequent periods due to the high cost to develop in these subsequent periods, even if the company becomes aware of technological opportunities (Cohen and Levinthal, 1990).

### 2.5.2 Relationship of absorptive capacity and technological capability

The dynamic process of building technological capability is an evolutionary process that involves effective interactions and consequent technological learning to improve the technological capability (Kim, 1997). Catch-up development occurs at the company and industry level based on technological learning, especially in the newly industrialized economies (Nalura, 2003). Technological learning allows companies in emerging countries to advance from the manufacture of simple goods to the design and development of more complex products (Nalura, 2003).
Intensity of effort

<table>
<thead>
<tr>
<th>Low</th>
<th>High</th>
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<tr>
<td>(1) Technological capability high and rising rapidly</td>
<td>Technological capability high but falling</td>
</tr>
<tr>
<td>(2) Technological capability low but falling rapidly</td>
<td>Technological capability low but falling rapidly</td>
</tr>
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</table>

Figure 2-3 Relationship of Absorptive Capacity and Technological Capability

SOURCE: Kim, Linsu (1999), Building technological capability for industrialization: analytical frameworks and Korea’s experience, *Industrial and Corporate Change*, 8, 1, P. 115
An effective productive technological learning process requires absorptive capacity. Understanding absorptive capacity is essential, because it is one critical determinant of the effective mastery of imported technologies. In other words, the different absorptive capacity affects the widely differing levels of efficiency in using the same imported technology in different emerging countries (Lall, 1993). The study of Stock et al. (2001) argues that the greater absorptive capacity, which provides a greater capability to acquire and exploit external information, would lead to more effective new product development. The absorptive capacity of a company thus is one of the pillars in the process of new technology generation and technological capability development.

The existing technological capability and intensity of effort indicate the dynamics of technological capability (Figure 2-3) (Kim, 1997, 1999). As shown in the Figure 2-3, organizations with both high existing technological capability and high intensity of effort (quadrant 1) might have high technological capability and acquire it rapidly. On the contrary, organizations with both low elements (quadrant 4) might have low technological capability and lose it rapidly. When existing technological capability is high but the intensity of effort is low (quadrant 2), technological capability may be high now but fall gradually, since existing technological capability will become obsolete as technology moves along its trajectory. Those organizations in quadrant 2 will gradually move down to quadrant 4. In contrast, organizations with low existing knowledge but high intensity of effort in quadrant 3 might have low technological capability now but will increase it rapidly through significant investment in learning, moving progressively to quadrant 1 (Kim, 1997, 1999). In short, the intensity of effort to diffuse technology internally is a more crucial element than the existing technological capability for a company’s long-term technology development and competitiveness.

2.6 Research Gaps in the Study of Technological Capability Development

2.6.1 Research Gaps

Literature review helps us to find research gaps in the process of generating technological capability. Most research on the evolutionary process of building up technological capability is based on the experience of NIEs’ development, particularly Korean development (e.g. Kim, 1997, 1999; Lee, 2001). Little is known about the process of
building up technological capability in China, though China has attracted a lot of attention from researchers as one of the largest countries in the world (e.g. Anderson, 1990; Al-Obaidi, 1993; Arayama, 1999; Marcotte and Niosi, 2000; Meyer, 2000; Bennett et al., 2000).

Most research on the experience of NIEs and emerging NIEs (e.g. Malaysia and Thailand) focuses on heavy and chemical technology (HCT) industries, labor-intensive industries or electronics industries (e.g. Lee et al., 1988; Kim, 1997; Kumar et al., 1999; Lall, 2000; Lee, 2001). New industries have emerged and developed fast particularly around ICT. These emerging industries have gradually played key roles in the development of national economies. The research on the development of technological capability in high-tech industries in emerging countries is neglected largely because companies in advanced countries are the leaders in the market and the market positions of companies in emerging countries are too low to be noticed by the world. There are special characteristics in high-tech industries, such as the fast changing speed and high intangible element of technology in these industries. These characteristics of high-tech industries will affect the TC development process of these industries. It is thus necessary to study the process of technological capability development in high-tech industries in order to enrich the research on technological capabilities.

On the other hand, most research is the general conclusions of experience from several industries, such as Kim’s study on the development process of a few industries in Korea (1997, 1999). Studies focusing on the dynamic process of building technological competence in an industry are few, such as Miyazaki’s study (1995) on the optoelectronics industry of Europe and Japan. Therefore, this dissertation focuses the research on one industry.

Companies currently compete with the business and innovation globalization (e.g. Gassmann and von Zedtwitz, 1998, 1999) and the diffusion of ICT (e.g. Roger, 1995, 1997; Boutellier et al., 1998). However, the research on the effort of ICT on the TC development is inadequate. The previous research results need to be modified to fit the new business environment as the consequence of ICT’s diffusion and business globalization. This dissertation strives to close this research gap.

Kim’s TC theories are widely accepted by many emerging countries including China. Kim proposed that most emerging countries develop TC in the mature-stage technology through three stages: acquisition, assimilation and improvement. Few companies in emerging countries reinvest in the mature technology. Nevertheless, ICT (such as the mobile phone technology) have not just been ‘imported’ from more advanced economies in their
mature stage; they have also been adopted and developed in a relatively emerging stage. They appear to have leapfrogged one or several technological stages despite the fact that the technological capability was not still well developed for the next stage. Additionally, companies in these industries invest in not only the relatively emerging stage of technology but also the mature-stage technology. Kim’s model, however, stipulates separate stages and a linear transition through these stages. Therefore, Kim’s model should be modified and a new TC development process should be explored.

Technology transfer and indigenous R&D are two dominant methods to obtain new technologies from outside or inside of organizations. TT is recognized as one important method to improve technological capability in emerging countries. The practices in high-tech industries suggest that technology alliance or technological cooperation, the externalized technology transfer mode, has become company’s favorite technology transfer method. This did not seem to support the widely accepted theories of Lall (1993) and other TT experts (e.g. Kumar et al., 1999; Lee, 2001) who suggest that internalized technology transfer modes such as FDI play a critical role in the TC development of emerging countries. In addition, internalized TTM especially FDI is increasingly becoming the dominant technology transfer mode (Lall, 1993; UNCTAD, 2001). FDI has been the center of economic development policies in many emerging countries, such as Singapore (Lall, 1993). It is also a method encouraged by the Chinese government to obtain foreign advanced technologies. However, internalized technology transfer modes do not facilitate to the development of indigenous technological capability (Lall, 1993). Thus, there is a research gap in the theories and practices regarding technology transfer and companies’ indigenous technological capability development. There is also a contradiction between governments’ development policies and companies’ favorite TT strategies. Thus, the favorite technology transfer mode to develop indigenous technological capabilities in companies is one of research focuses in this dissertation.

In general, it is necessary to study the process of technological capability development in high-tech industries.

2.6.2 Research Focus of this Dissertation

Based on literature review and research gaps in theories of technological capability, this research is going to focus on the process of technological capability development in a Chinese high-tech industry, particularly the manufacturers in this Chinese high-tech
industry, in order to close the research gaps. This research concentrates on the following areas:

- Explore the process of technological capability development in Chinese high-tech industries;
- Study the favorite technology transfer mode selected by Chinese companies;
- Modify Kim’s model to match the development of business environment;
- Identify the dominant determinants in the process of technological capability development.

2.7 Research Frameworks

2.7.1 Conceptual framework

External technology resources are the dominant sources to obtain and develop new technologies as well as to develop technological capability for companies in emerging countries (e.g. Lall, 1993, 2002; Kim, 1997). The previous research on NIEs suggests that the development of technological capability in emerging countries is a process to obtain technology from advanced countries and assimilate and improve the imported technology to build up emerging countries’ own technological capability (e.g. Lall, 1993, 2002; Kim, 1997). On the other hand, the existing technological capability affects the effectiveness and efficiency of technological capability development (Cohen and Levinthal, 1990; Kim, 1997). The process of technological capability development can be seen as a feedback loop or as a learning process, as shown in Figure 2-4. Figure 2-4 is the conceptual framework of this research. Figure 2-4 indicates that the improvement of technological capability is the goal of technological capability development; similarly it affects the selection of technology source and the development process.

2.7.2 Research framework

Based on Kim’s integrative analytical model (1999:121), Lall’s theories on relationships between technology transfer and technological capability development (1993), Cohen and Levinthal’s theories on absorptive capacity (1990), and the conceptual framework (Figure 2-4), a research framework concerning the process of technological capability development in the information era is proposed in Figure 2-5. Figure 2-5 depicts a
research model of technological capability creation in high-tech industries in emerging countries. It shows that this process includes two learning stages: technology transfer in alliances and intra-firm technology diffusion.

![Feedback Loop of Technological Capability Development](image)

**Figure 2-4 Conceptual Framework—Feedback Loop of Technological Capability Development**

*External stage: technology transfer in alliances*

As mentioned above, outside technology sources are critical resources for a company’s technology development in emerging countries as well as in advanced countries. A company in emerging countries acquires advanced technology from the external technology resources through technology transfer in order to generate and improve its technological capability (e.g. Lall, 1993, 2002; Kim, 1997). As technology changes rapidly and technological and economic globalization deepens, companies play in industry networks. The alliances with other organizations, such as customers, affect the technology distribution process, and take part in the development of new products and new technology. In other words, with the trend of globalization and the fast change of technology, the use of strategic technological alliances is growing and recognized as an increasingly pivotal method in the process of technological capability upgrading in NIEs (Nalura, 2003). Therefore, technology transfer can be regarded as a process of technology transfer in strategic technological alliances. A company’s absorptive capacity has an impact on the effectiveness and efficiency of technology transfer in alliances. The terminal purpose of acquisition technology in alliances is to upgrade technological capability of companies. On the other hand, technological capability (the existing or improving technological capability) influences the process of technology transfer in alliances, such as technology recipients’ strategies and technology transfer decisions (as shown in Figure 2-2).
Figure 2-5 Research Framework – Process of Technological Capability Development
Internal stage: intra-firm technology diffusion

The transferred technology is assimilated and combined with the existing technology; then it is developed to become the new technology with the corporate efforts (e.g. Kim, 1997, 1999). In this stage, with the diffusion of transferred technology internally, the company improves its R&D capability and absorptive capacity (Cohen and Levinthal, 1990). The improved R&D contributes to the company’s absorptive capacity (Cohen and Levinthal, 1990). In other words, a company’s absorptive capacity is often improved in a company’s R&D activities (Rosenberg and Steinmueller, 1988). On the other hand, the absorptive capacity influences a company’s efficiency of absorbing transferred technology and combining the transferred technology with indigenous R&D activities (Cohen and Levinthal, 1990; Kim, 1997). In general, a learning process is generated between R&D and absorptive capability. This learning loop can be regarded as a process of intra-firm technology diffusion.

Accordingly, the integration of TT process in alliances and ITD process results the improvement of a company’s technological capability. At the same time, technological capability affects these two processes according to the conceptual framework.

2.7.3 Development routine model

In this dissertation, R&D and marketing capabilities of a company are recognized as two important elements of its technological capabilities. In addition, companies in an industry can be categorized into four types of companies according to the combination of different levels of R&D and marketing capabilities (Figure 2-6). These four types of companies are:

- **Type I**: The first type of companies is weak at not only R&D capability but also marketing capability. Companies locate at quadrant I in Figure 2-6;
- **Type II**: The second type of companies has strong marketing capability, but weak R&D capability. Companies are at quadrant II in Figure 2-6;
- **Type III**: The third type of companies is good at R&D capability, but rather weak at marketing capability. Companies locate at quadrant III in Figure 2-6;
- **Type IV**: The fourth type of companies has strong marketing capability as well as strong R&D capability. Companies are at quadrant IV in Figure 2-6.
Of course, there are companies with the middle-level of marketing and R&D capabilities. The ultimate goal of all companies is to be a company that possesses not only strong R&D capability but also strong marketing capability, namely the company at quadrant IV. Thus, companies in quadrant I, quadrant II, and quadrant III strive to reach quadrant IV.

![Figure 2-6 Capability Development Routines based on R&D and Marketing Capabilities in Companies](image)

As shown in Figure 2-6, there are five development routines for the three types of companies (Type I, II and III) to become the fourth type of companies:

1) **Type I Company**: have three routines to follow.
   a. Develop from quadrant I to quadrant II, then to quadrant IV, routine a + routine d;
   b. Develop from quadrant I directly to quadrant IV, routine b; and
c. Develop from quadrant I to quadrant III, then to quadrant IV, routine c + routine e.

2) **Type II Company**: Develop from quadrant II to quadrant IV, routine d.

3) **Type III Company**: Develop from quadrant III to quadrant IV, routine e.

In general, there are five TC development routines based on different level of R&D and marketing capabilities: routine a-d, routine b, routine c-e, routine d, and routine e. However, in practice, the development routine of a company perhaps cannot follow these five routines completely due to the rapid changes of environment and the characteristics of the company.

The following cases are analyzed according to these research models.
3. Research Methodology

3.1 ‘Case study’ Methodology

The selection of research methodologies depends on the research questions. In addition, the purpose of research methodology selection is to maximize the research validity (Yin, 1989; Black, 1999). Yin (1989) argues that ‘case study’ is an empirical inquiry that investigates a contemporary phenomenon within its real-life context over which the investigator has little control, especially when the boundaries between phenomenon and context are not clearly evident. Many contemporary empirical and explorative studies are thus conducted based on case studies. Case study research is especially preferred to identify background information on “how” and “why” certain phenomena occur and decisions are taken. One of the unique strengths of the case study method is its ability to deal with a full variety of evidence: documents, interviews and observations (Yin, 1989). The case study method maximizes the comprehensive treatment and understanding of the topic. However, one of the main disadvantages of case study method is that the representation of research results is always narrow and idiosyncratic. Thus, it is difficult to provide an adequate generalization of insights. To improve the validity and generalization of the research results of cases studies, Yin (1989) and Eisenhardt (1998) offer detailed descriptions on how to perform case study research.

3.2 Research Method in this Dissertation

The purpose of this dissertation is to explore the process of technological capability development in high-tech industries and identify the key factors in this process for Chinese companies in particular, for companies in other emerging countries in general. Accordingly, this is explorative research which not only examines existing TC theories but also brings new insights into existing TC theories.

Every company creates its technological capability following its special development process due to its indigenous special competence and resources. No process of technological capability development in two countries is exactly the same. In other words, the process of the technological capability development of different companies in different industries is conceptual and unstructured. Thus, they are difficult to evaluate quantitatively. Additionally, the research on technological capability development is empirically oriented. I thus decided
to elaborate on the research questions in an in-depth, qualitative investigation of multi-case study. Accordingly, I can develop a sharper understanding regarding the research model of the TC generation process. According to replication logic (Yin, 1989), each case should be carefully selected to predict similar results (a literal replication) or to give contrary results but for predictable reasons (a theoretical replication) (Yin, 1989). In addition, the selected case samples can typically represent Chinese mobile phone manufacturers.

3.3 Case Selection of this Dissertation

According to Yin’s theory (1989), multi-case studies were designed. In total four cases are studied, each of which was treated as an independent experiment. According to the confidentiality requirement of companies, Company ‘A’, Company ‘B’, Company ‘C’ and Company ‘D’ were used to indicate these four companies.

Company ‘A’, Company ‘B’, Company ‘C’ and Company ‘D’ were selected for the in-depth multi-case study. This selection was based on the development characteristics of these four companies. All four Chinese companies are leading telecommunication manufacturers in China. Company ‘A’ has acquired a wide range of mature, growing and emerging technologies. Company ‘A’ has the experience to produce and invest in all generations (the 1st to the 3rd generations) of mobile phones. Company ‘A’ entered the mobile phone industry in 1990 as one of the earliest entrance companies in China and became one of the first group of companies to produce domestic brand mobile phones in China.

Company ‘B’ is famous as an innovative telecommunication company worldwide. Company ‘B’ is a leading telecommunication system equipment provider as well as a mobile phone terminal product provider. Company ‘B’ had strong R&D capability and a strong R&D team in telecommunication though not in mobile telephone terminal product when it became a mobile phone provider at the end of the 1990s. Company ‘B’ produces and invests in R&D in 2nd generation, 2.5th generation and 3rd generation mobile phones. Company ‘C’ was a commercial product manufacturer when it entered the Chinese mobile phone industry at the end of the 1990s. At that time, Company ‘C’ lacked technological capability in mobile phone technologies. Company ‘C’ created its special national marketing system during the period of pagers production. With its outstanding marketing capability and the development of R&D capability, Company ‘C’ has been the largest Chinese
domestic mobile phone provider for five years, following Motorola and Nokia in the Chinese market. Company ‘D’ is also a provider of telecommunication system equipment as well as mobile terminal products. Company ‘D’ entered the Chinese mobile phone industry in the middle of the 1990s, earlier than that of Company ‘B’ and ‘C’, but later than that of Company ‘A’. Company ‘D’ is the first enterprise to produce the 2nd generation mobile telephones in China. Being recognized industrial leaders, these four companies represent the development of the Chinese mobile phone manufacturing sector.

These four companies represent two main categories of China’s mobile phone manufacturers: one category consists of companies as telecommunication systems and equipment manufacturers, such as Company ‘A’, ‘B’, and ‘D’; the other category has extensive experience in commercial products marketing, such as Company ‘C’. In addition, these four companies represent another three categories of China’s mobile phone manufacturers: one type of company (few in number) has strong R&D capability without strong marketing capability, such as Company ‘B’; the second type of company has strong marketing capability but weak R&D capability in the mobile phone industry, and these companies have been the manufacturers of commercial products for a couple of periods, such as Company ‘C’; the third type of company was not strong in either R&D capability or marketing capability when they entered the Chinese mobile phone industry, such as Company ‘A’ and Company ‘D’. Moreover, these four companies represent two types of firm’s nature: state-owned enterprises, such as Company ‘A’ and ‘D’; and private enterprises, such as Company ‘B’ and ‘C’. Furthermore, these four companies all have extensive cooperation experience with MNCs and other organizations.

The profiles of these four companies are shown in Table 3-1. The brief information of the cases is introduced in Appendix I.
<table>
<thead>
<tr>
<th></th>
<th>Company ‘A’</th>
<th>Company ‘B’</th>
<th>Company ‘C’</th>
<th>Company ‘D’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Founded time (T1)</td>
<td>1958</td>
<td>1985</td>
<td>1992</td>
<td>1941</td>
</tr>
<tr>
<td>Nature</td>
<td>State owned</td>
<td>Private</td>
<td>Private</td>
<td>State owned</td>
</tr>
<tr>
<td>Location</td>
<td>Eastern China</td>
<td>Southern China</td>
<td>Eastern China</td>
<td>Northern China</td>
</tr>
<tr>
<td>Stock Exchange</td>
<td>Shanghai, Hong Kong</td>
<td>Shenzhen, Hong Kong</td>
<td>Shanghai</td>
<td>Shanghai</td>
</tr>
<tr>
<td>Time as Mobile Phone manufacturer (T2)</td>
<td>1990</td>
<td>1999</td>
<td>1999</td>
<td>1996</td>
</tr>
<tr>
<td>Main Product Before T2</td>
<td>Telecommunication equipment</td>
<td>Telecommunication equipment</td>
<td>Pagers (BP calls)</td>
<td>Telecommunication equipment</td>
</tr>
<tr>
<td>Main Product After T2</td>
<td>Mobile phone, Mobile system</td>
<td>Telecommunication equipment, Mobile phone</td>
<td>Mobile phone</td>
<td>Telecommunication equipment, Mobile phone</td>
</tr>
<tr>
<td>Main Partners</td>
<td>TI, Lucent, Samsung, Motorola, Quantum…</td>
<td>Motorola, TI, Quantum, DTT, Nortel…</td>
<td>Samsung, Sagem, Quantum, Motorola, Siemens…</td>
<td>Nokia, NEC, DMC, Quantum…</td>
</tr>
</tbody>
</table>
3.4 Data Collection in this Dissertation

Before collecting information for the case study, I gathered secondary data from publications, newspapers, websites, and so on to familiarize myself with interview companies and the Chinese mobile phone industry. During the in-depth cases studies, first- and second-hand data were collected. The interviews with top managers, technology managers, and strategy managers were conducted face-to-face and over the telephone to collect the first-hand data. I interviewed a total of 12 persons 23 times in these companies (details in Table 3-2). In order to compensate for the limited number of interviews, we made sure that our interviews were as long as possible, lasting on average 90 minutes and sometimes even up to 150 minutes.

Table 3-2 Summary of Interviews

<table>
<thead>
<tr>
<th>Company</th>
<th>People N=12</th>
<th>Times N=23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company ‘A’</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Company ‘B’</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Company ‘C’</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Company ‘D’</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

The interviews were semi-structured. The main research questions came from secondary data collection. These questions conducted in the interviews are presented in Appendix II. Sometimes the interviewees did not answer the questions according to the question list. In any case, I made sure that all questions for which I wanted to collect data were covered whenever possible.

In the field study, I improved the credibility and validity of the data through personal observation and other methods. I continued to collect secondary data, such as information published on the relevant websites, journals, newspapers, and interviews with external academic experts and experts in other competitive companies in this industry, in order to maximize the validity and reliability of the case study according to the theory stipulated by Yin (1989).
3. 5 Evaluation of Technological Capability  

Chinese mobile phone manufacturers are newcomers and followers in the world mobile phone industry. There are few patents\(^2\) in mobile phone technologies applied by Chinese companies. In addition, because of the weak protection of intellectual property rights in China, most Chinese local companies forbid employees to publish their important R&D results in journals. Thus, technological capability cannot be evaluated by the number of patents and publications. In this dissertation, technological capability development is qualitatively evaluated by (1) market scale to present the change of production capability; (2) change of R&D fields, for instance, developing from assimilation mature technology to invest in R&D in emerging technology; and (3) the usage level of indigenous intellectual property rights in a product.

R&D capability and marketing capability are recognized as two types of important technological capabilities. It is very difficult to measure a company’s R&D capability. In addition, the data, such as patents and publications, cannot expose the true R&D competence of a company. In this dissertation, R&D capability is measured by the following items: R&D capability ranking in the industry, the investment budget of R&D, the capability to undertake national programs, and the R&D team. R&D capability is rather difficult to evaluate. Yet, peer judgment reflects the social and market position of a company’s technological capability in the industry. Therefore, peer R&D capability ranking in the mobile phone industry is used as the most important criteria of R&D capability in this dissertation. Marketing capability refers to the national marketing channel and the sale’s scale of a company.

\(^2\) The patents here refer to those for key technologies used in mobile phones. Most patents applied by Chinese companies are about the product design, interface design, and so on, which are the application-level technologies with the standards open to all companies in this industry.
4 Development of China’s Mobile Phone Industry

4.1 Profile of China’s Mobile Phone Industry

China’s mobile phone industry is a new and emerging industry in China. Its development traces back to 1987 when the first set of mobile phones were imported in Guangdong province. Since then China’s mobile phone industry has developed dramatically. China’s mobile phone subscribers increased from 700 in 1987 to more than 337 million in 2004 (Figure 4-1), which were about 20 per cent of mobile phone subscribers in the world. The penetration rate of mobile phone in China was up to 25.9 per cent of the population in 2004, while the number was merely 0.30 per cent in 1995 (Figure 4-2). China has become the largest mobile phone market worldwide.

