KNOWLEDGE SHARING PROGRAM

2011 Modularization of Korea's Development Experience:

Building Technological Capabilities: Four Cases from Manufacturing Sectors in Korea

2012

Ministry of Knowledge Economy

Center For Economic Catch-up
Seoul National University

2011 Modularization of Korea's Development Experience:

Building Technological Capabilities: Four Cases from Manufacturing Sectors in Korea

2011 Modularization of Korea's Development Experience

Building Technological Capabilities: Four Cases from Manufacturing Sectors in Korea

Title	Building Technological Capabilities: Four Cases from Manufacturing Sectors in Korea
Supervised by	Ministry of Knowledge Economy, Republic of Korea
Prepared by	Center for Economic Catch-up, Seoul National University,
Author	Keun Lee, Professor, Director of Center for Economic Catch-up, Seoul National University Yoon-Ji Kim, Researcher, Overseas Economic Research Institute of Korean Export-Import Bank Jeehoon Ki, Doctoral Student, Seoul National University, Center for Economic Catch-up Hochul Shin, Doctoral Student, Seoul National University, Center for Economic Catch-up
Advisory	Young- Rak Choi, Professor of Management of Technology, Korea University
Research Management	Korea Development Institute (KDI) School of Public Policy and Management
Supported by	Ministry of Strategy and Finance (MOSF), Republic of Korea

Government Publications Registration Number 11-1051000-000238-01

ISBN 978-89-93695-82-3 94320

ISBN 978-89-93695-27-4 [SET 40]

KNOWLEDGE
SHARING
PROGRAM

Government Publications Registration Number
11-1051000-000238-01

Knowledge Sharing Program

2011 Modularization of Korea's Development Experience

Building Technological Capabilities: Four Cases from Manufacturing Sectors in Korea

Ministry of Knowledge Economy

Center For Economic Catch-up
Seoul National University

Preface

The study of Korea's economic and social transformation offers a unique opportunity to better understand the factors that drive development. Within one generation, Korea had transformed itself from a poor agrarian society to a modern industrial nation, a feat never seen before. What makes Korea's experience so unique is that its rapid economic development was relatively broad-based, meaning that the fruits of Korea's rapid growth were shared by many. The challenge of course is unlocking the secrets behind Korea's rapid and broad-based development, which can offer invaluable insights and lessons and knowledge that can be shared with the rest of the international community.

Recognizing this, the Korean Ministry of Strategy and Finance (MOSF) and the Korea Development Institute (KDI) launched the Knowledge Sharing Program (KSP) in 2004 to share Korea's development experience and to assist its developing country partners. The body of work presented in this volume is part of a greater initiative launched in 2007 to systemically research and document Korea's development experience and to deliver standardized content as case studies. The goal of this undertaking is to offer a deeper and wider understanding of Korea's development experience with the hope that Korea's past can offer lessons for developing countries in search of sustainable and broad-based development. This is a continuation of a multi-year undertaking to study and document Korea's development experience, and it builds on the 20 case studies completed in 2010. Here, we present 40 new studies that explore various development-oriented themes such as industrialization, energy, human capital development, government administration, Information and Communication Technology (ICT), agricultural development, land development and environment.

In presenting these new studies, I would like to take this opportunity to express my gratitude to all those involved in this great undertaking. It was through their hard work and commitment that made this possible. Foremost, I would like to thank the Ministry of Strategy and Finance for their encouragement and full support of this project. I especially would like to thank the KSP Executive Committee, composed of related ministries/departments, and the various Korean research institutes, for their involvement and the invaluable role they played in bringing this project together. I would also like to thank all the former public officials and senior practitioners for lending their time and keen insights and expertise in preparation of the case studies.

Indeed, the successful completion of the case studies was made possible by the dedication of the researchers from the public sector and academia involved in conducting the studies, which I believe will go a long way in advancing knowledge on not only Korea's own development but also development in general. Lastly, I would like to express my gratitude to Professor Joon-Kyung Kim for his stewardship of this enterprise, and to his team including Professor Jin Park at the KDI School of Public Policy and Management, for their hard work and dedication in successfully managing and completing this project.

As always, the views and opinions expressed by the authors in the body of work presented here do not necessary represent those of KDI School of Public Policy and Management.

May 2012

Oh-Seok Hyun

President

KDI School of Public Policy and Management

Contents | LIST OF CHAPTERS

Contents | LIST OF TABLES

Chapter 2

Contents | LIST OF FIGURES

Chapter 1

Chapter 2

Summary

The process of economic development involves growth of a certain number of industries, where firms may flourish and enhance their capabilities. The essence of enhancing the capabilities of private firms requires assuring them the initial rents (profits) and learning opportunities until they grow enough to compete successfully in world markets. This report has discussed several ways of doing this in four different sectors or technologies, with a focus on the role of the government.

In mainstream economics, the government is often considered as a “invisible foot,” such that its intervention into the market economies may often lead to worse results than without such intervention. While such assessment would be true on average across countries, this does not preclude the possibility that in certain context and under certain conditions, the government activism may lead to desirable outcomes. This report explores what such conditions would be based on the case examples from Korea’s past.

In general, it is our theoretical opinion, based on the concept of the SSI (Malerba 2004) and other work from a Neo-Schumpeterian perspective, that the specific forms of the government activism should be different in different sectors featured by the different regimes of technologies and markets. When we consider diverse forms of involvement, ranging from simple protection by tariffs, direct subsidies to production, indirect help through GRIs (government research institutes), sharing and provision of R&D expenses, public-private R&D consortium, and direct entry by the SOEs, we can easily reason that these tools would all have different degree of effectiveness in different market and technological environments. So, it is not easy to spell out the conditions and context in a simply way. The following is an attempt based on the 4 cases of technological development in Korea, including telephone equipment, steel industry, machine tools and TV/display sectors.

1. When Targeting May be Justified

Let us start from a commonly made observation that when the sectors/technologies are featured by more uncertain trajectories, direct technology targeting by the government would better be avoided. However, it is equivalent to say that when there is less uncertainty, targeting might work. Warning against targeting makes more sense in the context of the developed countries whose firms are on the frontier of technologies facing greater uncertainties. In the context of the latecomer there is a ready justification for targeting industries: these are the industries or technologies that the latecomer economies are importing or buying at monopoly prices because these products are monopolized by foreign companies. In this import-substituting targeted development, local efforts face less uncertainty or risk because targeted technologies are often mature technologies that are not impossible to emulate by means of concentrated efforts by local indigenous R&D consortium.

The case of TDX development discussed in chapter 3 is a good example. When the technological regimes are featured by the less frequent innovations and less fluid and thus stable technologies, a more directed involvement of the government in the form of sharing and/or providing a part of direct R&D budget can be justified. But, as the case shows, this process should ultimately lead to enhancement of capabilities among the private firms. Then, there would be less need for government involvement, which is the case in the later stage of technological development in Korea.

2. How to Do It Under the Uncertain Technological Regimes

While the above discussion is about justifying government targeting when there is less uncertainty, the next question is, then, what can be done under more uncertain environment, or when you are close to the frontier. The case of digital TV development discussed in chapter 6 indicates that the nature of the public intervention should be different. In this case of uncertain world, the role of the public research organization (PROs) or GRI seems to be important in reducing the uncertainly, especially about the choice of right technologies or standards. The role of the PROs, of course, should be a part of the broader public-private R&D consortium.

In the case of digital TV consortium, like the cases of TDX or DRAM, contribution of the GRI's is critical in conducting the role of "technology watch" to interpret and monitor the state-of-the art trend of R&D activities in foreign countries (Lee et al 2005); it was the KITECH and ETRI that carried out R&D activities and coordinated the consortium of the research projects in two specific fields of the whole project. The consortium served as a field to pool together the domestic resources from various sources, especially resources in the universities that is often a reservoir of new scientific findings. Otherwise, the degree of knowledge sharing among the private firms would have been impossible or much lower. The participating private firms all acknowledged the importance of the government's role in providing the legitimacy to the big projects that are often difficult to be supported by private firms.

3. Slow Progress with State Activism: Capital Goods

In general, capital goods, especially, machine tools industry, are featured by the low frequency and low volatility of innovation, which suggests that catching up would not be so difficult for latecomers. However, this is the sector that catching up has been most difficult and slow. The chapter five has identified several sources for difficulties. First of all, while small firms in the capital goods industry are usually specialized suppliers to big final goods assembly firms in consumer goods or other industries, and thus the tacit knowledge accumulated from the interface between the producer and the customer firms is very important, local client firms are reluctant to use locally made capital goods due to their poor quality and low precision level. In this matter, even the government policies to encourage the use of domestic products have hardly been effective. Furthermore, the government cannot simply protect local producers by charging high tariffs, because use firms would want to import the products at lower prices than using the unreliable domestic products.

Despite these intrinsic difficulties, the Korean economy has achieved a very slow but gradual catch-up in capital goods industry, giving rise to several successful companies. The chapter has attributed such achievement to several factors, strenuous effort by the government, niche markets in general-purpose machine tools and emerging economies, so-called BRICs and finally increasing introduction and adoption of IT or digital technologies in machine tools. This implies importance of a much longer term orientation in policy intervention in capital goods, than shorter-term oriented measures.

4. Classical Case of Positive Externalities and Linkages

A much easier case for state activism justifiable from a textbook economics is the case where there is a certain degree of positive externalities such that market failure prevails in terms of the gap between private and social return. The case of steel industry promotion by the establishment of POSCO would fit in this story. Given that there was no private firm that dared to take this job of starting integrated steel in the 1960 Korea with uncertain conditions, it would lead to market failure of under-production of steel by private actors. Furthermore, steel is an input to diverse sectors of production. Given high degree of scale economy and a limited size of domestic market as in the Korea's past, it was certain that it would be under-produced if it were left with private firms, and the private monopoly would charge excessively higher prices under monopoly. Just rely on imported steel would lead to no benefits from backward and forward linkages. Under these conditions, entry by establishing an SOE seemed to be a rational choice in the context of the past Korean economy.

Technological uncertainty was lower because steel production was old and mature technologies, and, furthermore, as discussed in chapter 4, Korea's entry and expansion at a later stage took advantage of the lowered price of factory equipments and facilities during the world wide recessions, namely the first and second oil shocks. Market uncertainty was lowered by the government and private effort to grow automobiles, ship building and other steel using industries.

Finally, when POSCO equipped itself with enough international competitiveness, the privatization began with the state share sold to the public.

5. Conceptualizing Toward a Korean Model of Technological Development

While the above 4 points suggest a mode of effective government intervention in diverse specific conditions, we can also attempt to find a grand conceptualization for a Korean model of technological development. If such a thing is possible, it would be a model of a three party cooperation or the GPG model, a cooperation of the Government research institutes-Private firms-Government ministries, with possibly different roles of each party, depending upon the nature of the projects. Given that whatever case of technological development should involve the three elements consisting of R&D, production, and marketing, the GPG model implies that government research labs are in charge of R&D, private firms in charge of production, and the government in charge of marketing in the form of direct procurement or protection by tariffs and exclusive standards.

While the case of TDX would be the most typical representation of this GPG model (let us call this GPG1), there are some variations depending upon the level of capabilities of private firms and public agents involved. The case of digital TV and CDMA is another variation that can be called a GPG2. In the GPG2, costs and risk of R&D are shared between government research institutes and private firms, and the GRIs do the role of technology-trend watching and coordination to bring in diverse actors into the consortium. This GPG2 model can be considered as a more advanced form of the GPG in that it is possible only when the capabilities of private firms are more advanced to be able to more R&D.

The case of the machine tool industry also belongs to the 'GPG2' with more R&D shifted to the hands of private firms rather than government research institute as the role of government was limited to providing the R&D fund and protection of infants by tariffs. The major role of the government (or ministries involved) tends to be funding R&D, guaranteeing the initial markets in the form of procurement policies, and/or local market protection by tariffs or exclusive standard declarations.

Another variation of the GPG model is the case of government agents conducting both R&D and production, and this is possible when capabilities of private firms are nil or the nature of projects tend to involve more production and less R&D. This variation can be called GPG0 but is actually not GPP but GG without P (without involvement of private firms), and the case of POSCO or steel development by the government-owned enterprise is a good example.

The opposite case to this GPG0 or GG mode GPG3 or PG, where government research institute is missing. An example is the case of development of automobile industry spearheaded by Hyundai Motors. As discussed in Lee and Lim (2001), in this case, the government or a government research institute was not involved in R&D but its role was limited to providing protection of infant industries by settomg tariffs. As R&D was done by a private firms or Hyundai Motors, it is the GP model, not GGP model, with private firms doing both R&D and production.

In sum, based on the cases in the Korean economy, we have identified the four modes of state activism for technological development, and in the increasing order of more role for a private firm, they are 1) the GPG0 (or) GG mode with the government doing market provision and government owned enterprise doing both R&D and production, 2) GPG1 mode with R&D by GRIs and production by private firms, 3) the GPG2 with more R&D shifted to the hands of private firms who are cooperating with the GRIs, and finally 4) GPG3 (or PG) mode where private firms doing both R&D and production. In all of these variations, the role of the government (or ministries involved) tends to be guaranteeing the initial markets with various forms of procurement policies, and/or local market protection by setting tariffs or exclusive standard declarations. The latter three modes are similar to the three stages on the roles of the GRIs discussed in Choi et al (2010: ch. 5).

Although we have arranged the 4 modes (GPG0-GPG1-GPG2-GPG3) of GPG in the order of increasing role of private firms, this does not mean that they have appeared in that sequence nor should be implemented in that order. Actually, the GPG3 mode of Hyundai Motors appeared earlier than the GPG2 mode of digital TV. In this sense, we are different from the traditional stage model of technological development, and are not proposing any such theory. Rather it is our view that it is not necessary for other latecomer countries to follow the modes in the above sequence but that they can or should choose whatever appropriate stage or variation in consideration of their specificities, in particular the level of capabilities of private firms, as well as the nature of regimes of technologies and markets.

In the above discussion of the modes of technological development, the focus has been on the roles of government ministries or research labs. However, it is worth noting that one common element across the four modes of technological development is that they all involved acquiring advanced foreign knowledge and technology through diverse channels. As discussed in many literature (Lee et al 2005), the role of foreign knowledge is very critical, without which the latecomers' catching-up effort is often at risk and takes too much time and costs. In general, the diverse channels of knowledge access and learning included a variety of modes such as training in foreign firms and institutes, OEM, licensing, JVs, co-development with foreign specialized R&D firms, transfers of individual scientist or engineers, reverse brain drains, overseas R&D centers, strategic alliances, and international

M&A's. All these constitute effective channels of knowledge transfer around which firms are able to strategize.

Then, we can say that successful technological development by the latecomers tend to involve three elements, namely, government supports, access to foreign knowledge, and finally private firms' effort, and the weight and specific role of the three elements would differ by the sectors and levels (or stages) of economic development.

Chapter 1

Introduction

Introduction

1. Introduction

As one of the most successful late-comer economies, Korea has been subject to research from diverse angles. While the more traditional literature tends to focus on the role of the government vs. markets in catching-up development (Amsden 1989; Chang 1994; World Bank 1993), there has also appeared another stream of literature, namely technology-based view on Korea (Hobday 1995; L. Kim 1997; Lall 1980; Dahlman, Westphal, and Kim 1985). Following the latter tradition, this report is to elaborate the process of technological development in Korea with a focus on the role of the government. Rather than examining overall economic development, this report focuses on the four sectors of telecommunication equipment, steel, machine tools, and TV/display industries. This report takes a "capability-based view" on the Korean or Asian experience in catching-up development, which was put forward in Lee and Mathews (2010) and Lee (2009).

Although this approach may be considered as an extension of technology-based view it is distinct from the government-market dichotomy since it has more sound micro-economic foundation. Our starting point is the recognition that the most fundamental barriers to sustained development is whether to build technological capabilities or not. Also, a country's long term destiny depends on the capability to produce and sell internationally competitive products for a prolonged period of time. One core element of the Korean model is its focus on building these capabilities, among private firms in particular.

Korea used to be in the same situation as other developing countries, continually facing external imbalances with persistent trade deficits during the first two decades of industrialization in the 1960s and 1970s. However, since the 1970s the government put the emphasis on technological development by publicly funding and conducting R&D and giving the results to private firms, promoting private R&D by tax incentives and, in the 1980s, even initiating public-private joint R&D for bigger and risky projects (Lee 2009). Intensification of R&D expenditure since the mid 1980s triggered by the government exemption of taxes on R&D expenditure laid the basis for catching up growth (Lee and Kim 2010).[1] This policy initiative succeeded in strengthening the manufacturing sector, which was an important factor behind the trade surplus that occurred in the late 1980s, for the first time in the modern Korean history. Since then, Korea has been able to overcome the persistent trap of external imbalances or stop-go cycles of crisis and reforms.

Countries that followed the Washington Consensus and focused on macroeconomic stabilization and trade liberalization experienced some improvements but these tended to be short-lived. While Rodrik (1996) noted the importance of sequential adoption of 10 policies of the Washington Consensus in East Asia, he misses the point that East Asia had further built up and upgraded capabilities before going to more marketization (next 5 policies in the Washington Consensus) since the mid 1980s (Lee and Mathews 2010).

When we see catching-up growth as the process of capacity building, what we have in mind is the capacity of private corporations. The capacity of latecomer economies to nurture capable private companies is the most important and fundamental criterion to determine the success or failure of sustained economic development or growth. They may initially be state-owned firms (eg. POSCO), when the risks for private capital are too high, but the idea is to move them towards private ownership (i.e. make them 'public' through an IPO) eventually.

Among various aspects of capacities, emphasis should be on technological capabilities because without these, sustained growth is impossible. In this era of open market competition, private companies cannot sustain growth if they rely upon low price products; they need to be able to move up the value-chain to higher-value added goods based on continued improvement through technological innovation. Furthermore, another important feature of the Korean model is that these private companies have been "locally owned" companies including locally controlled JVs, not foreign controlled subsidiaries of the MNCs. MNCs subsidiaries are always moving around the world seeking cheaper wages and bigger markets. Therefore, they cannot be relied upon to generate sustained growth in specific localities or countries although they can serve as useful channels for knowledge transfer and learning.

In what follows, we first set out the theoretical framework of our analytical narratives in Chapter 2, with a focus on the SSI (sectoral systems of innovation) of Neo-Schumpeterian economics. Then, chapters 3, 4, 5, and 6, discuss the technological development in each of the four sectors. Chapter 7 concludes the report with a summary and policy lessons.

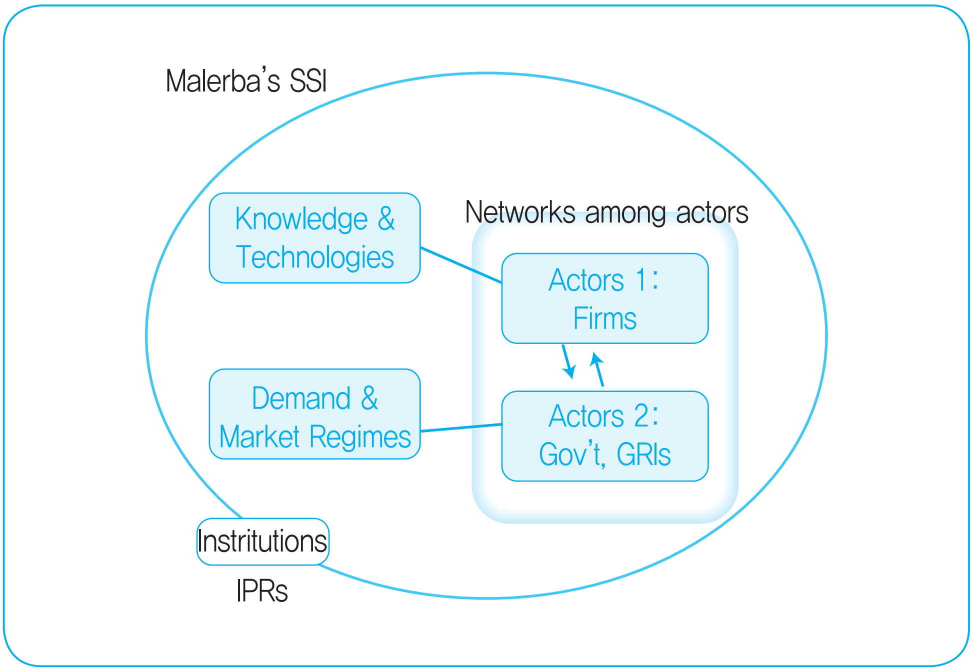
1 Emphasis on R&D was initiated jointly with turn of the focus of industrial policy from sector-specific to functional intervention with the promulgation of the Industry Development Law that came into effect since 1986 (See Korean Economy Compilation Committee 2010; Y. Kim 2005).

