GOVERNMENT INCENTIVES FOR TECHNOLOGICAL LEARNING IN KOREA:

How Korea could build an interrelation between government and market

By

Jang Saeng KIM

THESIS

Submitted to
KDI School of Public Policy and Management
in partial fulfillment of the requirements
for the degree of

MASTER OF PUBLIC POLICY IN ECONOMIC DEVELOPMENT

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Approval as of Dec, 2011

Abstract

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Technological progress is a key determinant of economic growth. As many scholars pointed out, it is one of the key measures that can analyze and explain success or failure of a country's economic development. This study addresses three issues as such: 1) what government incentives have been initiated, 2) how market (firms) has responded to government incentives, 3) what interactive framework between the two has played to achieve technological learning from 1960s to 1990s.

The study defines a framework of government incentives for technological learning on the basis of outward-looking development strategy as follows: 1) industrial policy as a demand of technology, 2) science and technology policy as a supply of technology. Tax exemptions and financial support are practical examples of incentives to stimulate economic units. For the market responses to the government incentives, the study introduces firms' continuous innovation for serving best goods and services with low cost to satisfy customers. The framework covers the following items based on firms' devotion for acquiring knowledge and intensity of efforts: 1) technology transfer and diffusion, 2) in-house R&D, 3) human capital, and 4) crisis management and organizational restructuring within firm.

As a conclusion, this study provides following implications for catching-up countries based on Korea's experience; 1) applied technology development policy tends to foster faster economic growth than that of basic scientific research oriented policy in the early stage of industrialization (the role of KIST and its spin-offs), 2) interactive linkage between government and market is essential (a case of semiconductor and CDMA industrial consortiums), 3) government incentive with high pressure to stimulate market should be sustainable in the early stage of development (monthly export promotion meeting as a platform of trouble shooting). In addition, the study points out common elements to develop technology as such: government leadership, appropriate strategy and commitment, well-trained manpower, effective technology supporting systems, attractive incentive mechanism, and intensifying efforts of business anchors.

Keywords: Government policy/intervention/incentives, Technological progress/learning/capability, Market response, Interactive/Interplay, Intensity of efforts, Crisis environment

Acknowledgements

Many people have given their precious time, good thinking and generous support to this thesis. First, my greatest thanks go to Joonghae Suh who has guided me with constant intellectual stimulation and warm encouragement from the beginning of the thesis. His emphasis on the importance of broad perspective in this research work reminded me to consider a famous saying: “Cannot see the wood for the trees.” I am also deeply indebted to Joon-Kyung Kim who has enlightened me though his lectures that encouraged myself to review the overall Korea’s development experience as well as his guidance of my thesis. I wish to record my special thanks to my colleagues at the KDI – Jihwan Kim and Jaehyun Yoon – for their sincere comments and help. The last but at least, I would like to express my sincere appreciation to my wife, Inagawa Noriko, and my new-born son, Sion, who have sustained me all these years with their love, support and understanding.

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1. Introduction

There has been a long controversy as to why some nations are richer and grow much faster than those that are still poor and grow much slower. The most noticeable recent examples are Japan and Four Asian Tigers: Korea, Taiwan, Singapore and Hong Kong. Especially, Korea has transformed itself from one of the poorest countries in the world in 1962[1] with no natural resources to one of dynamic advanced countries with highly advanced manufacturing industry nowadays[2]. Its annual GDP growth rate had maintained about 9 percent for three decades from 1960s[3].

In order to understand and explore these interesting stories, many scholars and economists of development economics have put in diverse efforts. Robert Solow (1956), the Nobel Prize winner in economics, developed a growth model with two main factors, capital and labor, and one dependent factor, technological progress, to the capital or labor. However, his model had limited explanatory power of the whole nature of economic growth. New growth theories, in order to supplement and contradict the Solow's limitation, assume that a country's economic and technological level of development is closely related and is positively correlated. Especially they emphasized the technology should be regarded as endogenous instead of as a free good and endogenous. Technology gap approach developed by new growth theorists defines that the technology levels and economic and social structures are main factors to achieve high economic growth in addition to capital and labor[4].

Reviewing those economic histories, this study has raised a question on how to acquire and upgrade technology and what incentives have been interplayed to do so.

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[1] GNI per capita of Korea was only 87 US Dollar (World Bank)
[2] Korea joined the Organisation for Economic Co-operation and Development (OECD) in 1996 and GNI per capita of Korea reached 27,839 US Dollar in 2008 (OECD)
[3] Korea GDP growth rate was 8.6% in 1960s, 9.5% in 1970s and 9.6% in 1980s (Jaspersen 1997)
[4] Those arguments will be reviewed and discussed in the literature review in chapter 2

Especially like many other developing countries, the Korean government initiated diverse policy tools for technological progress in order to achieve economic development. Also, technological change in developing countries is a process of technological upgrade through acquiring and improving existing technologies in the global market rather than a process of innovating and creating new technology. Therefore, this study premises that a critical determinant of economic development is different rates of technological learning by different countries because all countries have access to the same international array of technical knowledge and equipment. And this is a key to explain what made Korea different from other developing countries.

Probably, there are several influencing factors explaining the phenomenon such as stock of wealth, standard of living, and sociocultural difference. However the focus of this study limits technological learning of Korea in the early stage of industrialization from 1960s to 1990s (until 1997 when Asia financial crisis attacked to Korea, in particular). This study argues into 3 parts on the basis of findings from Lall (1992, 2001, 2003), Kim (1990, 1997), and Suh *et al* (2007) as such: first, what government incentives have been initiated; second, how market (and individual enterprises) has responded to the government incentives; third, what interactive framework between two has played to achieve sustainable technological learning. This study premises that interaction among stakeholders such as government, market and individual firm is the most powerful mechanism for achieving technological learning and progress, which are the sustainable growth engines toward advancing into an industrialized country.

2. Literature Review

What factors determine economic growth? There has been a long controversy among development economists as to the factors of economic growth. Capital, labor, (endogenous or exogenous) technology, social capabilities and etc. were pointed out as key determinant factors by many scholars. Among those, technology itself has been into severe debate in terms of its characteristics. However, it is undeniable that technological progress is a key determinant of economic growth which can explain why economic growth rate differ and why resource poor countries could develop faster than resource rich countries.

In this chapter, we will review the theoretical arguments from neoclassic school (or mainstream economics) to new theorist (or revisionists and institutionists) regarding determinant factors of economic growth. In addition, this chapter reviews technology as a key finding measure of explaining economic growth and growth dynamics and analyzes how to enhance technological capabilities. Table 2-1summarizes different perspectives between traditional school and new theory in terms of technology as a major determinant of economic growth.

2.1. Background Information of Theoretical Arguments for Economic Growth

The neoclassic economists have been discussing and analyzing ceaselessly what factors have contributed to economic growth. However, they mainly focused on the relationship among income distribution, capital and labor accumulation, and growth, rather than technology.

2.1.1. Solow Model

In 1956, through his paper “A Contribution to the Theory of Economic Growth”, Robert Solow proposed a neoclassical growth model to explain the production function of an economy. In the model, he introduced the concept of technological progress as the variable of the production function in addition to capital and labor variable, which can be written as follows:

$$Y = K^{\alpha}(AL)^{1-\alpha}$$

In the model, A is the technology variable. K and L are capital and labor variables, respectively. According to Solow, technology is a public good that everyone could access and use for free of charge. Solow assumed that the technological progress is exogenous, which is not affected by the actions of the firms and capital accumulation path is consistent with any growth rate of the labor force in addition to constant return of scale of capital and labor. Under these assumptions, the Solow model suggests that sustainable economic growth is possible only with technological progress. In fact, in 1957, using his model, Solow calculated that technological change accounted for seventh-eighths of US growth per worker over the first half of the twentieth century. He further concluded that in the long run, technological change drives long-run growth, not investment, which contrasts with the traditional view that investment was the dominant driver of long-run growth.

Solow also projected that due to technological borrowing, the poor countries could catch up developed countries. He argued that the marginal product of capital was higher in countries of low income with low level of capital than in countries of high income with high level of capital. His idea implies that capital should naturally flow from rich and developed countries to poor and developing countries and the poor countries would have higher growth rates than developed countries. In other words, all countries' growth rates will converge to a certain level and form a common steady state.

In contrast to the US case, the model does not fully explain the failure of growth in poor countries. For example, Paul Romer (1988) showed that the Solow model fails to explain the growth of poor countries. Using data on over a hundred countries complied by Robert Summers and Alan Heston (1978), Romer demonstrated that for the period 1960-1999, the poorest countries did significantly worse than the rich countries; only two-fifth of the poorest countries recorded positive growth, which was contrast to Solow's argument.