The Chinese mobile phone market enjoys rapid growth. Each month, a further four to five million new users are added to the market. In 2004, there were 65 million new mobile phone users in China (ChinaMobile, 2005). The number of mobile phone subscribers in China is expected to reach 500 million by 2007 (Xin, 2004). China has become the fastest developing mobile phone market as well as the largest potential mobile phone market in the world. Though the population of China is one of the factors that make China the largest mobile phone market in the world, the spectacular development of China’s mobile communication industry should not be ignored. In 2004, 35.1 per cent of mobile phones in the world were produced in China (ChinaMobile, 2005), making China the largest producer of mobile phones in the world. The Chinese mobile phone industry has become one of the pillar industries in China.

In the early 1990s, China began to produce the first generation TACS mobile phones. However, till 1997, there were only five companies producing mobile phones. In addition, there were no China’s domestic brands of mobile phones in the market at that time. The Chinese government thought that the situation was not beneficial to the development of China’s mobile phone industry. Thus, in 1997 China officially announced to support China’s mobile telecommunication industry. The Chinese government encourages Chinese companies to invest in the mobile phone industry.
Figure 4-1 The Development of Mobile Phone Users in China

Source: [http://www.chinamobile.gov.cn](http://www.chinamobile.gov.cn) and [http://www.cciddata.com](http://www.cciddata.com)

4.2 Overviews of China’s Mobile Phone Manufacturers

China’s mobile phone manufacturers grew from 5 companies in 1997 to 37 companies and about 200 manufacturing sites in 2004. Most ventures are foreign-funded companies (22 of the 37) with names such as Tianjin Motorola, Beijing Nokia, Beijing Ericsson, Beijing
Matsushita, Wuhan NEC, Shanghai Siemens, Shanghai Alcatel, and Shenzhen Philips. Others 15 companies have various types of technology cooperation with foreign companies as well.

**Figure 4-2 Development of Mobile Phone Popularisation Rate in China (1995 - 2004)**

![Graph showing the development of mobile phone popularisation rate in China from 1995 to 2004.](http://www.chinamobile.gov.cn) and ![Graph showing the development of mobile phone popularisation rate in China from 1995 to 2004.](http://www.cciddata.com)
34 of the 37 companies have the licenses to produce GSM mobile phones. 31 of the 37 companies produce GPRS mobile phones, while 24 of the 37 companies have the licenses to produce CDMA mobile phones.\(^3\) In these 37 companies, there are 17 companies producing all three kinds of mobile phones: GSM, CDMA, and GPRS mobile phones\(^4\).

These 37 companies concentrate on three areas. The first is the northern manufacturing base, including 9 companies in Beijing and Tianjin (for example, Beijing Nokia, Tianjin Motorola). The second area is the southern manufacturing base, also including 9 companies in Guangdong province (for example, Huizhou TCL, Shenzhen Philips, Shenzhen Samsung). The third is the eastern manufacturing base near the Yangtze River Delta (for example, Shanghai Siemens, Shanghai Alcatel, Ningbo Bird). The mobile phone production volumes of these three areas in 2002 were respectively 40.7 per cent, 27.8 per cent and 25.6 per cent of the total output in China.

### 4.3 Growth of China’s Domestic Mobile Phone Manufacturers

This dissertation concentrates on China’s domestic mobile phone manufacturers, which refer to the companies producing China’s domestic brand-name mobile phones. In fact, China’s domestic mobile phone manufacturers have various types of cooperation with foreign companies. In addition, some of them set up joint ventures to produce foreign brand-name mobile phones at the same time.

With the encouragement of China’s authority, many Chinese companies, not only from the telecommunications industry but also from other industries, are drawn into the mobile phone industry. In addition, China’s domestic mobile phone manufacturers have provided domestic brand mobile phones to Chinese and world markets since the end of the 1990s.

Most China’s domestic mobile phone manufacturers developed from telecommunication equipment manufacturers or from electronics consumer goods manufacturers. For example, ZTE Corporation is well known for its telecommunication exchange machines and mobile phones. TCL Corporation is the largest color television manufacturer in the world as well as an important mobile phone manufacturer in China.

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\(^3\) In China, companies must have the production licenses from the Chinese government before they produce mobile phones.

\(^4\) TACS mobile phones quit out of the Chinese market at the end of the 1990s.
companies from the telecommunication equipment industry have stronger R&D capabilities in telecommunication industry, but lower marketing capabilities than those companies from consumer goods manufacturers.

![Figure 4-3 Production Volume of Mobile Phones in China's Different Areas](http://www.mii.gov.cn)

China’s domestic mobile phone manufacturers are growing fast. The output of mobile phones by Chinese companies increased at the average annual growth rate of 76 per cent during the period from 1995 to 2004. The market share of Chinese domestic mobile phone manufacturers increased swiftly. In 2003 and 2004, Chinese domestic-brand of mobile phones held about 40 per cent of the Chinese market, up from zero before 1999. Particularly,
Bird Corporation has become the No.3 mobile phone manufacturer in China, following Motorola and Nokia. After a decade of development, China’s domestic mobile phone manufacturers have gradually generated technological capabilities through different kinds of technology cooperation and technology transfer. Most importantly, their special comparative competitive advantages, such as the well-established marketing networks, have led them to become the major rivals of Motorola and Nokia in the Chinese market. However, foreign brand mobile phones, such as Motorola, Nokia, Samsung, Siemens, and Sony-Ericsson are still the major products in the Chinese market.

4.4 Technological Capability Development of China’s Domestic Mobile Phone Manufacturers

In less than two decades, China’s mobile phone industry has explosively developed from the first generation to the second generation, then to the 2.5th generation mobile phone. In addition, it is going to open the 3G generation mobile phone market in 2005 or early 2006. In the following section, the development of technological capability of China’s mobile phone industry is presented according to the utilization of three generations of mobile phone technologies in China.

4.4.1 First generation of mobile phone technology

TACS was the first generation (1G) mobile phone technology, which was not used worldwide.

After importing the first set of mobile phones in 1987, the Chinese mobile phone industry entered the first generation mobile phone stage. China produced 1G mobile phones in 1990. Lacking the basic technology to produce mobile phones, Chinese companies had to depend on foreign technologies. They imported the turnkey technology or attracted foreign direct investment to establish joint ventures. What Chinese companies did was assembling all imported parts together and sold their products under the foreign brands. In short, it is original equipment manufacture (OEM). For instance, Tianjin Motorola, the first joint venture of Motorola in China (controlled by Motorola), produced TACS mobile phones in

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5 In the early 1990s, only joint venture under Chinese control, no foreign wholly-owned subsidiary was generally encouraged by Chinese government. Tianjing Motorola was a special case.
1992. Eastcom Corporation imported the turnkey technology from Motorola to produce Motorola-brand TACS mobile phones.

Through OEM, few Chinese companies gradually generated the production technology of mobile phones. However, the 1G mobile phone market was monopolized by Motorola mobile phones. Additionally, the domestic investment in R&D of TACS mobile phone failed in commercialization. At the end of the 1990s, the TACS system and market were closed in China. No companies produce TACS mobile phones currently.

4.4.2 Second generation of mobile phone technology

GSM is the second generation of mobile phone technology, which is a mature mobile phone technology.

In the middle 1990s, China began to produce GSM mobile phones. The manufacturers were domestic companies, foreign wholly-owned subsidiaries and joint ventures (in which the Chinese and foreign partners share the same stake). China lacked the basic production and development technologies of GSM mobile phones, which was like that of TACS mobile phones. Chinese domestic manufacturers used turnkey-imported technology or foreign investment to produce 2G mobile phones. For example, a joint venture Beijing Nokia, which was established in 1996, is the first company to produce GSM mobile phones in China. Before 1999, China produced all mobile phones under foreign brands. As the case with TACS technology, Chinese companies generated production and basic development capabilities of GSM technology via OEM and foreign investment.

During the late 1990s, Chinese domestic companies started to produce domestic brand mobile phones with their own intellectual property rights. Supported by the Chinese authority and attracted by the high profit, many Chinese domestic companies were drawn into producing GSM mobile phones. Most Chinese new entrants in this industry lacked basic technology for producing mobile phones. They thus imported the production lines to develop their production technology at first. In addition, some of them developed their R&D technology through M&A of institutes and technological alliances. For example, Bird Corporation acquired a research center in Sichuan province to be its institute to develop the mobile telecommunication technology. In addition, Bird Corporation set up alliances with France Sagem Corporation to develop mobile phone products. TCL Corporation recruited all
engineers of one foreign institute to set up TCL’s mobile phone R&D lab in order to develop new styles of mobile phones.²⁶

Although GSM is a mature technology in the world, Chinese mobile phone manufacturers invested heavily in the R&D of GSM technologies. Chinese companies, such as Eastcom Corporation and ZTE Corporation set up R&D centers in the USA and other advanced countries in order to keep abreast of the latest 2G technology and to develop indigenous GSM chip technologies. In addition, Chinese institutes, for instance, No.7 Institute of the Chinese Post and Communication Ministry⁷, researched the indigenous GSM mobile phone technology. Chinese domestic companies are improving their technological capability in mobile phones through reinvesting in GSM technologies.

In an effort to adapt to the rapid changes of models and appearance design in the mobile phone market and to survive in the more and more serious competitive market, some Chinese brand products are still own brand manufacturing (OBM)⁸ products. With the development of technological capabilities based on assembling imported parts, Chinese local companies have produced the mobile phones with their indigenous intellectual property rights. In other words, though the key chips in GSM mobile phones are imported, Chinese mobile phone manufacturers produce their GSM mobile phones with their own developed and designed parts and software, which we could call as own design manufacture (ODM)⁹.

### 4.4.3 2.5th generation of mobile phone technology

GPRS and CDMA are the 2.5th generation (2.5G) mobile phone technologies, and denoted as growing technologies. In 2001, China opened the 2.5G mobile phone market – a

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²⁶ In fact, this was a merge issue. However, there was no official declaration on this issue from this company.

⁷ The Chinese Post and Communication Ministry was the predecessor of Ministry of Information Industry (MII), China.

⁸ In the dissertation, OBM refers to own brand manufacture with all foreign inputs in the products. In addition, OBM is thought as one of the acquisition activities too in this dissertation.

⁹ In this dissertation, ODM refers to own design manufacture. A product is produced with part of foreign inputs, and own inputs with indigenous IPRs or own design.
growing technology market\textsuperscript{10}. Currently, all Chinese domestic companies produce 2.5G mobile phones, GPRS or CDMA mobile phones. Based on the production and development technology generated during producing 2G mobile phones\textsuperscript{11}, China’s mobile phone manufacturers mastered and improved the production technology of 2.5G mobile phones in a short time. While they are producing GSM mobile phones, Chinese companies have invested heavily in the research and development of 2.5G mobile phone technologies. For instance, ZTE Corporation, a famous Chinese telecommunication manufacturer, has invested in the R&D of CDMA mobile technology from 1995, well before ZTE started to produce GSM (2G) mobile phones in 1999. Take TCL as an example. TCL established its strategic alliance with Ericsson to develop 2.5G mobile phones based on the Ericsson’s 2.5G development platform. At the same time, TCL set up strategic alliance with Microsoft Corporation to develop pocket PC – PDA mobile phones using Microsoft pocket PC software.

Nevertheless, some 2.5G products sold at Chinese market are also OBM products. That is Chinese companies assemble the imported parts (mainly from Korea) and sell them under their own brands because of high licensing cost of the core 2.5G technology, such as the key chip in mobile phones and the fast changing market.

After a decade of development, Chinese domestic mobile phone manufacturers have gradually generated their technological capabilities and competitive advantages in 2G and 2.5G mobile phones via different kinds of technology cooperation and technology transfer.

\textbf{4.4.4 Third generation of mobile phone technology}

The third generation (3G) mobile phone technologies, such as CDMA2000 (a 3G standard developed in USA), WCDMA (a 3G standard developed in Europe) and TD-SCDMA (a 3G standard developed in China), are still considered emerging technologies. Like 2.5G mobile phone technologies, Chinese domestic mobile phone manufacturers have invested in the R&D of 3G mobile phone while 2G mobile phone market was opening in China, in 1998.

\textsuperscript{10} China Mobile and China Unicom are two mobile phone service providers in China. In the 2.5G mobile phone market, China Mobile provides the GPRS service, while China Unicom is providing the CDMA service.

\textsuperscript{11} As mentioned in this section, few China domestic mobile phone manufacturers have the experience in 1G mobile phone technology. The number of China 1G mobile phone manufacturers was less than 4.
The Chinese government encourages the investment in emerging mobile phone technologies in order to narrow the technology gap with developed countries in the future. With the government’s support and the technology alliance with Siemens, DTT Corporation proposed its TD-SCDMA standard, which became one of the three 3G standards in the world (CDMA2000, WCDMA and TD-SCDMA). Some Chinese manufacturers produce...
and improve 3G mobile phones (though only for the field test), which enable them to put products to the market as soon as possible, if 3G licenses are issued by the Chinese government.

The time to open 3G market is still under discussion. China is going to issue its first 3G mobile system license in 2005 or early 2006. According to evaluation, China 3G mobile phone market is going to be a huge market, as shown in Figure 4-4. The main development method of 3G mobile phone is setting up strategic alliances or cooperating with foreign companies for all standards of 3G mobile phone technologies because the Chinese government has not decided to adopt which standard(s) in the future Chinese 3G mobile phone market. Companies in the Chinese mobile phone industry, including Chinese domestic and foreign mobile phone manufacturers, mobile telecommunication equipment manufacturers, joint ventures, Chinese mobile phone service providers, and so on, set up a 3G Forum to discuss the problems in R&D and implication of 3G mobile phone technologies.

Table 4-1 Technology Transfer Mode of China’s Mobile Phone Manufacturers

<table>
<thead>
<tr>
<th>Production Time</th>
<th>R&amp;D Time</th>
<th>Technology Generation</th>
<th>Main Technology Transfer Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990s</td>
<td>1990s</td>
<td>1\textsuperscript{st} Generation</td>
<td>Turnkey plants imported, FDI</td>
</tr>
<tr>
<td>Mid 1990s –</td>
<td>Mid 1990s –</td>
<td>2\textsuperscript{nd} Generation</td>
<td>Turnkey plants imported, Goods imported, JV, Technology cooperation</td>
</tr>
<tr>
<td>2001 –</td>
<td>Mid 1990s –</td>
<td>2.5\textsuperscript{th} Generation</td>
<td>Goods imported, Technology cooperation</td>
</tr>
<tr>
<td>(2004)?</td>
<td>Mid 1990s –</td>
<td>3\textsuperscript{rd} Generation</td>
<td>Technology cooperation</td>
</tr>
</tbody>
</table>

4.4.5 Technology transfer in technological capability development process

As described above, technology transfer is an important method for Chinese mobile phone manufacturers to acquire the advanced technology in the process of technological capability development, in particular, when they lack sufficient production technology,
market competition is serious and products change fast. However, technology transfer modes which are preferred by China domestic mobile phone manufacturers change with the development of technological capability and the development of technology.

The technology transfer modes selected by Chinese mobile phone manufacturers are included in Table 4-1 and Figure 4-5. With the development of technological capability, technology cooperation (or technology alliance) has become the favorite technology transfer mode selected by Chinese mobile phone manufacturers. Especially, technology alliance (technology cooperation) is the preferred method to access the growing technology (2.5G mobile phone technology) and the emerging technology (3G mobile phone technology).

![Figure 4-5 Technology Transfer Modes in China local Mobile Phone Manufacturers](image-url)
4.4.6 Industry value network in China’s mobile phone industry

In an industry, all players work together to create values. Based on Porter’s value chain theory (1985), every company as well as industry operates along its value chain to create values. The value chains of each company in an industry integrate to form the industry value chain. With the complexity of, and radical changes in the telecommunications industry, the traditional linear telecommunication value chain is increasingly being deconstructed, which is leading to the development of a complex and rapidly evolving value network (Li and Whalley, 2002). Same changes take place in the mobile phone industry too. The value network of the mobile phone industry can be conceptualized in Figure 4-6.

The value network can be seen as a series of intertwined value chains where some nodes are simultaneously involved in more than one value chain. For instance, Motorola is one of the dominant competitors of Chinese mobile phone manufacturers. Motorola is a technology provider for some Chinese mobile phone manufacturers as well. The industry value network develops unevenly in different areas of the mobile phone markets. Within the value network, a multitude of market entry points exist, where a diverse range of companies can conceivably enter the market through different routes. Hence, many powerful new players from other industries are drawn into the previously neatly defined telecommunications market, such as TCL Corporation, a famous TV and fix telephone producer, as well as Bird Corporation, which produced BP callers, a popular communication consumer product in the 1990s in China, before producing mobile phones.

4.4.7 Summary

In less than two decades, the Chinese mobile phone industry has gone through all generations of mobile phone technologies. At the same time, China’s domestic mobile phone manufacturers have evolved from depending on foreign technologies to developing products with indigenous IPRs and to developing a worldwide accepted mobile phone technology standard.

In general, the process of technological capability development in China’s mobile phone industry is a process from OEM to OBM, then to ODM. From the perspective of technology transfer, this process proceeds from imported turnkey-plant and FDI, to joint venture, then to technology alliances and cooperation. During this process, China’s mobile phone manufacturers set up alliances with other companies and boost their R&D efforts in emerging mobile telecommunication technology.
Figure 4-6 Industry Value Network of the Mobile Phone Industry
In short, after a decade of development, China’s mobile phone manufacturers have gradually developed their technological capabilities and competitive advantages. They have invested in R&D in every generation of mobile phone technologies, including mature, growing and emerging technologies.
5 Technological Capability Development of Cases

In this chapter, I present the process of technological capability development of the four selected cases. Except Company ‘A’, the other three companies did not have the experience in producing the 1G mobile phone. Particularly, Company ‘B’ and Company ‘C’ became mobile phone manufacturers at the end of the 1990s when the 1G mobile phone and its technology were exiting the world market. In this chapter, these four companies are presented from two perspectives: (1) the process of technological capability development; and (2) the factors in this process. The development process of technological capability is displayed in accordance with the technology evolution in the mobile phone industry, changing from 1G mobile phone technology (only Company ‘A’), to the mature 2G, the growing 2.5G, and then to the emerging 3G mobile phone technologies. In every generation of mobile phone technologies, companies are examined from the technology source, existing capabilities, the company’s effort, and corporate performance.

5.1 Technological Capability Development of Company ‘A’

Company ‘A’ was established in 1958 as a state-owned factory of the Chinese Ministry of Posts and Telecommunications\(^{12}\) to produce communication equipment. In 1996, Company ‘A’ was listed as an A-Share company at the Shanghai Stock Exchange and Hong Kong Stock Exchange.

Company ‘A’ is mainly engaging in providing mobile phone system equipment as well as mobile terminal products. Since its entrance into the mobile phone industry in the 1990s, Company ‘A’ has become one of the largest companies in the Chinese mobile communication industry. Company ‘A’ has produced 1G, 2G, and 2.5G mobile phones. In addition, Company ‘A’ has tested its 3G mobile products with indigenous intellectual property rights. Mobile terminal products and mobile system equipment have become main products of Company ‘A’, making up about 90 per cent of the company’s annual sales.

Company ‘A’ invests heavily in R&D, especially in mobile terminal and system products. The company possesses a national-level R&D center and a mobile phone R&D

\(^{12}\) Chinese Ministry of Posts and Telecommunications was the ancestor of Chinese Ministry of Information Industry (MII).
center in the Silicon Valley. In addition, since the first technology transfer from Motorola in 1990, Company ‘A’ has set up strategic cooperation relationships with Texas Instruments (TI), Lucent, LG, Samsung, 3Com, Motorola, Interwave and other companies, with the purpose of furthering its knowledge in the field of mobile phone technologies, emerging 3G technologies and products, data communication, and communication network software.

5.1.1 Technological capability development of Company ‘A’

In the early 1990s, Company ‘A’ imported technologies from Motorola and set up the first production line of mobile phones in China to produce the Motorola-brand TACS mobile phones. From that time, Company ‘A’ generated its technological capability in the mobile phone industry not only through the cooperation with MNCs but also with indigenous R&D efforts.

First generation technology

When Company ‘A’ decided to enter into an agreement with Motorola on the 1G mobile phone (TACS mobile phone), this venture was thought to be a risky investment at that time because at the end of the 1980s the Chinese mobile phone market was predicted to be about 1 million users in 2005. However, Company ‘A’ believed that this was a good opportunity to reconstruct its dominant products.

In order to produce TACS mobile phones, Company ‘A’ imported turnkey mature technology from Motorola since neither company ‘A’ nor any other Chinese company had the basic production technology of mobile phones in the early 1990s. The company imported every part of TACS mobile phones and assembled the Motorola-brand TACS mobile phones domestically. Through imported turnkey-plant, including the quality management standard, production process management, and so on, Company ‘A’ generated the basic production and management skills. That is, acting as an original equipment manufacturer, Company ‘A’ ensured a quality standard required by Motorola. This method improved the company’s production technology and product quality.

By sending Chinese engineers to study in the USA and through on-site training, the engineers and technical workers of Company ‘A’ absorbed the production technology fast. In addition, without many competitors in the Chinese mobile phone market, Company ‘A’ had enough time and high profit to gradually assimilate and generate the production
technology, quality control management skills, modern production management skills, and other manufacturing management techniques from Motorola. Furthermore, Company ‘A’ cooperated with a research institute (No.4 Institute of China’s Post and Telecommunication Ministry) to develop the Chinese indigenous TACS mobile phones. However, this commercialization cooperation project failed because of the reconstruction of that institute.

Second generation technology

While manufacturing 2G mobile phones (GSM mobile phone), Company ‘A’ acquired the mature technology through production line import and a joint venture with Motorola (under the control of Company ‘A’). Established in 1994, this joint venture produced ‘Motorola’ GSM mobile phones. Its joint venture is an independent company. Company ‘A’ assembled imported components to produce the same brand, but different models of GSM mobile phones. Therefore, before 1998, Company ‘A’ produced ‘Motorola’ brand TACS as well as GSM mobile phones using OEM method, while its joint venture produced ‘Motorola’ GSM mobile phones. After 1998, Company ‘A’ has produced only its own brand mobile phones. Its joint venture still produces ‘Motorola’ brand mobile phones.

Thanks to the experience of producing TACS mobile phones, it was easier for the company to master GSM production technology than to master TACS technology because the main difference between TACS and GSM production technologies was the test and examination equipment and technology. Company ‘A’ improved its TC in GSM by sending Chinese engineers to study in the USA and through on-site training, like what Company ‘A’ did to generate its TC in TACS.