2. Theoretical Framework

In explaining the technological development in several sectors in Korea, this report uses the theoretical framework of the SSI (sectoral systems of innovation) that has been developed and evolved by a group of scholars following Neo-Schumpeterian tradition. In particular, we resort to Malerba (2004). The theoretical building blocks of Malerba's SSI consists of the following four: regimes of knowledge and technologies; demand conditions (or market regimes); actors and networks and coordination among them; and the surrounding institutions including IPRs, laws, culture and etc. However, the book edited by Malerba (2004) deals with cases and sectors from the developed countries. Thus, while we will apply the same framework, we expect some modification or adaptations necessary to make it more applicable to the specific context of Korea's pastwhen it was a developing country.

Similar adaptations have been made by Lee and Lim (2001), Lim, Lee and Song (2005), Mu and Lee (2005) and Mani (2005 a and b) in their analysis of the industry case studies of China, Korea, and India with theoretical concepts such as the sectoral innovation system or technological regimes as its sub-components. For instance, we will put more emphasis on a) importance of arranging access to foreign knowledge base, b) initial promotion and coordination by the government, and c) how to create and sustain competitive advantage and capabilities of local or indigenous firms.

Figure 1-1 | Building Blocks of the Sectoral Systems of Innovation (SSI)



Here, the degree of success in catch-up is primarily measured by catch-up in market shares which should be, if it is to be sustained, backed up by technological catch-up or learning. The key three building blocks of the SSI are discussed here with more specific connotations for catch-up. The first block or regime of knowledge and technologies is related to the probability of successful development of specific technologies or products by the late-comer firms or actors. The second block or demand conditions determine whether the technologies or products developed by the late-comers can succeed in markets and thus increase their market shares. The third block or actors include primarily firms, government and other supporting actors including financial systems. It is basically firms' strategic decision how to play with the demand conditions and given knowledge systems. Because the ultimate criteria for successful catch-up related to the level of technological capabilities of the firms, the focus in this paper is also about what is happening to the firms in charge of the whole process.

But, in the context of catch-up which tends to have low odds given the fierce competition from the incumbent firms from the developed countries, more often than not, the role of the government is critical during the initial stage of technology development and market development. The literature has found many cases that the governments provide a substantial portion of initial R&D expenditure or protection for the indigenous products. This emphasis on the role of the government is different from the usual situation in the advanced countries where the actors' focus should be more on financial systems and overall NIS. But, in most developing countries, financial markets are often deficient, calling for more intervention by the government in the form of credit rationing.

Regarding regimes of knowledge and technologies, we perceive this block as determinants of probability of physical development of specific technologies or products. Then among determinants, we will focus on the easiness of arranging access to foreign knowledge base. This focus can be considered different to the case of the advanced countries where the focus in the knowledge regime would be more on general property of knowledge base of the sector. Given that catch-up is basically a process of reducing the knowledge gap between the forerunners and latecomers, possibility of learning and transfer opportunity is a critical element. Importance of access to knowledge has been confirmed in many cases including Lee and Lim (2001) for six industries in Korea, Lim, Lee and Song (2005), Mu and Lee (2006) for China. As explained in Lee (2005), the access can be arranged in diverse forms including informal learning, training in foreign firms and institutes (Choi et al (2010), licensing, FDI, strategic alliance, co-development, and so on.

In sum, given our goal of explaining the divergent stories of catch-up or lagging behind, we will put more emphasis on a) the process of development of indigenous technologies by arranging access to foreign knowledge base, b) initial promotion and coordination role by the government, and c) how to create and sustain competitive advantage and capabilities of local or indigenous firms.

This work of elaborating the process of technological and market catch-up will also involve discussing the patterns of catch-up, such as path-following catch-up, stage-skipping catch-up, and path-creating catch-up (Lee and Lim 2001). First, there is a path-following catching-up, which means the late-comer firms follow the same path as that taken by the forerunners. The second pattern is a stage-skipping catching-up, which means that the late-comer firms follow the path to an extent but skips some stages, and thus save time. The third pattern is a path-creating catching-up, which means that the late-comer firms explore their own path of technological development. This kind of catching-up can happen when the latecomers turn to a new path after having followed the path of the forerunners, and thereby creates a new path. Beside these three pattern, it is also useful to consider another mode, namely path-revealing catch-up, discussed by Dr. Choi in Choi et al (2010) and National Academy of Engineering of Korea (2010). Path-revealing catch-up applies to the situation in which although the problems that need solutions are already uncovered but their solutions are not known and thus need to be discovered by the latecomers. In a sense, finding a new solution to the existing problems could be considered as going through a new path distinct from the incumbents.

As the analyses in the following chapters show, the Korean experience shows that there are cases of not only path-following but also stage-skipping or path-creating. These elements are not properly addressed in the more traditional but still influential framework of the variants of stage-based theory of technological development, including L. Kim (1997a), moving from duplicative imitation to creative imitation, and to innovation stage. The stage theory of technological development is more relevant in the context of technological development within the given technological paradigm or trajectory. So, in this stage theory, the issues of technological skipping or leapfrogging and the associated risks would tend to sit somewhat uncomfortably (Lee et al., 2005), and there is not much room for discussion of such issues as standard competition. Also, the framework by L. Kim (199a) focus on the situation at the firm-level while there is less room for involving the role of the government. It is for this reason that we are utilizing a broader and more flexible framework such as the SSI which allow for more room for interaction of diverse actors including government, public research labs, and institutions, in addition to firm-level variables. In particular, given our central position that the role of the government should differ depending upon the technology and knowledge regime of sectors, we consider the SSI framework is more relevant than other theories of technological development.

Combining the elements from the SSI framework with the patterns of catch-up, we can make, for example, the following statement (Lee and Lim 2001): A path-following or skipping catching-up is more likely to happen largely by private initiatives in industries where innovations are less frequent or cumulative and the innovation path is more predictable, and thus the catching-up target is more easily identified, whereas a path-creating catching-up is more likely to happen by public-private collaboration where the involved technology is more fluid and the risk is higher with bigger capital requirements. While the above is an example, the following chapters will provide more elaboration on the specifically effective mode of government activism in different contexts or in different regimes of technologies and market which interacts with firms and public actors with different levels of capabilities.

While this report focuses on the role of the government, it should be noted that the private firms are the ultimate reservoir of the technological capabilities and thus without close collaboration with private firms, nothing productive could happen. In a sense, one of the trickiest parts of the Korean model of the technological development lies in the interface between the public and private actors. Another critical interface would be that of foreign knowledge and domestic learning effort. As the analysis in the following chapters will show, one common element across the four stories of technological development is that they have all involved arranging access to foreign knowledge through diverse channels. As discussed in many literature (Lee et al 2005), the role of foreign knowledge is very critical, without which the latecomers' catching-up effort is often at risk due to its time consuming and costly nature. In general, the diverse channels of knowledge access and learning included modes such as training in foreign firms and institutes, OEM, licensing, JVs, co-development with foreign specialized R&D firms, transfers of individual scientist or engineers, reverse brain drains, overseas R&D centers, strategic alliances, and international M&A's. All these constitute effective channels of knowledge transfer firms may utilize for strategic development.

Then, we may say that successful technological development by the latecomers tend to involve the three things, namely, government supports, access to foreign knowledge, and finally private firms' effort, and the weight and specific role of the three elements would differ by the sectors and levels (or stages) of economic development.

In what follows, each chapter of the report deals in sequence with the telecommunication equipment sector with a focus on the telephone switch development (chapter 3), the steel industry with a focus on the case of POSCO (chapter 4), the machine tools sector with a focus on the SMEs (chapter 5), and finally the TV and display industry (chapter 6) with a focus on the leapfrogging into digital TV technology. The steel, telecommunication equipment, and TV industries are chosen because each of them represents the different degree and forms of the state involvement, namely from stronger to least involvement, as will be summarized in the final chapter, and the machine tools sector is chosen as it represents the case of the SMEs.

There will be some variations across sectors, but each chapter will include discussion of the technological regimes of the sectors/technologies, the process of the technological development and the promotion of indigenous firms, and the role of the government in interaction with the firms, and finally the lessons and policy implications.

2011 Modularization of Korea's Development Experience
Building Technological Capabilities:
Four Cases from Manufacturing Sectors in Korea

Chapter 2

Building Technological Capabilities

Building Technological Capabilities

1. Telecommunication Equipment Industry

1.1 Overview

Korea had telephone service bottlenecks in the 1970s and 1980s. Until the late 1970s, Korea neither had its own telecommunications manufacturing equipment industry nor a research and development (R&D) program. Consequently, the country imported most of equipments and technologies, and the Korean technicians merely installed foreign switching systems into domestic telephone networks of the country (See Table 2-1).

Table 2-1 | Evolution of the Telephone Switching System in Korea

Model		Global Commercialization	Installation in Korea	Technology acquisition Methods
Manual switch		1880s	1896~	Equipment import
Automatic switch	Electro-mechanical switch	1890s: Step-by-step switch	1935~: Strowger 1960~: EMD	Equipment import FDI, Technology Alliance
		1930s Crossbar witching	No installed	-
	Electronic switch	1960s~: Analogue electronic switch	1979~	Technology import, FDI
		1970s~: Digital electronic switch	1982~1985: TDX series	Technology import, FDI; Developed by Korea
		1990s: ISDN	1991~	Developed by Korea

Source: Adaptation based on Lee and Lee (1992); Recited from Mu (2002)

With rapidly developing industrial and commercial bases and a growing population (approaching 36 million people), the telecommunications services in Korea fell far behind the demand in the late 1970s. Hence, after prudent considerations, the Korean government decided that the country must build its own manufacturing capabilities and the R&D infrastructure necessary for the creation of state-of-the art digital phone switching systems.

The Korean consortium tried relentlessly and the Korean Electronics and Telecommunications Research Institute (ETRI) had developed a proprietary digital switching system, called the TDX (time-division exchange) series, in collaboration with the national network of switching system manufacturers and distributors from 1981 to 1983. Thus, the development of a switching system in Korea began with the manual switch, followed by the step-by-step switch, the analog electronic switch, the digital electronic switch, and finally the skipping crossbar switch.

This locally developed product took away market share of imported goods and those of multinational companies (MNCs). Its enhanced capabilities accumulated over the recent decades have led to developments in local capabilities in wireless telecommunications. By the early 1990s, the Korean market was dominated by Motorola. In the mid-1990s, Samsung and then LG entered the market and caught up with Motorola, whose share plummeted to almost zero in 1997. Since then, the foreign manufacturers never recovered their market shares in Korea.

This case shows that if local players develop indigenous capabilities, they can overcome difficulties associated with abrupt technological changes or discontinuities. The case of the mobile telecoms in Korea is a case of successful transition from digital switches (fixed lines) to mobile telecoms. More interestingly, they have taken advantage of the emergence of the new era to manage even a path-creating catch-up, such as the commercialization of the CDMA technology in Korea. This is in contrast with the stage-skipping catch-up, which they had devised in developing digital switches. On the other hand, if the latecomers fail to enhance their own capabilities, the shift in technological paradigm may serve as an additional barrier to catch-up, as what happened in Brazil and India. Therefore, paradigm (or generation) shifts may serve both as a window of opportunity (as for China and Korea) and a barrier to entry (as in India or Brazil) to the success of the latecomers (Lee, Manil and Mu 2011 forthcoming).

1.2 The Regime of Knowledge and Technology of Telephone Switches

As Mu and Lee (2005) have rigorously analyzed, the technological regime of the telephone switches was characterized by a more predictable technological trajectory and less frequent innovations, at least since the 1980s, particularly when Korea was just starting to develop the switches.

In the study by Mu and Lee (2005), the nature of the technical trajectory is addressed by examining the ages and life cycles of new technologies in switches and by counting the frequency of innovative patents. Given the history of telephone switches from the Manual switch (1880s to 1920s) to the electro-mechanical switch (1920s to 1960s) and then to the electronic switches, such as stored program control (SPC) switches (1965 to present), the relatively long life spans of the generations of telephone switches may be noticed. The average life-span of an electro-mechanical switch in service was roughly 35 to 40 years. However, some individual users have been using the electro-mechanical switches for as long as 55 years (Dittberner 1977). This type of switch is still being used worldwide, despite the introduction of the digital automatic switch over 35 years ago. This trend shows that the telephone switch industry is characterized by a more predictable technical trajectory compared to other industries, such as that of computer. While the life cycle of computer products is about six years, that of telecommunication switch equipment ranges from 20 to 40 years; that of transmission equipment is from 10 to 20 years (Duysters 1996).

In addition, the patenting trend in telephone switches shows that the regime is characterized by less frequent innovations (see Table 2 of Mu and Lee 2005). When the number of patents related to telephone switches was checked through key word search in the US PTO website, it was found that from 1977 to 1992,[2] the average annual growth rate of related patents was only -0.6%, whereas that of other emerging technologies, such as DRAMs (dynamic random access memory chips), is much higher (e.g., 30% in the case of DRAM during the same period, and the same is true for wireless communication technologies).[3] The frequency in innovation is also related to the age of the technologies, such that old technologies tend to show more stable technological trajectory.

Thus, given the more predictable technological trajectory and the less frequent innovations, it may be inferred that the fixed line telephone switch is relatively easy to be emulated and to be developed by the late-comers. However, the chances cannot be high, unless an effective access to foreign knowledge and/or a planned effort to achieve this goal exists. Furthermore, such nature of the technological regime is expected to lead to a stage-skipping catch-up because the late-comer can more easily aim to skip some stages and to target the later stages.

Actually, this was the case in Korea and China. China had only some experience in the development or production of electro-mechanical switches. It skipped the development and production of analogue electronic switches and jumped directly to that of digital automatic switches (Mu and Lee 2005). Similarly, Korea had an experience with manual and step-by-step switches. It then leapfrogged into analog electronic switches, and then into digital

2 We looked at this period because the Chinese project on developing local digital electronic telephone switches started in the mid-1980s but succeeded only in 1991.

3 For comparison of growth rates of US patents in several technology categories, see Lee and Lim (2001).

electronic switches, thus skipping crossbar switches (Mu 2002). The importance of access to a foreign knowledge base should thus be emphasized. It is important in determining the success of the local development of digital switches in late-comer countries.

1.3 The Development of Fixed-line Telephone Switches

In the process of the development of local digital switches (the so-called TDX) in Korea, some technologies were absorbed by licensing with the ITT, AT&T, and LM Ericsson/Erifon, just as prior experiences with producing analogue switches were absorbed with the help of licensing agreements.

The development of a Korean-owned digital switching system TDX series was based on technology purchased from advanced countries that dates back to the 1970s. Before developing and producing its own digital switches, Korea first purchased a licensing analogue switching technology because of its weak technology and financial capabilities. To purchase manufacturing technology on analog switching and produce switches in Korea by September 1977, the state-owned company Korea Telecom Co., Ltd (later acquired by Samsung Semiconductor & Telecom Co., Ltd, which was integrated with Samsung Electronics Co., Ltd.), purchased the M10CN technology from the Bell Telephone Manufacturing Company (BTM), the subsidiary of the International Telephone and Telegram Corporation (ITT, later purchased by Alcatel of France). Because one company alone was not able to meet the market demand for switches, another joint venture, GoldStar Semiconductor Co., Ltd., was created by the Lucky GoldStar Group and AT&T. GoldStar Semiconductor Co., Ltd., imported the No. 1A technology from AT&T in November 1979 (Hwang 1993).

Two years later, KTC continued to license digital switching S1240 technology from ITT, and Gold Star imported digital switching 5ESS technology from AT&T. Although the creation and importation of technology by the joint venture helped Korea to acquire knowledge of the switching system, they have not directly led to the development of local digital switching system in Korea.

Starting in 1979, under the guidelines set by the government in its fourth five-year national economic development plan, 300,000 new telephone-lines were activated each year. The effort, however, still left Korea farther and farther behind in meeting its explosive growth in demand for telephone services. As a result, in 1982, the government acknowledged that the local production of TDX switches would be insufficient to meet the growing demand for telephone service. Therefore, the Ministry of Post and Telecommunication opted for a strategy of simultaneously patronizing imported and self-developed technologies during this period. Such a movement hoped to help satisfy the demand for services and, at the same time, develop advanced information technologies, particularly the phone system networking technologies. However, a strong initiative for the development of local digital switches was advanced by a team of bureaucrats and engineers, because they computed that local development can save a fortune given the high prices of imported facilities (Oh 2009). Thus, they formed a tri-partite consortium among the ministry and KT (an SOE), the ETRI (a GRI), and private firms, including Goldstar and Samsung.

In this process of development of local technology, the ETRI publicly purchased digital switching designs and engineering technologies from Ericsson (Hwang 1993). On the basis of the imported digital switching design and engineering technology from Ericsson's AXE-10, the ETRI first developed a proto-type, called model TDX-1X, in July 1982 (J. Kim 2000, p. 136). This achievement made Korea the 10th country in the world to develop an electronic switching system. Thereafter, in December 1983, a Korean team successfully developed TDX-1, which is more effective than and distinct from the AXE-10 (Mu 2002).

ETRI transferred the technology of TDX-1 to four manufacturing firms: GoldStar Semiconductor Co., Ltd., Daewoo Telecom Co., Ltd., Dongyang Electronic & Telecom Co., Ltd., and Samsung Semiconductor & Telecom Co., Ltd. After the successful development of the TDX-1 switching system, ETRI continued to improve the technology in collaboration with a network of stakeholders, consisting of ETRI, TDX's manufacturing firms, KT, and the universities, to produce more advanced versions, such as the TDX-1A in 1986, which can accommodate up to 10,240 subscribers. The TDX-1A technology was quickly disseminated to manufacturers who mass produced the systems mainly for rural and small-city markets at first.

In December 1988, manufacturers of TDX developed the TDX-1B, which had a 20,000 line capacity, to improve the capacity and other features of TDX-1. Then, ETIR, together with TDX manufacturers, KT, and the universities developed a newly-designed large capacity switching system TDX-10 with 100,000-line capacity.

On March 1986, the locally developed switch, called TDX 1 (10, 240 line capacity), was first targeted at rural areas or smaller cities. The four areas where TDX1 was installed included Gapyoung, Jeonkok, Goryung, and Muju, which were rural areas, not cities (J. Kim 2000, p. 138). Only after the success of the experimental installation in these four areas did KT (Korea Telecom) decided to produce the model in large scale since late 1986. Starting 1987, the modified model (TDX-1A), with a capacity of 10,240 lines, was installed in a large scale covering 36 areas in the country with a total capacity of 189,000 lines. The same was true for the TDX 1B (22,528 lines) that was developed in 1989 by four private companies. The first large capacity switches to target the urban areas was the TDX 10 (over 50,000), which was developed in 1991.

1.4 The Roles of the Government

In Korea, the support and protection by the government were important factors in the sourcing of competitive advantages in the development of the Korean switching system and market competition. The ministry or the government procured locally developed switches in 1980s. J. Kim (2000) and Mu (2002) provide the details on the role of the government in this area.

The government policy statements, which are publicized in writing, offered valuable guideposts for outlining government priorities and for trying to solicit citizen support. During the early stages of the implementation of the Korean TDX program, the government decided to have ETRI, KTA (Korean Telecommunications Authority),[4] and the four domestic manufacturers (LGIC, Samsung Electronics, Daewoo Telecom, and Hanwha Telecom) joined the project by completely sharing and utilizing their resources to overcome deficiency in the country. With the government as the "grand coordinator," the combined ideas and actions of researchers, users, and manufacturers were brought to bear the challenge in an effort to meet the goals of the project. The synergy that this partnership created largely accounts for the success of the innovative experience.

After TDX-1 was successfully developed, the Korean government began to implement some polices to support the growth of local firms. For example, in the mid-1980s, the Korean government limited the imports of foreign switches as far as practicable. Also, to encourage manufacturers to learn the technology and promote investment, the Korean government implemented a quota mechanism for the market share of the four firms. These policies were incorporated in a legislation to provide a secure map for success. The Korean government passed a special law seeking to promote investments in the TDX project, which guaranteed domestic manufacturers a market for the TDX through purchases by KT of the technology by-products for early network modernization. The law also created a financial mechanism for the sustained funding of the ETRI research by requiring a portion of the profits earned by domestic TDX manufacturers to be allocated to R&D (Hwang 1993).

KT also provided R&D funds for the TDX series. It also prepared user requirements that specified the desired capacities for the TDX series-TDX -1, 1A, 1B, 1B/ISDN, 10, 10/ISDN, 10A-and the functions required for commercial telecommunication services.

The above narration suggests that the main tool of the government in promoting the development of telephone switch technology was its direct involvement through an SOE (KT) and a public research organization (ETRI). Then, one may wonder whether tariffs played any role in protecting the initial growth of local manufacturers against imported products. <Table 2-2> shows the trends of the tariffs of fixed-line telecommunication equipment (first row), compared with the average tariffs on producer and consumer goods.

As documented by Shin (2011), Korea maintained lower tariffs on capital goods, but imposed higher tariffs on consumer goods. This was because the economy had to rely on imported capital goods while it tried to promote export of consumer goods that served as the main source of foreign exchange earnings, which were needed to pay for imported capital goods.