In 1962, Nicholas Kaldor, James Mirrlees, and Kenneth Arrow pointed out the limitation of Solow's assumption for technological progress as an endogenized factor instead of neutral and exdogenized one in the name of vintage model of economic growth. They claimed technology can be embodied in learning by doing together with capital goods. In the vintage model, technological progress is interpreted as an externality, i.e., an unintended side-effect of other economic activities (investment) (Fagerberg, 1994).

2.1.2. Solow Residual, Total Factor Productivity and Growth Accounting

The Total Factor Productivity (TFP) is a measure of the physical output produced from an economy that is not caused by inputs such as labor and capital. TFP can be considered as a measure of a country's technological change if the inputs are not accounted for the output. In cases, TFP may also reflect omitted inputs. TFP cannot be measured as the omitted inputs directly. Instead, a residual, often called the Solow residual, takes place in explaining remaining output not caused by inputs. The Solow residual works on the principle that greater productivity of labor will affect the Gross Domestic Product (GDP) of a country's economy, along with concrete factors like capital allocation and available amount of labor. Some aspects of total factor productivity and the use of the Solow residual are in question among the community of economists due to possible inaccuracy of certain variables.

Technological growth and efficiency are regarded as two of the biggest sub-sections of total factor productivity, the former possessing special inherent features such as positive externalities and non-rivalness which enhance its position as a driver of economic growth. TFP is often seen as the real driver of growth within an economy and studies reveal that labor and investment are important contributors[5]. TFP suggests that capital accumulation and labor growth do not fully account for economic growth and technological progress is the ultimate source of economic growth. TFP cannot simultaneously measure all technological change, but just the free gifts from externalities and scale effects.

Griliches (1972) pointed out some conceptual and empirical problems regarding the measurement of TFP. The problems include a relevant concept of capital, measurement of output, measurement of inputs, the place of R&D and public infrastructure, missing or inappropriate data, weights for indices, theoretical specifications of relations between inputs, technology and aggregate production functions, and aggregation over heterogeneity.

It is well known that much technological change is concentrated in the industries producing capital goods. An excellent case study of such changes is found in Rosenberg's analysis of the US machine tool industry in the 19th and early 20th century. The development of cost-cutting, output-increasing tools of standardized production was one of the major reasons why the US began to overhaul Europe in economic growth and technological dynamism (Rosenberg 1976, 1994).

[5] TFP accounted for 51% of growth in U.S. economy from 1948 to 1979 (Denision, 1985)

As an effort to determine what proportions of recorded economic growth could be attributed to growth in capital stock, growth in the labor force, and changes in overall efficiency, Robert Solow developed a procedure, “growth accounting” or “sources of growth analysis”, to focus directly on the contribution of each term in the production function.

Using the formula $Y=F(K, L, A)$ where Y is output, K is capital, L is labor, and A is a parameter to capture the effects that are independent from capital stock and labor supply which might influence growth (increasing technology, worker skill levels, education, health, institutions, etc.). In this case, “A” is generally referred to total factor productivity. Since A captures not only efficiency gains but also the net effect of errors and omissions from economic data, the residual A is sometimes referred to as a measure of ignorance about the growth process.

Table 2-1 Different Approaches on Technology between Traditional and New Growth Theory

Mainstream Growth Theory	New Growth Theory
Nature of Technology	
Technology is codified information that can be transmitted fully between firms	Technology is an 'artifact', knowledge and skills Technology is not fully codifiable, has important tacit elements
Information on sources and characteristics of all technologies available to all firms	Use of technology requires development of capabilities, both technical and organizational
Using, diffusing and creating technology	
Selection of 'appropriate' technology consists of optimizing on a known production function	Firms are not on a fully known production function but on a 'point' with increasing information fuzziness' away from that point
Access to technology is costless	Search for technology can be costly
There is no learning process, or, if there is, learning is automatic and predictable (along a known learning curve)	Firms have different capabilities for accessing technology Absorption of technology can be costly and prolonged (this may not be fully understood by firms), needing conscious effort
Non-market links and interactions between firms are irrelevant	
There are no important externalities in the learning process	Technological development is a learning process; and learning to use technology is not always different from improving upon or creating tech.
Using a new technology is completely different from 'innovation' (move along versus shift of the production function)	Learning is not automatic or predictable and may itself have to be learnt (learning to learn)
	Co-evolution of technology, industry and institutions
There are no cumulative processes or path dependence in technology development	Learning is collective, cumulative and path-dependent
Firms maximize an objective function with full knowledge of alternatives	Efficient technology development needs corresponding development in factor markets (especially skills, technology and finance)
In an 'efficient' system there will only be one technology that is economically feasible and all firms will use it equally well. Any deviations from this are due to uncompetitive markets or government intervention in free markets	Firms do not maximize objective function but develop satisficing routines which are difficult to change. Adoption of innovation routines should be considered learning and diffusion process
	Learning relies heavily on interfirm interactions, vertical and horizontal; involves both technology and organizational routines
	Technologies differ by firm and there is wide variation in efficiency and mastery

Specificity, variety and modes of transfer	
At firm level, no specificity or variety within technologies	Many idiosyncratic features of technology and technological learning at firm level
Inter-sectoral differences rarely considered	High levels of specificity of each innovation and technological 'trajectory'. Large number of variants of particular technologies
At the country level, only differences in technology arise from different choices of technique reflecting different factor price ratios	At the country level, there are strong differences based on level of technological capability, skills and institutional structures, effectiveness of absorption and cost of learning processes
Best way to develop technologically is to have free trade, free flow of investment and appropriate educational policies	Development of appropriate set of technologies and technological capabilities may require both trade and investment interventions and technology (and other) policies
In equilibrium, there is no difference between different modes of technology transfer. Free markets yield best set of choices	Mode of technology transfer matters: externalized modes (licensing or capital goods) may be more conducive to technological deepening than internalized modes (FDI) where innovative functions remain abroad
Externalities	
Externalities arise only from imperfect appropriability of information and vertical technological linkages	Externalities are strong and pervasive
Externalities are limited and sporadic	Externalities are embedded in collective learning processes
Externalities are difficult or impossible to identify	Externalities are not only technological: they also arise in connection with managerial and organizational learning and from marketing. Some of these effects horizontally straddle sectors and even technologies
Externalities are not technology specific, so should be dealt with by non-selective measures	Many important externalities are technology and cluster specific
	Some technologies and clusters yield more dynamic growth and spillovers than others
	Externalities are not very difficult to identify although they should not be defined with reference to static equilibria

Risk and uncertainty	
Low levels of risk and uncertainty in absorbing and using existing technologies Innovation involves risk, which is adequately represented by an 'innovation possibility frontier' Liberalization does not create additional risk	High degree of uncertainty in absorbing technologies by industrial 'latecomers' Risk and uncertainty in predicting economic impacts of learning, especially in context of liberalization

Source: Lall, 2001

2.2. Importance of Technology for Economic Growth

Even though scholars from different schools have been discussing about different characteristics of technology for decades, they all agree that technology is a key factor for economic development. Table 2-2 shows a summary of diverse researches regarding the importance of technology for economic growth.

Table 2-2 Summary of Studies related to the Importance of Technology for Economic Growth

Year	Author	Title	Argument to technological progress
1956	Solow	"A contribution to the theory of economic growth"	Technological change drives long-run growth.
1962	Gerschenkron	*Economic backwardness in historical perspective*	"The early literature was especially concerned with the distinction between countries on-and behind-the technological frontier."
1962	Kaldor et al.	"A New Model of Economic Growth"	This research criticizes the Solow's assumption of technological progress as an exdogenized factor and redefined it as an endogenized one.
1962	Arrow	"The Economic Implications of Learning by Doing"	"No economist would ever have denied the role of technological change in economic growth."
1963	Ames et al.	"Changing Technological Leadership and industrial growth"	Technological differences are the prime cause for differences in GDP per capita across countries.
1973	Ōkawa et al.	*Japanese economic growth: trend acceleration in the twentieth century*	Social capability as one of main contributor for economic growth is regarded as a country's ability to engage in technological and organizational progress.
1976	Cornwall	"Diffusion, Convergence and Kaldor's Laws"	The growth rate of manufacturing output originates from the international diffusion process of technology.
1977	Chandler	*The visible hand: The managerial revolution in American business*	Firms with intrinsic capabilities based on technological know-now and strategies are one of key players for economic growth.
1982	Nelson et al.	*An evolutionary theory of economic change*	Technical advance influences market structure and it causes economic growth in broad sense.
1986	Abramovitz	"Catching up, forging ahead, and falling behind"	Technical competence is one of important elements of social capability.
1987	Fagerberg	"A technology gap approach to why growth rates differ"	Close correlation between the level of economic development and that of technological development is existed.