Although GSM is a mature technology in advanced countries, Company ‘A’ invested heavily in the research and development of GSM chip technologies, particularly the applied software of the chip. In 1996, Company ‘A’ established a mobile phone R&D center in Silicon Valley to monitor and develop the latest GSM technologies. Additionally Company

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13 Now, Motorola’s share in this joint venture has risen to 50% while the Chinese side holds another 50%.

14 Relatively updated models of mobile telephones were produced in the joint venture; while the outdated models were produced though OEM. In fact, the outdated models were still the latest models of mobile telephones in China.
‘A’ set up strategic alliances with some giant MNCs, such as Lucent, TI, in order to obtain the advanced technologies and cooperate in the R&D of new products.

After two years, the American R&D center of Company ‘A’ succeeded to develop its own brand GSM mobile phones with 50 per cent of indigenous intellectual property rights. This GSM mobile phone was the first set of Chinese domestic GSM mobile phone model approved by FTA (Federal Technology Authority) of Europe. Currently, most technologies\textsuperscript{15} in its mobile phones, such as the application software, have been the research results of Company ‘A’. Company ‘A’ was appraised as one of the ten largest mobile phone manufacturers in the Chinese domestic market in 2002.

However, some products are still own brand manufacture (OBM\textsuperscript{16}) products in an effort to catch up the fast changing of models and appearance designs in the mobile phone market and survive in the serious competitive market.

2.5th generation technology

Company ‘A’ prepared for the 2.5G mobile phone technology earlier than the time to open 2.5G market in China. The original purpose of its joint venture with Motorola was to produce CDMA mobile phone. Since China’s government decided to adopt GSM mobile phone technology in the middle of the 1990s, the joint venture had to produce GSM mobile phones and CDMA equipment before 2000. However, experiences and capability in CDMA equipment production generated via this joint venture provide Company ‘A’ the opportunity to master and improve its technological capability in the production and development of CDMA and later GPRS mobile phones in a short time. This joint venture has become the largest CDMA manufacturing base of Motorola outside the USA.

Besides the joint venture with Motorola, Company ‘A’ set up partnerships with other world giants in the mobile phone industry and invested heavily in order to develop 2.5G mobile phone technologies and specific products. Company ‘A’ has upgraded its technological capability to produce indigenous GPRS and CDMA mobile phones.

\textsuperscript{15} The technologies do not involve the core chip level technology of mobile telephones, which is mastered by few professional chip companies in the world, such as Lucent, TI.

\textsuperscript{16} In this dissertation, OBM also means the company sales the product with its own brand, but large amount of parts in the product are imported.
However, the company still manufactures GPRS and CDMA mobile phones via OBM because of high licensing cost of the core GPRS and CDMA technology and the fast developing market.

*Third generation technologies*

While Company ‘A’ produced domestic GSM mobile phones, the company already began to invest in the R&D of 3G technologies. With the technological capability generated in the production and R&D in TACS and GSM mobile phones, Company ‘A’ has the financial capital and technological capability to invest in 3G mobile phone technologies, but this input was not enough. Company ‘A’ thus cooperates with others, such as Samsung, LG, Quantum, TI, and Motorola. The company developed a CDMA2000 switching system. This CDMA2000 switching system has passed the trial network test and is about to be mass-commercialized. In addition, in 2002 the company signed a contract to build CDMA2000 infrastructure in Nigeria, which demonstrated that this indigenous CDMA2000 switching system technology was acceptable by other countries. The development of CDMA2000 equipment helps Company ‘A’ to master and improve the 3G mobile terminal technology. Furthermore, Company ‘A’ is a member of China 3G forum to cooperate with other companies in the development and implication of TD-SCDMA standard in China. Under the cooperation with others and own efforts, Company ‘A’ has developed 3G mobile phones with indigenous IPRs. Company ‘A’ has put its 3G mobile phones into field test.

5.1.2 *Factors in technological capability development process*

While studying the development process of technological capability, I find several factors that influence technological capability development of Company ‘A’. There are four important factors: the existing technological capability, nature of technology, diffusion of ICT, and industry value network.

*Existing technological capability*

The development process of Company ‘A’ reveals that the existing technological capability affects the TC development of Company ‘A’ and its selection of preferred technology transfer methods and technology sources. Entering the 1G mobile phone market without technological capability in mobile phones, Company ‘A’ had to use imported
turnkey-plant to obtain the production technology. With the development of technological capability in mobile phone, Company ‘A’ developed new products with indigenous IPRs. In addition, Company ‘A’ prefers to cooperate with other companies in R&D in 2.5G and 3G mobile phone technologies.

The cooperation history with Motorola also demonstrates that the existing technological capability of Company ‘A’ affected its cooperation with Motorola. The success in the 1G mobile phone motivated Company ‘A’ to further its cooperation with Motorola in the more advanced mobile phone technology, such as GSM and CDMA. Company ‘A’ suggested building up a joint venture with Motorola. But Motorola did not agree to this proposal because of the low existing technological capability of Company ‘A’ and Motorola’s strategy in China. Company ‘A’ had to import the GSM production line. After one year, the development of technological capability of Company ‘A’ in GSM mobile phone attracted Motorola to propose the joint venture suggestion to Company ‘A’. Their joint venture has become the largest Motorola’s oversea production base of CDMA mobile phones.

Nature of technology

The TC development process of Company ‘A’ illustrates that the nature of technology affects this process. Company ‘A’ cooperates with chip providers because the top level chip technology is controlled by several companies, particularly, CDMA chip technology is controlled by Quantum. Setting up alliances and cooperation with these companies, Company ‘A’ can decrease the cost of acquiring chip technology and conduct R&D based on the acquired chip technology. In this dissertation, this nature of technology is defined as the monopoly of technology. Company ‘A’ invests in 2.5G and 3G mobile phone technologies through setting up strategic alliances, cooperation with partners, and indigenous R&D efforts since 2.5G and 3G technology are growing and emerging technologies, which are complex, uncertain and highly risky.

Diffusion of ICT

A part of 2G and 2.5G mobile phones are OBM products though Company ‘A’ invested in R&D in new products and new mobile phone technologies. As mentioned above, this is because the mobile phone market is fast changing and highly competitive due to the
diffusion of ICT in the mobile phone industry. The diffusion of ICT makes it possible for Company ‘A’ to develop the latest mobile phone technology and simultaneously capture all stages of technologies: mature technology, growing technology, and emerging technology.

*Industry value network*

The development of the mobile phone industry makes all companies in this industry to form a network. As shown in Figure 4-6, every company is a part of the network, interacting with the suppliers, customers, competitors, and partners. The development of a company depends on that of other companies. As an important member of this industry, Company ‘A’ develops in the industry value network and depends on other companies. The influences from other members on the TC development of Company ‘A’ cannot be neglected. Company ‘A’ sets up alliances with other organizations in order to create added-value. In fact, all its partners are players of the mobile phone industry. Every alliance partner also has its distinct alliance network. All of these alliance networks combine together to form the industry value network (Figure 4-6). Thus, the industry value network influences the TC development of Company ‘A’.

In general, the existing technological capabilities, nature of technology (the complexity, uncertainty, and monopoly of technology in particular), diffusion of ICT, and industry value network have a primary impact on the TC development of Company ‘A’.

5.1.3 *Summary*

In sum, Company ‘A’ gradually generates and improves its technological capabilities in the mobile phone industry through assimilating and improving the transferred technology and cooperating with other organizations. Initially lacking the basic technology, Company ‘A’ acquired technology from outside. In addition, on-site training, overseas training, and indigenous R&D efforts facilitate the company’s TC generation. However, cooperation and alliances are the main methods for the growing and emerging technologies, while imported turnkey-plant is the main methods to obtain the mature technologies. Company ‘A’ has invested in the R&D of all these technologies.
Advanced technology owners, such as Quantum Corporation; DTT; TI; Lucent

Component suppliers

Software companies

Mobile telephone service providers, such as China Mobile; China Unicom

Shell designers

Competitors, such as Samsung

Distribution channels

Motorola

Figure 5-1 Alliance Map of Company ‘A’
### Table 5-1 Important Items in the Process of Technological Capability Development (Company ‘A’)

<table>
<thead>
<tr>
<th>Technology Generation</th>
<th>Existing TC*</th>
<th>Technology Source</th>
<th>Technology Transfer</th>
<th>Effort</th>
<th>TC Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Generation</td>
<td>No TC in mobile telephony industry</td>
<td>Motorola</td>
<td>Imported turnkey-plant; or called OEM</td>
<td>On-site training; Study in USA</td>
<td>Generate production technology, quality control management skills, and other manufacturing management techniques</td>
</tr>
<tr>
<td>Second Generation</td>
<td>Production TC in TACS; No TC in GSM</td>
<td>Motorola; TI; Lucent; others</td>
<td>Imported turnkey-plant; JV; Or called OEM, OBM</td>
<td>On-site training; R&amp;D centers</td>
<td>Generate production TC and other techniques in GSM; produce own brand mobile phones with indigenous IPRs</td>
</tr>
<tr>
<td>2.5th and Third Generation</td>
<td>Experience in the production and R&amp;D of mobile phone</td>
<td>Motorola; TI; LG; Lucent; Samsung; Quantum etc.; And own R&amp;D</td>
<td>Cooperation; Or called OBM, ODM</td>
<td>R&amp;D; On-site training</td>
<td>2.5G products with indigenous IPRs; investment in 3G</td>
</tr>
</tbody>
</table>

Existing TC*: the existing technological capability in the production and R&D of mobile phone when company started to invest in one generation mobile phone.
Company ‘A’ has built up strategic technological alliances with many companies, including the material suppliers, chip technology suppliers, electronic goods shops, mobile phone service providers, and so on. Figure 5-1 shows a general alliance network of Company ‘A’. For example, Company ‘A’ builds up strategic technological alliances with TI, who provides the core chip technology of GSM and research platform. Company ‘A’ cooperates with Quantum, who is the provider of core chips for CDMA. Company ‘A’ cooperates with China Mobile and China Unicom, two mobile phone service providers in China, as well as the competitors, other China’s mobile phone manufacturers, in order to develop 3G mobile phone technologies and products. Company ‘A’ cooperates with professional electronic shops to produce special goods for those shops.

In the TC development process, the absorptive capacity, nature of technology, diffusion of ICT, and industry value network are the main factors.

Important items in the TC development process of Company ‘A’ are concluded in Table 5-1.

5.2 Technological Capability Development of Company ‘B’

Mobile phones are the extension of operations of Company ‘B’. Company ‘B’ started to produce GSM mobile phones in 1999. In 2002, its Mobile Terminal Product Business Unit was established. Company ‘B’ officially has supported the development of mobile terminal products. Now Company ‘B’ is capable of providing products of 2G and 2.5G mobile phone technologies, such as CDMA and GSM products.

Since its establishment, Company ‘B’ has invested heavily in R&D. Company ‘B’ invests nearly 10 per cent\(^{17}\) of its annual sales into R&D. Company ‘B’ has set up a complete human resource management system from recruitment, training and appointment to incentive advancement. Company ‘B’ has 21,000 employees, of which 70 per cent have a bachelor or higher degree. Company ‘B’ has set up 13 wholly owned R&D centers and 9 subsidiaries worldwide. As the premier high-tech transfer base for China’s 863 Program, Company ‘B’ has undertaken several important projects including the 3G development project.

In a bid to grasp key technologies of mobile phone, Company ‘B’ claims independent intellectual properties over all the core software, hardware (mostly circuits and chips) and

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\(^{17}\) The number - 10 per cent of annual sales is a very high percentage for R&D investment in China.
overall design and integration. In addition, Company ‘B’ sets alliances and joint research laboratories with electronics giants, such as Motorola, Texas Instruments (TI) and Agere Systems to undertake R&D in promising telecommunication technologies, for instance 3G mobile telecommunication technologies. Moreover, Company ‘B’ is the first Chinese individual manufacturer of 3rd Generation Partnership Project 2 and has become a member of the International Telecommunications Union (ITU).

5.2.1 Technological capability development of Company ‘B’

Company ‘B’ decided to produce GSM mobile phone in 1999. Based on its excellent R&D teams, high technological development capabilities, and intensive R&D experience in mobile telecommunication equipment, Company ‘B’ develops its technological capability in different generations of mobile phone technologies (except the first generation mobile phone technology) in a short time.

Second generation of mobile phone technology

Though Company ‘B’ has strong R&D capability in the telecommunication, the company lacked the capacity to build up a mobile phone production line and to produce GSM mobile phones when they made decision to be a mobile phone producer in 1999. Company ‘B’ imported the production line from a British company18, which is not as famous as Motorola and Nokia. Based on this production line, Company ‘B’ assembled imported components into GSM mobile phones and sold them under its own brand. The purpose of this acquisition was to get acquainted with the design and production process of mobile phones (including the internal structure, appearance design, and software and hardware design), not for the commercial profit. Company ‘B’ mastered the production technology of mobile phones. In addition, Company ‘B’ developed the design and R&D capability in mobile phones through reverse engineering. Its first pattern of mobile phones was freely offered to mobile phone service providers.

At the same time, Company ‘B’ invested in new types of mobile phones with the indigenous design of the appearance, circuit plates, and the interface software. The mobile phones with indigenous technologies were put into market in 2000. However, the sales of GSM mobile phones were not satisfactory. It is because as an equipment manufacturer,

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18 The name of the British company is not told because of business secrecy.
Company ‘B’ did not have experience to sell products to consumers directly. Company ‘B’ had very weak marketing capability and had not completed its marketing network in the early 2000s. Through the cooperation with professional mobile phone marketing companies, Company ‘B’ improved its market scale and marketing capability. In addition, Company ‘B’ improves its production, design, and development capability of mobile phones.

2.5th generation of mobile phone technology

Though Company ‘B’ started to produce mobile phones in 1999, Company ‘B’ has invested in R&D in CDMA (one kind of 2.5G mobile phone technologies) system since 1995. Company ‘B’ has developed GPRS and CDMA mobile phones since 2000, before the time when China’s 2.5G mobile phone market opened. In addition, Company ‘B’ sets up an institute in Korea to conduct R&D in CDMA and develop new CDMA mobile phones. In September 2003, Company ‘B’ was awarded the “China Top Brand” title for its CDMA mobile phones.

In 2003, the CDMA mobile phone, a new source of revenue for Company ‘B’, was successfully put into the international market. In May 2004, Company ‘B’ won a US$100 million mobile phone order from VIVO (a Brazil telecommunication carrier), which was the most valuable mobile phone contract ever won by Chinese mobile phone manufacturers to date. On the basis of its strong CDMA technology and brand, in 2004 Company ‘B’ released the first CDMA-based global digital trunking architecture (GoTa) standard, which is the first standard proposed by a Chinese enterprise. GoTa is expected to become one of the leading technologies that may change the pattern of the international digital trunking market in the future. Nevertheless, a small part of 2.5G mobile phones in Company ‘B’ are produced via OBM.

Third generation of mobile phone technology

There are three standards of 3G mobile phone technologies. In addition, the Chinese government has not decided which standard(s) are to be adopted. Company ‘B’ has to invest in all three standards of 3G mobile phone technologies. In order to improve R&D capability in 3G mobile telecommunication technologies, Company ‘B’ built a new R&D center in Shanghai focusing on the R&D of 3G mobile system and terminal product, particularly WCDMA mobile telecommunication technologies.
In 1998, Company ‘B’ started to pay close attention to WCDMA technology. In March 1999, Company ‘B’ joined the global 3G standard work organized by ITU. In June 1999, Company ‘B’ participated in the Chinese 3G standard development work. At the end of that year, with DTT and other companies, Company ‘B’ organized 3G Forum as a platform for all members in China to discuss all relevant problems in the 3G mobile telecommunication.

In the 3G mobile phone field, Company ‘B’ acquires the standard technologies from Quantum and DTT to develop 3G technology and the products with indigenous technologies. In addition, Company ‘B’ has practiced to produce WCDMA mobile phones with some parts imported from Japan. Company ‘B’ has rolled out the smallest and lightest foldable WCDMA mobile phones in the world. Company ‘B’ cooperates with service providers, such as Shanghai Telecom, and Nortel, to do research and development in 3G mobile telecommunication technology because the 3G technology is an emerging technology.

Company ‘B’ improves its marketing capability through substantial marketing inputs, and upgrades its R&D capability in mobile phones through cooperation with other organizations and own intensive R&D efforts. Total sales of mobile phones of Company ‘B’ for the year 2004 exceeded 10 million sets, up 100 per cent over the previous year.

5.2.2 Factors in technological capability development process

Intensive R&D efforts

Company ‘B’ believes that the most important thing is to build up a strong and excellent R&D team. The core of competition in future is technology. High technological capability is the key for the company to succeed in the worldwide business.

During the process of technological capability development in mobile phones, Company ‘B’ invests heavily in the R&D team. Company ‘B’ sets up internal R&D process standards for different R&D labs and different R&D projects in an effort to enhance R&D management. In addition, Company ‘B’ modifies the R&D process standards every year in order to find and establish the best standards for different fields’ R&D. Moreover, Company ‘B’ completes and preserves its R&D files and documents for all finished programs. These
R&D documents not only conclude the successful and failed experience in the previous research but also offer knowledge base for the future research.

As mentioned above, Company ‘B’ invests nearly 10 per cent of its annual sales revenue into R&D. The investment in mobile phone is higher than company’s average, up to nearly 15 per cent of sales revenue. Company ‘B’ has set up a complete regular training system to improve the competence of employees. The employees are trained on-site or outside of company. Company ‘B’ has 21,000 employees, of which 70 per cent have a bachelor or higher degree. This high educated employee team has become the cornerstone of continually successful R&D activities.

Existing technological capability

Company ‘B’ is a world famous innovative telecommunication company. Company ‘B’ has strong technological capability and intensive R&D experience. Thus, Company ‘B’ could generate production technology in GSM mobile phones in a short time. Intensive R&D efforts improve the company’s existing technological capability in mobile phones. With the strong existing technological capability, Company ‘B’ prefers to develop new mobile phones via indigenous R&D. If the company has enough experience and knowledge to develop a new technology, Company ‘B’ conducts the programs alone, not with other companies.

The strong existing technological capability helps Company ‘B’ to select the partners to set up technology alliances. In addition, the strong existing technological capability attracts other companies to cooperate with Company ‘B’ in the development of new technology.

Nature of technology

The public or monopoly nature of technology has a significant impact on the process of technological capability development of Company ‘B’. As mentioned above, Company ‘B’ imported GSM production lines and production technology from a not-so-famous British company. It is because the production technology of GSM mobile phones is a public technology mastered by many companies not only giants. Company ‘B’ can select a company on the basis of cost, method, benefit and purpose of cooperation.
However, Company ‘B’ cooperates with DTT Corporation since DTT is the owner and innovator of TD-SCDMA technology standard. Company ‘B’ cooperates with Quantum Corporation as Quantum is the owner of key technology in WCDMA standard and CDMA technology. The TD-SCDMA standard technology, WCDMA standard technology, and CDMA technology are all monopoly technologies, not mastered by many companies. 3G mobile phone technologies are emerging technologies, which have high complexity, market uncertainty and investment risk. Company ‘B’ thus cooperates with others in order to reduce the investment cost and risk. In short, the monopoly and complexity of technology affect the process of technological capability development in Company ‘B’.

Therefore, intensive R&D efforts, strong existing technological capability, and the nature of technology are the important factors which influence the process of technological capability development in Company ‘B’. In addition, the diffusion of ICT shortens the life cycles and development cycles of mobile phones. Company ‘B’ produces part of mobile phones through OBM in order to grasp the market trends. Moreover, the development of value networks in the mobile phone industry accelerates the cooperation of Company ‘B’ with other companies, including the mobile phone service providers. In general, intensive R&D efforts, strong existing technological capability, the nature of technology, diffusion of ICT, and industry value network affect the process of technological capability development.

5.2.3 Summary

In short, Company ‘B’ generated its production technology through importing production lines from a foreign company. With its intensive R&D efforts (such as setting up internal R&D process standards, regular training, and heavy R&D investment), Company ‘B’ absorbs the transferred technology and improves its technological capability. In addition, Company ‘B’ cooperate with many companies, including the mobile phone service providers (China Mobile and China Unicom), marketing companies (which have distribution channels), competitors (e.g. Motorola), technology providers (e.g. Quantum), and so on. The alliance network is similar to that of Company ‘A’, as shown in Figure 5-2.
Figure 5-2 Alliance Map of Company ‘B’
<table>
<thead>
<tr>
<th>Technology Generation</th>
<th>Existing TC*</th>
<th>Technology Source</th>
<th>Technology Transfer</th>
<th>Effort</th>
<th>TC Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Generation</td>
<td>No production capability in GSM; Strong R&amp;D capability in telecommunication</td>
<td>A British company; Others; own R&amp;D</td>
<td>Production line imported; OBM</td>
<td>On-site training; R&amp;D investment</td>
<td>Generate production, design and development capability of GSM; produce own brand mobile phones with indigenous IPRs</td>
</tr>
<tr>
<td>2.5th Generation</td>
<td>Experience in production and R&amp;D in mobile phone</td>
<td>Motorola, TI, Quantum etc.; And own R&amp;D</td>
<td>OBM; cooperation</td>
<td>R&amp;D investment; Foreign R&amp;D centers</td>
<td>2.5G products with indigenous IPRs</td>
</tr>
<tr>
<td>Third Generation</td>
<td>Experience in production and R&amp;D in mobile phone</td>
<td>A Japanese company, Quantum, DTT…… Own R&amp;D</td>
<td>Alliances</td>
<td>Intensive R&amp;D investment; Foreign R&amp;D centers</td>
<td>WCDMA technology and products; R&amp;D in TD-SCDMA; 3G system</td>
</tr>
</tbody>
</table>

Existing TC*: the existing technological capability in the production and R&D in mobile phone when company started to invest in one generation mobile phone.
Company ‘B’ invests in GSM, GPRS, CDMA mobile phones, and three 3G standards, covering the mature, growing, and emerging technologies. Company ‘B’ has strong R&D capability which is originally generated from the experience of R&D in telecommunication equipment. Nevertheless, Company ‘B’ has weak marketing capability, which has improved in recent years with the investment in marketing. Intensive R&D efforts, strong existing technological capability, the nature of technology, diffusion of ICT, and industry value network affect the process of technological capability development in Company ‘B’.

The detailed items in the process of technological capability development in Company ‘B’ are shown in Table 5-2.

5.3 Technological Capability Development of Company ‘C’

Company ‘C’ was founded in 1992 as a pager manufacturer. By 1997, it had become the largest pager manufacturer in China. In 1999, Company ‘C’ moved into manufacturing mobile phones. Mobile phones and pocket PCs have become the staple products of Company ‘C’. In 2000, Company ‘C’ was successfully listed in the Shanghai Stock Exchange and started to issue its A-share.

Since its establishment, Company ‘C’ engaged in setting up the distribution and service network around China, even in small towns. Based on its marketing network, Company ‘C’ has been the largest domestic mobile phone provider and the No.1 mobile phone brand in China for five years. In 2004, Company ‘C’ became one of the global top-ten mobile phone manufacturers.19

Company ‘C’ invested heavily in research and development, as it put nearly 6 per cent of its annual sales revenue into R&D. Company ‘C’ has set up several research institutes in China. In addition, Company ‘C’ has built up an R&D group with 600 professional technical employees, who have a master, doctoral, or post-doctoral degree.