4 KTA was created to expand and manage basic telecommunications facilities in 1981, and was incorporated as Korea Telecom (KT) in July 1990.

The table shows that the nominal tariffs on telecommunication equipment were similar to the average tariffs on producer goods in the 1970s and earlier. They became lower starting in 1979, being reduced from 30% to 15 %, reflecting the acute demand for imported telephone switches to meet the ever-growing demand for telephone services. From 1983 to 1988, they continued to rise to 12.5% and to 17.5%. Since then, they gradually decreased to below 10% by the early 1990s. The period of high tariffs from the early to the late 1980s coincided with the period when Korea started the development and local production of telephone switches. Hence, although the level of protection was not that high, some efforts were made to protect local products through tariffs. However, the eventual decreases in the tariffs also suggest that the measure was not prolonged but was made to apply only during the critical period of the industry's relative infancy.

Table 2-2 | Nominal Tariffs of the Telecommunication Equipment Industry (1966~1993)

(Unti: %)

Year	1970	1977	1979	1982	1984	1986	1988	1989	1991	1993
Telephones & Telecomm. equipment	29.2	30	15	10	12.5	15	17.5	15	13	9
Sound, Image and Communication equipment *	34.6	33.6	29.1	25.8	24.6	21.9	19.2	14	12.4	9.15
Producer goods **	33	26.8	21.5	21.3	19.3	17.9	16.3	12.2	10.8	8.06
Consumer goods **	81.3	53.8	45.6	38.9	30.6	26.6	22.6	16.5	14.6	11.1
Total **	62.2	43.2	35.6	31.5	25.7	22.9	19.8	14.6	12.9	9.67

Source: Tariff Schedules of Korea, Shin (2011)
* Tariff rate for the sound, image and communication equipment industry is weighted average using value of output in the input-output table of Korea as weight.
** T ariff rate of producer goods industry and consumer goods industry. Total industry is weighted average using the industry real production data by Hong and Kim (1996) as weight

1.5 The Transition into the Mobile Telecommunication Technologies

The technological regimes in wireless telecommunication feature high frequency of innovations, highly uncertain (volatile) trajectories, large investments in R&D, and an ever-evolving knowledge base. Thus, catch-up for a late comer is difficult. Nevertheless, as the thesis of leapfrogging suggests, everybody is a beginner in this new generation of technologies, which implies some possibility for catching-up and aiming to beat the first-movers. On the other hand, it can also imply greater difficulty in catching-up. The final outcome depends on the existing level of capabilities and getting the necessary access to foreign knowledge base.

The development of the CDMA cellular phone system and the initiation of its services in Korea is one of the most successful cases of a path-creating catching-up or leapfrogging, led by private-public collaboration (Lee and Lim 2001). When the Korean firms and the government authorities considered the development of the cellular phone system, the analogue system was (and still is) dominant in the United States, and the TDMA-based GSM system was the dominant system in Europe. However, the Korean authorities (Ministry of Information and Telecommunication) paid attention to the emerging CDMA technology, which had high efficiency in frequency utilization and high quality and security in voice transmission.

Thus, despite great uncertainty over the development of the first CDMA system in the world, as well as the strong reservations expressed by the telephone service providers and the system manufactures, such as Korea Telecom, Samsung, and LG, the Ministry and the ETRI (Electronics and Telecommunication Research Institute) decided to pursue CDMA. Although the first test of the CDMA system was conducted in 1995, the Korean government first designated the development of the CDMA system as a national R&D project as early as 1989. This move also meant that the Korean authorities were quite well-informed in the trend of telecommunication technology and had a foresight. In 1991, the contract to introduce the core technology from and to develop the system together with the US-based Qualcomm was forged. In 1993, the Ministry declared CDMA as the national standard in telecommunications. Currently, Korean subscribers (more than 6 million now) account for more than 75% of the CDMA subscribers worldwide. Korea started the CDMA-based PCS service in 1997.

The high frequency in innovations and the high fluidity in trajectory in the telecommunication industry do not give the late-comers any incentive for exerting R&D efforts. Expected profits and other related gains from the first-mover advantages served as a strong enticement, and the high risks were shared by the government-led R&D consortium and knowledge alliance with Qualcomm Co. The ETRI also contributed to the reduction of technological uncertainty by providing accurate and up-to-date information on technology trends and by identifying the correct R&D targets that are more promising than the alternatives.

To achieve leapfrogging by taking a different path, the role of government was very critical in taking initiatives to form an R&D consortium with private firms and pushing them forward. However, the core technology was bought from Qualcomm, and thus Korean producers still have to pay heavy royalty equivalent to 5.25 % of their sales revenue per mobile phone unit, in addition to a lump sum for technology licensing. The localization ratio in the mobile phone was only 30%, and most of the parts of the core, including the MSM-electronic chip, are imported. However, ETRI succeeded in developing the MSM chip in 1997 and, subsequently, Samsung declared in 1999 that it can now produce most of the core chips required in CDMA mobile phones. These developments meant the completion of the core part assimilation stage in reverse engineering. The Korean firms are now world leaders in CDMA-based phones, and they are now entering the final stage of creation and design of new product concepts in reverse engineering.

The worldwide success of Korea in first developing the CDMA system through a co-development arrangement with Qualcomm (a US-based joint venture company at that time with the core CDMA technology) indicates the importance of access to knowledge, which helped overcome the disadvantages posed by the uncertainties facing the CDMA technology that emerged only after the GSM technology developed in Europe (Lee and Lim, 2001).

1.6 Summary: Lessons and Implications

The development process consisted of growing industries, where firms may flourish and enhance capabilities. Enhancing the capabilities of private firms requires assuring them of their initial rents (profits) and learning opportunities until they grow enough to successfully compete in the world market. One effective way to assure such opportunities is to target certain industries or technologies, and the obvious target industries would be those that exhibit externalities or market failures in terms of the gap between private and social returns. While mainstream economics accept only such industries, this study goes beyond the boundary, and more targeting opportunities, justifiable in the catching-up context, are available (Lee and Mathews 2010).

Cautions against aiming high is rooted in the uncertainty in making the right choices in industries or technologies. For example, no one can tell which industries or technologies will boom in a particular country. However, this concern makes more sense in the context of developed countries, firms in which are on the frontier of technologies that face greater uncertainties. In the context of the latecomer, a ready justification for targeting industries exists. These are the industries or technologies that the latecomer economies are importing or buying at monopoly prices, because these products are monopolized by foreign companies. In this situation, import-substitution targeting involves taking the rents away from the foreign companies to give to the local companies. In this import-substituting targeted development, local industries face less uncertainty or risk because the targeted technologies are often mature technologies that are not impossible to emulate through the concerted efforts of the local R&D consortium.

The case of TDX development in Korea in the 1980s provides the best example. Korea was then facing serious shortage of the (fixed line) telecommunication service. It had to import telephone switches at very high prices. Only after the local development of the switches was in full swing did the prices of the imported switches go down. Eventually, Korean products reclaimed the market from the foreign companies, and Koreans were able to offer telephone services at much affordable prices, which substantially helped the overall economic growth.

In addition, results of the analysis in this study show that the technological regime of the telephone switches in the 1980s was such that they were already mature and stable technologies. This fact made knowledge access and transfer feasible and targeting less risky, and also made the government involvement more effective. Thus, Korea was able to achieve a stage-skipping catch-up in that it skipped the crossbar switch, leapfrogged into the analog electronic switch, and finally into the digital electronic switch; while Korea experienced manual switch step-by-step.

This move indicates the importance of choosing the mode of government involvement (industrial policy), considering the nature of the sectors or technologies, especially the technological regimes of the sectors. In other words, when the technological regimes are characterized by less frequent innovations and less fluid and thus stable technologies, a more direct involvement of the government, in the form of sharing and/or providing a part of the R&D budget can be justified, as the case of TDX showed. As Oh and Larson (2011) assert, the TDX case is the best and the first example of a successful tri-partite cooperation, embodied in the GPG model, involving the government research institutes, private firms and the government (ministries). Under the model, the government research labs are in charge of R&D, the private firms are in charge of production, and the government is in charge of marketing in the form of direct procurement or protection by tariffs.

However, as in the case of the CDMA in its later stages showed, involving the private firms and enhancing their capabilities is the better way to developing technologies. The enhanced capability of the private firms had made possible the successful transition from the fixed line to the wireless technologies. Initiatives from private firms are greater compared with that of state-owned enterprises (KT) in the area of fixed-line telecommunications.

2. Steel Industry: The Case of POSCO

2.1 Introduction

The most important feature of the Korean steel industry is that the state-owned POSCO has been at the center during the course of building the technological capabilities of the industry. For latecomer countries in general, the government plays a critical role, especially at the initial stage of an industry's technological development (Lee and Mathews, 2010). The Korean government created a national steel firm in which it could play its role. The state-owned Pohang Iron and Steel Company (POSCO) was established in 1968.[5] POSCO was the first integrated steel mill in Korea. In 1970, the steel mill's first-stage construction commenced in Pohang. By 1983, its production capacity expanded four folds. Additional integrated steelworks were constructed in Gwangyang in the mid-1980s. As a result, the Korean steel production increased sharply. By 1993, the only Korean integrated steel firm broke the 30 million tonne mark, which placed Korea in sixth place in the global crude steel production. During the period of 1973 to 1993, the compound annual growth rate (CAGR) of the Korean crude steel output was 21.2%, whereas that of the world was 0.7%.

5 The original name of the company was Pohang Iron and Steel Company, which was changed to POSCO in 2002.

The CAGR of other major latecomers was lower: Taiwan, 16.7%; Brazil, 6.7%; and China, 6.6% (Mitchell, 1992, 1995; World Steel Association Web site). In 1998 and 1999, POSCO became the world's biggest steel producer, surpassing the former top producer Nippon Steel. Currently, POSCO has two integrated steelworks in Pohang and Gwangyang, and it produces approximately two-thirds of Korea's total steel output.

The current chapter discusses POSCO's origin and growth as a state-owned enterprise (SOE) and the Korean government's role in the firm's successful growth. Section 2 presents the characteristics and technological regimes of the steel industry. Section 3 provides a detailed story of the process of POSCO's technological development. Section 4 examines the government's role, with focus on how the government established the steel industry. The concluding section provides a summary and discusses some policy implications.

2.2 Technological Regimes of the Steel Industry

The technological regime of an industry can be defined by the combination of various factors, such as technological opportunities, accessibility to external knowledge flows, uncertainty of a technological trajectory, and so on, which are suggested in the literature on neo-Schumpeterian economics (Breschi et al., 2000; Park and Lee, 2006). In the context of catch-up, we discuss the technological regime of the steel industry in terms of 1) frequency of innovation, 2) predictability of technological trajectory, and 3) degree of access to the foreign knowledge base. Given that technological regime may change as the industry ages, addressed here are the regimes surrounding the Korean POSCO's construction of two integrated steelworks in the 1970s and 1980s.

First, the steel industry is characterized by low frequency of innovation. Looking into the history of technology development of steel manufacturing shows that each generation of the process technology of integrated steelworks has a long life span. Technology development in the steelmaking process is a good example. Commercially available since the 1860s, the open hearth furnace was widely used in Western Europe until the 1950s. The approximately 90-year-old technology was replaced by a new-generation basic oxygen furnace (BOF) since in the 1950s. This 60-year-old technology is still used widely. Another example is continuous casting.[6] Commercialized in the 1960s, this technology has been used for over 40 years. This history of technology replacement indicates the low frequency of innovation in the steel industry.

Furthermore, the steel industry has high predictability of technological trajectory because there is a long time gap between the creation of technology and its commercial use. Building a commercial plant adopting a new process technology requires thorough tests. The size of the test plant is gradually increased, that is, from a laboratory scale to a model plant, to a pilot plant and a demo plant, taking a very long time. The development

6 Continuous casting process transforms the molten liquid steel into semi-finished products, such as slabs, blooms, and billets.

history of the FINEX technology demonstrates such long test process.[7] In 1992, POSCO started conducting research with Siemens VAI and performed a lab-scale test (1992-1995), model plant test (15 tonne capacity per day: 1996-1998), pilot plant test (150 tonne capacity per day; 1999-2002), and demo plant (600,000 tonne capacity per annum; 2003-2005). Concluding the 15-year research and test, POSCO finally commercialized the FINEX technology: the construction of the first commercial FINEX plant with a 1.5 million tonne capacity per annum was completed in 2007 (Yun, 2006). As the FINEX project moved to the succeeding steps of the test, the technology became more and more likely to be commercialized. Given the long-term procedure, monitoring which new technologies are undergoing tests and at which stage can predict, to some extent, which would become the dominant technology of the next generation.

Thus, less frequent innovation and more predictable technological trajectory enable us to reason that latecomer countries in the steel industry may easily catch up with the forerunners. However, this high possibility of catch-up cannot be realized without access to the external knowledge base in the advanced economies. Fortunately, for latecomers, the steel industry features a high degree of access to the external knowledge base. Given that the steel industry is a facility-based industry, most of its technology is embodied in its facilities. Therefore, the purchase of facilities enables latecomer steel firms to obtain and use relevant technology.

In summary, the technological regimes of the steel industry are characterized by (1) low frequency of innovation, (2) high predictability of technological trajectory, and (3) high degree of technology transfer. These regimes imply two things. First, the latecomers in the steel industry may easily catch up with the current relative technology. Second, these regimes allow stage-skipping or path-creating catch-up because latecomers can identify future generations of technology more easily.

2.3 Growth of POSCO and Its Technological Development

Early stages of learning and building of capabilities[8]

In 1968, the state-owned steel firm POSCO was established. In 1970, construction of Korea's first integrated steelworks began. In those days, the integrated steel mill was entirely new to Korea. Even experienced workers in the steel industry did not have the knowledge and skills required for the integrated steel plant. To make matters worse, the knowledge they had accumulated from the small-scale separated process was not applicable to the large-scale integration. Thus, POSCO had to access the external knowledge base to learn skills and acquire knowledge required for the integrated steel factory.

7 The FINEX process produces molten iron directly using iron ore fines and non-coking coal without sintering and coking steps, which are essential in the century-old blast furnace methods (Source: Siemens VAI website)

8 This section is drawn from Song (2002, pp. 123-154).

The primary source of knowledge was overseas training. There were two types of overseas training: field observation training for 15 days to 30 days and on-the-job training for 2 month to 6 months (Pohang Iron and Steel Seven-year History Compilation Committee, 1975, pp. 526, 528: recited from Song, 2002, p. 128). In 1968 and 1969, 39 trainees were dispatched to Japan. For the Pohang project (1968-1983), a total of 1,861 workers were trained overseas (See Table 2-3). After returning from training, the trainees taught other workers. All the materials they brought back to POSCO were turned into microfilms and saved in a database.

At first, the "newcomer" POSCO focused on building technological capabilities for plant operation, maintenance, and repair. This emphasis is evident in Table 2-3, which presents the number of overseas trainees by area. In the first phase, the shares of plant operation, and maintenance and repair were 62% and 24%, respectively. However, the importance of these areas decreased over time. In phase IV-2, the same shares were only 16% and 10%, respectively. The importance of computerization in the plant and quality control increased. These transitions reflect the shift of POSCO's priority in building technological capabilities at the time.

Table 2-3 | Overseas Training for the Pohang Project

(unti: person, %)

Phase	Plant Operation[1]	Maintenance and Repair[1]	Computerization[1]	Others (e.g., Quality Control) [1]	Total[1]
I (1968-1975)	372 (62.2)	145 (24.2)	0 (0.0)	81 (13.5)	598 (100.0)
II (1973-1978)	134 (51.7)	54 (20.8)	28 (10.8)	43 (16.6)	259 (100.0)
III (1976-1980)	231 (45.5)	121 (23.8)	96 (18.9)	60 (11.8)	508 (100.0)
IV-1 (1978-1980)	63 (22.9)	106 (38.5)	70 (25.5)	36 (13.1)	275 (100.0)
IV-2 (1981-1983)	35 (15.8)	23 (10.4)	81 (36.7)	82 (37.1)	221 (100.0)
Total	1,017 (45.0)	556 (24.6)	330 (14.6)	357 (15.8)	2,261 (100.0)

Source: Song (2002), p. 129; Note: 1) Percent of total in parentheses

The overseas companies to which POSCO's trainees were dispatched changed over time. In phases I and II, the Japanese steel firms that sold their technology to the "small-company" POSCO were inclined to provide training. However, they were surprised at POSCO's fast-growing performance in the world export market. Since phase III, they became averse to the transfer of technology, considering POSCO as a potential competitor. As POSCO turned to other equipment suppliers in Western countries in later phases, the range of training countries was extended to the US, West Germany, the UK, France, and so on.

POSCO's oversees trainees aggressively obtained knowledge, even through informal ways. For example, in Japan, POSCO's trainees built close personal relations with Japanese engineers mainly through informal activities outside the working hours. They asked technical questions and requested the engineers to show them plant blueprints. In addition, when equipment broke down during their training at the steel mill, they sketched all the tools used for repair.

Technology consultations from retired Japanese technical experts were also an important source of knowledge. Equipped with a wealth of field experience, the Japanese experts taught POSCO's engineers plant operation skills. The contract period of one to two years was long enough for the transfer of systematic technology. POSCO's engineers aggressively asked questions even after the working hours.

With these aggressive efforts, POSCO quickly built sufficient capabilities for plant operation, and the skills of its workforce improved significantly over time. Its learning cycle of the first blast furnace (BF) operation reached the standard tapping ratio 107 days after its commencement, much earlier than the target of 120 days. The 29 days of the fourth BF topped the previous world record of 31 days. The firm's BOF operation exhibited increasingly shorter learning cycles as well. First, 107 days, second, 90 days, third, 70 days, and finally, 48 days. The learning cycle of the hot strip mill operation was shortened from six months in the first mill to five months in the second (Song, 2002, p. 148: recited from Ki, 2010, p. 39).

However, at the time, POSCO's technological capability building was limited mainly to skills for plant construction, operation, and maintenance. Its efforts included relatively less product development and quality improvement because the "just-started" POSCO gave priority to the construction of plants and the stabilization of the production process.

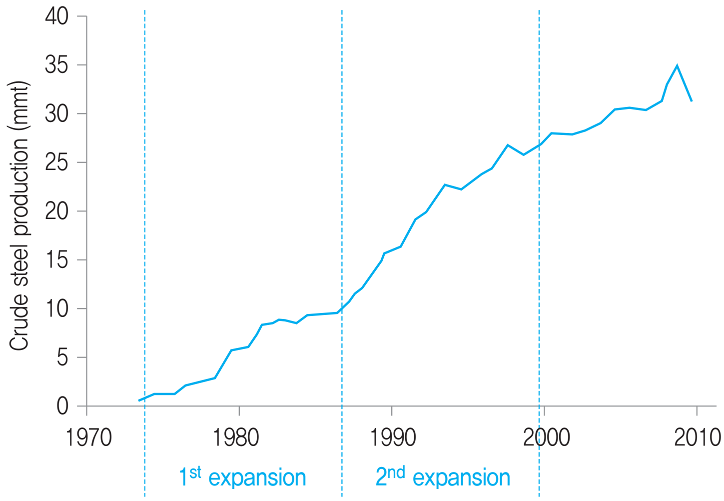
2.3.2 First Expansion (1973-1986) and a Window of Opportunity

Since construction of the first phase of its first steelworks was completed in 1973, the state-owned firm expanded its production capacity to four more construction phases by the mid-1980s (first expansion).[9] Crude steel production was further developed with the start of its second integrated steelworks operation in 1987 (second expansion). [Figure 2-1] presents the increase in POSCO's steel production without substantial decrease the first and second.

9 'Four more constructions phases' denotes phases II, III, IV-1, and IV-2.

During the first expansion, the world steel industry suffered a recession in the aftermath of the 1973 oil crisis. The global crude steel output in the next 10 years before the crisis (1964-1973) increased by 6.1% CAGR and then decreased by 0.5% CAGR in the following 10 years (1974-1983). Owing to the recession, the steel industry in developed countries, including Japan, which had massively invested in the expansion of production capacity, faced an overcapacity problem. Thus, new steel plant construction and even equipment purchase significantly fell off in their domestic markets. To find a way out of these difficulties, the steel and steel equipment industries in developed countries wanted to export their equipment and know-how's (Korea Iron and Steel Association, 2005, p. 151).

Figure 2-1 | Crude Steel Production of POSCO, 1968-2009



Sources: 1973-1974: Song, 2002, p. 150; others: World Steel Association Web site

These circumstances served as a window of opportunity for POSCO, which was about to construct a steel mill. At that time, there were many sellers but few buyers in the global steel technology and equipment market. Taking advantage of this opportunity, POSCO was able to substantially reduce the cost to purchase the equipment. For example, for the wire rod and bloom production equipment needed for phase IV-2 of the Pohang project, POSCO nominated the Morgan-Voest consortium and MDS-Thyssen consortium as competitive bidders. Hence, the firm was able to purchase the equipment at a very favorable price. In addition, for the repair project of the second BF, POSCO received quotation from Japan's IHI as many as eight times, eventually saving costs by 30% (Korea Iron and Steel Association, 2005, p. 163).