Year	Author	Title	Argument to technological progress
1987	Fagerberg	"A technology gap approach to why growth rates differ"	Close correlation between the level of economic development and that of technological development is existed.
1991	Romer	"Endogenous Technological Change"	Technological change drives economic growth and technology is neither a conventional nor a public good but instead is a non-rival, excludable good.
1991	Grossman et al.	*Innovation and Growth in the Global Economy*	The technical change through continuous investment has played a major role in the growth process.
1992	Wright et al.	"The rise and fall of American technological leadership: the postwar era in historical perspective"	Technology embedded in organizational structures would be crucial in the process of economic growth.
1994	Krugman	"The Myth of Asia's Miracle"	Technological advances have led to a continual increase in total factor productivity.
1994	Fagerberg	"Technology and International Differences in Growth Rates"	Different growth rates among countries are related to the level of technology.
1995	David et al.	"Accessing and expanding the science and technology knowledge base"	Innovation capability based on technological enhancement and diffusion is a key component to give a direct influence on economic performance.
1997	Kim	*Imitation to Innovation*	"Technological change has been a major determinant of national economic development."
1997	OECD	*National Innovation System*	Technological development is as important as investments in research and development and is a key to explain different economic growth rate.
2001	Lall	*Competitiveness, Technology and Skills*	Market-stimulating technology policy by NICs' government was one of key success factor for their rapid national growth.
2003	Lall et al.	*Competitiveness, FDI and Technological Activity in East Asia*	Technological activity and FDI inflows have contributed to export competitiveness and economic growth in East Asia
2007	Suh et al.	*Korea as a Knowledge Economy*	Korea's rapid industrialization is fueled by the government's strong commitment to technology-based national development.
2009	Lee et al.	"Both Institutions and Policies Matter but Differently for Different Income Groups of Countries: Determinants of Long-Run Economic Growth Revisited"	At the country level, technological capabilities one of the most important determinants of long-run economic growth is more important than openness or integration.

Source: Author's compilation

2. 3. New Growth Theory and Technology Gap

In an effort to explore additional factors of economic growth, a new theory was developed in the 1980s. In his paper, Romer (1990, 1991) stated that technological change 1) is an economic good and is the driving force of economic growth, 2) arises due to people responding to market incentives, and 3) is inherently different from other economic goods. Romer stated that technology is a good that was neither a conventional nor a public good but instead is a non-rival, partially excludable good. This was an important distinction in that private goods are seen as provided by markets and public goods either occur naturally or are provided by governments to compensate for market failure.

The distinction between rival and non-rival goods and the degree to which their use can be excluded from others is the key premise of Romer's model. A rival good is one that can be possessed by only one person at a time. The access that a person or a firm has to a rival or non-rival product is termed as excludability. Technology is considered as a non-rival input that is at least partially excludable otherwise there would not be an economic incentive to develop it in case where there is no way to at least partially limit free access. Human capital, on the other hand, is a rival good that is excludable.

Support to generate new technology is seen as a non-rival and partially excludable good which is a requirement for production. Imperfect markets require government support for innovation and technology. The neoclassical growth model, on the other hand, assumes perfect competition and argues that the market makes the best allocation of resources including investments in technology (actually technology is exogenous, not accounted for within the neoclassical model). The debate between public and private goods is important. Depending upon the theoretical approach, public support for innovation and improved business processes, activities at the heart of a value chain approach, can be justified.

In order to find an answer for different growth rate by new growth theorists, the technology gap model has been developed. Studies show that differences in growth rates among countries are only partially explained by growth of capital and labor. To explain the differences in growth rates, researchers including Posner (1961), Gomulka (1971), and Cornwall (1976 and 1982) developed the technology gap approach. According to this approach, the international economic system is characterized by marked differences in technological levels and trends and the differences can only be overcome through radical changes in technological, economic and social structures.

The technology gap approach assumes that a country's economic and technological level of development is closely related. More specifically, economic growth of a country is positively correlated with growth in the technology level of the country. The approach also assumes that a country with a lower technology level than the technologically advanced countries can increase its rate of economic growth though imitation efforts. The technology gap theorists claim that the country that introduces new goods in a market experiences an advantage. More specifically, the country that produces innovative goods enjoys a monopoly and a profit until other countries produce the goods.

According to neoclassical theory, the level of technological development of a country depends primarily on capital and labor. On the other hand, the technology gap theorists relate a country's technological level with its level of innovative activity. A high level of innovative activity is associated with a high level of new goods in output and new techniques used in production. Since new goods entails high prices and new techniques lead to high productivity, countries with high level of innovative activities are more likely to have high level of value-added per worker, or GDP per capita.

As part of the technology gap approach, Fagerberg (1987) suggests that measures of technological level and innovative activity may be divided into "technology input" measures and "technology output" measures. More specifically, a country's technology level can be measured by expenditures on education, R&D, and employment of scientists and engineers and innovative activities can be measured by patenting activity such as number of patents.

Like other approaches, the technology gap approach has problems. First of all, as the measurement of technological level, R&D is found to be unreliable due to poor quality of the related data, especially those earlier than 1970 and for non-OECD countries. In addition, the technology gap models are found to be less effective in explaining the differences in growth among developed countries, especially the small and medium-sized countries since most of them have similar levels of development.

2.4. National Innovation System

Criticism to mainstream of growth theory that considered technological change as a view of relation between inputs and outputs has created a new concept called national innovation systems (NIS) since late 1980s. Freeman (1987), Lundvall (1992), Nelson (1993), and etc. are the creators and contributors to the NIS approach.

A national innovation system can be interpreted as a series of process that consists of interactive sub-activities among various organizations and institutions in order to attain innovation and economic growth. The interactions among the players involved in technology development are as important as (or may more important than) investments in R&D activities. According to OECD (1997), even though there is no single definition of the NIS, OECD refers that the concept of national innovation systems rests on the premise that understanding the linkages among the actors involved in innovation is the key to improving technology performance. Innovation and technical progress are the results of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. Balzat and Hanusch (2004) describe the NIS to be a historically grown subsystem of the national economy, in which various organizations and institutions interact with each other in carrying out innovative capacity. The OECD paper also introduces other definitions that created by other influential scholars given in Box 1.

Box 1
National innovation systems: definitions

A national system of innovation has been defined as follows:

- "*.. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies*." (Freeman, 1987)

- "*.. the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state*." (Lundvall, 1992)

- "*... a set of institutions whose interactions determine the innovative performance ... of national firms*." (Nelson, 1993)

- "*.. the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country.*" (Patel and Pavitt, 1994)

- "*.. that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies.*" (Metcalfe, 1995)

Source: OECD (1997)

In short, the NIS can be considered as a systemic approach to innovation in the process of interaction between relevant players. There are several ingredients for the NIS: 1) Education system as an aim for producing talented and high skilled people who will contribute to knowledge transfer and diffusion activities, 2) science and technology capability that can be a main resource for R&D activities, 3) industrial structure and targeting that will be a key determinant factor for national competitiveness. In addition, Porter (2001) mentioned the importance of demand as a new element because the demand (both the level of demand and the type of demand) plays a critical role in pulling innovation processes.

The NIS studies give a big influence to policymakers. In case of national roadmap of R&D expenditure, the idea that allocating more R&D budget would automatically lead to better innovation was replaced by the idea that better coordination of R&D money would contribute to more innovation because innovation is the result of a complex interaction between different elements of a system. Since the late 1990s the NIS system became a dominant tool for many comparative studies in OECD and European countries.

However, NIS has limitations: 1) lack of substance and statistics, 2) focus on national aspects, 3) too broad approach, and 4) difficulty to conduct effective transnational comparisons.

3. Analytical Framework

3.1. Technological Progress

Technological change has become a major determinant of economic growth. In industrialized countries, many studies have found that more than 50 percent of long-term economic development is caused by technological changes that improve productivity and lead to new products, processes, or industries[6]. For this reason, the question often raised is how technology, a key of industrial development in advanced countries, can be effectively used for economic and social development in developing nations.