During its development process, Company ‘C’ set up technological partnerships with mobile phone giants, for instance, Samsung, Quantum, Motorola, and Siemens, to compete in the future mobile phone technology. Additionally, Company ‘C’ makes commercial alliances with foreign mobile phone service providers, such as AT&T, in an effort to enter the foreign market. Company ‘C’ has sold its mobile phones to more than 30 countries or regions.

5.3.1 Technological capability development of Company ‘C’

Unlike Company ‘A’ and Company ‘B’, Company ‘C’ has virtually put all efforts in the development and production of mobile phones (no mobile system and mobile equipment) since the company started to produce mobile phones.

Second generation of mobile phone technology

In 1999, after becoming the largest domestic pagers’ manufacturer, Company ‘C’ moved on to produce and sell GSM mobile phones. When Company ‘C’ made this decision, Company ‘C’ had no technology of mobile phones. Company ‘C’ cooperated with a French company. Under the support of the French company, Company ‘C’ built its first production line. Company ‘C’ used the technology from the French company and assembled imported parts and sold them under its own brand. Company ‘C’ shared the profit with this French company.

In order to grasp the production and development technology, Company ‘C’ sent employees to get trained in the French company. And the French company sent engineers to Company ‘C’ to train Chinese employees on-site. In addition, Company ‘C’ benefited through learning-by-doing during technology transfer. Moreover, Company ‘C’ sets up R&D institutes and cooperates with universities in order to do R&D in mobile phones. With intensive training and learning, Company ‘C’ mastered the production and development technology. In 2001, Company ‘C’ developed its first set of mobile phone with indigenous technology.

Though Company ‘C’ is weak at the production and R&D technology, Company ‘C’ has extensive marketing experience, strong marketing capability and a comprehensive national marketing network based on the successful marketing of pagers. With its efforts to improve and develop new products and its marketing capability, Company ‘C’ has become the largest local mobile phone manufacturer in the Chinese market since 2000. On the other hand, the profit from successful marketing provides a strong support to its R&D investment.

2.5th generation of mobile phone technology

In 2000, Company ‘C’ started to produce CDMA mobile phones. At the end of 2002, Company ‘C’ started to produce GPRS mobile phones. Since Company ‘C’ is a company without strong R&D capability in mobile phones but with enough production experience and
a famous brand, Company ‘C’ at first assembled imported parts, most were from Korea and Japan, to produce CDMA and GPRS mobile phones and sold them under its own brand. In other words, Company ‘C’ produced CDMA and GPRS mobile phones via OBM at first.

On the other hand, Company ‘C’ invests in R&D in the 2.5G mobile phone technology. Company ‘C’ cooperates with universities and other companies to undertake R&D activities in the 2.5G mobile phone technology. Currently, Company ‘C’ has developed and produced CDMA and GPRS with indigenous technology, but not all products.

*Third generation of mobile phone technology*

Though Company ‘C’ does not have strong R&D capability in the mobile phone industry, Company ‘C’ invests heavily in the emerging technology with the capital support from the successful marketing. Its investment in CDMA2000 started from 1999, through the cooperation with the State Key Laboratory of Mobile Communication of Southeast University in Nanjing. In addition, Company ‘C’ joins the 3G Forum and cooperates with other companies, such as Quantum Corporation and Samsung. Moreover, Company ‘C’ furthers its cooperation with the French company. In 2002, they set up a joint venture and a joint R&D center to explore the 3G mobile phone market. Company ‘C’ recruits talents to build up its R&D team. Company ‘C’ has set up three R&D centers and a joint R&D center.

### 5.3.2 Factors in technological capability development process

Company ‘C’ makes great efforts to become an innovative company and create an international famous brand in the telecommunication field. In the process of technological capability development, the following factors play critical roles in Company ‘C’.

*Marketing capability*

Company ‘C’ is famous for its extensive national market network and strong marketing capability. Company ‘C’ analyzes the market trend, market selection, and customer requirement in order to develop and produce the mobile phones which the market needs and welcomes. The strong marketing capability ensures the high profit of Company ‘C’. Company ‘C’ was one of the highest profit-earning public companies in the Chinese mainland stock exchange market, including the Shanghai and Shenzhen Stock Exchanges, in
2003. On the one hand, the profit provides enough financial support for costly R&D, new product development, and the build-up of technological capability. On the other hand, the fast development of new products improves the company’s competence and the profit margin of products. Therefore, in Company ‘C’, the marketing competence and R&D capability have become a feedback loop, as shown in Figure 5-3.

![Figure 5-3 Cycle of marketing capability and R&D](image)

**R&D efforts**

One of the strategies of Company ‘C’ is to gather outstanding personnel. Technological capability occupies the center stage of future competition. The company makes great efforts, such as a good work environment, to attract talent. Company ‘C’ has set up a post-doctoral research station. In addition, Company ‘C’ has associated with well-known universities, such as Zhejiang University, to train employees in order to improve R&D and management skills.

Company ‘C’ strives to become a learning organization. Learning is one of the most important methods in Company ‘C’ to improve employees’ competence. Company regularly sends employees to take professional training or invites talents of other companies to do on-site training for their employees. Every year Company ‘C’ puts over 6 per cent of annual sales revenue as its R&D budget. Company ‘C’ has built up a research team with nearly 1000 professional personnel and more than 100 Ph.D. With their efforts, Company ‘C’ introduces at least 20 new products to the market every year.

**Nature of technology**

A large number of technologies related to GSM mobile phones were public when Company ‘C’ moved to produce mobile phones. Thus, like Company ‘B’, Company ‘C’
could select a partner to obtain the production technology at a low cost from many foreign companies which mastered GSM technology.

However, the key technologies of 2.5G, especially those of 3G, are monopolistic, not public. Company ‘C’ has to cooperate with companies which master monopolistic technology. Company ‘C’ does not have many selections in 3G mobile phones like those in 2G mobile phones. In addition, the 3G mobile phone technology is emerging and complex. Company ‘C’ has no capability to do R&D in the 3G mobile phone technology alone. The complexity and emerging status of technology provide Company ‘C’ the impetus to cooperate with other companies and institutes.

**Diffusion of ICT**

The diffusion of ICT provides new opportunities to Company ‘C’. Company ‘C’ could use such new information and communication technology to develop new products and improve its competitive capability. In addition, with the diffusion of ICT, Company ‘C’ can collect and analyze the latest market information and product trends. Moreover, the diffusion of ICT makes it possible and convenient for Company ‘C’ to cooperate with other companies.

Thus, the marketing capability, R&D efforts, nature of technology, and diffusion of ICT have an impact on the TC development process of Company ‘C’. Besides these factors, the industry value network also affects the technological capability development of Company ‘C’, like Company ‘A’ and Company ‘B’.

**5.3.3 Summary**

In 1999, Company ‘C’ produced its first set of mobile phones via OBM. Company ‘C’ assimilates the transferred technology and combines it with indigenous efforts to improve existing technological capability. In 2001, Company ‘C’ developed its first set of mobile phones with indigenous technology at the application level. Since 2003, 80 to 90 per cent of mobile phones produced by Company ‘C’ have been made with indigenous technologies.
Figure 5-4 Alliance Map of Company ‘C’
Table 5-3 Important Items in the Process of Technological Capability Development (Company ‘C’)

<table>
<thead>
<tr>
<th>Technology Generation</th>
<th>Existing TC*</th>
<th>Technology Source</th>
<th>Technology Transfer</th>
<th>Effort</th>
<th>TC Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Generation</td>
<td>No technological capability in mobile phone; Strong marketing capability</td>
<td>A French company; Others institute</td>
<td>Production line imported; OBM</td>
<td>On-site training; foreign training; R&amp;D investment</td>
<td>Generate production, design and development capability of GSM; produce own brand mobile phones with indigenous IPRs</td>
</tr>
<tr>
<td>2.5th Generation</td>
<td>Experience in production and R&amp;D in mobile phone</td>
<td>Motorola; TI; LG; Lucent; Samsung; Quantum etc.; and own R&amp;D</td>
<td>OBM; cooperation; ODM</td>
<td>R&amp;D; regular training</td>
<td>2.5G products with indigenous IPRs; investment in 3G</td>
</tr>
<tr>
<td>Third Generation</td>
<td>Experience in R&amp;D in mobile phone</td>
<td>Institutes; Sagem; Quantum……</td>
<td>Cooperation</td>
<td>R&amp;D investment</td>
<td>R&amp;D in TD-SCDMA and WCDMA</td>
</tr>
</tbody>
</table>

Existing TC*: the existing technological capability in the production and R&D in mobile phone when company started to invest in one generation mobile phone.
Company ‘C’ is outstanding in its comprehensive marketing network in China. The profit from OBM provides a sustainable support for the company’s R&D, new products and technological capability development. On the other hand, the improvement of technological capability ensures the profit of new products and corporate competitive competence.

During the development process, Company ‘C’ sets up strategic alliances with foreign giants in order to gain a good platform for R&D in mobile phone technologies, such as the strategic alliances with Siemens. In addition, Company ‘C’ cooperates with foreign mobile phone service providers, such as AT&T, to explore the foreign mobile phone market. The alliance map of Company ‘C’ is shown in Figure 5-4.

The important items in the process of technological capability development of Company ‘C’ are listed in Table 5-3.

5.4 Technological Capability Development of Company ‘D’

Established in 1941, Company ‘D’ is a state-owned enterprise specialized in R&D, production and sales of telecommunication equipment and mobile terminal products. Company ‘D’ has been listed as an A-Share company at the Shanghai Stock Exchange.

In 1996, Company ‘D’ entered the mobile phone market via a joint venture with Nokia. This joint venture is the first company to produce GSM mobile phones in China. However, these mobile phones are sold under ‘Nokia’ brand. Company ‘D’ built up its own production lines to produce its own brand of mobile phones in 1999. Currently, Company ‘D’ has produced GSM, GPRS and CDMA mobile phones.

Company ‘D’ has invested in different generations of mobile phone technologies. With its R&D capability in telecommunication, Company ‘D’ has undertaken key R&D tasks in the State 863 Science and Technology Program and the State CDMA, Wireless WAP and GPRS programs.

Like other Chinese mobile phone companies, Company ‘D’ has formed strategic partnerships with foreign investors and created good cooperative environment with concerted efforts. Company ‘D’ has built up joint ventures with corporations from Finland, Japan, USA, and Korea, such as the joint ventures with Nokia, DMC Corporation and NEC.
5.4.1 Technological capability development of Company ‘D’

Second generation of mobile phone technology

In 1996, Company ‘D’ set up a joint venture with Nokia to produce GSM mobile phones, which was the first factory to produce GSM mobile phones in China. Through the joint venture, Company ‘D’ generated and improved its management skills and quality management techniques, but no development and production technologies. However, the joint venture sells the mobile phones under ‘Nokia’ brand. The focus of joint venture is production, not R&D.

In order to build up an indigenous R&D team, Company ‘D’ recruits telecommunication personnel and sets up research centers. In addition, a joint R&D center with TI and Intel was established in the USA in 1998 to do R&D in the mobile phone technology. The R&D center in the USA developed the first set of mobile phones with indigenous intellectual property rights for Company ‘D’ in 1999.

At the end of 1999, Company ‘D’ started to produce and develop own brand mobile phones. At the same time, the joint venture still produced ‘Nokia’ brand mobile phones. The company which produces the local brand mobile phones is different from the joint venture since this joint venture is not under the complete control of Company ‘D’. Company ‘D’ could not learn the latest technology from its joint venture. Thus, the technological capability of Company ‘D’ was still low when the company started to produce own brand mobile phones. Company ‘D’ imported the development platform and chips from Lucent in 1999. Through on-site training, training in the R&D center in the USA and foreign companies, and inviting foreign engineers to the company, Company ‘D’ generates and improves the technological capability.

2.5th generation of mobile phone technology

In 2002, Company ‘D’ put its 2.5G mobile phone (GPRS and CDMA) to the market. The company produced some parts of 2.5G mobile phones via OBM because it had limited 2.5G mobile phone technology, and the market was fast-changing and highly competitive. Company ‘D’ cooperates with companies from Korea, Taiwan, and other countries or regions to develop new 2.5G products.
Third generation of mobile phone technology

3G technology is the focus of the future mobile phone market. Company ‘D’ cooperates with other companies, particularly with Korean companies, to develop 3G mobile phone technologies. Though Company ‘D’ is a member of Chinese 3G development group, Company ‘D’ has not involved deeply in the development of 3G mobile terminal products.

5.4.2 Factors in technological capability development process

Like the other three companies, intensive efforts (such as training system), the nature of technology, and diffusion of ICT have an impact on its technological capability development. However, compared with other three companies, the development speed of Company ‘D’ is not fast though the company is one of the earliest Chinese companies to produce mobile phones. In addition, Company ‘D’ does not focus on the research and development of the third generation mobile phone technology. The problem comes largely from the state influence.

Company ‘D’ is a state-owned enterprise. The government affects its strategic decision and top-managers. Company ‘D’ cannot make and change its decisions promptly according to changes of the market. In addition, since 2003, the top-management team has changed frequently, which affects the development strategy of Company ‘D’. These changes have a long-lasting effect on the competence of Company ‘D’. Take 3G as an example. Company ‘D’ does not invest heavily in the 3G mobile phone technology, while its competitors put great investments in 3G and future mobile phone technologies.

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20 The CEO and some senior managers are different in every year.
Figure 5-5 Alliance Map of Company ‘D’
Table 5-4 Important Items in the Process of Technological Capability Development (Company ‘D’)

<table>
<thead>
<tr>
<th>Technology Generation</th>
<th>Existing TC*</th>
<th>Technology Source</th>
<th>Technology Transfer</th>
<th>Effort</th>
<th>TC Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Generation</td>
<td>No technological capability in GSM</td>
<td>Nokia</td>
<td>JV; OBM</td>
<td>On-site training; foreign training; R&amp;D</td>
<td>Generate production TC and other techniques in GSM; produce own brand mobile phones with indigenous IPRs</td>
</tr>
<tr>
<td>2.5th Generation</td>
<td>Experience in production and R&amp;D in mobile phone</td>
<td>Nokia; TI; Lucent; NEC; Quantum etc.; And own R&amp;D</td>
<td>OBM; cooperation; ODM</td>
<td>R&amp;D; On-site training; foreign training</td>
<td>2.5G products with indigenous IPRs;</td>
</tr>
<tr>
<td>Third Generation</td>
<td>Experience in production and R&amp;D in mobile phone, but not enough</td>
<td>Korean companies</td>
<td>Cooperation</td>
<td>R&amp;D; cooperation</td>
<td>No heavy investment in 3G</td>
</tr>
</tbody>
</table>

Existing TC*: the existing technological capability in the production and R&D in mobile phone when company started to invest in one generation mobile phone.
5.4.3 Summary

Company ‘D’ cooperates with other companies to seek the better technological capability development and improves the modern corporate management on the platform of the joint venture. When the technological capability was not enough for the production and development of mobile phones, Company ‘D’ imported foreign technologies and products, then learnt and generated its technological capability from the imported technologies and products. With its internal efforts, Company ‘D’ assimilated and combined the imported technology with the existing technology to improve its existing technological capability. For instance, Company ‘D’ sets up R&D centers and invests in the mature, growing and emerging technology. Like the other three companies, Company ‘D’ builds alliances with other organizations. With the development of technological capability, Company ‘D’ develops its indigenous technologies. However, the decision from government affects the development of Company ‘D’, particularly after 2002. Since 2003, the development of Company ‘D’ has been slower and slower.

Figure 5-5 is the alliance map of Company ‘D’\(^{21}\). Table 5-4 presents the important items in the technological capability development process of Company ‘D’.

5.5 Comparison and Conclusion of Four Companies

In this section, I compare the four cases. Because only Company ‘A’ has experience in the production of 1G mobile phones, the development process of 1G mobile phones is not addressed in this section. I present the comparison from the following five aspects:

1) Process of technological capability development;
2) Technology transfer;
3) Alliances of the four companies;
4) Main factors influencing the process of technological capability development; and
5) R&D and marketing capabilities of the four companies.

\(^{21}\) Most alliances were established before 2003. There is no further information about the alliances since the company has not decided its development and technology strategy. In fact, strategy changes fast because of the changes of top-manager team and CEO.
5.5.1 Process of technological capability development

The processes of technological capability development in Company ‘A’, ‘B’, ‘C’, and ‘D’ suggest that with the intensive internal efforts, companies develop from OEM or OBM (assembling imported parts and selling under own brands) to ODM. The method to acquire outside technologies changes from technology/turnkey-plant imported or joint venture (Company ‘D’) to technology alliances and technology cooperation. The changing technology acquisition methods of different companies are presented in Figure 5-6. In addition, during this process, companies set up alliance networks with competitors, component providers, mobile phone service providers, key technology or research platform providers, and so on. These alliance networks interact to be the industry value network (Figure 4-6).

In sum, the four companies at first acquired technologies from outside. Then they assimilate and improve the transferred technology, and develop new products and new technologies with their intensive internal efforts. However, the methods to access new technology are different in the different generations of technologies.

In addition, Company ‘A’, ‘B’, ‘C’ and ‘D’ produce GSM (2G, mature technology), GPRS and CDMA (2.5G, growing technology) at the same time. They put investment in R&D in 2G (mature technology), 2.5G (growing technology), and 3G (emerging technology) concurrently.
5.5.2 Technology Transfer

All four companies have extensive technology transfer experience in order to generate their technological capabilities and improve their competence. With the development of technological capability, the preferred technology transfer mode changes. In addition, the technology transfer modes for different stages of technology are different as well. Figure 5-7 shows that the changes of technology transfer modes in four cases. Figure 5-7 suggests that externalized technology transfer modes, such as technology cooperation, are favorite technology transfer modes selected by these four companies. In addition, these four companies invest in their own R&D.
5.5.3 **Alliances of companies**

Company ‘A’, ‘B’, ‘C’, and ‘D’ have set up alliances with many other companies. This section discusses the formation of alliances and the objective technologies in alliances. The data are collected from the interviews, the published documents of companies, and the journal ‘China Business Review’ from 1999 to 2004. In addition, the alliances here are all the technological cooperation signed formal documents and be published, not including the cooperation without formal documents. The alliances with component providers, designer
companies, distribution channels, and service providers, are not included in the following tables.

Formation of alliances

In this dissertation, the formation of alliances is divided into the equity and non-equity modes. The main technology alliances of the four companies are included in Table 5-5.

<table>
<thead>
<tr>
<th>Company</th>
<th>Equity Alliance</th>
<th>Non-equity Alliance</th>
<th>Total Alliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company ‘A’</td>
<td>3</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Company ‘B’</td>
<td>4</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Company ‘C’</td>
<td>1</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Company ‘D’</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>30</td>
<td>41</td>
</tr>
</tbody>
</table>

In general, the non-equity mode is the favorite alliance mode, as shown in Table 5-5. Table 5-5 indicates that the non-equity mode is the preferred alliance mode selected by Company ‘A’, ‘B’, and ‘C’. Company ‘D’ is rather indifferent concerning the equity or non-equity mode alliances.

Objective technology in alliances

Companies set up alliances for the different generations of mobile phone technologies. The alliances for first generation mobile phone technology are not calculated since in the four companies, only Company ‘A’ had experience in 1G mobile phones.

As mentioned above, the 2G mobile phone technology is a mature technology; the 2.5G technology is a growing technology; and the 3G technology is an emerging technology. Table 5-6 suggests that the 2G technology (mature technology) is not the main alliance objectives. In the three generation technologies (2G, 2.5G and 3G technologies), the four companies prefer to build alliances for the growing (2.5G) and emerging (3G) technology. In addition, the four companies set up alliances with other ICT companies in order to obtain
the latest software and hardware technology since they are not professional computer companies. The software and hardware technology (important ICT items) could be seen as the growing or emerging technology since such technology is adapted for the latest telecommunication technology. In sum, the growing technology and emerging technology are the focus of alliances.

Table 5-6 Objective Technology in Alliances

<table>
<thead>
<tr>
<th>Company</th>
<th>2G Technology</th>
<th>2.5G Technology</th>
<th>3G Technology</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company ‘A’</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Company ‘B’</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Company ‘C’</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Company ‘D’</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>10</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: NA means the objective technologies of alliances are technologies used in mobile phones, but not mobile telecommunication technologies. These technologies are the software technology, digital operation systems, and so on. They are provided by other computer companies, such as IBM, Intel, and Microsoft.

5.5.4 Factors in technological capability development process

The internal R&D efforts affect the process of technological capability development. The four companies train their technical employees and invest heavily to improve their technological capabilities. In addition, the existing technological capability (including marketing capability), nature of technology, diffusion of ICT and industry value network are also the main factors in their processes of technological capability development. The state influence is thought as an important factor by Company ‘A’ and Company ‘D’ in particular, which is a barrier to the state-owned enterprises’ development.

5.5.5 R&D and marketing capability

According to peer information relative to companies in the Chinese mobile phone industry and the interview results, it is widely accepted that Company ‘A’ had no strong
R&D capability and no marketing experience when it started to produce mobile phones in the early 1990s. As mentioned above, Company ‘B’ is famous for its strong innovative capability not only in China but also in the world. However, Company ‘B’ had no strong marketing capability since it had no experience in consuming products when it decided to be a provider of mobile terminal products. In contrast, Company ‘C’ had strong marketing capability generated from the distribution of pager products, but without strong R&D capability in the mobile telecommunication. The station of Company ‘D’ was like Company ‘A’ in mid-1990s. The comparison of R&D capability and marketing capability of the four companies is presented in Table 5-7.

Table 5-7 Comparison of R&D Capability and Marketing Capability of Companies (Industry Entrance Time)

<table>
<thead>
<tr>
<th>Case</th>
<th>R&amp;D capability</th>
<th>Marketing capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company ‘A’</td>
<td>Not strong</td>
<td>Not strong</td>
</tr>
<tr>
<td>Company ‘B’</td>
<td>Very strong</td>
<td>Weak</td>
</tr>
<tr>
<td>Company ‘C’</td>
<td>Weak</td>
<td>Very strong</td>
</tr>
<tr>
<td>Company ‘D’</td>
<td>Not strong</td>
<td>Not strong</td>
</tr>
</tbody>
</table>

Based on the research model of capability development routines (Figure 2-6) presented in Chapter 2, the existing technological capability (marketing and R&D capabilities in particular) affects a company’s TC development path. According to the comparison results shown in Table 5-7, Company ‘A’ had neither strong R&D capability nor strong marketing capability when the company entered the mobile phone industry. With great efforts, Company ‘A’ develops its R&D capability and marketing capability. But its R&D capability is still weaker than that Company ‘B’ since Company ‘B’ is widely recognized as a company with the strongest innovative competence in China. Additionally, its marketing capability is weaker than that Company ‘C’ as Company ‘C’ is widely accepted as one of the companies with the best marketing competence in China. Company ‘A’ is not a company with strong R&D capability or strong marketing capability. Thus, Company ‘A’ is at quadrant I in the capability development routine model, as shown in Figure 5-8.
Company ‘B’ is a company famous for its strong R&D capability in the telecommunications industry. But as an equipment manufacturer, Company ‘B’ has no strong marketing capability. Thus, Company ‘B’ is at quadrant III in Figure 5-8. Company ‘C’ is opposite to Company ‘B’. Company ‘C’ is famous for its comprehensive national marketing network and strong marketing capability. Nevertheless, Company ‘C’ has no strong R&D capability as its short history in the telecommunications industry. Company ‘C’ is at the quadrant II in Figure 5-8.