2.3.3 Second Expansion (1987-1999)

In 1981, when POSCO released a new integrated steel mill project, the global steel sector suffered a recession after the second oil crisis in 1979 (Korea Iron and Steel Association, 2005, p. 230). The low growth trend continued through the 1980s at 0.5% CAGR. With a significant lack of demand, the US, Japanese, and European steel firms carried out large-scale restructuring: curtailed production, shut down obsolete equipment, reduced employment, and diverted business portfolios (Korea Iron and Steel Association, 2005, pp. 233-37). Again, this global situation served as a window of opportunity to the Korean steel industry. Equipment suppliers were eager to join the Gwangyang project (Korea Iron and Steel Association, 2005, p. 205). As a result, POSCO was able to incite fierce competition among equipment suppliers for the supply contracts for equipment in the first phase construction (D'Costa, 1999, p. 66). In the ironmaking equipment, a new supplier, the UK's Davy McKee, won the contract over the previous contractor for the Pohang project Japan's IHI. Davy McKee's quotation was surprisingly 20% lower than that of IHI. Moreover, they provided POSCO a very favorable loan package: 2% annual interest for a 10-year repayment period with a three-year grace (Song, 2002, p. 181). The steelmaking equipment contractor Austria's Voest also provided a loan at a very favorable interest rate of 6.75% per annum. This rate was almost half that of normal interest rates, that is, 11% to 12%, in the international financing market. The Gwangyang project also secured hot strip mills at a low cost. As a result, POSCO saved $266 million or 33% of the planned equipment cost of $799 million for the first phase of the construction (Korea Iron and Steel Association, 2005, p. 206).

The recession also provided POSCO a chance to introduce various state-of-the-art technologies more easily than would normally be possible. POSCO imported pulverized coal injection, which was then an energy-saving method in the ironmaking process that was just put into commercial operation in nations with technologically advanced steel industry. Additionally, POSCO also adopted the most up-to-date foreign know-how in the rolling stage, such as hot charge rolling, online roll grinder, and pair cross mill, in Gwangyang steelworks. The Gwangyang mill was the first and second in the world to introduce online roll grinder and pair cross mill, respectively (Song, 2002, pp. 181-82). These early introductions of the high-level production methods provided the company the chance to "learn-by-doing" the advanced technology, which eventually became the foundation for the technological superiority of Gwangyang steelworks (Song, 2002, pp. 182-83). The low cost purchase of equipment and the introduction of up-to-date technology laid the groundwork for POSCO's cost advantages.

2.3.4 International Comparison of Efficiency

POSCO's productivity also improved with the introduction of state-of-the-art equipment and the improvement of work practice. In terms of yield ratio, man-hour per ton, and energy consumption, POSCO surpassed the US and advanced European countries by the 1980s. The firm reached Japan's world class level by the early 1990s: In 1992, POSCO's yield ratio was 94.4%, whereas Japan's average was 94.8%. POSCO's energy consumption was 5.29 million kcal per ton compared with Japan's 5.89 million kcal per tonne <Tables 2-4 and 2-5>.

Table 2-4 | PProductivity Comparison: POSCO vs. Major Countries

Indicator	Year	POSCO	US	Japan	Germany	France	UK
Production yield rate (%)	1978	81	72	85	75	77 (Total EC)	
Man-hours per tonne (MH/tonne)	1980	10.4	9.6	9.2	11.0	11.2	41.2
	1981	9.7	9.1	9.5	11.0	11.3	41.9
Energy consumption (10^3kcal/tonne)	1978	5,835	7,650	5,141	6,300	6,275 (Total EC)	
Labor costs (USD/tonne)	1980	16.7	183.4	93.7	164.1	172.0	410.1

Sources: Korea Iron and Steel Association (2005, p. 169); Song (2002, p. 149)

Table 2-5 | Productivity Comparison: POSCO vs. Japan in 1992

Indicator	POSCO	Japan
Production yield rate (%)	94.4	94.8
Steel product output per worker (tonne/worker)	880 (2)[a]	1,102 (1)
Energy consumption (10^3kcal/tonne)	5,290	5,890
BF tapping ratio (tonnes/day/m^3)	2.10	2.03

Source: Song (2002, pp. 231-32)
Notes: a. Tapping ratio is the output per day per m^3; b. World ranking in parenthesis

2.3.5 Upgrade of Technological Capabilities and R&D Efforts[10]

As POSCO steadily increased its share in the global steel export market, other rival steel firms from advanced countries gradually shunned the transfer of technology to POSCO. Moreover, similar to POSCO, they were also beginners in the up-to-date equipment of the 1980s. Thus, POSCO faced the need to upgrade its technological capabilities. As such, POSCO established the former Pohang University of Science and Technology (POSTECH) in 1986 and the Research Institute of Industrial Science and Technology (RIST) in 1987. The company intended to build a collaborative R&D system, which was composed of three parties: industry (POSCO), university (POSTECH), and institute (RIST). POSCO and the RIST together carried out research on product and processing technologies, with POSCO undertaking the pilot production and the RIST and POSTECH taking on fundamental research and business diversification.

This in-house R&D system enabled POSCO to introduce and stabilize the Gwangyang plant's up-to-date facilities. For example, POSCO imported pulverized coal injection equipment, which is an up-to-date energy saving method in the ironmaking process. This method had just been put into commercial operation in nations with technologically advanced steel industry in the 1980s. POSCO's Gwangyang steelworks also adopted state-of-the-art foreign technology in the rolling stage, such as hot charge rolling, online roll grinders, tandem cold rolling, and pair cross mill. The Gwangyang Mill was the first company in the world to introduce the online roll grinder and the second company to introduce the pair cross mill (Song, 2002, pp. 181-182: recited from Ki, 2010, p. 38; Choi et al., 2010, p. 38). These early adoptions represent POSCO's skipping old technologies in the 1980s, which is in contrast with its path-following behavior in the 1970s.

2.4 Role of the Government

2.4.1 The Beginning as an SOE and Financing

During the reconstruction period after the Korean War (1950-1953), the rising domestic demand for steel products led to the need for the construction of an integrated steelworks.[11] At the time, most Korean steelmakers used scrap iron, rather than pig iron, as raw material. With scrap metal running out, the need for a stable supply of pig iron increased. In addition, Korean steel firms in those days were small and specialized in only one segment of the whole process of steel production. This inefficient separation undermined the advantage of having an integrated steel mill.

In the absence of private capitalists able to take on a heavily capital-intensive integrated steel project, the government initiative was inevitable. However, the Korean government's

10 This subsection draws on Song (2002, pp. 258-282) and The National Academy of Engineering of Korea (2010, p. 83).

11 This paragraph was taken from the Korea Iron and Steel Association (2005, pp. 100-102).

six attempts for 11 years between 1958 and 1968 all foundered. The main reason for the failure lay in project financing. Opposing the Korean government's plan to build an integrated steel mill, the World Bank and the US Agency of International Development (USAID) indicated concerns about Korea's ability to repay foreign loans and the need for a large-capacity steel mill in a small developing economy (D'Costa, 1999, p. 64; Song, 2002, p. 57). Rather, they suggested developing first steel-consuming industries, such as machinery, automobile, and shipbuilding (Song, 2002, p. 57). The Korean government refuted their opinion and insisted that steel-consuming industries were not a prerequisite for the successful development of the steel industry and that the steel industry should grow first for the effective development of steel-consuming sectors.

Former president Park Chung-hee took the initiative and gave top priority to the steel project in the second five-year economic development plan (1967-1971). The steel project was one of the three key projects of the plan. The others were the Ulsan petrochemical complex and the Gyungbu Expressway (Song, 2002, pp. 42-43).

The Korean government created the state-owned steel firm POSCO in 1968. The government held 56.2% of the company shares, and the remaining 43.8% was held by the state-run Korea Tungsten Co. Two years later, the company commenced construction of the first phase of the nation's first integrated steelworks in Pohang. The chronic problem of financing was overcome by "ingenious" methods (D'Costa, 1999, pp. 63-64). Through agreements with the Japanese government in 1969, the Korean government allocated a part of the war reparation funds from the Japanese to the Pohang project. A total of $73.7 million from the war reparation funds for three years was assigned to the first phase. Another loan worth $50 million was provided by Japan's Export-Import Bank. Japanese sources accounted for approximately 60% of the capital needs in the first phase (Song, 2002, p. 76). The rest was covered by domestic capital.

<Table 2-6> presents the sources of financing by phase. Direct investment from the government accounted for 11.3% of the project's total costs. The government's intervention and assistance enabled POSCO to access domestic and foreign sources, accounting for approximately 66%. Domestic sources were state-run and private bank loans with very low interest rates, in fact negative in reality. To mobilize resources from abroad, the government negotiated with foreign lenders on behalf of its national producer and guaranteed POSCO's loan payments. Evident from <Table 2-6> is the increasing share of POSCO's own funds from 0% (phase I) to 53.4% (phase IV-2), whereas that from foreign capital declined from 59.1% to 33.3% over the same period. These changes indicate that POSCO's ability to generate internal funds was gradually enhanced while the government nurtured the industry through various instruments, which is addressed in the following subsection.

Table 2-6 | Financing for the Pohang Project[12]

(Unit: US$ milion)

Phase	Period	Govt. capital[1)]	Domestic funds[1)]	Own funds[1)]	Foreign capital[1)]	Total costs[1)]
I	1970-1973	111	26	0	197	334
		(33.2)	(7.7)	(0.0)	(59.1)	(100.0)
II	1973-1976	19	39	157	376	591
		(3.2)	(6.5)	(26.6)	(63.6)	(100.0)
III	1976-1978	225	101	293	768	1,387
		(16.2)	(7.3)	(21.1)	(55.4)	(100.0)
IV-1	1979-1981	121	336	327	768	1,552
		(7.8)	(21.7)	(21.1)	(49.5)	(100.0)
IV-2	1981-1983	0	47	189	118	354
		(0.0)	(13.3)	(53.4)	(33.3)	(100.0)
Total		476	549	966	2,227	4,218
		(11.3)	(13.0)	(22.9)	(52.8)	(100.0)

Source: Song (2002), p. 118. Note: 1) Percent of total costs in parentheses

2.4.2 New Law and Supporting Measures

The Steel Industry Promotion Law was announced on January 1, 1970, three months before construction of the first phase of the Pohang plant. This law demonstrated President Park's unwaveringfocus on the steel project. At a cabinet meeting on June 10, 1969, the president gave directives to strengthen policy instruments to develop the steel industry. Government officials from the Research Committee on the Integrated Steel Project Planning and POSCO devised supporting measures by July that same year.

The law, which was valid for 10 years, empowered the government to grant POSCO various financial and administrative support for 1) access to long-term and low-cost foreign capital, 2) purchase of equipment and raw materials, 3) construction of port facilities, water and electricity systems, roads, and railroads, and 4) research and technical training. Furthermore, the law provided 5) reduced prices on electricity, gas, and water, and 6) discounts for rail transport and port dues (D'Costa, 1999, p. 65; Korea Iron and Steel Association, 2005, pp. 132-133). At the same time, the law made changes in the Regulation Law on Tax Reduction and Exemption and in the Tariff Law. POSCO was exempted from corporate tax and received an 80% tariff cut on the import of equipment (Nam, 1979,

12 Original units are in Korean won. The won-dollar exchange rates used in the conversion are calculated by averaging the daily exchange rates for each phase: 361.00, 448.89, 484.00, 555.36, and 729.31 won/dollar for phases I, II, III, IV-1, and IV-2, respectively.

p. 78).[13] After an extension of another 20 years, the Steel Industry Promotion Law was discontinued in 1986 (D'Costa, 1999, p. 65).

Construction of the first phase for 1.03 million tonne production capacity was completed between 1970 and 1973. By 1983, four expansions had been carried out, increasing the total capacity of the Pohang Mill to 9.6 million tonne (D'Costa, 1999 p. 65). Empowered by the law, the government was able to provide a large fund for the Pohang project in various forms. The government pumped $476 million into the project. Additionally, in the form of infrastructure support, tax and tariff cuts, and discounts for public utility charges, the government invested approximately $840 million (Song, 2002, pp. 118-119).[14]

When passed, the Steel Industry Promotion Law was criticized as being beneficial solely to POSCO. To be eligible for the previously mentioned government support, 1) a steel firm should have an integrated steel mill with more than one million tonnes annual capacity, and 2) the government should hold over 50% stake in that company. POSCO was the only firm to meet those criteria. As a way to establish the steel industry, Park's administration concentrated all available resources on the single state-owned POSCO and its integrated steel mill rather than created the environment for private firms to grow in a market mechanism and with free competition. The absence of a capitalist class for a capital-intensive steel project enables us to argue that such direct intervention was inevitable and justifiable at the time.

2.4.3 Heavy Industry Drive to Consolidate Demand Basis

Since 1973, POSCO had received further boost through a substantial change in the economic growth policy of the Park administration. The Heavy and Chemical Industrialization (HCI) Program (1973-1979), designed to shift the Korean economy away from the low value-added light industry, selected six heavy and chemical industries for intensive nurture: steel, petrochemicals, automobiles, machine tools, shipbuilding, and electronics (D'Costa, 1999, p. 65). This program accelerated POSCO's growth in two ways. First, the government strengthened its support for the steel industry mainly through low-interest financing and tax cuts. Second, and more importantly, the HCI drive made the government realize the necessity for the expansion of the Pohang plant and furthermore the construction of an additional integrated steel plant. The selected sectors from the program were mostly steel intensive; thus, a significant increase in steel demand was expected from these industries. As a result, following the announcement of the HCI strategy, the Pohang plant was expanded four times from 1973 to 1983. Construction of the second steel plant began in 1985 against the backdrop of the thriving heavy industry (Song, 2002, pp. 99, 159-160).

13 Steel firms with an integrated mill with more than 100 thousand tonnes annual capacity were eligible for this tariff cut.

14 This amount was converted from 650 billion won by multiplying the daily average won-dollar exchange rate during the Pohang project.

As separate administrative organizations, the Heavy and Chemical Industry Promotion Council and its planning office have been set up to implement the program at President Park's orders.[15] The planning office served as a bridge directly connecting President Park to the industrial world, excluding the Economic Planning Board, which was the core organization at that time responsible for development planning and implementation. The Board had a different opinion on the HCI drive from the President. Whereas the President wanted to invest intensively in the heavy chemical industry, the Board preferred a stable and gradual development of the heavy chemical industry according to the economic theory of comparative advantage (Park, 2005: recited from Park, 2011). Therefore, President Park considered stronger organizations rather than the Board to be necessary to drive the program firmly. There were pros and cons to the direct connection between the president and the industrial world. The goals of the program were quickly achieved, but only certain industries and firms, especially Chaebols (Korean business conglomerate), benefited from the program; thus, the economy developed unevenly (Park, 1994 and 2011). After President Park's death, because of the criticisms on the HCI drive, the role of the Board was restored.

2.4.4 Tariffs

The history presented above suggests that the main tool for the government to promote the steel industry was the direct involvement through an SOE. Therefore, one could wonder whether tariffs played a role in protecting the initial growth of the indigenous steel manufacturing against imported products. <Table 2-7> shows the trends of the tariffs on the steel products compared with the average tariffs on the producer and consumer goods. The tariffs on the steel products were almost identical to the average tariffs on produce goods, which gradually decreased over the entire period. Thus, arguably, the steel industry did not enjoy protection in terms of tariff rates even in its initial stage in the 1970s. One of the reasons is that steel is a key input in many other sectors, and thus imposing high import tariffs on the widely used intermediate goods was not advantageous to the whole economy.

15 This paragraph was taken from Park (2011).

Table 2-7 | Nominal tariff on steel products, 1966-1993

(unit: %)

Year	1966	1968	1970	1972	1973	1974	1977	1978	1979	1980	1982
Steel*	26.2	32.2	32	32	29.3	29.3	25.1	25.1	19.6	19.6	19.5
Producer goods**	30.1	33.2	33	33.2	30.8	30.7	26.8	26.9	21.5	21.3	21.3
Consumer goods**	73.3	80.9	81.3	82	67.4	68.2	53.8	53.6	45.6	45.1	38.9
Total**	59.1	62.6	62.2	63.3	53.6	54.1	43.2	42.8	35.6	35.2	31.5
Year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**
Steel*	19.5	17	17	16.5	16.5	16	9.83	9.41	9.41	8.98	7.95
Producer goods**	21.4	19.3	19.1	17.9	17.7	16.3	12.2	10.8	10.8	9.53	8.06
Consumer goods**	38.2	30.6	29.3	26.6	25.4	22.6	16.5	14.7	14.6	12.8	11.1
Total**	31	25.7	25	22.9	22.1	19.8	14.6	12.9	12.9	11.3	9.67

Source : Tariff Schedules of Korea: recited from Shin (2011)
Notes : * Weighted average by output value in the input-output tables of Korea
** Weighted average by the industry real production data by Hong and Kim (1996)

2.4.5 Privatization

As POSCO grew steadily through the Steel Industry Promotion Law and HCI program in the 1970s, the government in the 1980s gradually decreased support for the steel industry and POSCO. In 1981, the Regulation Law on Tax Reduction and Exemption was revised to change POSCO's tax status from nontaxable to taxable (Song, 2002, pp. 193-194). In 1986, the Steel Industry Promotion Law was discontinued and was replaced with the Industrial Development Law.[16] The new law encouraged market mechanism and free competition among firms instead of direct intervention and regulation from the government (Choi, 1991). In addition, the law shifted the government's industrial policy from directly nurturing target industries to universal functional support, indicating that the government support focused on technical development and productivity improvement (Kim, 2005; Korean Economy's Six Decade Editorial Committee, 2010, p. 233). This universal law terminated discounts on public utilities. Tariff cuts on imported equipment were also discontinued against the backdrop of import decontrol in 1988 (Kwak, 1997, p. 218; POSCO History Compilation Committee, 1993, p. 630: both recited from Song, 2002, p. 194). As a result, government capital accounted for only 4.7% of the financing for the Gwangyang project, compared

16 The Industrial Development Law replaced seven industry promotion laws in the steel, machinery, shipbuilding, electronics, non-ferrous metals, petrochemical, and textile industries.

to its share of approximately 30% of the financing for the previous Pohang project. The government capital investment in the Gwangyang project was less than half of that in the Pohang project (Song, 2002, p. 1994). The significantly decreased government support suggests that the state-owned POSCO in the 1980s had to run a business under conditions almost identical to that of private firms (Song, 2002, p. 289). However, the reduced support was sufficiently offset by POSCO's high business performance sustained since the 1970s. The share of POSCO's own funds in financing the Gwangyang project was 45%, almost twice that of the financing for the Pohang project (Song, 2002, p. 193). POSCO's high performance made the SOE very attractive to potential investors waiting for its privatization.

On December 3, 1987, the government announced the "Public offering plan of the SOEs," including POSCO.[17] The purpose of the plan was to invigorate the financial market and financially help low-income people by assigning them the SOEs' stocks. For POSCO, the plan was to reduce the state's and the state-run Korea Development Bank (KDB)'s shares in POSCO from 71.4% to 35% or below. The following year, 34.1% of the company's stock was sold to 3,222,000 persons, including 20,000 employees of the company. The partially privatized company was then listed on the Korean stock market, KOSPI. As a result, POSCO's employees and the Korean people came to hold 10.0% and 27.3% shares, respectively, whereas the government's stake shrank from 33.4% to 20.0% and that of KDB went from 38.0% to 15.0% (See Table 2-8).

Table 2-8 | Changes in Shareholder Composition After 1988 Partial Privatization

Shareholders	Before		After	
	# of shares	Ratio (%)	# of shares	Ratio (%)
Government	14,118	33.4	18,357,828	20.0
KDB	16,084	38.0	13,768,370	15.0
POSCO Employees	-	-	9,178,914	10.0
The people	-	-	25,026,028	27.3
Total	30,202	71.4	66,331,070	72.3

Source: Kang, 2001, p. 80

17 Discussion from this paragraph until the end of the subsection was taken from Kang (2002, pp. 34-5), Kang (2001, pp.79-80), and POSCO Thirty-five-year History Compilation Committee (2004a, pp. 440-5).

Given the importance of the nation's only integrated steel producer, the government did not want a specific private company, especially Chaebol, to acquire POSCO. To prevent this situation from happening, the government widely offered stocks to the people. In accordance with the government's intention, POSCO specified a limit on stock acquisition before the privatization: the stake of any shareholder should not exceed 1%.[18]

Approximately 10 years later, the second privatization of POSCO was undertaken. On July 3, 1998, the next Kim Dae-jung administration (1998.2 to 2003.2) announced the privatization plans of 11 SOEs, including POSCO. The purpose of the privatization was to introduce free competition and market mechanism in the SOE-dominated industries and to improve the efficiency of the management system of SOEs. Moreover, because of the 1997 Asian financial crisis, the financially struggling government desired to secure financial resources, especially foreign currency, through privatization.