In order to discuss about technology and technological activities, let us have common understandings on the definitions. Technology can be defined as an aggregation of practical processes that transforms inputs to outputs on the basis of accumulated knowledge, skills, know-how, and know-why that contribute to the process formulation. Kim (1997) stated it clearly and concisely as follows:

"Technology is the physical application of knowledge, skills and others to the establishment, operation, improvement, and expansion of facilities for such transformation and to the designing and improving of outputs therefrom."

The term technological capability refers to the complex of capability such as skills, experience and effort that enables a country's economic agents like enterprises to efficiently buy, acquire, use, adapt, assimilate, improve and create technologies in order to develop new

[6] See the references: *Imitation to Innovation* (Kim, 1997), *Why Growth Rates Differ* (Denison et al., 1967), *Innovation and Growth in the Global Economy* (Grossman *at al.*, 1991) and "Technological Innovation and the Economy" (Goldsmith, 1970)

products and processes in response to changing economic environment. And technological learning is used to depict the dynamic process of acquiring technological capability. The technological learning takes place at two different levels: individual and organizational. The prime actors in the process of organizational learning are the individuals within a firm. Organizational learning is not, however, a simple sum of individual learning; rather, it is dynamic and complex combination of knowledge which is acquired, assimilated, generated and distributed across the organization and is integrated into the strategy and management of the organization. Only effective and systematic organizations can translate and accumulate individual learning into organizational learning.

In this part, we will argue the efforts and interaction of two major stakeholders, government and market (including firms), under the regime of incentives. That is, how government creates or manipulates environment through intervention with appropriate incentives in order to improve national technological capability and how market has responded to the government incentives in order to upgrade its own technological capability. In addition, details on the kinds of implemented incentives would be explained.

3.1.1. Different Processes of Technological Progress

In order to explain the process of technological progress in developing countries, Kim (1997) created the model of technological progress in catching-up countries. In addition, he incorporated this model into the technological trajectory model by Utterback (1994) and Lee et al. (1988). Figure 3-1 illustrates a map of technological progress in two trajectories: one in advanced countries and the other in catching-up countries. The technological trajectories refer to the evolutionary process for enhancing technological capability across industries and sectors.

Technological Trajectory in Advanced Countries

Utterback (1994) devised the technological trajectory model in advanced countries, which can be explained by three stages: fluid, transition and specific. Despite the fact that this model is too simplified to fully explain the nature of technological change in different countries and industries, at least it provides a comprehensive overview of technological capabilities in those countries. The upper part of figure 3-1 shows the above three stages.

First, firms own a new technology exhibit a fluid pattern in innovation. The new product with state-of-art technology is often turned out to be crude, expensive, and unreliable, but it fits into some market needs. At this stage, technical entrepreneurs initiate new venture firms, concentrate their efforts to enhance their capability in product innovation in a way to prepare themselves for competition in the market. High failure risk, massive trial and error and frequent product changes happen frequently. Therefore, the production system remains to be fluid and the organization maintains its flexibility for quick and appropriate response on the changes in market and technology.

Second stage is transition. As market need for products becomes more formulated and specified, a transition period begins. Mass-production system has been introduced to achieve competitive product price with good quality. Cost competition leads to radical change in processes, rapidly lowering costs. Large firms take advantage of their capabilities in production, marketing and management as well as R&D. In many cases, larger firms with considerable capital and management resources absorb small innovative firms.

The last stage of technological progress is specific. An industry and its market mature and price competition becomes more severe. In addition, the production process becomes more automated, integrated, systematized and specific. In this stage, only a highly standardized product system is in demand for competition with others. The innovation efforts are diminished and only operational improvements replaced into the room of innovation effort. Finally, firms are becoming more reluctant to invest in R&D. Industry dynamism may be regenerated through new and fresh ideas introduced by new invaders or industries. Product life extension in this specific state may be an appropriate strategy when a series of additional changes (minor innovation) are taken place to add new values. Industries with technologies are typically transferred to catching-up countries where production costs are lower since most traditional manufacturing sectors in advanced countries lose their competitiveness to those in catching-up countries at this stage.

However, it is possible that this model might change significantly according to changes in technoeconomic paradigm. For example, the spread of microelectronic technology like semiconductor across industries may allow mature industries to regenerate by becoming more flexible and information-intensive and by redesigning mature products.

Technological Trajectory in Catching-up Countries

In addition to the effort of Utterback (1994), Kim (1997) developed a three stage model which entails acquisition, assimilation, and improvement through researches on several different industries in Korea. The bottom part of figure 3-1 illustrates the model.

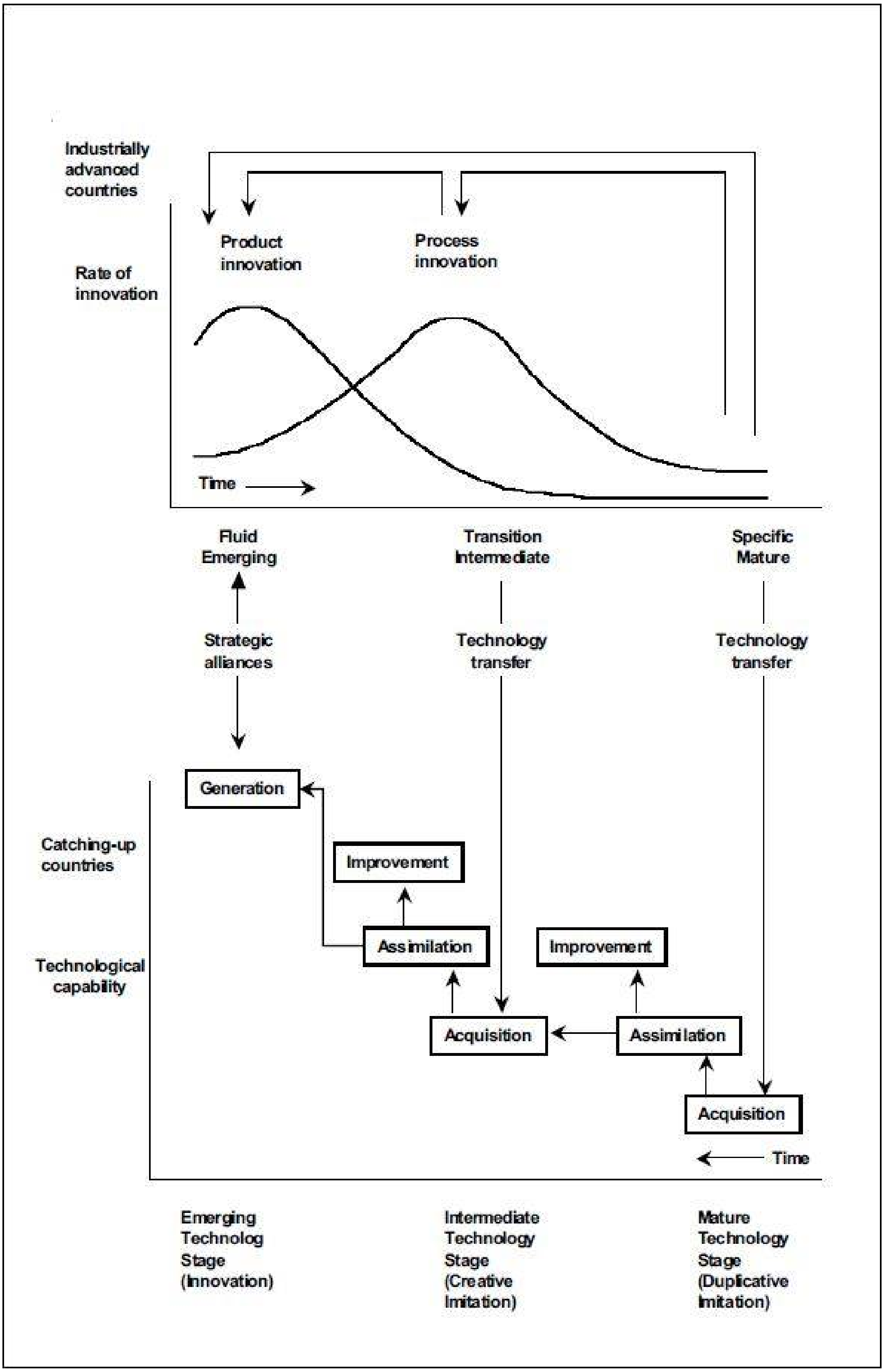
In the early stage of industrialization, catching-up countries acquire mature foreign technologies from advanced industrialized countries. Becoming local capability is not able to accommodate production operations, domestic firms have to import foreign packages such as foreign technology including production know-how and specifications, imported components and parts, and production operational techniques, and appropriate technician invitation. Only standard product assemble is possible due to low labor costs and low technological capability.