Company ‘D’ is also a company with neither strong R&D capability (compared with Company ‘B’) nor strong marketing capability (compared with Company ‘C’). Company ‘D’ is also at quadrant I in Figure 5-8. It is difficult to distinguish which R&D capability and marketing capability are relatively strong between Company ‘A’ and Company ‘D’. However, the interviewees in Company ‘D’ and Company ‘A’ all recognize that the market
response speed of Company ‘A’ is faster than that of Company ‘D’. The strategy of Company ‘A’ is more flexible than that of Company ‘D’, though both companies are state-owned companies.
6 Process of Technological Capability Development and Factors in this Process

Based on the research framework proposed in Chapter 2 and the case data presented in Chapter 4 and Chapter 5, this chapter analyzes the process of technological capability development and factors in this process in Chinese high-tech industries. The process of technological capability development is explored from two stages: the external stage of technology transfer in alliances and the internal stage of intra-firm technology diffusion. The process of technological capability development is the integration of the external and internal stages.

6.1 Process of Technological Capability Development

6.1.1 Stage of technology transfer in alliances

Importance of technology transfer

A company can obtain and develop the advanced technology through R&D intra-company and/or through technology transfer outer-company. The imported technology plays a considerable important role in the economic and technological development process of latecomers because of their low technological capabilities and large technological gaps with leading companies in the world (Kim, 1997; Lee, 2001). Moreover, outside sources of technology are often critical to the internal innovation (R&D) process, no matter at which organizational level the innovating unit is defined, especially under the globalizing economic environment (e.g. Burgelman et al., 1996).

The most important benefit of technology transfer for companies in the host economy is the technological capability improvement gained from the assimilation and diffusion of transferred technology, especially the production capacity improvement to generate the comparative competitive advantage (Kogut and Zander, 1992; Kim, 1997; Lall, 2002). In addition, previous studies suggest that recipients’ ultimate purpose of technology transfer is to generate their technological capabilities (Wei, 1995). The evolution of technological
capability of China’s mobile phone industry and the development of these four companies supports this theory.

Figure 4-5 ‘Evolution of Technology Acquisition Method’ indicates that technology transfer plays a crucial role in a company’s process of technological capability development, particularly when the company lacks enough basic technologies. The development processes of four companies in the mobile phone industry suggest that technology transfer plays a critical role in their TC development, particularly when they entered the mobile phone industry without basic production technology. For instance, Company ‘A’ imported turnkey-plant to produce the first generation (TACS) mobile phones since Company ‘A’ had no technology for the mobile phone production in the early 1990s, as shown in Table 5-1. Company ‘A’ absorbs the transferred technology and integrates the transferred technology with own existing technology and own intensive efforts to develop its technological capability in the mobile phone industry. Company ‘B’ imported the production line to produce its first set of the second generation (GSM) mobile phones since the company was weak at the production and development technology of mobile terminal products, though Company ‘B’ had abundant R&D experience in mobile telecommunication equipment (Table 5-2). Based on the transferred technology and its internal efforts, Company ‘B’ has improved its technological capability in mobile phones. The technological capability development of Company ‘C’ and ‘D’ in mobile telecommunication terminal products is similar, developing from acquisition of advanced technology from outside of companies as well. Consequently, the analyses of cases indicate that technology transfer is pivotal in the process of technological capability development in emerging countries. The companies’ TT purpose is to build up their technological capabilities. This finding supports the previous research on Korea and other NIEs: imported technology is particular important for companies at the elementary development stage as companies have low technological capability (e. g. Kim, 1997; Lee, 2001).

However, the development of China’s mobile phone manufacturers does not support all previous technology transfer theories, such as the preferred technology transfer modes in the process of technology transfer and the position of recipients in technology transfer. The analyses of four companies give some new insights into the detailed issues relative to technology transfer, which are different from previous technology transfer theories.
Evolution of technology transfer mode

As mentioned in Section 2.3.2, technology transfer modes are changing with the economic and technological development of host economies (e.g. Lall, 1996; Kim, 1997; Kim and Nelson, 2000). The analyses and conclusion of technology transfer modes’ evolution in the Chinese mobile phone industry and these four companies (Table 4-1 and Figure 5-7) support this theory that technology transfer is changing in the process of technological capability development.

Table 4-1 and Figure 4-5 suggest that turnkey imported was the dominant method to obtain the mature technologies (such as 2G mobile phone technology) when Chinese manufacturers lacked the basic production technology. On the other hand, with the development of technological capabilities, Chinese manufacturers prefer technology cooperation or alliances as their main methods to master and develop new technologies in the growing technology (2.5G mobile phone technology) and the emerging technology (3G mobile phone technology). Evolution of Technology Transfer Mode in Companies (Figure 5-7) supports this result too.

Previous studies on technology transfer regard FDI as an important and preferred technology transfer method for companies in emerging countries to acquire advanced technologies from developed countries (e.g. Kim, 1994, 2000; Lall, 1996). The development of NIEs (except Korea) suggests that FDI plays a great role in their economic and social development (e.g. Kim, 1994, 2000; and Lall, 1996). Additionally, FDI is still one of the dominant methods to improve technological capabilities in many countries, such as Indonesia, Brazil and Singapore (Lall, 1996; Kumar et al., 1999; UNCTAD, 2001). Moreover, the Chinese government makes incentives to attract FDI to develop Chinese companies’ technological capability and competitive advantages.²² Nevertheless, the research results suggest that FDI is not the favorite technology transfer mode selected by Chinese mobile phone producers, as the conclusion presented in Figure 4-5. This finding does not support previous research outcomes: FDI is increasing with the development of information and communication technology and technology globalization (Lee, 2001; Lall, 2002).

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²² Since the launch of open policy in 1978, FDI has been the most favour method selected by China government to access the new and advanced technology and management skills. In the tenth five-year plan, China makes incentives to attract foreign direct investment in high-tech industries, infrastructure and agriculture.
Figure 4-5 and the development of four companies suggest that FDI is not the main method chosen by Chinese mobile phone manufacturers though FDI is the method supported by the Chinese government. In fact, technological alliances have become the increasingly favorite method chosen by Chinese companies. Figure 5-7 certifies it too. The experience of Company ‘D’ means that the joint venture (50%:50%) does not help the company to develop technological capability in mobile phones but help to improve management skills. In addition, the joint venture of Company ‘A’ is independent to Company ‘A’, and is not assumed to play an important role in its development process of technological capability by its managers. Company ‘C’ established a joint venture with the French company after the company generated the competitive competence in the mobile phone industry as the largest local mobile phone provider in China. Thus, the majority joint venture is not the preferred technology transfer mode selected by Chinese mobile phone manufacturers, especially when companies lacked the production technology and had no strong competitive competences. In addition, the joint ventures of these companies are not under the control of MNCs, at least Chinese partners take 50 per cent share of joint ventures. I assume it is because internalized technology transfer mode, such as FDI and joint venture under MNCs’ control, is not a good method for the recipients to generate local R&D capabilities (Lall, 1993, 1996). Chinese mobile phone manufacturers thus choose externalized methods to gradually generate their indigenous technological capabilities and the competitive advantage in the world market.

The experiences of four companies indicate that they prefer externalized technology transfer mode, such as setting strategy alliance and cooperating with partners, and combining with indigenous R&D efforts to develop 2.5G and 3G mobile phone technologies, the important growing and emerging technologies in this industry. This result is opposite to some previous research outcomes, which state that FDI is an important and favorite technology transfer method selected by companies in emerging countries to acquire advanced technologies from developed countries (e.g. Kim, 1994, 2000; Lall, 1996). For instance, Company ‘B’ prefers to develop 2.5G and 3G technologies itself. Company ‘B’ set up an R&D center in Korea to do R&D in CDMA technology. In addition, Company ‘B’ cooperated with many foreign giants to research future technology and future standard because of the complexity of the future technology. As shown in its alliance map (Figure 5-2), Company ‘B’ has set up an alliance network in order to develop the new technology and new products. Company ‘A’, ‘C’ and ‘D’ prefer to set up alliance and cooperate with other companies to develop new technology and new products too, although Company ‘C’ built a JV, as shown in their alliance maps (Figure 5-1, Figure 5-4, and Figure 5-5), and Figure 5-6.
The fact that externalized technology transfer modes have become the favorite technology transfer modes is a consequence of the high speed of the new technology development in this industry, the spread of production and innovation globalization, and intellectual property rights (IPRs) management. According to Roger’s diffusion theory (1995, 1997), the fast speed of technology development and diffusion in the mobile phone industry makes it impossible and unnecessary for a company to invest in R&D in all technologies for one type of mobile phones alone. Fast development of mobile phone technologies coupled with the diffusion of ICT provides companies in emerging countries with opportunities to innovate and challenge MNCs in growing and emerging technologies despite the fact that their technological capabilities are not well developed for the next stage technology. In addition, the industry value network makes all companies in an industry integrate to develop new products and new technology. All members in the industry value network, from the chip providers to the manufacturers and the service providers, take part in the innovation of a new technology. For example, the four companies all set up alliance networks with key technology providers, component providers, mobile phone service providers, and so on. Moreover, as one kind of emerging technologies, the mobile phone technology and its market are still unstable. All companies in this industry have to work together for the future technology and future market. Most importantly, Chinese companies could obtain IPRs of new technology through cooperation and alliances with other companies to develop new technology. Otherwise, Chinese companies cannot obtain the key technology, or have to pay high cost for the utilization of new technology, because of the supplier’ protection of IPRs. This is also the reason why DTT developed TD-SCDMA standard with Siemens. FDI thus is not the favorite method selected by Chinese mobile phone companies, while technology cooperation/alliance has become the dominant method in this industry. This research result is different from the government’s favorite: FDI and joint venture. In addition, this does not support Lall’s theory that the internalized method is growing (Lall, 2002), and Lee’s idea (2001) that the internalized technology transfer mode is preferred in the information and communication industry. However, this result supports Nalura’s studies (2003) that technological alliance activities in high-tech industries increase in Asian NIEs and strategic technological alliance is an increasingly important tool in the process of technological capability upgrade in these countries.

In short, the technology transfer mode is changing with the development of technological capability of recipients. In addition, externalized technology transfer modes, not internalized technology transfer modes, are the favorite methods selected by companies
in emerging countries to obtain the advanced technology. In particular, the technological alliance is the preferred method of companies.

In sum, the research results certify that the outside technology source is pivotal for the companies’ TC development in emerging countries. In addition, companies in emerging countries prefer technological alliances as the method to acquire the technology from outside, in order to develop and improve their technological capabilities, particularly at the early stage of their business lives in an industry.

**Role of recipient in technology transfer**

As shown in Figure 2-2, not only technology suppliers but also technology recipients influence the technology transfer process. It is widely recognized that technology suppliers play significant, if not dominant, roles in technology transfer (Dunning, 1988; UNCTAD, 2001). Our research results suggest that recipients have a more important impact on technology transfer mode selection than previously thought. This means that some suppliers do not play a role in technology transfer as significant as previously found. Thus, our research results do not completely support previous research outcomes.

In the cases, Company ‘A’ selected Motorola Corporation to be its TACS technology supplier from three companies, Motorola, Ericsson, and Nokia according to its strategy and other issues. Company ‘B’ and Company ‘C’ selected their GSM technology suppliers from many companies, which were not the famous mobile phone giants. The influence of different research perspectives cannot be neglected. It is also because the TACS and GSM technologies are mature and public. Many companies master the public technologies. Accordingly companies in emerging countries have many choices while selecting their public technology suppliers.

Additionally, I assume the increasing role of recipients is likely a consequence of increasing alliances in companies’ development processes. The four companies cooperate with other companies, including the mobile phone giants for the development of 2.5G and 3G mobile phones. Take Company ‘B’ and Company ‘C’ as examples. Company ‘B’ decides its alliance partners according to its program purpose and its strategy. In addition, Company ‘B’ prefers to develop the indigenous technology by itself if it is possible. Company ‘C’ selects its alliance partners based on its strategy too. I assume that it is not easy to distinguish who is the technology supplier and who is the technology recipient in
some R&D alliances of growing and emerging technologies. Companies in such alliances are partners, working for the same program. Thus, it is difficult to distinguish the supplier’s role and recipient’s role clearly in some alliances. Therefore, with the increasing of technological alliances, the role of technology supplier is not as important as subscribed in previous research. In other words, the role of technology recipient is not minor.

Summary

In general, the multi-case analyses certify the previous theory that technology transfer is an important process in the progress of technological capability development in emerging countries. In addition, the case analyses suggest that the externalized technology transfer modes, the technology alliance in particular have become the favorite technology transfer methods for companies in emerging countries. Moreover, this research hypothesizes that technology recipients have more initiative in the suppliers’ selection.

With the development of technology, such as the mobile phone technology developing from 1G to 2G, 2.5G then to 3G, companies prefer to cooperate with several companies for one project, especially the projects for growing technology and emerging technology. Take 3G Forum as example. Most companies in the mobile phone industry, including equipment manufacturers, terminal products providers, and service providers, take part in this forum. With such cooperation, the boundary of technology supplier and technology recipient is not clear. The technology transfer process has changed to be the process to establish an external alliance network and transfer technology in alliances. For instance, companies set up the alliance networks shown in Chapter 5. In other words, the technology transfer process has changed from the process shown in the upper part of Figure 6-1 to the process shown in the lower part of Figure 6-1.

6.1.2 Stage of intra-firm technology diffusion

The link between the technology transfer and technological capability improvement is not direct. There are several steps between technology transfer and effective mastery of technology (Lall, 1993). The intra-firm technology diffusion to accelerate the development of technological capability is one of the main benefits of acquiring advanced technologies from the other organizations (e.g. Kogut and Zander, 1992; Kim, 1997; Lall, 2002). The
more deeply the technology and knowledge are improved and stored in memory, the more endeavors should be used (Cohen and Levinthal, 1990; Burgelman et al., 1996). The development of the four Chinese mobile phone manufacturers supports this theory that the intensity of effort is a crucial element for the company’s long-term technology development and competitiveness.

![Figure 6-1 Evolution of Technology Transfer Process](image)

In these four cases, companies make a great effort to assimilate and develop the transferred technology as well as to do R&D activities to develop indigenous technology. In other words, companies invest extensive energy to accelerate the diffusion of technology internally. Firstly, companies build up an internal learning system. For instance, learning is the key element of the Company ‘C’ strategy. Company ‘C’ builds a learning organization. Employees learn from each other. The new information and new technology diffuse in this learning process. Company ‘B’ has an internal technology document management system to benefit the learning of all employees and the intra-firm technology diffusion and accumulation. Secondly, these four companies all are completing their training systems. Company ‘A’ trains its employees on-site, sends employees to foreign companies, and organizes the technology seminars, and so on. Company ‘B’ trains its core technology employees in the different positions. Company ‘C’ sends its employees to its partner companies or invites engineers to train employees in China. Company ‘D’ sends technicians
to be trained in foreign R&D centers and companies. Thirdly, these four companies invest heavily in technology diffusion and technology development. As presented in Chapter 5, these companies set aside more than 6 per cent of annual sales as R&D and training budget. Such a budget for mobile phone in Company ‘B’ is high, up to about 15 per cent. Fourthly, companies take incentives to technology development and technological capability improvement. For example, Company ‘B’ is building its technology platform for all R&D project teams. Based on this technology platform, all R&D members share the internal technology and innovative experience and learn from the failed projects. With these intensive efforts, the four Chinese mobile phone manufacturers diffuse and assimilate the transferred technology intra-firm, and develop and diffuse new technology, which lead to the development of technological capabilities.

Therefore, high intensive efforts accelerate the intra-firm diffusion and improvement of technology. With the internal diffusion of technology, companies are improving their technological capabilities. In other words, the intra-firm technology diffusion with highly intensive efforts plays a pivotal role in the technological capability development.

6.1.3 Process of technological capability development

Based on the research framework (Figure 2-5), the stage of technology transfer in alliances and the stage of intra-firm technology diffusion are involved in the process of technological capability development. In other words, the process of technological capability development integrates the stage of technology transfer in alliances and the stage of intra-firm technology diffusion.

As mentioned above, technology transfer is important for technological capability development. In addition, this stage has become the process of establishing an external alliance network and transferring technology in this alliance network. The stage of intra-firm technology diffusion with highly intensive efforts bridges the channel between the outside source of technology and indigenous technological capability and accelerates technology movement in this channel. In other words, intra-firm technology diffusion with intensive efforts has an increasingly critical impact on the development of technological capability. Integrating these two stages, a company’s technological capability is upgraded. The process of technological capability development in Chinese high-tech industries thus can be recognized as a process to generate and manage the technology external alliance networks and internal technology diffusion with intensive efforts. Accordingly, I propose that:
**Finding 1:**
The process of a manufacturer’s technological capability development in high-tech industries is a process involving technology alliance networks building up to access advanced technology together with intensive efforts to speed up technology diffusion internally.

In general, the process of technological capability development can be described as the process shown in Figure 6-2.

![Figure 6-2 Process of Technological Capability Development](image)

### 6.2 Revision of Kim’s Model
As mentioned in the chapter 2, based on the TC development experience of Korea in the 1980s and the early 1990s, Kim (1997) proposes a three-stage TC development model.
TC development in emerging countries follows the technology trajectory: acquisition, assimilation and development (Kim, 1980, 1997). In addition, technological capability develops from mature technology to growing technology and eventually to emerging technology in emerging countries (Kim, 1980, 1997). Furthermore, it suffices for companies in emerging countries to use the transferred mature technology efficiently (Kim, 1980, 1997; Lall, 1990). Moreover, the technological capability in different stages is developed independently. However, this research results from the development process of Chinese mobile phone manufacturers do not fully support Kim’s theory.

Through the case analyses, I found that the development of TACS (1G) and GSM (2G) mobile phone technologies, such as the development in Company ‘A’, followed the technology trajectory of acquisition, assimilation and development. Kim’s technology trajectory matches for some but not for all generations of mobile phones. For instance, Company ‘B’ accessed, assimilated and developed the GSM mobile phone technology at the same time rather than consecutively from acquisition, to assimilation, then to development. In addition, the four companies attend the Forum to develop TD-SCDMA (one kind of 3G standard) mobile phone products. I assume it is because Company ‘B’ has strong R&D capability to assimilate the transferred GSM production technology and develop new GSM products at the same time. It is also because no company has the experience in the TD-SCDMA mobile phone production which is emerging. Companies thus cooperate to develop TD-SCDMA products and resolve the problem in the development process. Therefore, the research results indicate that Kim’s technology trajectory does not fit all kinds of technologies.

In these cases, Chinese mobile phone manufacturers conduct R&D and production concurrently on several types of technologies (mature, growing, and emerging). This finding contradicts Kim’s theory that technological capability develops from one stage to the next, step by step. For instance, the four manufacturers started to put heavy investment to develop the indigenous 2.5G technology while they were still producing 2G mobile phones. Company ‘B’ invested in the 2.5G technology earlier than producing 2G mobile phones. Company ‘A’, ‘B’, ‘C’, and ‘D’ all manufacture some models of 2.5G mobile phone products through OBM. Although the 3G mobile phone market is still close, most Chinese companies as well as foreign invested companies are members of the 3G Forum to discuss 3G development and technologies. In addition, companies produce and test 3G mobile phone samples. The 3G technology is emerging and there is no standard accepted by all companies in the world. Thus, companies in emerging countries must cooperate with others,
even with those in advanced countries, to invest in and develop 3G mobile phone technologies. This result does not support Kim’s theories of technology trajectory (1980, 1997) completely. I hypothesize that this concurrent pursuit of different technologies is a consequence of the rapid development of the Chinese market (with annual GDP growth rates of 8-10 per cent for more than twenty years) as well as the intense competition and technological development of the mobile phone technology itself.

In these cases, the four Chinese manufacturers acquired GSM technology from MNCs, then assimilated and developed their own GSM technology. However, the four companies developed new GSM mobile phones with indigenous IPRs while they were producing GSM mobile phones through OBM. In other words, currently they produce GSM mobile phones in two ways: OBM and ODM. Therefore, the development of GSM technologies follows Kim’s technology trajectory but the stages of the technology trajectory also occurred at the same time. This result contradicts Kim’s theory of distinct stages. Again, we assume that this behavior is motivated by the mobile phone industry being an emerging industry worldwide and that the technology in this industry is high-tech and based on ICT. With the diffusion of ICT, companies introduce the new technology and new products into the market more and more quickly. The development of applied software has become the competitive focus of this industry. The diffusion of ICT also provides companies in emerging countries the chance to challenge MNCs in the emerging technology stage. Therefore, companies have to acquire and assimilate the transferred technology and invest in the development of new technology at the same time. The study also reveals that the Chinese government’s policy is one of the factors influencing companies’ investment in emerging technology. The Chinese government encourages companies to invest in emerging technologies, particularly in high-tech and information technologies, in order to catch up and compete with foreign companies in the future. For instance, DTT’s investment in TD-SCDMA is under governmental support.

Moreover, the case analyses indicate that companies in emerging countries invested in the mature technology, growing technology, and emerging technology as well. For example, Company ‘A’ attempted to invest in the R&D of TACS mobile phones. The four companies all invested in the R&D of GSM during production in an effort to develop technological capabilities. TACS is going to quit the market and GSM is a mature technology. This result opposes Kim’s theories (1980, 1997) and Lall’s studies (1990), which suggest that companies in emerging countries do not need to research and develop the mature technology. However, it supports the study results of Gao (2003), which reveal that companies in
emerging countries reinvested in the mature technology and that this was effective to develop their technological capabilities. Interview discussions with managers reveal that two factors encouraged companies to reinvest in the mature technology. Firstly, the development of mature technology helps a company to improve its existing technological capability and to expand the application of mature technology. Secondly, the transferred mature technology was at first considered as a growing, or even an emerging technology in host countries. Thus, companies in host countries reinvest in the mature technology.

In short, I think that Kim’s 3-stage model should be refined. Based on my observation of receding technologies, I propose a fourth stage to complement the three stages identified by Kim (1997). I define the recessive stage as the stage in which the technology will vanish soon; it will be replaced by a mature technology after a short time. According to the characteristics of technology in the mobile phone industry, the emerging stage is defined as the period in which the technology is new and there is (are) no one/several standard(s) accepted by all countries. In addition, the emerging technology is only adopted in several countries and at the early stage of commercialization. The commercial result is uncertain. The growing stage is the period when the technology is diffusing, there are technology standards in the world and the commercialization proceeds smoothly, but the dominant technology is not public. The mature stage is the period that the commercialization of the technology succeeds and most technology is public.