The second, complete privatization of POSCO was conducted in December 1998. The government's entire stake, 3.14% shares, and the KDB's 2.73% shares in its 23.57% shares in POSCO were sold to foreign investors in depositary receipt (DR) form. The rest of KDB's stake was repurchased by the company and sold to foreign investors in DR form several times. Privatization for over three years was finalized on October 4, 2000, 32 years after the state created the company in 1968. <Table 2-9> shows the shareholder composition immediately after the privatization from 1998 to 2000. Notably, POSCO was privatized after becoming internationally competitive. In 2000, global business magazines Forbes and Fortune ranked the company number one among global steel firms in terms of net income to sales ratio and net income to total asset ratio. The stake of foreign investors steadily increased since the privatization, which increased from 25.1% in 1997 to 66.5% in 2003.

Table 2-9 | POSCO Shareholder Composition After the Complete Privatization from 1998 to 2000

Private banks	Treasury stocks	Employee ownership	Foreign investors	Others	Total
8.0	19.1	0.1	48.9	23.9	100.0

Source: POSCO Thirty-five-year History Compilation Committee (2004a, p. 442)

18 The limit was raised to 3% in 1998 and was erased from articles in the company in 2000.

2.5 Summary and Concluding Remarks

The most important feature of the Korean steel industry is that the state-owned POSCO has been at the center during the course of building the technological capabilities of the industry. This chapter describes the birth and growth of POSCO, and the role of the Korean governments in this process.

In the absence of private capitalists who dared take on a heavily capital-intensive integrated steel project in Korea, government intervention was inevitable. Thus, the Korean government created a national steel firm and assigned the SOE to the integrated steel project. By establishing the Steel Industry Promotion Law of 1970, the government provided various financial and administrative support to the SOE. The HCI program enforced between 1973 and 1979 provided further boost to the SOE. The Korean government's support through various instruments substantially helped POSCO achieve international competitiveness.

However, notably, this successful development was made possible by the combination of government activism and the SOE's aggressive technological learning and capacity building. In its early stage, POSCO simply purchased and used stabilized or standard technologies and facilities. At the time, overseas training was the primary source of learning. In the 1980s, as POSCO increasingly threatened rival companies in the global export market, access to foreign knowledge base became more difficult than before. Thus, POSCO established its own R&D system, which was composed of three parities: industry (POSCO), university (POSTECH), and institute (RIST). The in-house R&D system facilitated the company's stage-skipping catch-up, as it adopted the most up-to-date technologies and facilities in the second steel mill project. The building of POSCO's technological capabilities can be considered a path-following catch-up at the initial stage and a stage-skipping catch-up at the later stage, according to the classification of the three types of catch-up proposed by Lee and Lim (2001).

Typically, state activism is justified when there is a certain degree of positive externalities such that market failure prevails in terms of the gap between private and social returns. POSCO's case fits into this category. Steel is an input in diverse sectors of production. Given the high degree of the scale economy and a limited size of the domestic market, as in the history of Korea, steel goods was certain to be underproduced if left with private firms, and private monopoly would charge much higher prices under monopoly. Relying on imported steel alone would lead to no benefits in terms of backward and forward linkages. Under these conditions, entry by establishing an SOE seemed to be the rational choice in the context of the Korean economy at the time.

As a matured industry, technological uncertainty was low in steel production. Furthermore, the Koreans' entry and expansion at a later stage took advantage of the lowered price of factory equipment and facilities during global recessions, namely, the first and second oil shocks. Market uncertainty decreased through government and private efforts to develop automobiles, shipbuilding, and other steel-consuming industries. Finally, after its stable establishment in terms of international competitiveness, this SOE was completely privatized in 2000.

3. The Case of the Machine Tools Industry

3.1 Introduction

Developing an intermediate-good industry in a country is important. Intermediate-good industries, like machine parts, are a major path by which the export of final goods exerts influences on domestic demand. Furthermore, most of the producers in this industry are small and medium enterprises (SMEs) that largely account for employment.

However, catching-up with the intermediate-good industries in Korea was not easy because they are the symbols of rapid economic growth. While Korea has generated several world-class giants, such as Samsung, LG, and Hyundai, these are all companies involved in the consumer goods industry. In capital goods industries, this is not the case. The weakness of the intermediate capital goods industry originated from the beginning of the Korean economic development in the 1960s. Korean economic growth has focused on the industry of final products, while relying on the imports of core parts, intermediate materials, and supplies. The main source of these intermediate goods is Japan. Therefore, Korea still experiences persistent trade deficits with Japan, given its practice of more exports of final products, thereby requiring more imports of intermediate goods from Japan.

The patterns of catching-up in the capital goods industry are quite different from those in the consumer goods industry, because the firms in the former now deal with other client firms rather than only with the consumers. Small firms in the capital goods industry are usually specialized suppliers for big final goods assembly firms in the consumer goods industry or other industries. Thus, the tacit knowledge accumulated from the interface between the producer and the customer firms is very important. In this industry, important knowledge on production cannot simply be embodied in production equipment, and technical licensing alone cannot solve the problem of poor design capability in the product development stage (Lee and Lim 2001).

In this light, the chapter deals with the important question of how to grow local corporate capabilities using the case studies of the capital goods firms in Korea. The sectoral systems of innovation (Malerba 2004) were relied upon as the theoretical framework for analysis, whereas Y. Kim and K. Lee (2008) look at the machine tool industry from the perspective of the "middle-income country trap." The present paper proposes a Korean government policy that promotes the use of domestic machine tools and their development up to the present, including their advantages and disadvantages.

3.2 Regimes of Technologies and Markets, and the Barriers for Catch-up

3.2.1 The Regimes of Technologies and Markets

The machine tools industry is referred to as the "machine that makes machines," that is, it is the "mother machine." In other words, the machine tools industry is the foundation of the manufacturing industry, playing a pivotal role as the determinant of productivity and quality of products. Thus, the machine tools industry influences the development of other industries, and, furthermore, it serves as the criterion of the nationwide industry level.

According to classification by Pavitt (1984), the machine tools industry is a typical specialized supplier industry in which the tacit knowledge accumulated from the interface between the producer and customer firms is critical. In this industry, crucial know-how is not easily embodied into the production equipment because the equipment used in the production process is usually a general-purpose machine. It follows that the skills accumulated by workers are much more important. In addition, licensing is confined within a few specific models and, therefore, does not give much help in acquiring or improving design capability. Furthermore, a producer needs the ability to skillfully revise the design of a machine for various products to meet the diverse requests of customers, but this ability is not acquired only with technology licensing. This fact partly explains why catch-up is difficult in the machine tools industry, which has low innovation speed. The implicit knowledge feature of the machine tools industry makes the path for technological catch-up different from that in the electronics industry. As mentioned above, in the machine tools industry, experience over the long term carries more weight, while intensive R&D for a short period hardly leads to an effective catch-up.

The above discussion explains why catch-up is not easy in machine tools industry despite its low innovation frequency and volatility.

While the above discussion suggests a somewhat mixed picture of the possibility of catch-up in the machine tools industry, this study views that it is the demand conditions that give rise to more difficulties for catch-up. Stable or long-term market demand is critical because real R&D capability in machine tools is acquired from the tacit knowledge accumulated in the process of developing and producing the products over longer-term interactions with the user firms.

However, in most developing countries that tend to specialize in producing final consumer goods, the user firms are seriously reluctant to use locally made machine tools due to their poor quality and low level of precision that could hurt the competitiveness of their final goods in an unpredictable manner. Since the quality of a machine directly determines quality of final consumer goods made by the machine, the final goods industry, sensitive to the quality of its own products, shuns from using locally made, poor-quality machine tools, which has also been the case in Korea. From the perspective of the user firm, the risk of adopting locally made capital goods are simply too high. Outside of the export market, the domestic market is in itself weak, making the accumulation of tacit knowledge difficult by expanding production and interacting with various user firms. Latecomers, therefore, cannot expect any comparative advantage in neither cost nor quality (Lee and Lim, 2001). Furthermore, late-comer firms have few incentives to research and develop, in line with the fact that they perceive a low possibility of success in the market since they cannot expect any of the benefits such as cost competitiveness, quality differentiation, or first-move advantages (Lim, 1997).

3.2.2 Barriers to Catch-up: Weak Demand leading to Weak R&D

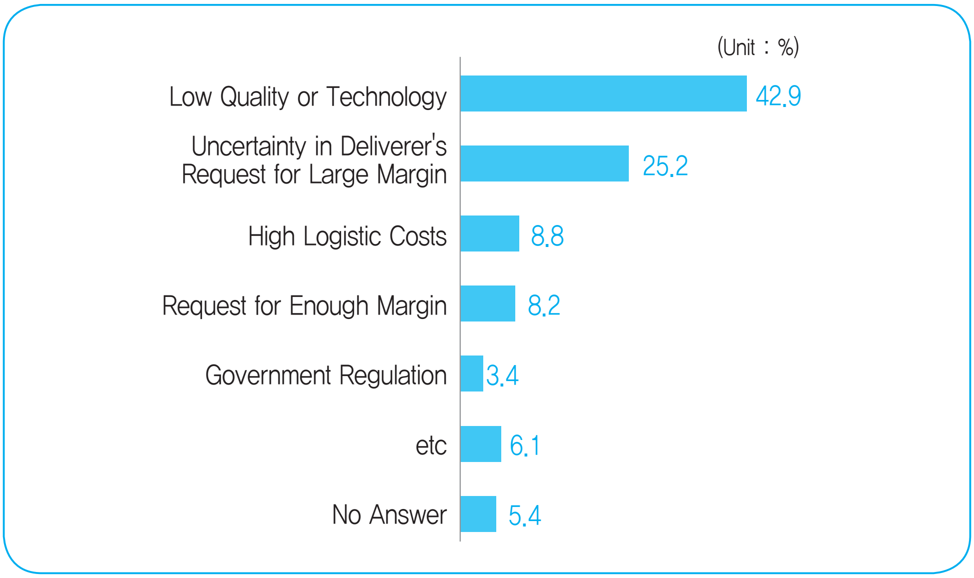
The first difficulty encountered by local machine tools firms is on creating and maintaining market demand from user-client firms, who are conglomerates producing final consumer goods. As mentioned above, since capital goods, machine tools in this case, directly determine the quality of the final products, the user firms or large enterprises that produce final goods are likely to be very fastidious in choosing which machine tools they should use for their production processes (Lee and Lim 2001). User firms cannot be blamed for this because local machine tools firms used to either produce low-end or low-technology machines for general purposes, or show poor performance in making high-end or high-technology machines. Meanwhile, the user firms have been able to import from Japan more reliable machine tools often at affordable prices. Given the big gap in the quality of the products made in Japan and Korea, it is not a surprise that the user firms preferred to use Japanese products. No user-producer interaction was possible in Korea.

This is different from the case of Europe where the difference in quality among the producers in Europe is small, and thus geographical proximity is an important factor in choosing the products, thereby allowing more chances for local user-producer interaction.

A survey on how to promote co-prosperity partnerships between SMEs and large firms conducted by the Federation of Korean Industries (KFI) in 2004 reveals that one of the most frequent answers for the difficulties in the partnership was “lack of quality or low level of technology of the products by the SMEs” (42.9%) (Y. Kim 2006). The low level of trust in the quality of the products by the SMEs in machine tools leads big user firms to adopt a wait-and-see attitude, avoid being the first user, or take advantage of the fact that there are few buyers of the products by the SMEs.

Furthermore, the typical conditions of the buyers’ market in the capital goods industry give an upper hand to big-buyer firms in their dealings with the seller SMEs. The buyer firms often ask for extraordinary discounts in transactions. An annual survey on the difficulties confronting SMEs as conducted by the Korean Federation of Small and Medium Business (KFSB) has pointed out the problem of subcontracting, which is associated with the requests for discount of buyer firms. This still holds for the development process; the cost for developing new items is not fairly compensated due to the conglomerate's demand for a lower price, thereby taking away incentives or opportunities for development or incurring expenditure for the next rounds of R&D.

Figure 2-2 | Difficulties in Transaction with Supplier firms: Survey to Conglomerates



Source: The Federation of Korean Industries

Surveyed: 147 firms engaged in manufacture, construction, distribution, etc.

The uncertain or unfair demand from user firms makes machine tool firms hesitant about investing big chunks of capital to develop capital goods, whereas the size of R&D expenditure to develop machine tools is usually quite big especially compared to the size of the firms in charge of this business. They are usually small or medium-sized, specialized firms and as such often do not have enough financial capacity for big R&D projects.

The results of a survey on the difficulties in the machine parts industry by FKI in 2005 confirm this (Y. Kim 2006). A machine parts producer considers as most serious difficulty in the development process the "insufficient R&D funds" (32.7%). This insufficiency of R&D funds does not simply mean that the funds are not enough but that there are structural barriers for the SMEs to put more money into R&D. The barriers are the uncertain demand from local users, the relatively bigger size of the required R&D budgets, and the involved risks as compared to the size of the firms. The same survey also points out the "long turn-over period" (24.6%) as an additional source for the difficulty in conducting R&D. Moreover, the SMEs are not paid for the delivery of goods as scheduled in the contracts with the user firms. Instead, the user conglomerates have tended to delay payments, taking advantage of their bargaining power.

This suggests that the problem of insufficient funds in SMEs is connected with the power imbalances between the buyer and the seller firm, deteriorating the condition of R&D for SMEs. A chief executive officer (CEO) of a Korean semiconductor machine firm (Jusung Engineering Co.) said in an interview, “only with a quality 30% higher for a 30% lower price can locally produced machine tools be chosen by user conglomerates.” While the local development of products with an enhanced quality level is already quite difficult, the even lower prices requested by user firms add to the problem. This situation suggests the difficulty associated with the development of local capital goods.

Thus, it might be better for machine tools firms to form a long-term alliance or network with large user firms from the beginning of the business to develop certain items. In many cases, big conglomerates in Korea themselves have started to develop machine tools or parts.

3.3 The Role of the Actors: the Government and the Firms

3.3.1 Promotion by the Government: A Slow Progress

a. The Background

While it has been typical for the government to intervene through helping late-comer firms in overcoming the barriers to catch-up in various forms, this study finds that in the capital goods industry, government activism tends to have limited effectiveness for several reasons. Lee and Lim (2001) aptly point out that even government policies that encourage the use of domestic products were not and cannot be effective. Since the quality of the machine tools employed directly determines the quality of the output, customer firms, sensitive to the quality of their own products, cannot afford to use domestically produced machine tools following the “order” of the government.

As noted in the preceding section, it is difficult for the capital goods industry to grow in latecomer economies. Since no firms are willing to enter this industry, latecomer economies are more likely to end up being underdeveloped. Given such possibility of low-technology equilibrium, Rodrik (1995) emphasizes the need for government intervention that will move firms out of a “bad” equilibrium to a “good” one. Rodrik argues that as long as the high-technology industry is much more capital intensive, policy support, such as subsidies and wage promotion policy, are effective in the transition to good equilibrium.

Consistence with such prescription, the Korean government also has been heavily involved in this sector. In the ex-post sense, the Koreans saw the slow but steady success in localizing the production of formerly imported machineries over the last three decades. However, as emphasized above, the limited success was inevitable. In what follows, a brief review of related government policies is provided.

b. Policy Initiatives

There have been relentless efforts by the government to promote domestic production of machines (See Table 2-10). Following the start of the project of promotion of the machine industry in 1966, there have been many short or long term national plans to promote localizing production of machineries. These initiatives include localization project in the 1970s, the five-year project for localization of machine part and material since 1987, the measure for nourishing capital goods industry at 1995, the 2003 measures promoting the growth engine for the next generations, and so on. The ministry of commerce, industry, and energy (now ministry of knowledge economy) has been in charge of these plans.

In the 1970s, localization policies on machineries were in the form of prohibition of imports. With a specific target of localization, a specific enterprise is selected and financed for the introduction of related technology or equipment. There was also the establishment of a joint company with a foreign partner. For example, in the automobile industry, although assembling firms are permitted to import engines, they were compelled to procure other parts from local firms, and so part-supplying firms were intensively supported.

Industrial development in the 1970s was mainly centered on the growth of final goods or assembly industry, which relied on imported technology and equipment to contribute to enlarging export volume within a short period. However, the center of growth policies was on the conglomerates or big business, while the dependency of smaller supplier firms on the big clients intensified. Moreover, the effects were limited because the focus was not much on development of key man powers and promoting of local technologies. In the case of items subject to import control, negative effects of absence of competition were partly there too.

In the 1980s and thereafter (1977-1999), localization policies were pursued in the name of the import-source diversification policy, which was aimed at curbing the sharp increase in the importation of Japanese products.[19] The number of items under import source control increased from 261 to 924, but had gradually decreased to 15 since 1993 until the abolition of import control in 1999. Localization measures were to identify the target goods and to provide R&D money for firms in charge of localization development. These policies in the 1980s were in a sense an extension of the import substitution policies as they were also aimed at the localization of low-technology, general-purpose parts and materials of 4,202 items.

Policies after 2000 were aimed to tackle the negative side effects of previous localization policies that were often perceived as too protective. Therefore, this time the main target was development of technologies reflecting market demands. They enacted an ‘Act for encouraging machine part industry’ in 2001. In this program, after survey on the demand

19 The import-source diversification policy is meant to control imports from countries with which Korea has too much trade deficits. The importing firms are then guided to import from other countries. This policy came into effect in 1977 and was abolished in July 1999 following the recommendation of the World Trade Organization (WTO).

by client firms and researchers, the items were selected, and then indirect inducement for entry by supplier firms were promoted by issuing certification of credibility who acted as a signal for firms selected. As a result, some successful cases of firms which took part in this program (global sourcing through technology development) had been observed. For example, Mando started to supply ABS and steering to GM, Ford, Daimler, so called big 3 of automobile producer in the world; Simmtech started to supply PCB to Infinion and Stetz.

Recently, the Korean government is focusing on strengthening the country's global competitiveness by devising the "the Second basic development plan for parts and materials industry (2009)," which is aimed at specialization and increasing the scale of firms and technical development. This plan aims at inducing large-scale investment by firms in parts and material industry by increasing the size of government sponsored investment fund. As a part of this program, they have also initiated the so-called "demand-related R&D project," which attempts to match big assembly firms on the demand side with part supply firms on the supply-side from the early stage of development of key parts and supplies.

Table 2-10 | Policies of Machine Parts Technology in Korea

Year	Policies for localization
1969	- Annual plan to localize for the 13 types of machine
1970	- Establishment of plan to localize machine tool of major industry and heavy industry. -Provision of institution for support of localization. - Announcement of localization of 148 items including internal combustion engine of boiler.
1973	- Plan for localization of plant
1976	- Mandatory rate of localization of plant - Measures for promotion of localization of machine - Announcement of standard localization rate of machine equipment
1977	- Establishment policy for localization of machine industry
1978	- Promotion Plan of localization of 6 part 36·items such as machine of metal processing and bearing. - Measures for promotion of localization of machine. - Expansion of item financed to purchase domestic machine from 11 to 199. - Base plan for promotion of machine industry.
1981	- Foundation of research association of NC process machine
1982	- Provision of plan for localization of industry equipment.
1983	- Measures on modernization of machine part industry - Measures to substitute for machine and electronics import.

Year	Policies for localization
1985	- Policies of promotion of domestic machine - Proposal to increase of localization rate in machine part - Permission of cash loan to lease firm for promotion of use of machine - Extension of finance support to domestic machine.
1986	- Plan for improvement of imbalanced trade with Japan. - Implement the first of 5-year plan for localization of machine part
1987	- Implement the second of 5-year plan for localization of machine part.
1992	- Promotion of use of domestically developed product. - Implement of loan of Korean currency indicated foreign currency. - Center for settlement of difficulties of domestically developed product - G7 Project for leading technology
1995	- Implement of policy for encouraging capital goods industry
2001	- Enforcement of 'Act for encouraging machine part industry'
2003	- Program for growth engine for next generation.
2009	- Material & Component Technology 2012

Source : Ministry of Commerce, Industry and Energy

Also, in terms of nominal tariff, the Korean government used complex strategies to promote the machine tools industry. The Korean government did not imposed high tariffs on important machine tools, such as lathes and drilling machine. These kinds of machine tools were very important to the quality of the output, so Korean government maintained relatively low tariff rate for import. In the 1970s, tariff rate of some machine tools increased up to 20% with the localization policies, but tariff rate imposed on them was lower than weighted average tariff rate of producer goods industry or weighted average tariff rate of total industry during the same period (See table 5-2). However, some of machine parts, such as bearings or gaskets, were relatively less important to the quality of the output than machine tools, so the Korean government imposed high tariff on them to promote local products. Tariff rate of these machine parts was in the range of 45% to 70% in early 1970s.

However, the Korean government gradually lowered tariff rates with two “Import liberalization five-year plans” after 1980s even though tariff rate of some machine tools increased temporarily in mid 1980s, so tariff rates of machine tools and machine parts were in the range of 7% to 9% in 1993.