After the implementation, technologies are quickly spread in the country, especially stealing experienced technical personnel from the early acquisition. Increased competition from newcomers leads to indigenous technical efforts such as imitative reverse engineering without direct transfer of foreign technologies in the assimilation of foreign technologies for production of differentiated items. Engineering and limited development rather than research is emphasized in this stage.

Lastly, successful assimilation and emphasis on export promotion gradually increased domestic technological capability. Therefore, imported technologies are diffused to other activities through local efforts in research, development and engineering.

This three-stage of technological trajectory in catching-up countries takes place not only in mature technology in the specific stage but also in growing and emerging technologies in the transition and fluid stages.

Figure 3-1 Integration of Two Technological Trajectories



Source: Kim (1997)

3.1.2. Government as an Environment Creator

When we discuss about the role of government for enhancing technological progress, it is a common reaction to think about government intervention. As numerous literatures demonstrated, many East Asian governments intervened inclusively and they (but not all East Asian countries) succeeded in becoming industrialized countries.

Those studies have a universal tendency that the government interventions in East Asian economies have focused on the role of selectivity in order to maximize effectiveness of limited resources in activities. Selectivity can be defined as the intensive investment of particular industries or sectors according to the government priority or picking winners. The selective policies can also be used together with a term of vertical policies because the intervention usually applies in a more direct way as a top-down approach in other word.

However, there are other types of interventions: functionality and horizontality. Functional intervention is a policy for improving factor market such as improving capital, human resource, and information regardless particular sectors or industries.

Horizontal interventions as pointed out by Teubal (1995 and 1997) are a collection of policies that addresses activities that markets are not capable to create in developing countries such as finance for innovation or R&D activities in enterprises. The horizontal intervention designs to provide specific economic benefits, but not to point selective industries or actors. Teubal mentioned that the horizontal policies attribute to stimulate generic technological activities that are socially desirable. The "Socially Desirable Technological Activities (SDTAs)" includes as such: technology transfer and diffusion, the promotion of industrial R&D, and the infrastructure development. The Asian NIEs adopted several horizontal policies to foster intensifying technological upgrade activities though adaption and absorption of imported technologies and it led to new technology creation later on.

Lall (2001) argues that technological development generally involves below three characteristics and he described economically justifiable policies for technological development as “Market-Stimulating Technology Policies (MSTPs).” The MSTPs included three major categories of policy:

- Category 1 (*Priorities*): Setting national priorities for industrial and technological development in the broader context of economic and social objectives.
- Category 2 (*Incentives*): Providing signals to economic agents for industrial or technological activity where markets fail to do so adequately.
- Category 3 (*Institutions*): Generating non-market mechanisms, institutions and organizations, including policy mechanisms, to underpin the previous two categories.

The first category is a national priority setting. In the technology sphere, priority setting is generally chosen when a nation is eager to achieve higher technological growth within certain target and time period: launching more complex and new industry, increasing local innovative capabilities, and so on.

The second category is an incentive provision. Once national priorities have been made, next step is to give signals to economic agents to take action in response to those priorities. This involves the formulation and implementation of technology policies at the program level such as technology infrastructure provision program at the horizontal level, design of targeted subsidizing program on industrial training or research at the vertical level, and the inducement program on technologically demanding areas chose. Table 3-1 organizes several examples of horizontal and vertical technology policies.

Table 3-1 Examples of Horizontal and Vertical Technology Policy[7]

Horizontal Technology Policy	Vertical Technology Policy
- Grants for enterprise R&D - Support of R&D personnel in SMEs - Teaching company scheme - Broad technology support to SMEs - Promotion of technology transfer - Support of cooperative pre-competitive consortia	- Infant industry promotion of new activities - Subsidization and credit allocation for capital-intensive investments - Restricting FDI to build up local capabilities - Targeting strategic technologies for promotion in national laboratories - Financing private R&D in selected technologies - Targeting enterprises for R&D support in particular technologies - Subsidizing joint R&D by enterprises and institutions in specific areas - Building R&D institutions in selected activities - Providing subsidized credit for upgrading selected activities - Intervening in technology transfer processes to build specific capabilities.

Source: Author's compilation

The third category is institution building. It can refer to establishment or institutionalization of appropriate policy mechanisms as a form of new institutions and organizations in the public or private sector in order to support the interaction between government and market agents. Examples in the public sector are technology institutions providing public (or semi-public) goods such as basic research, extension in services and standards for the private sector and it was supposed to the foster of large conglomerates

[7] In case of the Asian NIEs, they utilized more diverse vertical technology policies (or incentives) have been introduced than that of horizontal technology policies. This table, therefore, concentrates more on the vertical policy examples.

especially in Japan and Korea. Also competition policy, intellectual property protection or corporate governance provisions can be concerned in the stage.

3.1.3. Technological Progress and Government Incentive

Lall (1992) classified the determinants of technological development under 3 factors: incentive, factor market and institution. This study merges the second factor (factor market) into first factor which is incentive because only higher level of factor market can be helpful for technological development and in order to achieve higher standard of factor market government intervention with appropriate incentives would be crucial. Also skills, finance for technological activity and access to information within and beyond domestic as the most important factor markets should be created and generated by government incentives in order to motivate the economic agents to do industrial or technological activities.

The main incentives inducing and enforcing investment in technological learning are macroeconomic environment, trade policy, domestic industrial policy, domestic demand and factor markets provision as depicted by Lall. The importance of good macro environment for sustainable upkeep of higher technology level is obvious and do not need to explain further detain here.

As for trade policy, while it enters in trade, a country become realize its existing and non-existing comparative advantage and understand the concept of economies of scale in capital intensive or labor intensive activities. Facing severe competition in the global trade regime is a way of an effective stimulus and it would lead the country to enhance its technological capabilities. Close and frequent contact with export markets is an excellent way of acquiring advanced technologies. In case of developing countries (and as the Asian NIEs has been doing), trade market intervention would be necessary or essential prerequisite in crude term because firms try to avoid massive investment in uncertain and high risk business in the free market system. Trade policy can turn those firms' behavior into right director through provision subsidies. However, be aware that all such interventions are very difficult to design due to government needs enormous information and appropriate experiences. In case of Asian NIEs succeeded the polities under conditions as such: strong leadership commitment to competitiveness, flexibility in policy making, skilled and less corrupted bureaucracy, supporting interventions in factor markets, close interaction with industry, and exposures to export competition while retaining a protected domestic market as a discipline cushion both firms and the government. (World Bank 1993 and Lall 2001)

Domestic industrial policy is to remove market-unfriendly obstacles or barriers which oppose effective market mechanism and to create appropriate market-friendly system according to the national objectives. It would lead to the best stimulus to technological learning. Such as antitrust policies, intellectual property rights protection can play a crucial role. However, Asian NIEs especially Korea and Taiwan did not allow multinational corporations (MNCs) to enter their domestic market until domestic firms and market developed their own capabilities to compete with global market in terms of competitiveness and their size.

Domestic demand also plays an important role in influencing national capabilities as well as enterprises' capabilities. The more intensity of competition happens, the better domestic quality of product has been made. Also, the size of domestic market not only on total incomes but also its distribution, greater equity with a broader base of demand influences the kinds of activates and the interaction among industries and firms. However, the lack of demand itself is a practical problem in many developing countries. Therefore, government intervention together with industrial policy and trade policy is needed to create the domestic demand for technological progress.

Most important factors in technological progress are technical skills, finance for technological activity, and access to information, domestic and international. In order to improve skills, government promotes education and training programs and activities. At the beginning of industrialization, literacy rate and secondary education provision are crucial. As technologies become more demanding, the education system has to focus more on provision of specific technical, engineering and scientific education and training. Also underfinancing for technological activity would lead to market failures. Direct and subsidized policies to selected clusters, industries or firms are needed. Some Asian Tigers have been able to use them to promote industrial and technological development by carefully integrating them with other incentive and factor market interventions and imposing requirements on beneficiaries in terms of competitive performance in export markets (Stiglitz, 1996). Information accessibility is also vital to technological learning. Technology transfer via foreign direct investment (FDI) in Singapore or combination of Foreign Loan and technology transfer without FDI in Korea are good examples how to improve accessibility to technologies. There are diverse incentive policy examples as such (see Table 3-2).