Thus, a four-stage model is developed: a technology develops from the emerging stage to the growing stage, then to the mature stage and finally to the recessive stage. In our cases, the TACS mobile phone technology could be interpreted as the recessive technology. China produced TACS mobile phones from the early 1990s and began to produce GSM mobile phones in mid-1990s. However, TACS usage declined and all TACS systems were closed down in 1997 in China. The history of TACS in China is only several years long. In addition, currently there is no country adopting TACS technology for commercial usage in the world.

6.2.1 Four stages of technological capability development process

Based on the multi-case study, I hypothesize a four-stage TC development process model, as shown in Figure 6-3. In Figure 6-3, T1, T2, T3, T4 mean different generations of technologies, developing from the 1st generation to the 4th generation. There will be n-generation technology (Tn) with the technology development in one industry. Every
generation technology undergoes four stages: developing from emerging to growing, mature and recessive. There is a concurrent area in the model, where we find different generations of technologies at different stages at the same time (e.g. the grey area in Figure 6-3). In addition, time goes in the same direction at the upper part and lower part of the figure in this new model. Furthermore, the technologies in the two parts of Figure 6-3 all are various generations’ technologies in one industry. Therefore, this extended model eliminates the confusing points in Kim’s theory.

Figure 6-3 illustrates that in advanced economies, technology life cycles are long and relatively distinct (upper part of the figure). Companies in emerging countries acquire, and then assimilate foreign technologies in order of maturity: first, technologies that are already in a recessive stage (argument: no concerns of losing intellectual property rights by transferor), then second, technologies that are mature (argument: to gain incremental value through OEB or OEM producers), then third, technologies that are growing (argument: to make use of increasing technological capabilities in host countries). In the forth stage, domestic companies develop indigenous technologies themselves, as they have reached the international level of technological capabilities. Since technology is changing fast, different stages of technologies concur, such as the grey part in Figure 6-3. Companies can concurrently import and assimilate these technologies. Hence, their technology stages mingle and become interlaced.

Companies in emerging countries acquire and assimilate the recessive stage of technology. Companies in emerging countries could invest to improve the acquired recessive stage of technology. However, this is not necessary since the recessive technology is going to quit the market soon. In addition, not all companies in emerging countries undertake the activities in the recessive stage.

Then companies acquire and assimilate the mature technology. Companies in emerging countries invest heavily to upgrade the mature technology in order to improve the technological capability and R&D experience for the next generation of technologies. Companies improve their technological capabilities through the assimilation and development of mature technology with intensive efforts.

With the development and diffusion of ICT, the life cycle of technology is getting shorter. It is necessary and possible for companies in emerging countries to acquire the growing technology, even to develop growing and emerging technology when they assimilate and develop the mature technology.
Rate of Innovation in Technology (in advanced countries)

Emerging  Growing  Mature  Recessive

Technology Activities (in emerging countries)

Acquisition  Assimilation  Acquisition

Figure 6-3 Four Stages of Technological Capability Development
Based on the four-stage TC development process model, I propose that:

**Finding 2:**
Companies in emerging countries would undertake concurrent activities (such as acquisition, assimilation, and development) in mature, growing, and emerging technologies at the same time.

### 6.3 Summary of Technological Capability Development Process

In general, the multi-case analyses suggest:
- Technology transfer is a pivotal process to develop technological capability in Chinese high-tech industries;
- Companies in Chinese high-tech industries prefer externalized technology transfer modes, technology cooperation or alliances in particular, to access the outside technology;
- Companies make intensive efforts to accelerate intra-firm technology diffusion and the integration of the transferred technology and existing technology;
- Companies have set up alliance networks;
- Kim’s three-stage model is modified and extended to a four-stage one.

In sum, the process of technological capability development in the mobile phone industry is the process involving the following activities:
1. building up external alliance networks;
2. accessing technologies in alliance networks; and
3. accelerating the intra-firm technology diffusion with intensive internal efforts.

### 6.4 Factors in Technological Capability Development Process

According to the research framework and the theories of technological capability, technology alliance, technology transfer, diffusion of innovation, absorptive capacity, and industry value chain, in this section I analyze the factors which affect the technological capability development of China’s mobile phone industry based on the research results
presented in Chapter 4 and Chapter 5. The dominant factors are examined from four aspects: the nature of technology, diffusion of ICT, industry value network, and absorptive capacity.

6.4.1 Nature of technology

As mentioned in the Literature Review, the nature of technology has a considerable impact on the process of technology transfer (e.g. Lall, 1993) and alliance formation (e.g. Simonin, 1999). In this dissertation, the nature of technology focuses on the complexity and uncertainty of technology. In addition, I propose the monopoly of technology as an important nature of technology in this dissertation. Therefore, the nature of technology concentrates on three main perspectives: complexity, uncertainty, and monopoly. The impact of the nature of the technology on technological capability development is analyzed from: the stage of technology transfer in alliances and the stage of intra-firm technology diffusion.

Monopoly of technology

Monopoly and public are two opposite natures of technology. A technology is monopolistic or public, but not both. Monopolistic technology is one controlled by a few companies. In the mobile phone industry, the key chip technology normally is monopolistic. For its usage in a mobile phone set, the components with the monopolistic technology have the standard technical interfaces. For instance, a chip can be used in different sets of mobile phones. In addition, its entering barrier is too high for most companies. Public technology is mastered by many companies. It is not difficult for companies to find and acquire the public technology. Generally, the products with the public technology are the standard products. In general, while growing to become a mature technology, technology sometimes changes from monopolistic to public.

Stage of technology transfer in alliances

The technology transfer mode is the bridge between a technology supplier and a technology recipient (Figure 2-2). Technology transfer mode influences the effectiveness of technology transfer. As mentioned in section 2.3 and as shown in Figure 2-2, the nature of technology is one of the important factors which affect the TTM selection (Lall, 1993;
UNCTAD, 2001). Extensive research suggests that the complexity and uncertainty of technology have an impact on the formation and performance of alliances (e.g. Colombo, 2003; Chen, 2004; Simonin, 1999). According to Tsang’s research (1998), the high cost and uncertainty of R&D investment motivate a company to form a strategic alliance with others to pool their resources together. Osborn and Baughn (1990) and Hagedoorn and Narula (1996) have illustrated that the differences in the form of alliance derive from the complexity and uncertainty of innovative activity. This research suggests that the complexity and uncertainty of a technology do not have a positive impact on the selection of an internalized technology transfer mode, which does not fully support previous results: the nature of technology, such as the complexity and uncertainty of a technology, positively affected the preference towards an internalized technology transfer mode (Lall, 1993; Tsang, 1997).

As mentioned above, Chinese mobile phone manufacturers prefer externalized technology transfer modes, technology cooperation and alliance in particular, for the growing technology and emerging technology. In addition, the analyses in the TC development process support that technology transfer modes are changing with the development of technology. The comparison of favorite technology transfer modes of the four companies for the different generations of technology suggests that the nature of technology, in particular the complexity, uncertainty and monopoly of technology, affects the TTM selection. Take Company ‘B’ and Company ‘C’ as examples. Company ‘B’ imported production lines to access the GSM mobile phone technology in 1999. According to the research model in Figure 6-3, the GSM mobile phone technology is a mature technology, of which most is public. Many foreign companies mastered the production and development technology of GSM mobile phones at the end of the 1990s. Company ‘B’ had many choices. In the end, Company ‘B’ selected a British company, not Motorola or Nokia, mobile phone giants, as its GSM production technology supplier. In addition, the complexity and uncertainty level of GSM technology is lower than that of 2.5G mobile phone technology. Based on its strong R&D capability, the development cost of GSM technology and products is not very high for Company ‘B’ after the company mastered the production technology. It is similar to Company ‘C’. Company ‘C’ selected a French company as its GSM technology supplier in order to build its production line at a low cost. This is also because most GSM technology is public, and its uncertainty and complexity is not as high as that of the growing and the emerging technology. The 2.5G mobile phone technology is a growing technology. The key chip technology of CDMA is owned by Quantum Corporation.
Due to the exclusive nature of technology, mobile phone manufacturers, except Nokia, have to cooperate with Quantum in order to obtain core chips of CDMA at a relatively low price.

The 3G mobile phone technology is an emerging technology. In addition, it is a very complex technology as 3G technology covers internet technology, digital camera technology, TV technology, video conference technology, and so on. Moreover, its uncertainty is very high due to the following reasons. At first, the 3G market in Europe was not as successful as expected. It is uncertain whether 3G will succeed on the Chinese domestic market. Second, TD-SCDMA has not been commercialized yet. Everything relative to product development is new for this standard. The new product development is of complexity and uncertainty. Most importantly, it is still unknown which standard is going to be adopted in China. Thus, Company ‘B’ invests in all three 3G standards. Company ‘B’ as well as the other three companies set up alliances to do R&D in 3G in order to reduce R&D risk and cost. DTT is one of their partners since DTT is the owner of TD-SCDMA standard technology.

Therefore, the complexity, uncertainty, and monopoly of technology have an impact on the TTM selection, which supports the previous studies. But externalized technology transfer modes, such as technology cooperation and technology alliance, have become the preferred methods to obtain the technology with high complexity, high uncertainty, and high monopoly. This result is opposite to Lall’s (1993) and Tsang’s (1997) studies, which conclude that the more uncertain and complex the technology is, the more FDI is taken as the technology transfer method.

My analyses further indicate that the monopoly of transferred technology affects the role of technology supplier in the TTM selection. For instance, Company ‘B’ had much initiative in the selection of the GSM production technology supplier because of the mature status of GSM technology, which is a public and not a monopolistic technology. Company ‘B’ played a dominant role in this process. Like Company ‘B’, Company ‘C’ chose a French company, but not one of the leading possible suppliers such as Alcatel, Motorola or Nokia, as its first technology supplier, most likely because the GSM production technology is not monopolistic. Many companies master and develop such technologies. Therefore, Chinese companies have many possible GSM production technology sources to choose from. In addition, many foreign companies (except Motorola, Nokia and other giants) have few opportunities to enter the Chinese market without transferring such non-monopoly production technology. They preferred to transfer such technology at low cost to Chinese companies in order to enter the Chinese market. Thus, Chinese companies can choose a
most suitable company to acquire the needed technology at the lowest cost. Chinese companies (the technology recipients), not foreign companies (the technology suppliers), have important roles in the determinant of public (e.g. GSM) technology transfer. On the other hand, a technology supplier has more influences on technology transfer mode selection when Chinese companies acquire a monopolistic technology than it does for a public technology. For example, the key chip of CDMA mobile phone is a monopolistic technology under the control of Quantum. Chinese companies, such as the four companies in this research, have to transfer the key chip technology from Quantum through licensing and cooperation. Chinese companies have no critical role in this transfer process. We therefore propose that in this case the technology supplier has a significant impact on TTM selection. In addition, the public nature (or so-called non-monopoly) of technology will reduce the role of suppliers in TTM and TT partner selection, which does not fully support the previous theory that suppliers play a dominant role in technology transfer.

In sum, the complexity, uncertainty, and monopoly of technology positively influence the technology recipient to favor an externalized technology transfer mode, technological alliance in particular. In addition, the public nature of technology reduces the role of technology suppliers in the technology transfer process. In other words, the public nature of technology enhances the effort of technology recipients in technology transfer process. On the other hand, the monopoly of technology increases the effort of technology suppliers on technology transfer process.

With the development of technology and companies’ technological capability, the technology transfer process has moved to being a process to build up alliance network, and a round-way technology transfer has happened in alliances, as shown in Figure 6-1. As mentioned in Chapter 2, the nature of technology, including uncertainty and complexity of technology, influences the formation of R&D alliances (e.g. Tsang, 1998; Simonin, 1999; Colombo, 2003; Chen, 2004). However, this theory has not been tested from the aspect of companies in emerging countries since it is widely recognized that MNCs play leading roles in the formation of alliances. The research results suggest that the uncertainty, complexity, and monopoly of technology influence Chinese companies toward building R&D alliances with other companies, which supports the previous study from companies in emerging countries.

Table 5-7 suggests that these four Chinese mobile phone manufacturers favor building alliances in 2.5G mobile communication technology (growing technology) and 3G
technology (emerging technology) if the software, hardware technologies and other technologies are considered as the technologies relative to the changing mobile telecommunication technologies. For instance, Company ‘B’ started to invest in R&D in CDMA equipment in 1995, earlier than the time when Company ‘B’ produced its first set of GSM mobile phones in 1999. In addition, Company ‘B’ formed a joint R&D center in South Korea for R&D in CDMA mobile communication technology in 1999 when it produced GSM mobile phones. In fact, Company ‘B’ only imported a GSM production line when the company started to produce mobile phones because of the weakness in basic production and design technology at that time. Company ‘B’ has built R&D alliances in 2.5G and 3G mobile communication technologies with TI, Nokia, Nortel, Ericsson, LG, Samsung, Agere, and so on, and has even built alliances with Intel, IBM and Microsoft for the software and hardware technology used in the mobile phones. The other three companies are the same as Company ‘B’, focusing on growing and emerging technologies. Therefore, Chinese companies prefer to build up alliances in growing and emerging technologies, which are the latest and most advanced technologies. It is because 2.5G is a growing technology, whose market is also growing, and 3G is an emerging technology, whose market is a future market. These two generations technologies are current and future competition centers in China and in the world. Nevertheless, there are two standards of 2.5G mobile phone technology in China: GPRS and CDMA. No one knows which will be the dominant standard in the Chinese market. For the 3G technology, there are three standards, and the government has not decided which one is going to be adopted in China. The future market is uncertain. Chinese companies thus have to form alliances to invest in all standards of technologies. The uncertainty of a company’s investment in different standards of technologies is high. Companies search for alliances to lower the investment cost. In addition, Chinese local companies could not do R&D in 3G technology by themselves because of its complexity. Moreover, the uncertainty and complexity of mobile communication technology also drive companies to pursue the non-equity contractual agreement as alliance form (Osborn and Banghn, 1990; Hagedoorn and Narula, 1996; Colombo, 2003), as shown in Table 5-6.

Therefore, the nature of technology (its complexity and uncertainty), is one of the main determinants of alliance formation. This supports previous studies that the higher the uncertainty of the investment is, and the higher the complexity of the technology is, the more companies favor alliance methods (Tsang, 1998). In addition, this result also supports the studies in the telecommunications industry: companies prefer the non-equity mode of alliances in this industry, particularly at the starting cycle of a new technology (Sussan and
Oh, 1996; Colombo, 2003).

In short, this research indicates that the more highly complex, uncertain, and monopolistic the technology is, the more a company will favor an externalized technology transfer mode, the technological alliance in particular, to access the advanced technology.

Stage of intra-firm technology diffusion

The diffusion of the transferred technology in a company improves the assimilation and development of the transferred technology. In addition, the diffusion of transferred technology enhances the development of technological capability, which is examined in the previous chapter. According to Roger’s theory (1995), the complexity of innovation determines the adoption rate of innovation. In other words, Roger (1995) argues that the complexity of technology influences the diffusion speed of technology. However, Roger’s study on diffusion of innovation is from the inter-firm aspect. The second stage in the technological capability development process in this dissertation is studied from the intra-firm aspect. Roger’s theory cannot be adopted directly here. Nevertheless, this research suggests that the nature of technology, including its complexity, uncertainty and monopoly, has an impact on the intra-firm technology diffusion. This result supports Roger’s theory from an intra-firm aspect.

These four companies have generated mobile phone production technology through on-site training and learning-by-doing. I assume that this is because the production technology is not as complex as the development technology. With its efforts, the production technology is diffused smoothly in the company. For instance, Company ‘A’ mastered the GSM mobile phone production technology in a short time since this production technology is similar to that of TACS, is not complex. Company ‘A’ invested heavily in the development of new products and new technology, such as by sending employees to foreign companies and setting up an R&D Center in the USA. It is because the technology relative to the new product and technology development is more complex and difficult to master than the production technology. In addition, 2.5G and 3G mobile phone technologies are more complex and uncertain than 2G mobile phone technology. The adoption and improvement of 2.5G and 3G technologies in companies is slow. This motivates companies to produce part of 2.5G mobile phones via OBM though companies develop new products and new technology for 2.5G mobile phones themselves, and 2.5G mobile phones are the
investment center of companies. The key chip technology is monopolistic, controlled by few companies. For example, Quantum owns a large amount of patents for CDMA key chip technology. Lucent and TI own GSM and GPRS key chip technologies. The key chip technology has great complexity and the cost for Chinese companies to invest is too high. Chinese mobile phone companies acquire and use such technology, but do not diffuse it further in companies since they lack enough technological capabilities and capital to do R&D in such technology. Chinese companies cooperate and sign strategic alliance agreements with these companies.

Thus, the complexity, uncertainty, and monopoly of technology have a negative impact on intra-firm technology diffusion. In short, the nature of technology influences the process of intra-firm technology diffusion.

![Figure 6-4 Impact of Technology Nature on Technological Capability Development](image)

**Summary**

The analyses indicate that the technology transfer in alliances and intra-firm
technology diffusion are critical to the development of technological capability. The nature of technology, such as the complexity, uncertainty and monopoly of technology, influences two stages – technology transfer in alliances and intra-firm technology diffusion, then affects the development of technological capability, as shown in Figure 6-4. The effect of technology’s nature on the development of technological capability is indirect.

In sum, this research suggests that the nature of technology, especially the complexity, uncertainty, and monopoly of technology, has a considerable impact on the stage of technology transfer and the stage of internal technology diffusion. The complexity, uncertainty, and monopoly of technology motivate companies in emerging countries to access advanced technology and improve their technological capability through the alliance method. The nature of technology thus affects the process of technological capability development.

6.4.2 Industry value network

The research on the telecommunications industry certifies that value chains have rapidly evolved into value networks, with multiple entry and exit points, creating enormous complexities for all players involved (e.g. Gulati et al., 2000; Li and Whalley, 2002). The value networks are a phenomenon occurring across the entire telecommunications industry (Li and Whalley, 2002). It is the same in the mobile phone industry in emerging countries. The research analyses indicate that companies’ alliance networks are built up due to the value network of the mobile phone industry (Figure 4-6). Companies’ alliance networks in fact are their value networks since these alliances are set up with the suppliers, customers, and so on, in an effort to create added value. All alliances partners are the players in the value network. All alliance networks integrate together to form the industry value networks.

According to Porter’s theory (1985), the value chain (which has moved to be the value network) has an impact on the strategy decision. However, this influence on the technological capability development is neglected in previous research. This research proposes that the industry value network affects the process of technological capability development. The interviewed corporate managers regard that the mobile phone industry as involving many different subjects of technologies. They believe that it is impossible for their companies to master and invest in all kinds of technologies embraced in a mobile phone and undertake R&D activities in one kind of technology alone. No company can survive
independently. Thus, technology cooperation is compulsory to research and develop new products and new technology in this industry. This is also the reason why these companies cooperate with software and hardware companies, and component providers.

There are interactions among companies. The alliance maps shown in Chapter 5 suggest that the four companies have the same alliance partners. Their alliance networks interact directly or indirectly. Companies cooperate with other companies to develop the new products and new technology and combine different components from different companies together to be one product based on the public technology standards.

Therefore, I propose that: the industry value network encourages companies to cooperate with others during the process of technological capability development.

6.4.3 Diffusion of ICT

The diffusion of ICT is not only the diffusion of itself – a new and developing technology – but also of the incentive of the successful diffusion of other new technology and innovations (Baskerville and Pries-Heje, 2001). The diffusion of ICT affects the development of numerous industries (Santangelo, 2002). However, the role of ICT in the mobile phone industry has rarely been mentioned (Nalura, 2003). The multi-case studies reveal that the diffusion of ICT influences the development of technological capability and has a significant effect on technology transfer.

Technological capability development

The research analyses above reveal that companies in emerging countries prefer externalized technology transfer modes, especially technology cooperation or technology alliance, to access advanced technologies, which contradicts Lall’s (1993) and Tsang’s (1997) research. The research analyses suggest that the diffusion of ICT has an impact on this research result of different favorite alliance methods.

The diffusion of ICT improves the adoption of new technology in industries. On the other hand, it makes it more difficult for the owner of the new technology to protect the intellectual property rights than before. Technology suppliers will prefer technology transfer mode (TTM) which is under their control, such as FDI, in order to prevent the illegal leakage of the transferred technology in host economies (Lall, 1993; Tsang, 1997). In addition, the key element of mobile phone technologies, which have a highly extensive ICT
component, is tacit knowledge, embedded in different aspects of human and organizational activities (Polanyi, 1966). Lee (2001) suggests that FDI is the preferred TTM for transferring ICT or related technologies since the successful transfer of tacit knowledge depends on the communication among individuals. However, such TTM is the barrier for technology recipients to absorb and improve the transferred technology and generate their indigenous technological capability. FDI is not effective for generating indigenous know-why (Lall, 2000). The practical evidence indicates that FDI is not the favorite TTM in emerging countries. For instance, these four companies do not prefer the FDI method to access new technologies. Therefore, the diffusion of ICT enhances a contradiction between the technology recipient and technology supplier.

The diffusion of ICT, especially the wide usage of the internet, provides opportunities and methods to companies in emerging countries to enhance their communication among individuals, access new technology, set up alliances with other companies, and to coordinate overseas activities (Nalura, 2003). Companies in emerging countries have more chances to undertake and coordinate alliances. In addition, R&D via alliance increases the opportunities for companies in emerging countries to obtain IPRs of the new technology, and reduce the control of foreign companies over IPR. For instance, DTT Corporation developed TD-SCDMA standard with Siemens. DTT has the IPRs of this standard. The technology managers in Company ‘C’ and Company ‘D’ all believe that they can own IPRs of the technology developed in alliance to improve their competitive advantages in the future. Therefore, the diffusion of ICT provides opportunities to companies in emerging countries to undertake and manage R&D activities via alliances to possess IPRs of new technologies. In other words, the diffusion of ICT has a positive impact on the opportunities in R&D activities.

On the other hand, the diffusion of ICT shortens the life cycle of products and accelerates the diffusion of technology relative to the new products. The product life of mobile phones has been reduced to 3-5 months. Thus, companies need to introduce new products with new technology as quickly as possible. In order to keep abreast of the market changes, Chinese mobile phone manufacturers have to produce some products via OBM. For example, these four companies have experience assembling imported components of CDMA mobile phones and selling under their own brands. Thus, the diffusion of ICT and innovation also has a negative impact on the investment in indigenous technology development.
In short, it is very difficult to define the effort of ICT diffusion in technological capability development as positive or negative. Companies set up alliances to develop the new technology, whilst they produce some products via OBM as a result of the serious competition from the diffusion of ICT. Therefore, no matter whether the effort of ICT diffusion in technological capability development is positive or negative, it is definitely true that the diffusion of ICT affects the process of a company’s technological capability development.