Table 2-11 | Nominal Tariff of Machine Tools Industry (1964~1993)

Year	1964	1966	1968	1970	1972	1973	1974	1977	1978	1979	1980	1982
Lathes	5	5	20	20	20	20	15	20	20	15	15	
Drilling Machines	5	5	20	20	20	20	15	20	20	15	15	
Boring Machines	5	5		10	10	10	10	20	20	15	15	15
Grinding Machines	5	5	10	10	10	10	10	20	20	15	15	15
Gear Cutting Machines	5	5	10	10	10	10	10	20	20	15	15	15
Forging Machines	5	5	10	10	10	10	10	20	20	15	15	15
Shearing Machines	5	5		20	20		20	20	20		15	15
Bearings	30	30	50	50	50	50	40	30	30	30	30	30
Transmission Shafts, Cranks, Speed Changers	30	30	53.3	45	45	45	18.8	21.3	21.3	17.5	17.5	17.5
Gaskets and Joint	70	70	70	70	70	70	50	35	35	25	25	25
Metalworking and Industrial Machinery*		16.4	20.4	20.4	20.4	19.3	19.3	22.1	22.1	17.2	17.2	17.1
Producer goods**		30.1	33.2	33	33.2	30.8	30.7	26.8	26.9	21.5	21.3	21.3
Consumer goods**		73.3	80.9	81.3	82	67.4	68.2	53.8	53.6	45.6	45.1	38.9
Total**		59.1	62.6	62.2	63.3	53.6	54.1	43.2	42.8	35.6	35.2	31.5

Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Lathes	15	20	20	20	20	20	15	13	13	11	9
Drilling Machines	15	20	20	20	20	20	15	13	13	11	9
Boring Machines	15	20	20	20	20	20	15	13	13	11	9
Grinding Machines	15	20	20	20	20	20	15	13	13	11	9

Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Gear Cutting Machines	15	20	20	20	20	20	15	13	13	11	9
Forging Machines	15	20	20	20	20	20	15	13	13	11	9
Shearing Machines	15	20	20	20	20	20	15	13	13		
Bearings	30	30	30	25	25	20	15	13.6	13.6	11	9
Transmission Shafts, Cranks, Speed Changers	17.5	17.5	17.5	15	15	13.6	10.7	9.57	9.57	8.43	7.29
Gaskets and Joint	25	25	25	22.5	27.5	20	15	13	13	11	9
Metalworking and Industrial Machinery*	17.1	19.5	19.5	19.4	19.4	19.3	14.8	12.9	12.9	10.9	8.98
Producer goods**	21.4	19.3	19.1	17.9	17.7	16.3	12.2	10.8	10.8	9.53	8.06
Consumer goods**	38.2	30.6	29.3	26.6	25.4	22.6	16.5	14.7	14.6	12.8	11.1
Total**	31	25.7	25	22.9	22.1	19.8	14.6	12.9	12.9	11.3	9.67

Source : Tariff Schedules of Korea, Shin (2011)
*Tariff rate of metalworking and industrial machinery industry is weighted average using value of output in the input-output table for Korea as weight.
**Tariff rate of producer goods industry, consumer goods industry, total industry is weighted average using the industry real production data by Hong and Kim (1996) as weight.

Although it is not easy to evaluate the net benefits of various policy measures to promote part and supplies industry, including machine tools, technological competitiveness of Korean firms have steadily increased, and the gap between Korea and advanced countries has decreased. Results of a survey on Korean materials and parts industry show that competitiveness of Korean parts and materials industry was only 50% of that of the advanced countries in the 1980s, but it reached 74.2% of the United States in 2001, and more recently 92.6% in 2009.

The size of firms in this industry also became larger. The number of the so-called "core firms" in this industry[20] has increased from 155 in 2004 to 241 in 2009, representing an

20 Firms in the parts and material industry, sales of which are over 200 billion won and exports of which are over 100 million dollars

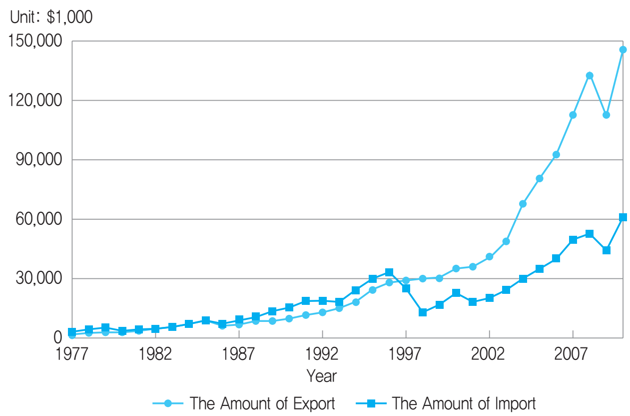
increase of more than 50 percent. Since 2003, the average output value of firms in parts and material industry exceeded hat of average manufacturing firms.

However, there are still rooms for further changes. Since the 1960s, Korea has imported almost all its main machine tools and thus has suffered from large trade deficits. It is only since the 2000s that trade in the machine tools industry had either stricken a balance or indeed had surplus (See Figure 2-3). Japan has consistently been the biggest supplier country of machines, but there is no sign of Korea striking a balance of machine trade with Japan, and there was the persistent trade deficit of Korea in terms of its trade in machineries with Japan.

The huge trade deficit with Japan is due to structural reasons. At present, the main Korean export products are final consumer products and general-purpose electronics parts. However, for the high-end parts and machineries, the Korean industries still rely on the Japanese products. In short, the Korean industry has not been fully escaping the stage of doing assemblies using key materials and machinery imported from Japan. The same is the case for semiconductor products, one of the representative export items of Korea. Only 20 percent of the production equipment in the semiconductor industry is made domestically. About 80 percent of the front-end process equipments are imported primarily from Japan and the United States.

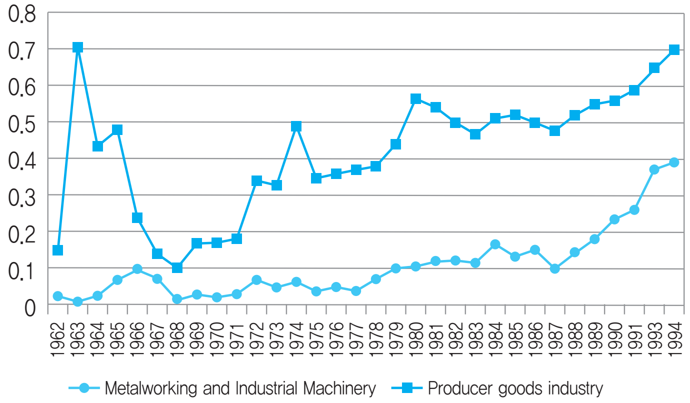
Anyway, Korean achieved a slow catch-up and achieved trade surplus in the capital goods, especially machine tools, since the late 1990s. The catching-up is also reflected in the increasing trends of RCA, which started to pick up only since the late 1980s (See Figure 2-4). Finally, by the mid-2000s, the RCA of Korea has caught up with that of Japan (See Table 2-12).

Figure 2-3 | Trends in Korean Export/Import of Machines



Source: Korea International Trade Association (www.kita.net)

Figure 2-4 | Standard Balassa Revealed Comparative Advantage (RCA) Index of Metalworking and Industrial Machinery Industry and Producer Goods industry



Source: Calculation based on NBER database: recited from Shin (2011)

Table 2-12 | RCA Index of Parts Export in Korea, China, and Japan[21]

Year		1999	2000	2001	2002	2003
RCA index of parts export	Korea	0.75	0.99	1.06	1.27	1.44
	China	0.66	0.72	0.85	0.94	1.00
	Japan	1.33	1.35	1.34	1.31	1.43

Source: Ministry of Commerce, Industry and Energy (2009)

21 Revealed Comparative Advantage (RCA) index is the indicator devised to compare competitiveness of countries that have distinct economic size. If RCA index is greater than one, the countries have comparative advantage rather than other countries in specific export (import) products.

$$RCA_{ij} = \frac{\frac{X_{ij}}{X_j}}{\frac{X_i}{X}}$$

X_{ij}:world export of i countryin product
X_j:world export in j product
X_i:all export of i country
X: all export of world

b. Private Firms Grabbing the Window of Opportunity

The preceding section emphasizes the intrinsic difficulty of catch-up in the machine tool sector implied by its knowledge regime, demand conditions, and the reactions by the incumbent firms. Despite this, the Korean firms have made slow but steady catch-up. This was possible owing to several factors, aside from the strenuous effort by the government.

First, while accumulation of knowledge in this industry requires close interaction with the user firms, the general-purpose machine tools were less subject to this constraint. Actually, growth of machine tool industry in Korea has been fast in general-purpose machines instead of specific ones in the market (Lim 1997). One of the factors that supported growth of the general purpose machine tools industry is the fact that it does not require much interaction with user firms nor very high level of technology and skills. These machine tools can be standardized and sold in mass markets to any users. For this reason, the producers of those tools can be free from the whims of the specific user firms.

Second, recent changes in the knowledge regime owing to IT revolution has opened up the new possibility of catch-up along stage-skipping or leapfrogging strategies. The share of mechatronics like NC processors, CAD/CAM, and PLC, the base of which is the IT industry, has recently increased, and therefore, stage-skipping catch-up becomes more feasible. Moreover, Korea is likely to gain competitive edge in terms of technology with a strong base of the IT industry. Actually, [Figure 2-3] shows the sudden surge of machine tool exports since the late 1990s that coincided with the emergence of new digital paradigms.

Third, the robust rise in demand from the late emerging economies, headed by China and the rest of the BRICs (Brazil, Russia, India, and China), served as markets for the Korean-made machine tools. The recent improvement of the trade balance of machine trade is actually due to the expansion of these new markets. While growth of the global machine tools market slowed down to 0.1% from 1999 to 2003, the Chinese and Asian market growth rate was 14%. The Korean firms successfully penetrated these markets with competitive quality and reasonable prices. While the major export partners in machine parts have been the United States and Japan up to 2001, the Chinese share in export has become larger and larger, hitting 32.8% in 2010.

3.4 Summary: Lessons and Implications

This chapter has dealt with the question of why making a catch-up is more difficult in capital goods industries that are usually led by small or middle-sized companies. It relies upon the sectoral systems of innovation (Malerba 2004) as a theoretical framework for analysis. The chapter has identified several sources of difficulties in catch-up in capital goods industry, particularly machine tools industry. First, while small firms in the capital goods industry are usually specialized suppliers to big final goods assembly firms in consumer goods or other industries, and thus the tacit knowledge accumulated from the interface between the producer and the customer firms is very important, a serious difficulty lies in the fact that local client firms are reluctant to use locally made capital goods due to their poor quality and low precision level. In this matter, even government policies encouraging the use of domestic products were not and cannot be effective.

Despite these intrinsic difficulties, the Korean economy has achieved a very slow but gradual catch-up in capital goods industry, generating several successful companies. The chapter has attributed such achievement to several factors, namely, strenuous effort by the government, emergence of niche markets in general-purpose machine tools, and increased adoption of IT and digital technologies in machine tools by emerging economies, the so-called BRICs.

This case of the machine tool industry in Korea shows that any late-comer firms that wish to record a successful catch-up should have these barriers in mind from the beginning of the roads toward catch-up. We observe that a successful catch-up in capital goods requires the ability to produce goods of better quality and lower prices than those produced by incumbent firms from advanced countries. The Korean case shows that government policies that for a long period mobilized diverse incentives, including collaboration between big firms in the demand side and small parts supply firms in the supply side, helped to a certain extent in the steady accumulation of technology competitiveness. This implies importance of a long-term orientation on policy intervention in capital goods, compared to shorter-term oriented measures.

4. The Digital TV Industry

4.1 Introduction

Along the tradition of Neo-Schumpeterian economics, there has been proposed a thesis of leapfrogging by Perez and Soete (1988), Freeman and Soete (1997) and Freeman (1989, 1995). The idea of leapfrogging emphasise the importance of utilising emerging technological opportunities in the process of catching up. Perez and Soete (1988) focus on how a catching-up country, not bound by costly investment in capital goods and infrastructure of old paradigm, can leapfrog into a new technological paradigm ahead of the advanced countries.

Seen from this view, the emergence of digital technology since the 1990 was also an opportunity for the latecomers to rise ahead against the forerunners. Actually, in the mid 1990s, Korean companies emerged as the world leaders in several innovative digital products. Korea was the first country in the world to develop the CDMA (Code Division Multiple Access) based digital mobile telecommunication. Also, it was via an LG product that the UK enjoyed its first digitally broadcast TV programmes, and via Samsung products that Americans watched the historic launch of the space-shuttle, Discovery. Samsung and LG command numerous world-firsts in terms of technologies and licences in related fields of digital technology. Samsung and LG have enjoyed the top market shares in digital TVs either in the U.K. or in the U.S. since the late 1990s. Now, the absolute majority of the TV exports of by Korea is accounted by export of digital TV, which replaced analogue TV. This signified the shift from analogue to digital goods as the main export item in Korea.

This chapter aims to provide a detailed story of emergence and growth of digital TV industry in Korea, and thereby to examine the leapfrogging thesis in the case of digital TV industry. The period of analysis is from the early 1990 to the years of 2002 or 2003. For detailed information, this chapter relies heavily on Lee, Song and Lim (2005), which is a detailed case study, based on the interviews of R&D staffs of the leading firms, like Samsung Electronics and LG Electronics, and materials from newspapers and governmental documents and reports, as well as researchers in governmental research institutes. Thus, the study focuses on what kinds of advantages and disadvantages the Korean firms had in this story of catch-ups, and also on how the risks of the early entry to emerging industry were tackled by the Korean firms. We find that the special feature of digital TV, such that the standards were fixed before the market formation, was important in reducing the risks involved with leapfrogging by the Korean firms.

Section 2 discusses the technological regime of the digital TV technology, and section 3 provides a detailed story of the process of emergence of digital TV industry in Korea since the early 1990s, describing it as a case of leapfrogging and elaborating how it was possible. Section 4 examines the role of the government with focus on the question of how the government helped the private sector to overcome the risks involved with this leapfrogging. Concluding section provides a summary and discusses policy implications.

4.2 The Regime of Technology of the Digital TV Industry

The technological regime of digital TV technology can be discussed in terms of technological opportunity, appropriability, the acquisition of the knowledge base, and the required conditions for infrastructure investments.

Technological opportunity of digital technology is immense as it is featured by frequent innovations (See Table 1 of Lee et al., 2005). Immense technological opportunity implies more competition in this field, but the point is who get the returns from innovation, in other words, appropriability conditions. Appropriability of innovation outcome in IT is specially influenced by the standard settings. Producers of the products adopting more dominant or successful technology standard can appropriate returns from R&D investment more easily than others. In this competition for standard setting, forming alliances, cultivating partners and ensuring compatibility are critical (Shapiro and Varian 1998). Owing to the network externality, competitive advantage of products depend not only on the performance and price of my products but also those of complementary products made by collaborative partner firms and governments who share the same technological standards. Since cultivation of sufficiently big market size earlier than others or rivals and the losses to the losers are substantial, eg. the R&D, the involved parties want to set the standard first before putting their product to markets and then under anarchic competition.

As the digital TV technology is featured in very frequent innovations and heavily influenced by standard setting and complementary products, speedy entry into market and speedy formation of collaborative partners are critical for success. In addition, building an infrastructure compatible with your technology standard is essential in digital TV industry since the performance rely heavily on the quality of the infrastructure, such as broad casting system.

What are the implications of these technological characteristics of the digital TV for catching-up by the late-comer firms? The answer is that catch-up would not be easy, and risks are especially high. In other words, the earlier stage a catching-up firm enters the industry, the higher the risk is.

In this regard, one important counter-balancing fact, as noted above, is that digital TV joins shares with other telecommunication industries, and that technological standard is fixed before the market is formed (Choh 1999, Wallenstein 1990, Cargill 1989). Standards for CDMA wireless communication and digital broadcasting system were initially established in the US or in the EU even before the market was formed. In digital TV technology, the standard was formed by the so-called "Grand Alliance" in the US in 1993 and later evolved to be finalised by the FCC in 1997. This is in contrast to what happens in traditional industries, such as automobile and other consumer durable goods, where the standard or the dominant design is established as a result of competition in the market (Klepper 1996, Clark 1985).

Since standards form before markets do, future technological trajectory can be assessed more easily even at an early stage of technological evolution. This characteristic tends to reduce the risk of the early entrants and hence the catch-up by the late-comers. What the late-comer firms, like those in Korea, should do was simply to develop products compatible with that standard after digital TV standard was set by the alliance among the leading firms.

4.3 The Process of Technological Development

4.3.1 The Initial Conditions

Maybe the biggest advantage of the Korean firms had with regard to the development of digital TV was the fact that Korea lagged behind Japan and others, and did not have much incentive to stick to analogue technology led by Japan. Thus, Korea was very prompt and decisive in investing in digital TV technology as the Korean firms and government regarded development of digital TV as an opportunity to catch up with Japan.

In terms of human resources, Korea did not have sufficient human resources for commercially successful production of digital TV in the beginning of the 1990s when Korean firms becan developing into digital TV. Korea was also distant from the main sources of the related knowledge, namely the U.S and the Europe. However Korea did have human resources for interpreting R&D trend of foreign firms and applying the knowledge from the foreign sources into developing digital TV. Korean companies can also be said to have some engineering capability in digital TV in that roughly 60% of the production process of digital TV sets is as same as that of analogue TV. Also to be noted is the fact that Korean firms and the government have had an important tradition of successful the public-private R&D consortium, originating from the TDX (telephone exchange system) development (Kang 1996), 256 Mega bit D-RAM (Lee and Lim 2001), and more recently world first development of CDMA mobile phone system (Lee and Lim 2001, Song 1999). Accumulated knowledge and experience from these projects must have been useful for the case of digital TV, too, as the involved parties are all the same, same private firms and same government ministries and research institutes.

Not having strong human resources for digital TV technology, the Korean firms had to rely on newly recruited manpower. LG Electronics did not have human resources who were knowledgeable about digital signal receiving and sending and compression of images. They recruited internally those engineers who were knowledgeable about electronics in general and who have an experience in developing TV and other electronics products in the firm. Although it recruited Ph.D. from both the U.S. and Korea, the main leading research group were those from LG who intensively absorbed new knowledge on digital TV and carried out R&D activities. Samsung also did not have human resources. When Samsung's research team was established, all the members except for the project leader were newly recruited researcher. The leading researchers were recruited from those of the US firms to the US branch of the firm.

Much locational advantages for digital TV did not exist in Korea, either. Domestic market did not exist when digital TV sets were first produced in 1998. Thus, all the products were made for foreign market, and it can be said that the local market was not the driver of R&D activities.

The discussion so far indicates that the Korean firms did not have sufficient capability to be the leader in this new industry. In what follows, we will elaborate how the Korean firms overcome this difficulty.

4.3.2 How that was possible in Samsung and LG

Korean firms have been closely watching the technological activities of the GI and other leading firms in the U.S. In the case of Samsung, it was as early as September1989 when it first established an R&D team for digital TV and a U.S. branch (AML: Advanced Media Lab) in Princeton, New Jersey in the U.S.. This lab served as a channel for accessing the knowledge sources in the U.S. as this overseas lab recruited engineers and scientists, with knowledge about digital signalling and ASIC designs, from the U.S. companies such as DSRC and RCA. One interesting thing about the Samsung' domestic research team was the fact that they recruited in 1989 only those engineers who has no experience with analogue TV but had majored in digital signalling in Korean or foreign schools. This practices can be considered as an “unlearning” along Nonaka (1988, 1994) such that any new project had better be started with personnel free from the influence of old routines or pre-conceptions (Lee and Lim 2001). Korean researchers were sent to the US branch to learn the technology on digital signal processing.

Although it was very short (only 6 months), there was also a collaborative project for digital TV between GI (general instrument co.) and Samsung in 1991. Such collaboration was realized because the GI needed a partner in developing prototype digital TV. But, Samsung R&D staff indicated that the collaboration was not a formal and thus they were not able to learn much from the GI. In their words, the GI persons told them to do this and that small things, namely teaching “leaves” but not teaching the whole “tree.” Thus, their main role was to provide hardware-level assistance in GI’s R&D activities.

In the case of LG, according to interview, in-house research team for digital TV technology was established in 1990. As early as 1990, LG had a minor share of 15% in Zenith, and a research lab in Chicago, and thereby was able to send several researchers to Zenith. For digital TV, except for digital signal receiving and retrieval part, the existing technology on analogue TV, especially monitor technology, can be used. Thus, the research by the Korean firms focused on digital signal receiving and retrieval and related software, with a view to develop a prototype. The core technology related to digital signalling was owned by Zenith, namely VSB technology. With its minor share in Zenith, LG was able to get some help and use the technology without the fear of patent violation.