Table 3-2 Examples of Incentive Policy

➢ Quantitative and tariff restrictions on imports ➢ Strong export subsidies and targeting ➢ Subsidized and guided credit ➢ Promotion of giant conglomerates ➢ Boost enrollment on technical study and fields. ➢ Industrial training was made by subsidies with considerable investment in government training institutions. ➢ Infant industry promotion ➢ Support of large firms to credit subsidization, technology targeting, FDI restrictions ➢ Development of research institutions and extension services ➢ Financing of links between industry and universities ➢ Forced firms to invest in formal R&D to absorb new technologies to best practice levels, enter new areas and lower the costs of importing technology ➢ Government targeted strategic technologies for promotion, often by getting private industry to collaborate with public research institutes in projects paid for by the government ➢ The financing of technology expenditures was also fostered by a large number of subsidized credit and venture capital schemes (Korea has the largest indigenous venture and capital industry of developing countries in Asia).

Source: Author's compilation

3.1.4. Market as a Collection of Principal Agents of Technological Learning and Progress

The foregoing government intervention does not actually suggest a solution as to why there exist different growth rates between catching-up countries and between firms within a nation. Several studies especially Lall (2001), Lall et al., (2003) and Kim (1997) found the answer regarding the above question; that is technological change at the firm level. The studies depicted three representing factors to upgrade technological level as such: first, in-house effort in acquiring and intensifying knowledge; second, interactive framework not only between existing technological capability and its production experience (such as trial and error and experience accumulation) within a firm, but also between domestic and foreign technologies; third, R&D activities and interaction within a firm and with other domestic and international firms. Those efforts are induced or constrained under the interplay mechanism with the dynamic government intervention and incentive in particular the early stage of industrialization.

In the initial stage of development, firms lack knowledge and experience on how to learn, assimilate and improve imported knowledge and equipment. In order to enhance its technological level, firms in developing countries usually acquire advanced technologies mainly from the industrialized or technologically advanced countries. Whereas explicit knowledge can be easily and equally transferred to all countries, the tacit knowledge and technology cannot do so. Because the tacit knowledge is not embodied into the transferred explicit knowledge such as equipments or instructions, patents, blueprints and books. Therefore, technological learning is needed a significant and intensified effort. Without deepen efforts of individuals or organizations within a firm to internalize such knowledge, technological learning and progress cannot take place. Kim (1997) emphasized that the intensity of effort or commitment is a more crucial element than existing tacit knowledge for long-term learning and competitiveness of firms.

In addition, as technological capability at a firm is not the sum of explicit knowledge, but a collection of both tacit and explicit knowledge, national capability is also more than a sum of individual firm capabilities and it would be added up the variety of relevant factors such as externalities, synergy, non-market mechanism, inter- and outer-firm's networking and linkages, business operation, and systematic and supportive institution building.

Absorptive capacity is also a critical mass. In order to upgrade the productivity of technological learning, first, existing tacit knowledge, as an essential element in technological learning, can play a role of influencing learning processes sustainably. In other word, today's tacit knowledge should become a soil for tomorrow's increased tacit knowledge through knowledge sharing activities within a firm.

In the case of the Asian NIEs, government and firms sometimes created (either intended or unintended) crisis into the firms in order to upgrade its capability. When a crisis happens, discontinuous technological learning also takes place and firms get into trouble. Firms have to find out exit strategy in order to avoid the crisis and to deploy the crisis as a new momentum of market dominance in other sense. In such a case, the only firm that invests not only human capital but also capital goods heavily in order to acquire new tacit and explicit knowledge as well as knowledge exchange activities can survive and take a lead in the global market. A crisis can also be generated naturally when a firm loses its competitiveness in the domestic or international market. And when new coming top management or board member inject or propose challenging goals, crisis may be created.

The strategic importance of top and middle management should not be overlooked in late industrialization. Their role is vital in discontinuous learning. It is entrepreneurial-minded top management that introduces constructed crises. This forces discontinuous learning that articulates metaphors and symbols to give organizational directions, creates task-force teams to manage organization-wide learning process, provides resources to support learning activities to make crises creative, and clears away any obstacles in the learning process. Middle management translates the ideas of the top into reality on the shop floor in managing constructed crises.

Other findings are as such: all acquiring knowledge should be customized into firms' characteristics since each firm may have a different learning experience; firms in developing countries usually do not know how to utilize the learning technologies for enhancing its capabilities, so, enterprises may not be able to estimate how much and how many days they do contribute for building up their capabilities; different technologies can also have different degrees of dependence on interaction with outside sources of knowledge or information; technological learning in a firm does not take place in isolation and the process is rife with externalities and inter-linkages (Greenwald and Stiglitz, 1986).

3.1.5. Individual Firm's Absorptive Capacity and Innovation

A number of researches have been conducted regarding individual firm's absorptive capacity and innovation. According to Cohen and Levinthal (1990), an individual firm's absorptive capacity, which they defined to be an ability to recognize value of new, external information and apply it to commercial ends, is critical to the firm's innovative capabilities. At the most elemental level, this prior knowledge includes basic skills or even a shared language but may also include knowledge of the most recent scientific or technological developments in a given field. Cohen and Levinthal (1990) also show that the absorptive capacity is correlated with the firm's level of prior related knowledge. They argue that the ability to exploit external knowledge is considered to be a critical component of innovative capabilities and the ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge. In other words, the development of absorptive capacity and innovative performance are dependent on the works or experiences done in the past. In this regard, prior related knowledge allows the firms to have higher absorptive capacities and lack of investment in an area of expertise would undermine future development of a technical capability in the area.

At the organizational level, March and Simon (1958) showed that a majority of innovations result from borrowing rather than invention. This argument is supported by extensive research on the sources of innovation conducted by Hamberg (1963), Myers and Marquis (1969), Johnston and Gibbons (1975), and von Hippel (1988). For example, von Hippel showed that as an organization develops a broad and active network of internal and external relationships, individuals' awareness of others' capabilities and knowledge is strengthened, and thus the absorptive capacities of the individuals and organization are upgraded.

At the level of the firm, absorptive capacity is generated in a variety of ways. Studies by Tilton (1971), Allen (1977), and Mowery (1983) show that firms that conduct their own R&D could better utilize externally available information. This implies that absorptive capacity may be created as a byproduct of a firm's R&D investment. According to Abernathy (1978) and Rosenberg (1982), through direct involvement in manufacturing, a firm is better able to recognize and exploit new information relevant to a particular product market. For example, production experience provides the firm with the background necessary both to recognize the value of and implement methods to reorganize or automate particular manufacturing processes. In this regard, firms invest in absorptive capacity directly in a number of ways including sending personnel for advanced technical training.

The importance to innovative performance of information originating from other internal units in the firm, outside the formal innovating unit such as R&D laboratory for marketing and manufacturing, is well recognized by a number of researchers. For example, Mansfield (1968) showed that a firm's absorptive capacities could be increased through cross-function interfaces that allow some amount of redundancy in expertise. In fact, according to Clark and Fujimoto (1987), Japanese firms that rotate their R&D personnel through marketing and manufacturing operations were able to enhance diversity of background of their personnel that is positively related with the firm's absorptive capacities.