Four-stage technological capability development model

Roger’s DOI model (1995) suggests that the development and diffusion of ICT closes information gaps among different organizations, and accelerates the adoption of innovations. It means that ICT speeds up the diffusion of mature, growing, and even emerging technologies in emerging countries. The development of the Chinese mobile phone industry supports this idea. The mature, growing, and emerging technologies exist in the mobile phone industry concurrently. Therefore, the different levels of technologies (mature, growing and emerging technologies) are interlaced because of the increasing diffusion of ICT.

In addition, the high profit of mobile phones encourages more and more Chinese companies to compete in the mobile phone industry. This increases the diffusion of new technology in this industry according to Roger’s model (Roger, 1995). The increasing diffusion of new technology and more and more competitors make the competition fiercer and fiercer in the Chinese mobile phone industry. Companies have to acquire the growing technology and assimilate and improve the mature technology at the same time in order to survive in the competition, just as what the four companies do. Moreover, the high compatibility of new technology encourages its diffusion (Roger, 1995). As a kind of ICT, the diffusion of new mobile phone technology increases because of its high compatibility. In addition, the fast development of mobile phone technology coupled with the diffusion of other information and communication technology and its high compatibility provides companies in emerging countries with opportunities to cooperate with MNCs in growing and emerging technologies and to capture all stages of technologies despite the fact that their technological capabilities are still not well developed for such new technologies. Thus, companies in emerging countries could develop emerging technologies and compete with companies in developed countries at the stage of emerging technology based on the TC
generated from the acquisition, assimilation and development of mature technologies. Therefore, the TC development process (acquisition, assimilation and development) is interlaced, too. In conclusion, I propose that with increasing adoption (diffusion) of information and communication technology,

- The stages of technological capability development become interlaced.
- The levels of technology in the technological capability development process become interlaced.

**Summary**

In sum, the diffusion of ICT affects the process of technological capability development. Companies prefer the alliance method to develop technological capability due to the diffusion of ICT. The diffusion of ICT also affects the improvement of management skills, internal communication, and intra-firm technology diffusion. The development of the four companies indicates that the usage of ICT makes it easy for companies to master the development trend of the market and introduce new products, and so on.

**6.4.4 Absorptive capacity**

Cohen and Levinthal (1990) propose that the absorptive capacity of a company is critical to its innovative capabilities. In addition, the absorptive capacity of a company in emerging countries is pivotal to its effectiveness of technology transfer (Lall, 1993) and technological capability development (Kim, 1997, 1999). There are two important elements in absorptive capacity: the existing technological capability and intensive efforts (Cohen and Levinthal, 1990; Kim, 1997). In the previous analyses, the influence of intensive efforts has been examined, which is recognized as a critical effort in technological capability development. Thus, in this section, the effect of absorptive capacity on technological capability development focuses on the effect of existing technological capability.

Figure 2-2 reveals that the existing technological capability of recipients is an important determinant of technology transfer. The different absorptive capacity affects the widely differing levels of efficiency in the usage of the same imported technology in different host emerging countries (Lall, 1993). These research results support previous research, which states that existing technological capabilities of a technology recipient influence the recipient’s TTM decision (Lall, 1993; UNCTAD, 2001).
In the process of technological capability development, the favorite technology transfer mode selected by recipients is changing. In this research, the favorite TTM of the four companies has generally changed from importing turnkey-plant or production line at the early stage of mobile phone manufacturing, to building alliances currently. I assume that the increasing technological capability is one of the important factors in this result. The four companies (and other Chinese mobile phone manufacturers in general) lacked the basic production technology when they entered the mobile phone industry. They had to depend on foreign companies and import all components for assembly at that time in order to get the production technology. With the generation of indigenous technological capabilities through the learning from the imported technology on-site, Chinese companies have the ability to search for other methods, such as technology cooperation, to develop new products with indigenous IPRs. For instance, the four companies set up alliances with other companies to take R&D activities in growing and emerging technologies. Thus, with the developing TC, Chinese technology recipients prefer externalized methods, such as technology alliances. This result supports previous studies about the role of technological capability in technology transfer (e.g. Lall, 1993), but does not fully support the theories of preferred technology transfer mode (e.g. Lall, 1993).

With the development of TC, companies have more opportunities to cooperate with MNCs than before. Take Company ‘A’ as an example. When Company ‘A’ decided to produce GSM mobile phones, Company ‘A’ lacked strong technological capability and had little experience in this industry. Motorola did not agree to set up a joint venture with Company ‘A’. Company ‘A’ had to import the GSM technology from Motorola. Soon Company ‘A’ generated and improved its TC through the assimilation and imitation of the imported technology. Company ‘A’ got the chance to establish a joint venture with Motorola to develop CDMA mobile equipment and GSM mobile phones in 1996. Afterwards Company ‘A’ cooperated with Motorola in contractual agreement. With the TC improvement, Company ‘A’ has more and more opportunities to cooperate with foreign giants in growing and emerging technologies, as shown in its alliance map (Figure 3-1). Thus, the existing technological capability is a critical factor which influences a company’s cooperation with giants.

In sum, existing technological capability has a positive impact on technology transfer and alliance building. The existing technological capability is an element of absorptive capacity (Cohen and Levinthal, 1990). Hence, the absorptive capacity has a positive impact on the effectiveness of technology transfer – the assimilation and improvement of
technology. As shown in the research framework, the determinants of the technology transfer process indirectly affect the process of technological capability development. Thus, the absorptive capacity of a Chinese company has a positive impact on its assimilation and improvement of technology.

### 6.4.5 Governmental control

When I compare the four cases in this dissertation, I observe that governmental control over a company affects the company’s development. In this dissertation, Company ‘A’ and Company ‘D’ are state-owned enterprises controlled by the Chinese Ministry of Information Industry (MII), while Company ‘B’ and Company ‘C’ are non-state-owned companies. During the interviews, the managers in Company ‘A’ and Company ‘D’ all thought that state interference was the biggest problem in their companies’ development. In addition, state influence in Company ‘A’ is less than that in Company ‘D’ because Company ‘A’ is a public completely A-share company, while only some subsidiaries of Company ‘D’ have gone public.

Let me take Company ‘D’ as an example to explain the effort of governmental intervention on state-owned enterprises. In Company ‘D’, the company’s development strategy and top-management team should be approved by MII. The CEO is not selected by the employees or shareholders. MII decides who is to be the CEO of Company ‘D’. It is the same in Company ‘A’. In addition, Company ‘D’ should submit its application for setting up international technological alliances to MII. It takes a long time to get feedback from the ministry. Most importantly, Company ‘D’ has no initiative in such activities. Moreover, Company ‘D’ needs to complete many documents, such as bureaucratic reports, which are required by the ministry. Therefore, Company ‘D’ has to assume additional responsibilities assigned by the ministry. Following the directive of MII, Company ‘D’ has changed several CEOs recently. Company ‘D’ has developed slowly since 2002. Though the company works, there are problems in its operation. For instance, the corporate strategy changes with each new CEO. Company ‘D’ does not update its website on time. Some web-pages still display the news and reports from 2002. Therefore, governmental interference is a big barrier to the development of state-owned companies. The non-state-owned companies in China have more motivation and initiatives in their development than state-owned companies. In short, I hypothesize that governmental control in a company’s management affects the TC development of the company.
Figure 6-5 Factors in the Process of Technological Capability Development
6.4.6 Summary

In short, the nature of technology (particularly the complexity, uncertainty, and monopoly of technology), industry value network, diffusion of ICT, and absorptive capacity of companies have an impact on the process of technological capability development (Figure 6-8). The effort of governmental control on the TC development process should be tested in future research. In addition, it is certified again that the externalized technology transfer, especially the technology alliance, has become the favorite method to access the advanced technology for Chinese companies in high-tech industries.

In sum, the research results suggest that:

- The higher the complexity, the uncertainty, and the monopoly the technology has, the more likely companies prefer the alliance method to access advanced technologies and intensive efforts to accelerate intra-firm technology diffusion.
- The industry value network gives incentives to companies to cooperate with others in technology development.
- The diffusion of ICT has an impact on alliance building and technological capability development.
- The absorptive capability, the existing technological capability in particular, affects the methods selected by companies to access and develop new technologies.
- For state-owned enterprises, governmental control has a negative impact on their technological capability development.

Therefore, I formulate the following findings:

Finding 3:

The nature of technology (especially, the complexity, uncertainty, and monopoly of technology), industry value network, diffusion of ICT, and absorptive capability (particularly, the existing technological capability) are the main factors influencing the process of technological capability development.
Finding 4:
For state-owned enterprises, governmental control is an important factor affecting the process of technological capability development.
7. Technological Capability Development Routine

In this chapter, the routine model proposed in Chapter 2 is examined and new theoretical constructs are formulated.

In this dissertation, R&D capability and marketing capability are recognized as two important elements of a company’s technological capabilities. As presented in Figure 5-8, these four companies have different levels of R&D capability and marketing capability, so they are located at the different quadrants. As mentioned in the chapter ‘Research Methodologies’, these four companies represent the general conditions of Chinese mobile phone manufacturers when they entered the Chinese mobile phone industry: (1) a type of company without either strong R&D capability or marketing capability (quadrant I); (2) a type of company with strong R&D capability but weak marketing capability (quadrant III); and (3) a type of company with strong marketing capability but weak R&D capability (quadrant II). The technological capability development of these four companies suggests that different levels of R&D capability and marketing capability affect their distinct technological capability development routines.

7.1. Technological Capability Development Routine of Company ‘A’

As one of the earliest mobile phone producers in China, Company ‘A’ entered the mobile phone industry in the early 1990s. At that time, both the R&D and marketing capabilities of Company ‘A’ in mobile phones were weak. Thus, the company can be put in quadrant I (the point of ‘Early 1990s’ in Figure 5-8). However, in the early development stage of the Chinese mobile phone industry, the profit was very high since there was no serious competition. Company ‘A’ expanded its market scale, built its marketing network and improved its R&D capability at the same time. Company ‘A’ concentrated on improving its R&D capability, not marketing capability since there was a huge, high-profit market with less than five competitors. Without strong marketing capability, Company ‘A’ still reaped high profits at that time. Thus, its development speed of marketing capability was slower than that of R&D capability, and its investment in marketing was lower than that in R&D before the end of the 1990s. When many Chinese companies entered this industry at the end
of 1990s, Company ‘A’ improved its R&D capability and marketing capability nearly to the middle level, as shown the point of ‘End of 1990s’ in Figure 7-1. After 1997, the high profit and low entrance barrier of the mobile phone market attracted more and more companies to compete in this market. The more and more serious competition in the Chinese mobile phone market led to a price war after 2002. Company ‘A’ has increased its investment in marketing in order to keep and improve its market position in the seriously competitive market. Company ‘A’ has set up a national market network. The R&D is the future competitive center; hence, it is of course the investment center of Company ‘A’. But the growth rate of R&D investment (compared with marketing investment) is smooth. In short, based on the R&D capability and marketing capability, the technological capability development routine of Company ‘A’ is presented in Figure 7-1.

![Figure 7-1 Capability Development Routine of Company ‘A’](image-url)
7.2. Technological Capability Development Routine of Company ‘B’

In the Chinese telecommunication industry, Company ‘B’ is famous for its excellent R&D capability. Though Company ‘B’ had no production technology for mobile phones when it started to produce mobile phones, the company had strong R&D teams and extensive experience in R&D in mobile telecommunication equipment. In other words, when it became a mobile phone provider, Company ‘B’ had strong R&D capability to master new technology in a short time and to develop new products, but weak production capability. In addition, at that time (the end of the 1990s), Company ‘B’ had weak marketing capability because as a telecommunication equipment provider, Company ‘B’ sold equipment only to telecommunication service providers and had no experience in consumer goods marketing. Thus, Company ‘B’ was at quadrant III at the end of the 1990s, as seen from the point ‘End of 1990s’ in Figure 7-2. In order to succeed in competition, Company ‘B’ has increased the advertisement budget and invited famous movie stars to do advertisements in the national, provincial, and main cities’ TV channels and outdoors. The company made these efforts because the market scale means the success of the products, and the profit from the market keeps the company running. It is definite that Company ‘B’ has kept its heavy investment in R&D as a world innovative high-tech company. The extensive efforts in marketing and excellent R&D capability contribute to the fast development of Company ‘B’. The mobile phones produced by Company ‘B’ have become one of the top ten famous brands in China. In addition, its CDMA mobile phones have become one of the most trusted CDMA mobile phones in China. In sum, the development routine of Company ‘B’ is shown in Figure 7-2.

7.3. Technological Capability Development Routine of Company ‘C’

Company ‘C’ is famous for its comprehensive marketing network. When Company ‘C’ started to produce GSM mobile phones in 1997, Company ‘C’ lacked the basic production and development technology for mobile phones. But Company ‘C’ had built up an excellent national network (covering important Chinese towns and villages) based on its marketing of pager products. Company ‘C’ had strong marketing capability but weak R&D capability at that time, located at Quadrant II (point of ‘End of 1990s’ in Figure 7-4).
The development idea of Company ‘C’ is: the profit from the market supports the company’s R&D and product development; and then new products with the new technology provide new profits. There is a circulation among the marketing advantage, profit, and R&D, as shown in Figure 7-3. Company ‘C’ is investing to improve its sales network and keep its marketing advantage. For example, Company ‘C’ is the first Chinese mobile phone producer to invite a world famous star to do TV advertisement on all important TV channels and advertisement in cities and towns. The national marketing network has helped Company ‘C’ to become the No. 1 local brand mobile phone in China and the largest local mobile phone provider. However, after 2002, the competition in the Chinese mobile phone industry has become increasingly serious and the profit margin has been lower and lower. New products and new technology thus have become the development focus of Company ‘C’. According to its development strategy, the development routine of Company ‘C’ is as shown in Figure 7-4.
Figure 7-3 Circulation between Marketing and R&D

Figure 7-4 Capability Development Routine of Company ‘C’
7.4. Technological Capability Development Routine of Company ‘D’

As a state-owned company and the earliest GSM mobile phone provider, the basic development condition of Company ‘D’ was similar to that of Company ‘A’ when it entered the mobile phone market in the middle of the 1990s through a joint venture. In the mid-1990s, Company ‘D’ had no basic technology for mobile phone production and no marketing experience for mobile phones since this was its first time producing mobile terminal products. Thus, Company ‘D’ was located at quadrant I, too (the point of ‘Mid-1990s’ in Figure 7-5).

![Figure 7-5 Capability Development Routine of Company ‘D’](image_url)
Company ‘D’ had the chance to invest in GSM mobile phone technology earlier than most other companies since Company ‘D’ was the first company to get a GSM mobile phone production license. Hence, the R&D and marketing capability of Company ‘D’ at the end of the 1990s were improved. However, this joint venture helped Company ‘D’ to improve its management skills and the marketing channels, but did little for the development and production technology for mobile phones. In short, the R&D and marketing capabilities of Company ‘D’ at the end of the 1990s were just a bit higher than that in the middle of the 1990s.

After the end of the 1990s, the competition increases more and more serious. Company ‘D’ has invested in the development of new technology, new products, and new market. Company ‘D’ has set up its sales agency network. Nevertheless, the improvement has recently been slow due to the governmental influence on its top-management team as a state-owned enterprise. The technological capability development routine of Company ‘D’ is described in Figure 7-5.

7.5. Summary

These four companies have their respective capability development routines according to their distinct R&D and marketing capabilities. In general, the technological capability development routines of Company ‘A’, ‘B’, ‘C’ and ‘D’ can be summarized as three development routines, as shown in Figure 7-6. Thus, the development routine b, routine d, and routine e in Figure 2-6 are confirmed. Company ‘A’ and ‘D’ have developing following Routine b. Company ‘B’ has following Routine e. And the development routine of Company ‘C’ is Routine d.

The development routines a–d and c–e in Figure 2-6 can not be certified from these four companies. However, a failure story of a Chinese mobile phone manufacturer (called Company ‘E’ in the following part) suggests that the development routine c–e does not fit Chinese mobile phone manufacturers.
Company ‘E’ entered the mobile phone industry at the end of the 1990s, too. At that time, Company ‘E’ had neither strong technological capability nor strong marketing capability since the company had no experience in producing and distributing such consumer goods (the point of ‘End of 1990s’ in Figure 7-7). As one of the earliest companies to produce Chinese local brand mobile phones, Company ‘E’ had a good reputation with the public. According to its development strategy, Company ‘E’ invested more heavily in R&D than in marketing, while most companies in this industry made efforts to enlarge their market scales through OBM and distribution networks in order to accumulate the capital for R&D, such as Company ‘A’ and Company ‘C’. Before 2000, the profit of mobile phones was very high and the competition was not serious. However, the R&D performance of Company ‘E’ was not as good as the company’s expectation. Its net profit was not as high as other companies largely due to its lower investment in marketing. I assume this was the consequence of high profit of mobile phones at the end of the 1990s and
the fast changes of the market and technology in the mobile phone industry. It was easier for companies to improve their turnover via OBM than to invest in the highly risky and costly R&D. In addition, without marketing capability, having only high technology capability is not sufficient to compete in this market, where product trends change rapidly and the differences among different brands of mobile phones are small. The market position of Company ‘E’ was therefore decreasing. Then Company ‘E’ changed its strategy, decreasing its investment in R&D and increasing its investment in marketing, while other companies, such as Company ‘C’, were increasing their investment in R&D using the capital generated through OBM. Nevertheless, the average profit of a mobile phone began to be lower and lower due to the more and more serious price war. Company ‘E’ could neither obtain a profit level as high as its expectation nor develop new technology to improve the profit margin of new products. It is probably because a company may not appreciate the new information if it does not invest in technological capability in a period of time (Cohen and Levinthal, 1990). Thus, Company ‘E’ did not succeed in the competition. The development routine of Company ‘E’ is shown in Figure 7-7.

![R&D Capability Diagram](image)

**Figure 7-7 Capability Development Routine of Company ‘E’**
The mistake in its strategy turnaround is possibly a reason why Company ‘E’ failed in this competition. Nevertheless, the failed development of Company ‘E’ reveals that the development routine from quadrant I to quadrant III then to quadrant IV (routine c-e) is not a good routine for companies with weak R&D and marketing capabilities at the early stage of a company’s development process.

No evidence can be found that routine a–d is not a good routine or does not exist. However, I hypothesize that the development routine from a then to d is not a good development routine for companies in emerging industry due to the importance of investment in R&D. Technological capability, especially R&D capability, is important for the development of companies. Lack of R&D investment in an area may foreclose the future development of technical capability in that area (Cohen and Levinthal, 1990). In particular in an emerging and fast changing industry, once a company ceases investing in its technology or absorptive capacity, it may never assimilate and exploit new technological information in that field, regardless of the value of the information (Cohen and Levinthal, 1990). Therefore, it is impossible for a company in an emerging and quickly moving industry to succeed without investment in R&D capability. The routine a-d is not a satisfactory development routine for companies without strong R&D capability and marketing capability.

The capability development routine based on R&D capability and marketing capability is thus concluded in Figure 7-8. In comparison with Figure 2-6, there are no routines c–e and a-d in Figure 7-8.

Figure 7-8 reveals that companies with different levels of R&D and marketing capabilities follow distinct routines to develop their technological capabilities.

Finding 5:

With different levels of marketing capability and R&D capability, manufacturers follow distinct routines to develop their technological capabilities.

As shown in Figure 7-3, R&D, the marketing advantage, and profit work together to form a loop. However, it is possible that the loop will be blocked. The existing R&D and marketing capabilities would affect this loop. Without marketing capability, the performance of R&D cannot change to be the competitive advantage of products and be introduced to the
market successfully. On the other hand, without R&D capability, a company cannot develop new products and new technologies even if this company has strong capital.

R&D Capability

![Diagram showing the relationship between R&D Capability and Marketing Capability. The diagram is divided into four quadrants: I Weak, Weak; II Weak, Strong; III Strong, Weak; IV Strong, Strong. Points e, b, and d are marked on the diagram, indicating different stages of capability development.](image)

**Figure 7-8 Capability Development Routine Based on R&D Capability and Marketing Capability**

In short, at the early development stage, companies in an emerging industry without strong capabilities should improve their marketing capability in order to accumulate the profit to support their R&D activities. With the development of marketing capability, companies improve their production capability in an effort to match the market expansion. The production experience provides a company with the background necessary both to recognize and exploit new information relevant to a particular product market (Abernathy, 1978; Rosenberg, 1982). It is the strong marketing capability of Chinese mobile phone manufacturers that allowed Chinese mobile phone producers to gain more than 50 per cent of the Chinese market in 2003. At the same time, companies must invest in their R&D capability; otherwise they may not be able to seize the future opportunities.
8. Conclusions

8.1. Summary of Dissertation Research

8.1.1 Dissertation research

Technological capability is critical to the competition in the national and world market. In addition, technology transfer is widely regarded as a pivotal process in the technological capability development in emerging countries (e.g. Kim, 1997; Lall, 2000; Lee, 2001). The development of technological capability in emerging countries has attracted extensive attention not only from academics, but also from business managers and government officials (Lall 1990, Miyazaki 1995, Kim 1997). However, there are several research gaps in the previous studies. For instance, few studies focus on the TC development in high-tech industries. Few studies present the technological capability development of industries in China. In addition, the practice contradicts some theories, such as Kim’s model, and favorite technology transfer modes. This dissertation research is conducted in order to close these research gaps.

The goal of this dissertation is to explore the process of technological capability development in high-tech industries in China. In this dissertation, the process of technological capability development and the main factors in this process are examined to answer one ‘how’ and two ‘what’ research questions. A high-tech industry, the Chinese mobile phone industry is selected as the research objective of this dissertation.

8.1.2 Key findings

Based on the results of in-depth multi-case studies of the Chinese mobile phone industry, the process of technological capability development in high-tech industries is explored. This research reveals that the process of technological capability development in high-tech industries in China is a process of acquisition of advanced technology in an established external alliance network and diffusion of technology internally with intensive efforts. In other words, this process embraces two stages: the stage of technology transfer in alliances and the stage of intra-firm technology diffusion. In these two stages and the TC development process, some new insights are found:
- The externalized technology transfer mode (TTM), especially the technology alliance and technology cooperation, has been preferred by companies to access new technology. This phenomenon does not confirm previous research which states that the internalized TTM, especially FDI, is highly favored (Lall, 1993; UNCTAD, 2001; Lee, 2001).
- With the development of technology and industry, the process of technology transfer has become technology transfer in alliance networks.
- The effective process of intra-firm technology diffusion under extensive internal efforts has a positive effect on the improvement of a company’s technological capability.

Additionally, the research suggests that practical evidence does not completely support Kim’s three-stage TC development model. Therefore, Kim’s model is extended in this dissertation. I proposed four stages of technology, adding a complementary stage of recessive technology. Based on the four-stage model, I observed that:
- The boundaries among the different stages are fuzzier than predicted by Kim: the acquisition, assimilation and development activities can be done concurrently; and mature, growing and emerging technologies can all be found in companies in emerging countries at the same time.
- Companies in emerging countries may concurrently invest in the R&D of mature, growing and emerging technology.