As the “Grand Alliance” was formed in 1993 to coordinate the basic standard for digital TV technology, it became less uncertain for the Korean to finalize the specifications of the prototype TV sets. Finally, it was in October 1993 (eight month earlier than the proposed deadline of June 1994) that the consortium, with Samsung and LG as the de facto leader, first demonstrated publicly the technical possibility of digital TV broadcasting and receiving with a prototype at the Daejon EXPO (an international convention event).

In reaching to the point of this achievement, an important part of the LG’s and Samsung’s research seemed to be done mainly within Korea but complemented by research in the US. As a matter of fact, as shown in table 3 of Lee et al (2005), no digital TV patents by LG has included a person residing outside Korea as an inventors, and about a half of the Samsung’ patent has included as an inventor a person residing outside Korea. However, it also implies that there was some role played by the overseas R&D centers in the case of Samsung, and the fact of no non-Korean resident as inventor in the case of LG imply that LG might have less need for overseas R&D center owing to the patents held by its overseas subsidiary, Zenith.

However, according to Lee et al (2005), Zenith’s contribution to LG’s development of TV sets was not that heavy as might seem from the outside because many former staffs of Zenith left Zenith upon LG’s acquisition. Also, it was in 1994, two years before the LG’s acquisition of a major share of Zenith, that the Korean team succeeded in demonstrating a prototype digital TV. Only in 1996 LG’s share increased to more than 50% and finally to 100% in 2000. From LG's point of view, the main purpose of the acquisition was the use of Zenith-held patents related to the critical VSB (tuning) technology and other digital broadcasting standards. Overall, we can still say that the access to foreign knowledge base in the form of either overseas R&D outposts or acquisition of a foreign firm had been important.

While the development of the prototype was an impressive achievement, there was a long way to go from this prototype. The October 1993 prototype was not a really marketable product as it consisted of several cabinet size systems. What they have done is a minimum demonstration of the physical feasibility. The critical next step was to pack all the functions into small ASIC chips. In other words, without the chip, commercialisation can be said to be impossible. Thus, despite that the government regarded the project as a success and once wanted to declare the successful completion of the consortium, it was the private companies that persuaded the government to launch its second stage to develop the chips right after the end (June 1994) the first-stage 5 year project. The new 4 year project to develop the ASIC chip started from December 1995. In this process, there was again a division of labour among the firms. For example, LG is supposed to be in charge of a chip for video decoder, whereas Samsung, of audio and channel decoder. However, later it was turned out that each company had developed the chips assigned to other companies. This phenomenon reflected again both the limits of the consortium as well as the rivalry between these two companies. Anyway, both companies succeeded in developing a set of chips by 1997 (world first), and the consortium took their products for the various tests in the US. After these tests, Samsung and LG revealed their market-ready product at the CES (Consumer Electronics Show) in January 1998. Samsung's brand was Tantus with a 55 inch screen, and LG used Zenith as its brand name in their 64 inch screen products. At the CES, Japanese firms revealed only "digital ready" TV, without digital tuner.

It was reported that Dr. Paik, the research head at the GI who was the first to prove the feasibility of digital signalling in 1990, was surprised and impressed at the new of LG's development of ASIC chips in 1997. After the development of ASIC chip in 1997, LG's R&D turned its focus to MPEG and TV-related software. It was during this final stage that Dr. Paik joined LG in 1998 as a CTO. In other word, his main role took place during the later stage of developing market-ready TV sets. After this, LG's overseas R&D center was established in 1999 in New Jersey, with name Triveni, with a view to develop broadcasting equipments, not TV sets.

In sum, while the initial core technology was owned by the US firms, digital signalling by the GI and digital tuning (VSB) by Zenith, the Korean firms were able to develop a prototype digital TV and eventually a commercially successful digital TV owing to their command of complementary technologies, such as ASIC chips, HD level MPEG, display (PDP, LCD), and related software to be embedded in TV sets. These two firms are producing digital TV, either a "built-in" digital TVs with a digital tuner or "digital ready" TVs without digital tuner (which can receive digital TV programs only with a set-top box). Out of these two-stage-based research consortia, Samsung and LG have emerged as the world leader in not only digital TV set but also in related display technology, TFT-LCD, Projection Display and Plasma displays. They became able to produce and sell a variety of digital TVs of different display methods. These complementary technologies were especially important for the commercialisation of the initial core technology.

4.4 The Role of the Government

Initial actions toward HD TV by the Korean government and firms were heavily influenced by the Japanese lead in analogue HD TV. The Japanese group came to Korea during the 1988 Seoul Olympic game, and staged a promotion tour of their achievement in the hope that the Koreans will follow the Japanese role model. Recognizing that HD TV will be a next generation hot consumer items with immense technological and market potentials, the Korean government first established the Committee for Co-development of HDTV in 1989 (Korea Electronics Technology Institute (KETI) 2000). This committee had a participation of three ministries (Ministry of Industry and Resources, Ministry of Information and Communication, and Ministry of Science and Technology) and 17 institutions comprising private firms, government research institutes (GRIs), and universities. This committee started and coordinated a 5-year project (June 1990 to July 19994) to develop HD TV.

The Korean government wanted to promote HD TV as one of the most important export items for the next generation, the 21st century. The government-initiated research consortium was led by the Korea Electronics Technology Institute, joined by Samsung, LG, Hyundai, Daewoo Electronics and other private firms. The research project was the first to interpret and absorb the foreign knowledge and eventually develop HD TV sets (KETI 2000). The total budget for the 5 year was 100 billion Korean Won (roughly 100 million US dollars) with the government and the private sector to pay a half of the total amount, respectively.

Right after the Korean initiated the project, the GI, a leading firm in digital TV technology, staged a historic demonstration of the possibility of digital TV in 1990. The head of the research team at the GI was a Korean American, named Dr. Woo-Hyun Paik who joined the LG electronics in 1998 as the CTO (Chief Technology Officer). At the turn of this event, the Korean research project for HD TV decisively fixed, in spring 1991 , digital HD aimed at US markets as its target, leaving aside Japanese or European-led analogue HD TV. But, the problem was the fact that US standard was not yet determined at the time. In this regard, one interesting strategy by the Korean team was the decision to develop several alternative standards simultaneously, with different private companies in charge of different standards. At that time, there were four identified leading standards in the US. Thus, Samsung was chosen or assigned to develop the standard by GI and MIT coalition, LG, that by the Zenith and AT&T coalition, Daewoo, that by the RCA, and the Hyundai, that by Fajouja.

This public-private coalition encouraged private firms to stick to this risky R&D activity by channelling R&D funds and forming a network of researchers from firms, universities and governmental research institutes. In the project, there was a clear division of labour among the participating units. As shown in <Table 2-13>, the whole project is divided into digital signalling (satellite and terrestrial), display (CRT, LCD, PDP) and ASIC chips (application-specific integrated circuits chips, encoding, decoding, demultiplexer, display processor). Each unit, GRI or private firm, is assigned to different tasks with some intentional overlaps among them, namely two units to take the same task to avoid the monopoly of the research outcomes.

Table 2-13 | Division of Labor in HDTV Development Projects in Korea

	R&D areas		Research organization
Digital Signal Processing	Satellite broadcasting		Korea Institute of Industrial Technology
	Terrestrial broadcasting		LG Electronics Inc.
			Daewoo Electronics Co., Ltd.
			Samsung Electronics Co., Ltd.
			Hyundai Semiconductor Inc.
Display	Direct-view CRT	G/B	Hankuk Electric Glass Co., Ltd.
			Samsung Corning Co., Ltd.
		S/M	Goldstar M/C
		CRT	LG Electronics Inc.
			Samsung SDI Co., Ltd.
			Orion Electronic Company
			Korea Institute of Industrial Technology
	Projection CRT		Korea Institute of Industrial Technology
	Projection LCD		LG Electronics Inc.
			Orion Electronic Company
			Korea Institute of Industrial Technology
	PDP		Orion Electronic Company
ASIC	ASIC Chip		Goldstar IT (= LG)
			Samsung Electronics Co., Ltd.
			Hyundai semiconductor Inc.
			Electronics and Telecommunications Research Institute

Source: KETI (2000) page 426.Recited from Lee et al., (2005) While each unit is supposed to share the results with other firms via the KETI, the private companies are observed to have tended to do research on diverse aspects of the digital TV technology and to keep important or core findings within itself. While this kind of behaviour might have possibly undermined the cost-effectiveness of the collaborative research, it was inevitable to a certain extent and to be balanced against the benefits of the consortium, and it also symbolized the dynamic spirit of competition. As a matter of fact, the R&D staffs of both Samsung and LG acknowledge one important benefit of such consortium, especially the role of the government. The government-led consortium had the effect of providing the private companies the legitimacy of the project, without which their project would have stopped because the private companies cannot just keep pouring money into project with uncertain cash outcomes. Furthermore, the consortium provided the firm's R&D team with the opportunity to meet and collaborate with university and other public sector researchers. The R&D staffs acknowledged that interaction with university professors, especially those who just returned from the U.S. with a Ph.D degree in digital technology related fields were particularly helpful.

However, core research activities were conducted by the two private companies, Samsung and LG, as shown by the fact that more than 90 percent of Korean patents related to digital TV and registered in the US are were not by the government research institutes but by either LG and Samsung (See Table 3 of Lee et al 2005). Also, the Korean government was slow in building infrastructure for digital TV broadcasting. When of domestic production starting in 1998, the government did not even declare the standard for digital broadcasting. Thus, initial market for the Korean-made digital TV set was to be found in other countries, such as the U.S. and the U.K., which was critical for eventual success of this venture.

Now, let us finally examine the trends of tariffs on television shown in <Table 2-14>. As expected, Korea tended to impose a very high tariff (as high as 100% sometimes) on television set during the 1960s and 1970s when it was very much an infant industry. From the late 1970s, it was reduced to around 50% and remained about 30% through the mid 1980s. Only after 1993, it was reduced to less than 10%. Thus, it can be argued that digital TV did not enjoy any protection from tariffs as it started in the late 1990s.

Table 2-14 | Nominal Tariff of Television (1958~1994)

(unit: %)

Year	1958	1964	1966	1968	1970	1972	1973	1974	1977	1978	1979	1980	1982
Tele-vision	60	80	80	100	100	100	100	90	45	45	50	50	35
Year	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	
Tele-vision	32.5	33.3	32.5	29	27.3	23.8	16.3	13.6	13.6	11.4	9.2	8	

Source : Tariff Schedules of Korea, Shin(2011)

4.5 Summary and Policy Implications

This chapter verified the leapfrogging thesis with the case study of digital TV in that it has elaborated how the emerging new technological paradigm can serve as a window of opportunity for the catching-up firms. The study has also identified the disadvantages and risks facing the catching-up firms, and elaborated how these can be overcome by the public-private R&D consortium. We find that this case of digital TV can be considered as a "path-creating catch-up" among the three types of catch-up proposed in Lee and Lim(2001). We also find that this case is very similar to the case of the development of CDMA mobile phones in the sense that access to foreign knowledge base was very critical for the success. As proposed in Lee and Lim (2001), it is shown that a path-creating catching-up is likely to happen by public-private collaboration when the technological regime of the concerned industry featured by more fluid trajectory and high risk.

This study has the following implication for government policy and firm strategies (Lee et al 2005).

First, a long list of success with the public-private R&D consortium, from TDX, D-RAM, CDMA and finally to digital TV in Korea, confirms the positive role of the government and the government research institutes in technological catch-up by the late-come firms. Although the collaboration and knowledge sharing among the private firms has certain limits within the framework, the private firms all acknowledged the important function of the government in providing the legitimacy to the big projects that are often difficult to be supported by private firms. The consortium also served as a field to pool together the domestic resources from various sources, especially resources in the universities that is often a reservoir of new scientific findings. Contribution of the GRI's is also critical in conducting the role of "technology watch" to interpret and monitor the state-of-the art trend of R&D activities in foreign countries. It was the ETRI who identified the small firm like Qualcomm as the R&D partner, and the KETI was the coordinator in the consortium to develop digital TV.

Second, the experience of digital TV, besides CDMA, underscore the importance of getting access to the global knowledge base, without which leapfrogging catch-up is almost impossible as the late-comer firms cannot generate radically new technologies themselves. In addition, we want to emphasize the change in the channels for knowledge access. While in the past or in the path-following catch-up, the main channels has been license or FDI, the current cases of a path-creating or leading catch-up during the paradigm shift period show the importance of new channels such as co-development with, and acquisition of, foreign firms as well as collaboration based on complementary assets owned by late-comer firms. Horizontal collaboration with forerunning firms is possible only when the late-comer firms have something to give in return. While absorption capacity was emphasize in the old story of technology transfer via license or FDI, now complementary assets, which have been created with speedy R&D activities and investment in production, seems to be important in these new ways of accessing knowledge.

Third, when the involved catch-up is in the area of information or other emerging technology, the critical role of standard setting should be emphasized. Isolated development without paying attention to the issue of standards might lead to a failure of the whole project. In standard setting, collaboration and getting partnership with rivals or suppliers of complementary products are important. Also critical is who create and get access to the market first as the size of the market determines the success or failure of one standard against other. Again, in this competition for standard setting and market creation, the role of the governmental is crucial because it can facilitate the adoption of specific standards and thereby influence the formation of markets at the right times.

Chapter 3

Summary and Concluding Remarks

Summary and Concluding Remarks

1. Summary and Concluding Remarks

The development process consists in growing industries, where firms may flourish and develop enhanced capabilities. The essence of enhancing the capabilities of private firms requires assuring them the initial rents (profits) and learning opportunities until they grow enough to compete successfully in world markets. This report has discussed several ways of doing this in four different sectors or technologies, with a focus on the role of the government.

In mainstream economics, the government is often considered as an "invisible foot," such that its intervention into the market economies may often lead to worse results than without such intervention. While such assessment would often be true across countries, this does not preclude the possibility that in certain context and under certain conditions, the government activism could lead to desirable outcomes. This report explore what such conditions would be using the case examples from Korea's past.

In general, it is our theoretical opinion, based on the concept of the SSI (Malerba 2004) and other work from a Neo-Schumpeterian perspective, that the specific forms of the government activism should be different in different sectors featured by the different regimes of technologies and markets. When we consider diverse forms of involvement, ranging from simple protection by tariffs, direct subsidies to production, indirect help through GRIs (government research institutes), sharing and provision of R&D expenses, public-private R&D consortium, and direct entry by the SOEs, we can easily reason that these tools would all have different degree of effectiveness in different market and technological environments. So, it is not easy to spell out the conditions and context in a simply way. The following is an attempt based on the four cases of technological development in Korea, including sectors of telephone equipment, steel industry, machine tools and TV/display.

1.1 When Targeting Can be justified

Let us start from a commonly made observation that when the sectors/technologies are featured by more uncertain trajectories, direct technology targeting by the government would better be avoided. However, it is equivalent to say that when there is less uncertainty, targeting might work. Warning against targeting makes more sense in the context of the developed countries whose firms are on the frontier of technologies facing greater uncertainties. In the context of the latecomer there is ready justification for targeting industries. These are the industries or technologies that the latecomer economies are importing or buying at monopoly prices because these products are monopolized by foreign companies. In this import-substituting targeted development, local efforts face less uncertainty or risk because targeted technologies are often mature technologies that are not impossible to emulate by concentrated efforts by local indigenous R&D consortium.

The case of TDX development discussed in chapter 3 is a good example. When the technological regimes are featured by the less frequent innovations and less fluid and thus stable technologies, a more directed involvement of the government in the form of sharing and/or providing a part of direct R&D budget can be justified. But, as the case shows, this process should ultimately lead to enhance capabilities of the private firms. Then, there would be less need for government involvement, which is the case in the later stage of technological development in Korea.

1.2 How to Do It Under the Uncertain Technological Regimes

While the above is about justifying government targeting when there is less uncertainty, the next question is then what can be done under more uncertain environment, or closer to the frontier. The case of digital TV development discussed in chapter 6 indicates that the nature of the public intervention should be different. In this case of uncertain world, the role of the public research organization (PROs) or GRI seems to be important in reducing the uncertainly, especially about choosing the right technologies or standards. The role of the PROs, of course, should be a part of the broader public-private R&D consortium.

In the case of digital TV consortium, like the cases of TDX or DRAM, contribution of the GRI's is critical in conducting the role of "technology watch" to interpret and monitor the state-of-the art trend of R&D activities in foreign countries (Lee et al 2005); it was the KITECH and ETRI that carried out R&D activities and coordinated the consortium of the research projects in two specific fields of the whole project. The consortium served as a field to pool together the domestic resources from various sources, especially resources in the universities that is often a reservoir of new scientific findings. Otherwise, the degree of knowledge sharing among the private firms would have been impossible or much lower. The participating private firms all acknowledged the important function of the government in providing the legitimacy to the big projects that are often difficult to be supported by private firms.

1.3 Slow Progress with State Activism: Capital Goods

In general, capital goods, especially, machine tools industry, are featured by the low frequency and low volatility of innovation, which suggest that catching up by the latecomers would not be difficult. However, this is the sector that catching up has been most difficult or slow. The chapter five has identified several sources for difficulties. First of all, while small firms in the capital goods industry are usually specialized suppliers to big final goods assembly firms in consumer goods or other industries, and thus the tacit knowledge accumulated from the interface between the producer and the customer firms is very important, local client firms are reluctant to use locally made capital goods due to their poor quality and low precision level. In this matter, even the government policies to encourage the use of domestic products were not and cannot be effective. Furthermore, the government cannot simply protect local producers by charging high tariffs, because use firms would want to import the products at lower prices than using the unreliable domestic products.

Despite these intrinsic difficulties, the Korean economy has achieved a very slow but gradual catch-up in capital goods industry while generating several successful companies. The chapter has attributed such achievement to several factors, strenuous effort by the government, niche markets in general-purpose machine tools and emerging economies, so-called BRICs and finally increasing introduction and adoption of IT or digital technologies in machine tools. This implies importance of a much longer term orientation in policy intervention in capital goods, than shorter-term oriented measures.

1.4 Classical Case of Positive Externalities and Linkages

A much easier case for state activism justifiable from a textbook economics is the case where there is a certain degree of positive externalities such that market failure prevails in terms of the gap between private and social return. The case of steel industry promotion by the establishment of POSCO would fit this story. Given that there was no private firm that dared to take this job of starting integrated steel industry in the 1960 Korea with uncertain conditions, it would lead to market failure of underproduction of steel by private actors. Furthermore, steel is an input to diverse sectors of production. Given high degree of scale economy and a limited size of domestic market as in Korea's past, it was certain that it would be under-produced if it is left with private firms, and the private monopoly would charge too higher prices under monopoly. Just rely on imported steel would lead to no benefits from backward and forward linkages. Under these conditions, entry by establishing an SOE seemed to be a rational choice in the context of the past Korean economy. Technological uncertainty was lower because technology required for steel production was old and mature. Furthermore, as discussed in chapter 4, Korea's entry and expansion at a later stage took advantage of the lowered price of factory equipments and facilities during the world wide recessions, namely the first and second oil shocks. Market uncertainty was lowered by the government and private effort to grow automobiles, ship building and other steel using industries.

Finally, when POSCO boasted enough international competitiveness, the privatization began with the state share sold to the public.

1.5 Conceptualizing Toward a Korean Model of Technological Development

While the above four points suggest a mode of effective government intervention in diverse specific conditions, we can also attempt to find a grand conceptualization for a Korean model of technological development. If such thing is possible, it would be a model of the three party cooperation or the GPG model, namely cooperation of the Government research institutes, Private firms, and Government ministries, with possibly different roles of each party, depending upon the nature of the projects. Given that whatever case of technological development should involve the three things of R&D, production, and marketing, the GPG model implies that government research labs in charge of R&D, private firms in charge of production, and the government in charge of marketing in the form of direct procurement or protection by tariffs and exclusive standards.

While the case of TDX would be the most typical representation of this GPG model (let us call this GPG1), there are some variations depending upon the level of capabilities of private firms and public agents involved. The case of digital TV and CDMA is another variation that can be called a GPG2. In the GPG2, costs and risk of R&D are shared between government research institutes and private firms, and the GRIs do the role of technology-trend watching and coordination to bring in diverse actors into the consortium. This GPG2 model can be considered as a more advanced form of the GPG in that it is possible only when the capabilities of private firms are more advanced to be able to conduct more R&D.

The case of the machine tool industry also belongs to the ‘GPG2’ with more R&D shifted to the hands of private firms rather than government research institute as the role of government was limited to providing the R&D fund and protection of infants by tariffs. The major role of the government (or ministries involved) tends to be funding R&D, guaranteeing the initial markets in the form of procurement policies, and/or local market protection by tariffs or exclusive standard declarations.

Another variation of the GPG model is the case of government agents doing both R&D and production, and this is possible when capabilities of private firms are nil or the nature of projects tend to involve more production and less R&D. This variation can be called GPG0 but is actually not GPP but GG without P (without involvement of private firms), and the case of POSCO or steel development by the government-owned enterprise is the representative.