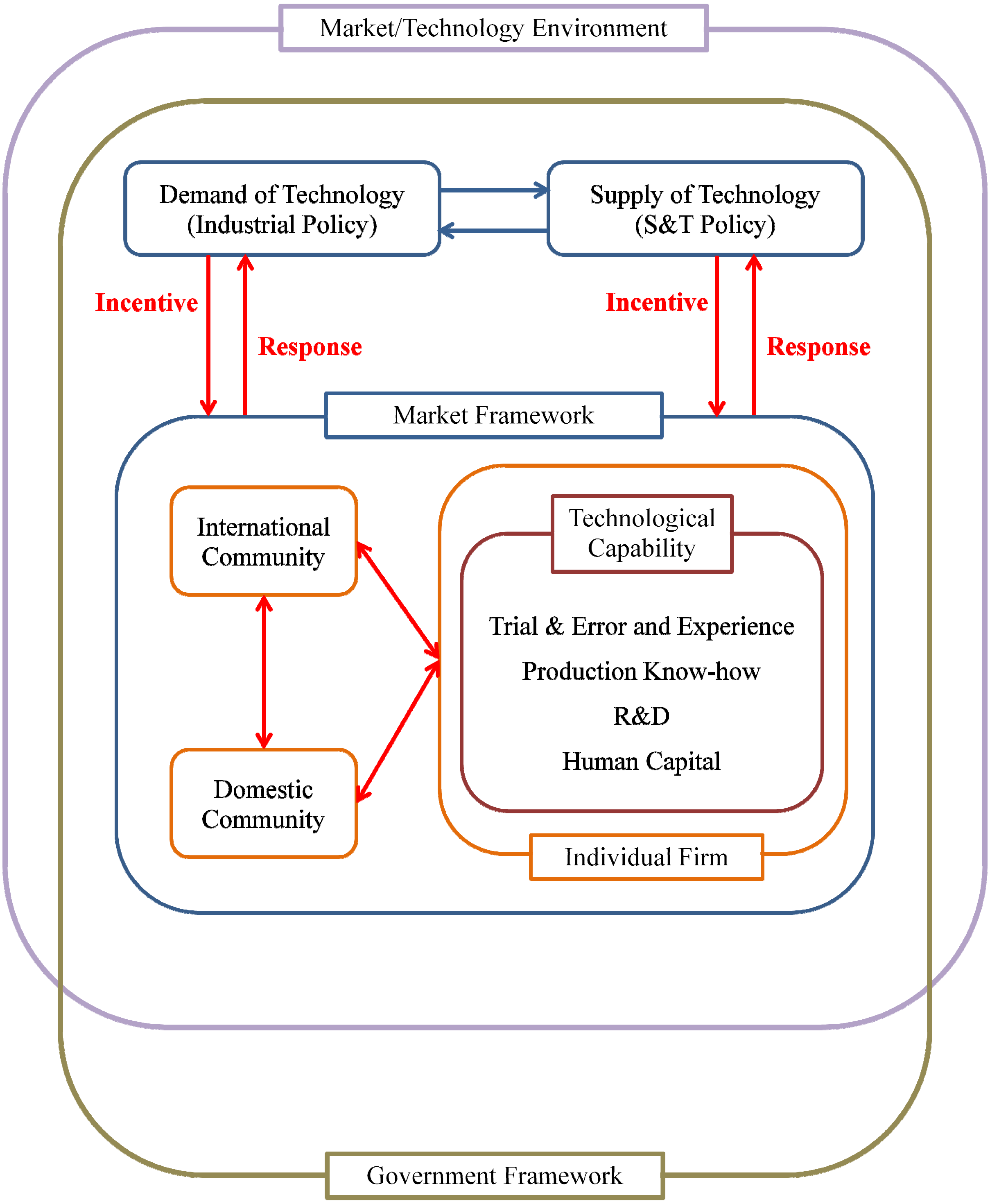
3.2. Analytical Framework of Technological Learning

The process of technological learning and progress at the government level as well as at firms' level is extremely dynamic and complex. Therefore, explaining or analyzing the complete nature of technological change is almost impossible. At the same time, it is also very difficult to simplify the concept with one simple analytical tool. Nevertheless, in this chapter, the study attempts to explain the dynamic learning process in simplified terms based on Korea's industrialization experience (Figure 3-2). This chapter introduces a comprehensive analytical framework consisting of two interrelated frameworks: government incentives and market response. These frameworks are used as tools to analyze both incremental and discontinuous learning of Korea.

As the government has influenced or has been influenced by market and technology environment, it affects all aspects of technological progress to the market through diverse policy instruments and incentive programs. From the technology perspective, the government in the early stage of industrialization, in particular, creates the demand of technology in the name of industrial policies and supplies technological requirements through science and technology policies. In response to the government incentives, the market undertakes its role seriously if the incentives coincide with the purpose of economic units at the market: serving qualified goods and services with low cost in order to meet the needs of customers.

At the firm level, a firm can improve its technological capability by interacting with the international and domestic community. It can also upgrade its technology level though internal efforts such as trial and error, experience and production know-how accumulation, and R&D activities.

Figure 3-2 Analytical Framework of Technological Learning



Source: Author's construction

3.2.1. Framework of Government Incentives

The framework of government incentives (Figure 3-3) is designed to analyze the government intervention consisting of various policies and incentives for technological industrialization in catching-up countries. In fact, the role of government in the early stage of development is a critical mass as many scholars concluded the role of government was one of key instruments for being industrialization in Asian NICs[8].

Since most developing countries do not have enough resources for all industries, the government usually plays a role as a facilitator or a leader in order to maximize the effectiveness of the resource allocation through appropriate intervention and incentives to the market. In that sense, the government gives influence on the technological progress under the overall approach of the nation's development agenda with direct and indirect policy instruments. Such policies affect a firm's interactions with the international community by regulating the inflow of foreign technology. They also affect the firm's interactions with the domestic community by influencing the availability and efficacy of local supporting institutions and the quality of educational institutions.

The government intervention was a fundamental background not only to create new industries and market but also to operate the market and industries in a sound way. Market mechanism perspective includes both the demand side of technological development that creates market needs for technological change and the supply side of technological development that strengthens technological capability. In this study, we define that the former

[8] See the references: *Competitiveness, FDI and Technological Activity in East Asia* (Lall *et al.,* 2003), *The four Little Dragons: The Spread of Industrialization in East Asia* (Vogel, 1991), and *The East Asian Miracle: Economic Growth and Public Policy* (World Bank, 1993).

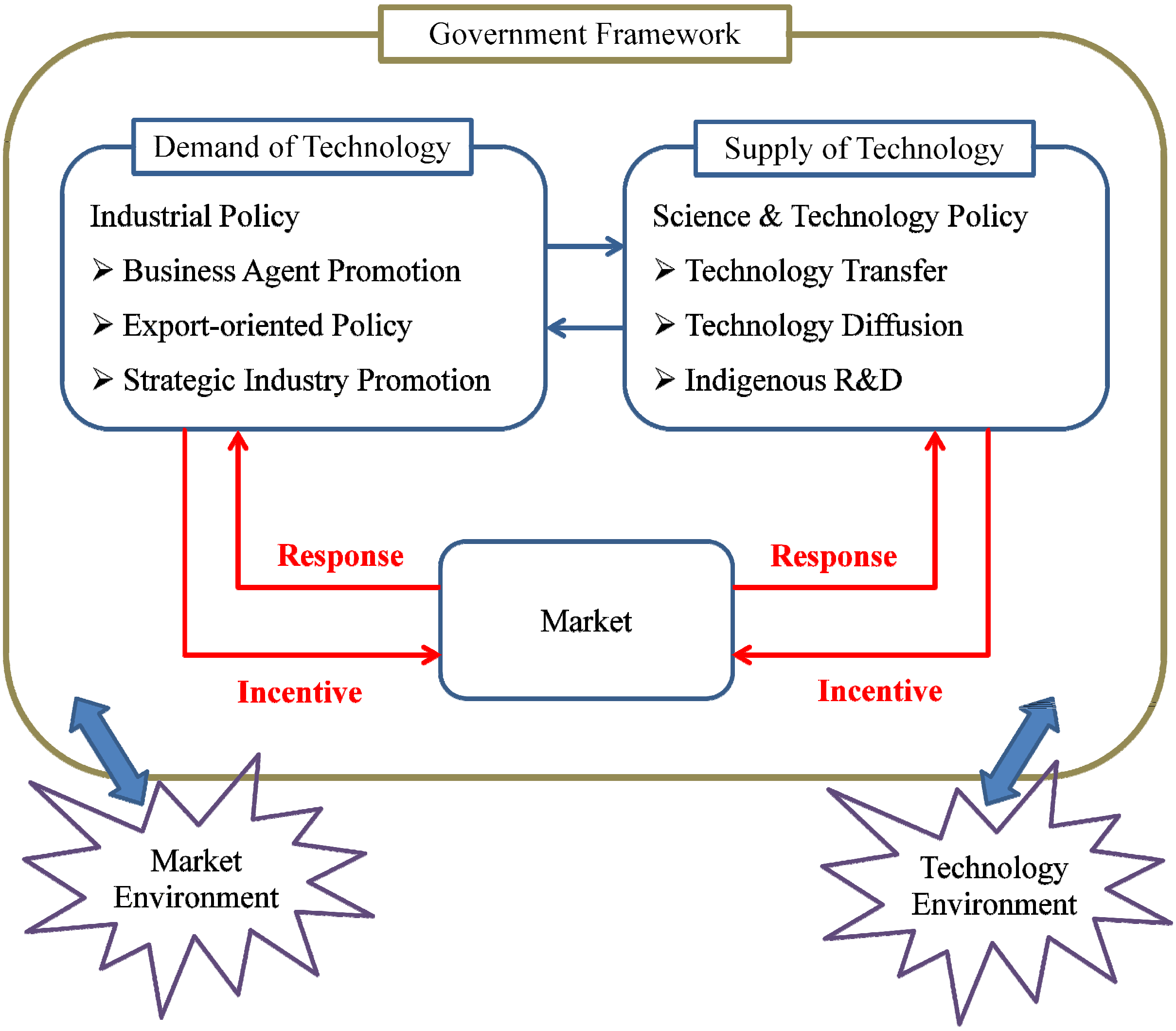
is realized by industrial policies and the latter is attained by science and technology policies[9]. In other words, first, industrial policy is designed to define and build up market needs for the necessity and appropriateness of technological learning and to motivate the demand side of technology continuously; second, science and technology policy is planned to satisfy the market needs created by the industrial policy through provision of technological capability.