Furthermore, the nature of technology containing the complexity, uncertainty and monopoly of technology, the industry value network, the diffusion of ICT, and the absorptive capacity, in particular the existing technological capability, are recognized as the main factors in the process of technological capability development in this dissertation. My research results indicate that these factors are having an increasing impact on the process of TC development. Additionally, the effort of governmental control the development of state-owned enterprises is considerably negative.

To be precise, the nature of technology affects this process as follows:
- The higher the complexity the technology has, the more likely companies prefer strategic alliances to develop technological capability.
- The higher the uncertainty the technology has, the more likely companies prefer strategic alliances to develop technological capability.
The higher the monopoly the technology has, the more likely companies prefer alliance method to acquire the technology in order to reduce its utilization cost.

In addition,
- As they improve their technological capabilities, the recipients change their preferred technology transfer mode.
- In technology transfer, technology suppliers do not play as significant a role as mentioned in the previous studies. The public nature of technology improves the recipient’s role in technology transfer, while the monopolistic nature of technology enhances the supplier’s role in technology transfer.

The impact of the industry value network on the process of TC development is:
- The industry value network facilitates companies in an industry to cooperate with others during the process of technological capability development.

The diffusion of ICT has an impact on the process of TC development:
- The diffusion of ICT has an effect on alliance building and technological capability development. However, the diffusion of ICT also affects Chinese companies in manufacturing products via OBM.
- The diffusion of ICT provides Chinese companies with the opportunities to cooperate and compete with MNCs in growing and emerging technologies and to master all stages of technologies despite the fact that their technological capabilities are not well developed for such new technologies.

The absorptive capacity has an effect on the process of TC development:
- The absorptive capacity has a positive impact on the effectiveness of technology transfer – the assimilation and improvement of technology.
- The absorptive capacity of companies improves their positions in the process of technology transfer.

Moreover, R&D capability and marketing capability are defined as two important elements of technological capabilities in this dissertation. This research reveals that, based on the different combination of R&D and marketing capabilities, companies’ particular TC development routines are distinct, though there is a general process of TC development for
companies in emerging countries. I propose a technological capability development routine model based on companies’ R&D and marketing capabilities. This model suggests that:

- Companies’ different levels of R&D and marketing capabilities lead to their special development routines.
- Without marketing support or capital support from other sources, it is not sensible for a company with weak R&D capability in emerging countries to invest heavily in R&D activities.
- A company’s R&D capability and marketing capability depend on each other. On one hand, the development of new technology improves the competitive advantage and profit margin of products in the hypercompetitive market. In other words, the R&D capability improves a company’s marketing advantage. On the other hand, marketing performance provides the capital for R&D activities. Thus, marketing capability supports the improvement of R&D capability with financial capital.

**8.1.3 Summary**

In short, this research proposes new theoretical constructs. The new findings are:

- The process of a manufacturer’s technological capability development in high-tech industries is a process involving technology alliance networks building up to access advanced technology together with intensive efforts to speed up intra-firm technology diffusion.
- Companies in emerging countries will undertake concurrent activities (acquisition, assimilation, and development) in recession, mature, growing, and emerging technologies at the same time.
- The nature of technology (especially, the complexity, uncertainty, and monopoly of technology), industry value network, diffusion of ICT, and absorptive capability (particularly, the existing technological capability) are the main factors influencing the process of technological capability development in high-tech industries.
- For state-owned enterprises, governmental control is a considerable important factor affecting the process of technological capability development.
- With different levels of R&D and marketing capabilities, manufacturers follow distinct routines to develop their technological capabilities.
8.2. Implication of Dissertation Research

This research has analyzed the development of the Chinese mobile phone industry. This research contributes to the deep understanding of Chinese high-tech industries and the process of their technological capability development. This research investigates Chinese industries and Chinese companies from a new perspective. This will help companies in other countries, particularly companies in high-tech industries, to make the proper strategy for Chinese market.

The experiences of Chinese companies provide new insights into the theories of technological capability development and technology transfer in emerging countries. The research results contribute importantly to the broader understanding of technological capability generation in high-tech industries in emerging countries. The new models and research findings formulated from the experiences of Chinese companies indicate that there is no model that can fit all companies, all industries, or all countries. The environment and the background of a country, those of an industry and even those of a company will affect a special development route of a company. It is like the different industrialized routes of Britain, Germany, Russia and France (Gerschenkron, 1951). Thus, this research suggests that managers and government officials cannot take others’ experiences directly when they make their technology development strategies.

The Chinese government encourages foreign companies to invest directly in China in order to attract foreign capital. However, this research suggests that FDI is not necessarily the highly preferred method selected by Chinese companies since FDI is not an effective method to generate indigenous technological capability, although the government thinks differently. There is a dilemma for the Chinese government: to attract more FDI, which is not good for indigenous TC development, vs. to attract less FDI in favor of indigenous TC development. Since many emerging countries adopt FDI as the leading development policy, China as well, this dilemma will be found in other emerging countries too. In other words, China and other emerging countries should strike a balance between the national acquisition of foreign capital and the companies’ acquisition of more supports to develop indigenous technological capabilities. In general, the government in emerging countries should consider the development requirement of industries and companies when it makes policy.

The results of this research will further our understanding of the determinants in the process of technology transfer and the process of technological capability development. In addition, the results of this study suggest that the role of recipients in technology transfer
must not be neglected. MNCs, as the dominant suppliers, should rethink the role of recipients in technology transfer to find a balance between the benefits of technology transfer and protection of intellectual property rights. Furthermore, the model about the factors in the TC development process provides a new decision-making framework for companies in emerging countries when they develop the strategies for technology transfer, intra-firm technology diffusion and technological capability development. The importance of absorptive capacity suggests that it is pivotal for companies to invest in their absorptive capacity in an effort to appreciate new technological opportunities promptly when they emerge.

This research does enhance our understanding of R&D alliances from the perspective of Chinese companies. The results suggest that companies in China and other emerging countries should improve their technological capabilities in order to facilitate alliance formation to utilize the latest technology from foreign alliance partners and develop in the industry network.

The four-stage TC development model provides new insights into technology management in China in particular, in emerging countries in general. It suggests that technology managers should employ different methods to manage different phases of technologies. In addition, managers in developed countries and emerging countries alike need to balance the effort in investment and intellectual property management in different phases of technologies, particularly the technologies belonging to distinct phases but developing concurrently. Furthermore, companies in developed countries need to consider cooperation with companies in emerging countries to develop the emerging technology. Moreover, the four-stage model also suggests that companies in emerging countries have more opportunities in growing and emerging technologies to develop technological capability and compete with MNCs in the world.

There is a general development process of technological capability proposed in this dissertation for companies in China in particular, for those in emerging countries in general. However, this research also reveals that the R&D and marketing capabilities of a company affect a company’s specific TC development routine. It also poses a dilemma for companies in emerging countries: the balance between R&D capability and marketing capability, which should be the development and investment focus of a company. In addition, a company should make the strategy based on the consideration of firm-specific characteristics affected by the company’s culture, existing capability and competitive environment. Moreover,
marketing capability is critical for the development of companies in a fast moving field, while R&D capability is pivotal for continual and successful development.

**8.3. Further Research**

This research is based on four cases in an emerging high-tech industry (the mobile telephone industry), which limits the generalization of research findings. Therefore, it is necessary that further research examine the process of technological capability development in other industries to test the new theoretical constructs formulated in this dissertation. In addition, this is explorative research focusing on China. The research results need to be examined in other emerging countries to formulate generalized propositions for emerging countries.

In the model of development routine based on the R&D and marketing capabilities, the development routine a-d in Figure 2-6 has not been tested in this dissertation. In future research, this routine needs to be examined. In addition, the development routine a-e in Figure 2-6 needs further investigation in the future. Moreover, the development routine model based on R&D and marketing capabilities should be tested in other industries to sharpen the propositions.

This dissertation suggests that governmental intervention has become an important factor affecting the development of technological capability of Chinese state-owned companies. This hypothesis should be further analyzed. In addition, research on factors in the TC development process should be furthered in the future due to the fast changing of development environment.

In sum, as high-tech industries develop fast, it is necessary to explore and modify the research models of the TC development process and TC development routine again in the further research.
References

Arayama, Yuko (1999), *China against Herself: Innovation or Imitation in Global Business*, Westport, Conn.: Quorum Books
Bae, Zong-tae and Lee, Jinjoo (1986), Technology development patterns of small and medium sized companies in the Korea machinery industry, *Technovation*, **4**, 279-296


Caloghirou, Yannis; Kastelli, Ioanna; and Tsakanikas Aggelos (2004), Internal capabilities and external knowledge sources: complements or substitutes for innovative performance? *Technovation*, 24, 29–39


Dawson, Ross (2000), Knowledge capabilities as the focus of organizational development and strategy, *Journal of Knowledge Management*, 4, 4, 320-327


Hyman


Fan, Peilei (2004), Catching up through developing innovation capability: evidence from China’s telecom-equipment industry, Technovation, 1-10
Freeman, Christopher and Hagedoorn, John (1994), Catching up or failing behind: patterns in international inter-firm technology partnering, World Development, 22, 771 – 780
Gee, Sherman (1981), Technology Transfer, Innovation, and International Competitiveness, Chichester, UK: John Wiley &Sons
Grant, R. M. (1996), Toward a knowledge-based theory of the firm, Strategic Management Journal, Summer Special Issue 17, 109 - 122


Kim, Linsu (1999), Building technological capability for industrialization: analytical frameworks and Korea’s experience, *Industrial and Corporate Change*, 8, 1, 111-136


Kumar, V.; Kumar, U.; and Persaud, A. (1999), Building technological capability through importing technology: the case of Indonesian manufacturing industry, The Journal of Technology Transfer, 24, 81 – 96


Lall, S. (1987), Learning to Industrialize: The Acquisition of Technological Capabilities in India. London: Macmillan

Lall, S. (1990), Building Industrial Competitiveness in Emerging Countries, Paris: OECD

Lall, S. (1993), Promoting technology development: the role of technology transfer and indigenous effort, Third World Quarterly, 14, 1, 95 – 108


Lall, S. (2002), The Economics of Technology Transfer, Cheltenham: Edward Elgar


Lane, P. J. and Lubatkin, M. (1998), Relative absorptive capacity and inter-organizational learning, Strategic Management Journal, 19, 461-477

Lee, Jinjoo, Zong-Tae Bae, and Dong-Kyu Choi (1988), Technology development processes: a model for a developing country with a global perspective, R&D Management, 18, 3, 235-250


Lee, Young S. (2001), Technology Transfer and the Role of Information in Korea, Research Proposal for ADBI, available by

http://myhome.hanafos.com/~youngsae/tech_trans20011019.htm

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Li, Jiatao and Zhong, Jing (2003), Explaining the growth of international R&D alliances in China, *Managerial and Decision Economics*, 24, 101–115


Marx, Karl (1867), *Capital*, New York: Modern Library


Nalura, R. and Dunning, J. (1999), Emerging countries versus Multinationals in a globalizing world, the dangers of falling behind, *Forum for Development Studies, 2, 261-287*


170
Tan, Yiguo and Wu, Qilin (2003), *Shou Ji Feng Yun* (Chinese), Guangzhou, CN: Guangdong Economic Publisher


Wang, Jian-ye and Blomstrom, M (1992), Foreign investment and the mode of technology transfer, *European Economic Review*, 36, 137 – 155


Wei, Liu (1995), International technology transfer and development of technological capabilities: a theoretical framework, *Technology in Society*, 17, 1, 103 – 120


Xie, Wei (2004), Technological learning in China’s color TV (CTV) industry, *Technovation*, 24, 499-512

Xin, Wei (2004), A wait for the next generation of mobile phones: the delay in issuing licenses for China’s third generation mobile system looks set to benefit domestic firms, *China International Business*, February, 30-31


Appendix I: Brief of Studied Cases

1. Company ‘A’

Company ‘A’ was established in 1958 as a state-owned factory of the Chinese Ministry of Posts and Telecommunications to produce communication equipment. In 1996, Company ‘A’ was listed as an A-Share company on Shanghai Stock Exchange and Hong Kong Stock Exchange. However, Company ‘A’ is still a company controlled by the Chinese Ministry of Information Industry.

Company ‘A’ mainly engages in providing solutions for mobile communication networks. Meanwhile, it involves such areas as mobile phone system equipment as well as mobile terminal products. Since first entering into the mobile telephone industry in the early of the 1990s, Company ‘A’ has become one of the largest companies in the Chinese mobile phone industry. Mobile terminal products and mobile system equipment have become the main products of Company ‘A’, making up nearly 90 per cent of annual sales.

Company ‘A’ invests heavily in R&D (around 5 per cent of annual sales), especially in mobile terminal and system products. The company possesses a national-level R&D center and a mobile phone R&D center in the Silicon Valley. Company ‘A’ undertakes national research programs in telecommunication technology. Few years ago, Company ‘A’ transferred one of its R&D centers to the Ministry of Information Industry as a government center because its outstanding R&D team and R&D experience can remedy the government’s lack of such institute.

Since the time when technology was introduced by Motorola in 1990, Company ‘A’ has set up strategic cooperation relationships with Texas Instruments, Lucent, LG, Samsung, 3Com, Motorola, Interwave and others, with the purpose of furthering its knowledge in the field of R&D of mobile telephone technology, emerging 3G technology and products, data communication, and communication network software.

Company ‘A’ produces telephone systems and terminal products. Currently, Company ‘A’ has generated the capabilities to develop and produce GSM, CDMA, GPRS mobile phones for the Chinese market, and 3G mobile phones for the field-test.
2. **Company ‘B’**

Company ‘B’ is one of China's largest listed telecommunications manufacturers and wireless solutions providers.


Company ‘B’ is one of the pioneers of China’s telecommunications equipment manufacturing industry and a comprehensive provider of the telecommunication equipment, mobile terminals and services. With its three product series, i.e. wireless, network and terminal (mobile telephone), Company ‘B’ is capable of providing global customers with diversified integrated telecommunications networking solutions and a wide range of professional services. Company ‘B’ has been involved in the market of international telecommunications operation services.

Mobile phones are the extension of operations of Company ‘B’. Company ‘B’ started to produce GSM mobile phones in 1999. In 2002, Mobile Terminal Product Business Unit was established in Company ‘B’. Company ‘B’ officially supports the development of mobile terminal products. Now Company ‘B’ is capable of providing products of 2G and 2.5G mobile telephone technologies, such as CDMA and GSM products.

Since its establishment, Company ‘B’ has invested heavy in research and development. Company ‘B’ invests nearly 10 per cent of its annual sales income into R&D every year. Company ‘B’ has set up a complete human resources management system from recruitment, training and appointment to incentive advancement. Company ‘B’ has 21,000 employees, of which 70 per cent have a bachelor or higher degree.

Company ‘B’ has set up 13 wholly owned R&D centers and 9 subsidiaries worldwide. As the high-tech achievement transfer base for China’s 863 Program, Company ‘B’ has undertaken several important projects including 3G, high-performance Ipv6 routing platform and 3Tnet (a demonstration network for China’s informationization). In addition, Company ‘B’ is one of the major high-tech enterprises involved in the China Torch Program and an experimental company for technology innovation.

In a bid to grasp key technologies in mobile phone R&D, Company ‘B’ has independent intellectual properties to all the core software, hardware circuits, core chips and overall design and integration. Company ‘B’ sets alliance and joint research laboratories with electronic giants, such as Motorola, TI and Agere Systems to undertake R&D in future
telecommunication technologies, for instance the 3G mobile telecommunication technologies.

On the basis of its strong CDMA technology and brand, in 2004, Company ‘B’ released the first CDMA-based global digital trunking architecture standard – GoTa, which is the first proposed by a Chinese enterprise. Company ‘B’ has become the first to achieve the patent authorization of Chinese telecommunications enterprises to other internationally renowned vendors. The GoTa products have entered dozens of countries, including Malaysia, Norway, and Russia. GoTa is expected to become one of the leading technologies that may change the pattern of the international digital trunking market in the future.

Company ‘B’ was the first Chinese individual manufacturer member of 3GPP2 (3rd Generation Partnership Project 2) and has become a sector member of the International Telecommunications Union (ITU).

Company ‘B’ has become one of the fast-growing Chinese telecommunications manufacturers with the most robust development. Company ‘B’ was accredited as “China’s Top Ten Listed Companies”, and was consecutively listed among the “Top 50 Listed Companies with the Greatest Growth Potential in China Securities and Asia Business” for four years.

3. Company ‘C’

Company ‘C’ is a professional manufacturer of mobile terminal products. Company ‘C’ was founded in 1992 as a pager manufacturer. By 1997, Company ‘C’ had become China's largest pager manufacturer. In 1999 Company ‘C’ moved into mobile phone manufacturing. Mobile telephones, system equipment and pocket PCs have become the main products of Company ‘C’. In 2000, Company ‘C’ was successfully listed in Shanghai Stock Exchange and started to issue A-share.

Since its establishment, Company ‘C’ has engaged in setting up its distribution and service network around China, even in the small towns. Based on its completed marketing network, Company ‘C’ has become one of the leading mobile telephone providers and the largest domestic mobile telephone provider in China for five years. In addition, Company ‘C’ was one of the highest profit-earning public companies in the Chinese mainland stock

With regard to the Quality Control System, Company ‘C’ has already passed ISO9001 certificates in 1999, and now is carrying on ISO14001 environment management system authentication.

Company ‘C’ always sticks to the tenet “taking human factor as a dominant basis, science and technology as an initiator of the enterprise”. Company ‘C’ invests heavy in research and development, nearly 6 per cent of its annual sales income into R&D. Company ‘C’ has set up five institutes in China. In addition, Company ‘C’ has build up an R&D group with 600 professional technical employees, who have masters, doctoral, or post-doctoral degree.

During its development process, Company ‘C’ has set up technological partnerships with mobile telephony giants, for instance, Samsung, Quantum, Motorola and Siemens to compete in the future mobile telephony world. Additionally, Company ‘C’ makes commercial alliances with foreign mobile telephone service providers, such as AT&T, in an effort to enter foreign markets. Company ‘C’ has distributed its mobile telephones to more than 30 countries or areas.

4. Company ‘D’

Company ‘D’ is a state-owned enterprise specializing in R&D, production and the sales of telecommunication equipment and mobile terminal products.

Company ‘D’ was established in 1941, originating from the Coppersmith Department of Peking Telephone Bureau set up in 1906 during the Qing Dynasty. Company ‘D’ has been active during the entire development of China’s telecommunication industry for a century.

For decades, Company ‘D’ has braved numerous difficulties and pioneered in quite a number of fields in the history of China’s telecommunication industry. In 1958, Company ‘D’ began to develop microwave equipment and became the first microwave manufacturer in China. Company ‘D’ has become one of the largest national high-tech enterprises engaged in R&D, production and distribution of communication products. Company ‘D’ has been listed as an A-Share company on Shanghai stock exchange.

In 1996, Company ‘D’ entered the mobile telephone market via a joint venture with Nokia. This joint venture is the first company to produce GSM mobile phones in China. However, these mobile phones are sold under the ‘Nokia’ brand. Then Company ‘D’ built up its own production lines to produce its own brand of mobile phones in 1999. Currently, Company ‘D’ produces GSM, GPRS and CDMA mobile phones.

Company ‘D’ has invested in different generations mobile telephone technologies. With its strong R&D capability in telecommunication, Company ‘D’ has undertaken some key R&D tasks in the areas of the State 863 Science and Technology Program and the State CDMA, Wireless WAP and GPRS programs.

Like other Chinese mobile telephone companies, Company ‘D’ has formed strategic partnership with foreign investors and created a good cooperative environment with a concerted effort in a bid to achieve win-wins. Company ‘D’ has built up joint ventures with corporations from Finland, Japan, USA, and Korea, such as the joint ventures Nokia, DMC Corporation and NEC. In addition to this, Company ‘D’ has invested and established its R&D Institute (Mobicom Company) in New Jersey, USA, as the group’s overseas R&D institution for the purpose of tracking the latest digital technology and mobile communication technology in the world.

However, as a state-owned enterprise and due to the increasing control of MII, the top-management team of Company ‘D’ has changed several times since the end of 2002. This affects the implementation and continuity of the company’s development strategies and technology strategies.
Appendix II:

Questions in Interviews

The questions in the interviews concentrate on four aspects: the technology development process, corporate efforts, factors in the technological development, and the technology alliance.

**Technological Capability**
1. How do you evaluate your R&D capability and marketing capability in this industry?
2. What is your evaluation of R&D and marketing capabilities of other companies?

**Development Process**
3. Why and how did your company enter the field of mobile telephone manufacturing?
4. On entering this field, which existing techniques/technologies in your company were particularly useful? If none, then how do you get the key technologies? (e.g. your company’s in-house effort, collaboration with other companies or technological institutions, national projects, technology imported).
5. How does your company develop different generations of mobile telephone technology (1G, 2G, 2.5G, and 3G)?
6. What are the key products that best represent your company’s technological progress? What is the background for developing these products?
7. What is your assessment of the technology development achievement in your company?
8. What is the strongest technological capability of your company? What is your competitive advantage?
9. What are the key proprietary technologies developed by your company? Under what conditions are these technologies developed?
**Company Efforts**

10. What are the key strategies or policies for your company to compete with other companies in the industry?

11. What are your company’s technology strategies?
   - How does your company improve technological capability?
   - How does your company access the latest technology?
   - How much does your company invest in technology development (R&D and TT)?
   - How does your company train its employees?
   - How many people in your company are doing jobs related to technologies? What is their educational background?

**Factors of Technological Capability Development**

12. What are the key factors affecting technological capability development in your company?

13. What do you think about the ICT’s influence on your company’s technological capability development process?

**Technology Alliance**

14. What are the main methods in your company to acquire new technology?

15. Does your company cooperate with others and set up alliances with them?

16. How does your company set up alliances with others?

17. What are the main objectives of your cooperation and your research?

18. What will affect your company’s decisions regarding cooperation projects and cooperation partners?
Curriculum Vitae

I, Jun Jin, was born on the 10th of May 1973 in Hangzhou, China.

- EDUCATION:
  - 10/02 – 10/05  University of St. Gallen, St. Gallen, Switzerland
    Doctoral Programme “Internationales Management-Ostasien”
  - 9/99 – 3/02  Zhejiang University, Hangzhou, China
    MBA: Technology Management
  - 9/91 – 7/96  Zhejiang University, Hangzhou, China
    Bachelor: Engineering in Biomedical Engineering

- EXPERIENCE:
  - 7/04 – 03/05  Asia Research Centre, University of St. Gallen, Switzerland
    Research Assistant
  - 7/96 – 9/02  Zhejiang Provincial Medical Equipment Co, Ltd, Hangzhou
    Project Manager
  - 9/99 – 3/02  Centre of Management Science and Strategy, Zhejiang University, Hangzhou, China
    Research Assistant