The opposite case to this GPG0 or GG mode is that of GPG3 or PG, where government research institute is missing. An example is the case of development of automobile industry spearheaded by Hyundai Motors. As discussed in Lee and Lim (2001), in this case, the government or a government research institute was not involved in R&D but its role was limited to providing protection of infant industries by tariffs. As R&D was done by a private firms or Hyundai Motors, it is the GP model, not GGP model, with private firms doing both R&D and production.

In sum, based on the cases in the Korean economy, we have identified the four modes of state activism for technological development, and in the increasing order of more role for a private firm, they are 1) the GPG0 (or GG) mode with the government doing market provision and government owned enterprise doing both R&D and production, 2) GPG1 mode with R&D by GRIs and production by private firms, 3) the GPG2 with more R&D shifted to the hands of private firms who are cooperating with the GRIs, and finally 4) GPG3 (or PG) mode where private firms doing both R&D and production. In all of these variations, the role of the government (or ministries involved) tends to be guaranteeing the initial markets in the form of procurement policies, and/or local market protection by tariffs or exclusive standard declarations. The latter three modes are similar to the three stages on the roles of the GRIs discussed in Choi et al (2010: ch. 5).[22]

Although we have arranged the four modes (GPG0-GPG1-GPG2-GPG3) of GPG in the order of increasing role of private firms, this does not mean that they have appeared in that sequence nor should be implemented in that order. Actually, the GPG3 mode of Hyundai Motors appeared earlier than the GPG2 mode of digital TV. In this sense, we are different from the traditional stage model of technological development, and are not proposing any such theory. Rather it is our view that it is not necessary for other latecomer countries to follow the modes in the above sequence but that they can or should choose whatever appropriate stage or variation in consideration of their specificities, in particular the level of capabilities of private firms, as well as the nature of regimes of technologies and markets.

In the above discussion of the modes of technological development, the focus has been on the roles of government ministries or research labs. However, we also note that one common element across the four modes of technological development is that they have all involved arranging access to foreign knowledge in diverse channels. As discussed in many literature (Lee et al 2005), the role of foreign knowledge through very critical, without which the latecomers' catching-up effort is often at risk and demands too much time and costs. In general, the diverse channels of knowledge access and learning included such modes as training in foreign firms and institutes (Choi et al 2010), OEM, licensing, JVs, co-development with foreign specialized R&D firms, transfers of individual scientist or engineers, reverse brain drains, overseas R&D centers, strategic alliances, and international M&A's. All these constitute effective channels of knowledge transfer around which firms are able to strategize.

22 In chapter 5 of Choi et al (2010), Dr. Hwang discussed the GRI-domination stage, the public-private consortium domination stage, and finally the private firm stage.

Then, we can say that successful technological development by the latecomers tend to involve the three things, namely, government supports, access to foreign knowledge, and finally private firms' effort, and the weight and specific role of the three elements would differ by the sectors and levels (or stages) of economic development.

Amsden, A. 1989. Asia's Next Giant. New York: Oxford University Press.

Antonelli, C, 1997, Localized Technological Change, New Information Technology and the Knowledge-based Economy : The European Evidence, Laboratorio di Economia dell' Innovazion, Universita di Torino.

Bank of Korea, 1970, 1980, 1990, Input-Output Table of Korea

Breschi, Stefano; Franco Malerba and Luigi Orsenigo. 2000, Technological Regimes and Schumpeterian Patterns of Innovation, The Economic Journal, 110(463), 388-410.

Cargill, C.F. 1989, Information Technology Standardisation: Theory, Process and Organisations, Bedford MA: Digital Press

Carlsson B. Stankiewitz R. 1995, On the nature, function and composition of technological systems in Carlsson B. (ed), Technological systems and economic performance, Kluwer Dordrecht

Chang, Ha-Joon. 1994, The political economy of industrial policy, New York : St. Martin's Press

Choh, K., 1999, Innovation and standardization in technological trajectories: a Schumpeterian perspective and three models of standardization in the information technology industry Proceedings of International Conference on Standardisation and Innovation in Information Technology, Aachen, Germany.

Choi, Jong Won, 1991, The Competition Policy and Major Industrial Policy-Making in the 1980`s, Journal of Korean Development, Vol. 13, No. 2, pp 97~129 (in Korean).

Choi, Youngrak, Hwang, Kyung-hyun, Ahn, Hyun-sil, and Song, Sung-su, 2010, Patterns and Modes of S&T Development in Korea, Research paper 2010-10 of Science and Technology Policy Institute (in Korean).

Clark, K. B., 1985, The interaction of design hierarchies and market concepts in technological evolution, Research Policy vol. 14, pp. 235-251.

C., Perez and Soete, L., 1988, Catching up in technology: entry barriers and windows of opportunity in Technical Change and Economic Theory, Pinter Publishers, New York.

D'Costa, Anthony P. 1999. The Global Restructuring of the Steel Industry : Innovations, Institutions, and Industrial Change. London ; New York: Routledge.

Dittberner, Donald L. 1977, Telephone Switching-Technologies in Conflict, in Paul Polishuk and Michael A.O'Bryan (Ed.), Telecommunications and economic development, Horizon House International

Duyster, Geert. 1996, The Dynamics of Technical Innovation: The Evolution and Development of Information Technology, Aldershot: Edward Elgar

Edquist, C. (ed.), 1997, Systems of innovation; Technologies, Institutions, and Organizations. Pinter.

Federation of Korean Industries (www.fki.or.kr), 2004, The Survey to Improve the Cooperation of Conglomerates and SMEs (In Korean)

Federation of Korean Industries (www.fki.or.kr), 2005, The Survey on the Difficulties in the Machine Parts Industry by FKI in 2005 (In Korean).

Freeman, C. and Soete, L., 1997, Development and the diffusion of technology in Freeman, C. and L. Soete (eds.), The Economics of Industrial Innovation, Pinter Publishers, London.

Freeman, C., 1995, The Information Economy: ICT and the Future of the World Economy in S. A. Roseu (ed.) Changing Maps: governing in a world of rapid change, Clarleton University Press, Ottawa.

Freeman, C., 1989, New technology and catching up in R. Kaplinsky and C. Cooper (eds.), Technology and Development in the Third Industrial Revolution, Frank Cass & Co, London.

Freeman, C. 1987, Technology and Economic Performance: Lessons from Japan, Pinter, London

Gao, Yuning and Angang Hu. 2009. A Comparative Study of the Development Mode of China's Iron and Steel Industry, Journal of Chinese Economic and Business Studies, 7, 283-97.

Hobday, Mike, 1995, East Asian latecomer firms: Learning the technology of electronics, World Development, Volume 23, Issue 7, Pages 1171-1193

Hogan, William Thomas. 2001. The POSCO Strategy: A Blueprint for World Steel's Future. Lanham, Md.: Lexington Books.

Hong, Sung-duk and Kim, Jung-ho. 1996, The Long-Term Change of Total Factor Productivity of Korean Manufacturing from 1967 to 1993, Korea Development Institute

Hughes T.P., 1984, The evolution of large technological systems, in Bijker W. Hughes T. Pinch T. (ed.), The social construction of technological systems, MIT Press Cambridge.

Hwang, Jongsung, 1993, Development Strategy and State Role for Information/ telecommunication Industry in Korea: The Digital Switch Industry (in Korean), Doctoral Dissertation of Department of Political Science, Graduate school, Yonsei University, December

Kang, B. 2002, Neo-liberal economic reform and POSCO's privatization, Masterberal economic reform and POSCO's privatizationat

Kang, E. Y. 2001, A Study on the Privatization of Public Enterprise in Korea, Master's thesis, Sogang University (in Korean).

Kang, J. 1996, Samsung Electronics: myths and secret, Koyowon, Seoul.

Ki, Jeehoon, 2010, Changes in industrial leadership and catch-up by the late-comers in the world steel industry : Windows of opportunity and sectoral systems of innovation, Master's Thesis of Department of Economics, Graduate school, Seoul National University

Kim, Jungsoo. 2000, Information and Telecommunication revolution: the leadership of Oh-Myung (in Korean), Seoul : Nanam

Kim, Linsu. 1997a, Imitation to Innovation: The Dynamics of Korea's Technological Learning, Boston: Harvard Business School Press.

Kim, Linsu. 1997b, The dynamics of Samsung's technological learning in semi-conductors, California Management Review 39(3)

Kim, Linsu. 1980, Stages of development of industrial technology in a developing country: a model, Research Policy 9(3), pp.254-277.

Kim, Yong Bok, 2005, The Industrial Policy Processes of Korea in 1980s: the case of the Industry Development Law, Journal of International Politics, Vol. 8, No. 1, pp 1~19 (in Korean).

Kim, Yoon-Zi and Lee, Keun, 2008, Making a Technological Catch-up in the Capital Goods Industry: Barriers and Opportunities in the Korean Case, Global Economic Review, vol. 37 (2), pp. 135-155

Kim, Yoon-Zi, 2006, The Middle-Income Trap and Technological Catch-up in the Machine Tool Industry (in Korean), Gi-sul-hyuk-sin-yon-gu (in Korean), Vol 14. no. 1

Klepper, S., 1996, Entry, Exit, Growthand Innovation over the Product Life Cycle, American Economic Review, Vol. 86, No. 3.

Korea Customs Service, Various Issues, Tariff Schedules of Korea

Korea Electronics Association, 1999, The History of Korean Electronics Industry for 40 years

Korea Federation of Small and Medium Business (www.kbiz.or.kr), 2004, The Annual Survey on the Difficulties of SMEs (In Korean)

Korea Iron and Steel Association ed. 2005. Hangug Cheolgangsan-Eob Baljeonsa (the History of the Iron and Steel Industry in Korea). Seoul: Korea Iron and Steel Association.

Korean Economy's Six Decade Editorial Committee, 2010, The Korean Economy: Six Decades of Growth and Development Vol. 2, Korea Development Institute (in Korean).

Korean Trade Commission (www.ktc.go.kr), 2004 , Handbook of the Measures the Trade Dispute Settlement (In Korean)

Kwak, Sang-gyong, 1997, Cheolganggong-eob-e daehan jeongbujeongchaeg-ui hyogwabunseog (Effectiveness analysis of government policy on the steel industry), Han-ilsan-eobjeongchaeg bigyo-yeongu (Comparative study of Industrial Policy between Korea and Japan), D. Cho, A-ibi-eseu: 215-226 (in Korean).

Lall, Sanjaya 1980, Vertical inter-firm linkages in LDCs : An empirical study, Oxford Bulletin of Economics and Statistics, Volume 42, Issue 3, pages 203-226

Lee, Jong-wha, 1996, Government Interventions and Productivity Growth, Journal of Economic Growth, 1:391-414(September 1996)

Lee, Junghoon and Lee, Jinjoo, 1992, Technological development process and technological innovation strategy of telecommunication industry in Korea: Case of electronic switches' development (in Korean), Telecommunication Review, Vol.2, No.11

Lee, Keun and Mathews, John A. 2011. Upgrading in the Same Industry and Successive Entries in New Industries for Sustained Catchup, E. Amann, J. Cantwell and M. Bell, Forthcoming in a Book on the Innovative Firms.

Lee, Keun and Mathews, John A. 2010, From Washington Consensus to BeST Consensus for world development, Asian-Pacific Economic Literature Volume 24, Issue 1, pages 86-103

Lee, Keun and Kim, Y. 2010, IPR and Technological Catch-Up in Korea, in Odagiri et al 2010. (Hiroyuki Odagiri, Akira Goto, Atsushi Sunami, Richard R. Nelson, eds. Intellectual Property Rights, Development, and Catch Up: An International Comparative Study , Oxford U.Press).

Lee, Keun and Park, Tae Young. 2010. Catching-up or Leapfrogging in Indian It Service Sector: Windows of Opportunity, Path-Creating and Moving up the Value-Chain in Tcs, Infosys, and Wipro, Asialics Conference.

Lee, Keun. 2009. How Can Korea be a Role Model for Catch-up Development?: A 'Capability-based View', WIDER Research Paper

Lee, Keun. Lim, C. and Song, W. 2005, Emerging Digital Technology as a Window of Opportunity and Technological Leapfrogging: Catch-up in Digital TV by the Korean Firms, International Journal of Technology Management, vol. 29, no. 1&2

Lee, Keun. 2005, Making a Technological Catch-up: Barriers and Opportunities," Asian Journal of Technology Innovation, Vol 13, no. 2: 97-131

Lee, Keun and Lim, Chaisung, 2001, The Technological Regimes, Catch-up and Leapfrogging: Findings from the Korean Industries, Research Policy, Vol. 30

Lim, C. 1997, Sectoral Systems of Innovation in the Period of Cluster Forming-the Case of the Korean Machine Tool Industry, Science Policy Research Unit, University of Sussex, Brighton

Lundvall, B.A. (ed.), 1992, National Innovation Systems: Towards a Theory of Innovation and Interactive Learning, Pinter, London.

M. Callon. 1992, The dynamics of techno-economic networks, in Coombs R. Saviotti P. Walsh V. (eds) Technical change and company strategies, Academy Press, London.

Marlerba, Franco, 2004. Sectoral Systems of Innovation: Concepts, issues and analyses of six major sectors in Europe, Cambridge: Cambridge University Press, pp. 9-41.

Malerba, F. 2002, Sectoral Systems of Innovation and Production, Research Policy.

Malerba, F. and L. Orsenigo, 1990, Technological Regimes and Patterns of Innovation: A Theoretical and Empirical Investigation of the Italian Case , Technologies and Market Structure, Michigan University Press, Ann Arbor

Malerba, S and S. Breschi, 1997, Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics, and Spatial Boundaries, Systems of Innovation, London: Pinter

Mani, S. 2005, The Dragons vs The Elephant : Comparative analysis of innovation capability in the telecom industry of China and India, Economic and Political Weekly, September 24

Markusen, Ann R. 1985. Profit Cycles, Oligopoly, and Regional Development. Cambridge, Mass.: MIT Press.

Mathews, John A. 2005. Strategy and the Crystal Cycle. California Management Review, 47(2), 6-31.

Mitchell, B. R., 1992, International historical statistics : the Americas 1750-1988 Basingstoke, Hants, England : New York, N.Y., USA Macmillan ; Stockton Press.

Mitchell, B. R., 1995, International historical statistics : Africa, Asia & Oceania, 1750-1988 New York : Basingstoke Stockton Press ; Macmillan.

Mu, Qing. Mani, Sunil. And Lee, Keun, 2011, Explaining variations in the telecom equipment industry in China, Korea, India and Brazil, in Malerba, F. and Nelson, R., eds. (2011: forthcoming), Catching-up in the Sectoral Systems of Innovation. Oxford: Oxford University Press.

Mu, Qing and Lee, Keun. 2005, Knowledge diffusion, market segmentation and technological catch-up: The case of the telecommunication industry in China, Research Policy Volume 34, Issue 6, Pages 759-783

Mu, Q. 2002, Market segmentation, knowledge diffusion and technological leapfrogging in China: the case of telephone switch. Ph.D. thesis, Economics Dept. , Seoul National University, December.

Nam, J., 1979, Cheolganggongeobui teukseonggwa sugeupgujo (Characteristics and the Structure of Supply and Demand of the Steel Industry). Seoul, Korea Development Institute (in Korean).

National Academy of Engineering of Korea, 2010, Process of Technological Development and Problems of Korean Major Industries, Research paper 10-01-06 of National Academy of Engineering of Korea (in Korean).

Nonaka, I., 1994, A Dynamic Theory of Organizational Knowledge Creation, Organizational Science, Vol.5, No. 1, pp.14-37.

Nonaka, I., 1988, Creating Organizational Order Out of Chaos: Self-Renewal in Japanese Firms, California Management Review, Vol. 15, No. 3.

OECD. 1985. World Steel Trade Developments, 1960-1983 : A Statistical Analysis Paris OECD.

____. 1995. World Steel Trade, 1983-1993. Paris OECD.

Oh, Myung, and J. Larson. 2011.Digitial Development in Korea: Building an Information Society. London: Routledge.

Oh, Myung. 2009. Dream Korea after 30 Years (30년후 한국을 꿈꿔라 in Korean), Seoul: Woongjin House.

Park, K.-H., Lee, K., 2006. Linking the technological regime to the technological catch-up: analyzing Korea and Taiwan using the US patent data. Industrial and Corporate Change 15, 715-753.

Park, Young Goo. 2011, Administrative Agency in Charge of Heavy and Chemical Industrialization Plan in the 1970s: Heavy and Chemical Industry Promotion Council and Its Planning Office, Journal of Korean Administration History, Vol. 28, pp. 257~285 (in Korean).

Park, Young Goo. 2005, Gujobyeondonggwa junghwahaggong-eobhwa (Economic structural change and heavy chemical industrialization). New perspective on history of Korean economic development : from late Chosun dynasty to 20th century rapid economic development D.-g. Lee. Paju, Nanam (in Korean).

Park, Young Goo. 1994, A Microeconomic Study on Heavy and Chemical Industrial Adjustment in the 1970s -Signaling Approach, Journal of Trade and Management, Vol. 10, pp. 5~32 (in Korean).

Pavitt, K. 1984, Sectoral Pattern of Technical Change: Towards a Taxonomy and a Theory, Research Policy, Vol. 13, pp. 343-373

Perez, Carlota and Luc Soete. 1988. Catching-up in Technology: Entry Barriers and Windows of Opportunity, G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete, Technical Change and Economic Theory. London: Pinter Publishers, 458-79.

Pohang Iron and Steel Seven-year History Compilation Committee , 1975, Seven Years of Pohang Iron and Steel. Pohang, Pohang Iron and Steel (in Korean).

POSCO History Compilation Committee , 1993, Yeong-ilman-eseo gwang-yangmankkaji: pohangjecheol 25nyeonsa (Twenty Five Years of POSCO) (in Korean).

POSCO Thirty-five-year History Compilation Committee, 2004a, Thirty Five Years of POSCO Vol. 1. Pohang, POSCO (in Korean).

POSCO Thirty-five-year History Compilation Committee, 2004b, Thirty Five Years of POSCO Vol. 2. Pohang, POSCO (in Korean).

Rodrik, D. 1996, Coordination failures and government policy: A model with applications to East Asia and Eastern Europe, Journal of International Economics, Vol. 40(1-2)

Rodrik, D. 1996. Understanding economic policy reforms, The Journal of Economic Literature, 34 (1): 9-41.

Rodríquez-Clare, A. 1996, The division of labor and economic development, Journal of Development Economics, Vol. 49(1)

Romer, P. 1990, Endogenous technological change, Journal of Political Economy , Vol. 98, 71-S102.

Shapiro, C. and Varian, H. R., 1998, Information Rules: A Strategic Guide to the Network Economy, Boston, Harvard Business School Press.

Shin, Hochul, 2011, Asymmetric Trade Protection, Strategic Opening, and the Performance of Korean Industries : 1967~1993, Master's Thesis of School of Economics, Graduate school, Seoul National University, August

Song, Sungsoo. 2002. The Historical Development of Technological Capabilities in Korean Steel Industry: POSCO from the 1960s to the 1990s, Program in History and Philosophy of Science. Seoul: Seoul National University, 335.

Song, W. 1999, The Process of Development of Mobile Communication Technology: interaction between Technology Politics and Technology Learning, Science and Technology Policy Institute, Seoul.

Stigler, G. 1951, The division of labor is limited by the extent of the market, Journal of Political Economy, Vol. 61, pp. 185-193

Wallenstein, G., 1990, Setting Global Telecommunications Standards: the stakes, the players and the process, Artech House, Dedham, pp. 19-20.

Wengel, J and P. Shapira, 2004, Machine tools : the remaking of a traditional sectoral innovation system, Sectoral Systems of Innovation - Concepts, issue and analyses of six major sectors in Europ, Cambridge University Press

World Bank 1993, The East Asian Miracle: Economic Growth and Public Policy. New York: Oxford University Press.

Young, A. 1928, Increasing returns and economic progress, The Economic Journal, vol. 38, pp. 527-542.

Yun, S., 2006. Finex, POSRI (in Korean).

[Web sites]

Siemens VAI Web site (http://www.industry.siemens.com/industrysolutions/metals-mining/en/metals/ironmaking/finex/Pages/home.aspx) (Accessed on Mar 21, 2011)

World Steel Association Web site (http://www.worldsteel.org/) (Accessed on Mar 21, 2011)

www.ksp.go.kr

Ministry of Strategy and Finance, Republic of Korea

427-725, Republic of Korea Goverment Complex 2, Gwacheon, Korea Tel. 82-2-2150-7732 www.mosf.go.kr

KDI School of Public Policy and Management

130-868, 87 Hoegiro Dongdaemun Gu, Seoul, Korea Tel. 82-2-3299-1114 www.kdischool.ac.kr

ISBN 978-89-93695-82-3

Knowledge Sharing Program
Development Research and Learning Network

- 130-868, 87 Hoegiro Dongdaemun Gu, Seoul, Korea
- Tel. 82-2-3299-1071
- www.kdischool.ac.kr