The government policy is also corresponded with market and technology environment domestically and internationally. When there is a crisis in either domestic or international market, the government recognizes and adjusts its policies to a more appropriate way in response to the crisis. When also a new market or technology paradigm is introduced, the government has to make policy changes into right direction and circumstance. At the same time, the government can give influence to the market and technology by creating a new intervention toward market.

In addition, this study emphasizes the importance of effective linkages between the policies as a key to attain industrialization. Also the linkages between the two catalyze with involvement of incentive mechanism. The policies after all lead the market to response to the government incentives. Especially, in the early stage of industrialization, policy coordination is critical to derive market's active response to intensify its efforts for technological upgrade.

[9] In some cases, the role of industrial policy for demand of technology and science and technology policy for supply of technology can be reoriented according to a country's context. However, this framework is developed based on Korea's development experience in early stage. Even in the Korea case, industrial policy has also played a role to supply technology from the 1980s. It is discussed in the following chapter (Korea case).

Figure 3-3 Government Incentive Framework



Source: Author's construction

3.2.2. Framework of Market Dynamism

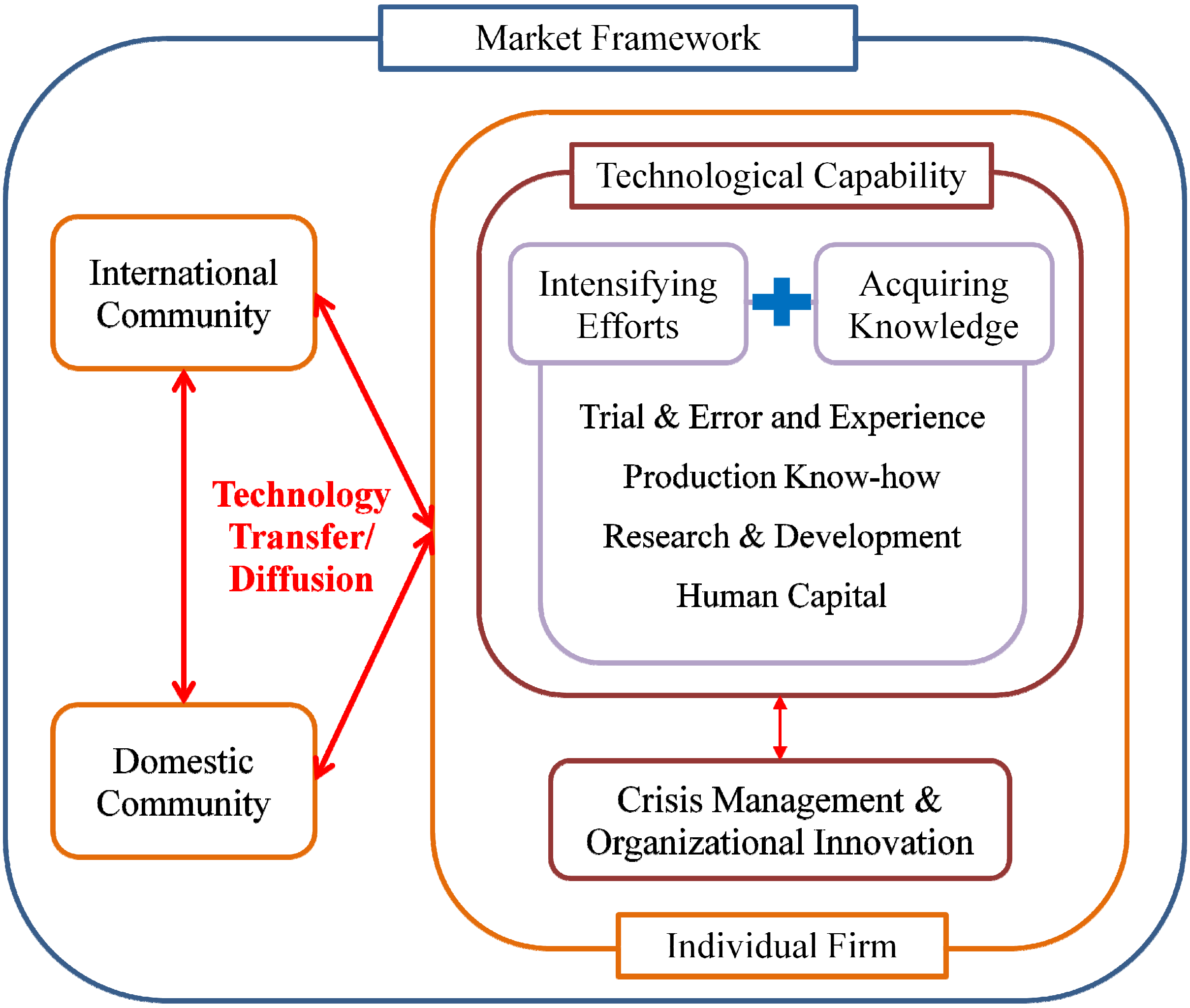
As figure 3-4 shows, there are three main sources where activities of technology transfer and diffusion for enhancing technological capability take place: international community, domestic community, and individual firm's efforts.

First, international community is a very important channel of technological learning for firms in catching-up countries. Learning unfamiliar or new technologies, utilizing international expertise and experts, upgrading ability through technology assimilation, and screening valuable technologies are examples of how to deploy international sources. Frequent contacts to international community help firms become more proactive to seek technological opportunities and develop a broad and active network with the community. Second group is the domestic community. Technological capability is also improved by interactions and interplays with domestic players such as universities, GRIs, public support agencies, buyers and suppliers, and other firms. Like examples we mentioned above, including international community, domestic community also help firms utilize domestic resources in the way of exchanging knowledge, expertise and experts, and of improving an eye for technological value. The most significant benefit of domestic interaction is to organize joint research projects among Government Research Institutes (GRIs), private firms, and universities. The Asia NICs usually utilize such a joint project in the form of a contract-based program funded by their government (Lee, 2010).

Last but at least, firm's in-house effort is the core concept of upgrading technological capabilities within the market dynamism framework. By interacting with international and domestic community, a firm can accumulate knowledge and improve its level of technology on the basis of its intensifying efforts. On the gained knowledge base together with devotional and passionate manpower within a firm, the firm can initiate innovation in operation, process, and production continuously. Such existing technological capability, production experience and trial and error with the government policy and incentive coordination are the main sources for technological progress and capability at the firm. Most importantly, once a firm has improved its technological capability, indigenous R&D activities take place and it becomes the main innovation engine for upgrading the firm's technological capability.

In addition, proactive and appropriate crisis management and organizational culture also contribute to the technological progress. For either intended or unintended crisis or either government originated or naturally created crisis, firms are openly exposed to enormous emergency situation and crisis environment. When there is a crisis, daily technological learning processes lose their continuity and activities of sustainable technological progress have been disconnected. It leads a firm into new challenges. In order to overcome those crises, a firm has to find a solution to continue its competitiveness in the market. Attaining such a healthy organization, following characteristics have to be in place: efficiency and effectiveness, productivity, lower turnover rate, acceptance and appreciation for diversity, respect, pride and enthusiasm, revitalization of communication, and strong sense of goal and vision.

Figure 3-4 Market Dynamism Framework



Source: Author’s construction

4. Evolutionary Process of Technological Learning in Korea

4.1. Overview of Korea's Technological Learning

Technological progress is a key determinant of economic growth. As many scholars pointed out, it is one of key measures that can analyze and explain the success or failure of a country's economic development. The Korean government also recognized the technological learning and progress as a main growth engine of catching-up to achieve an advanced economy.

In the early 1960s, Korea had just experienced massive and tragic historical events such as the period of Japanese colony and Korean War. Korea was a country with no hope and suffered from almost all problems most resource-poor and low-income countries were facing at the time. In 1962, Korea's per capita gross national income (GNI) was less than that of Lao PDR and most African countries such as Malawi and Mali[10]. But beginning in 1962, the Korean economy grew from $87 in 1962 to $20,759 in 2010 (see Table 4-1) which is now more than 20 times that of Lao PDR and a world of difference with that of African countries[11]. Nowadays, Korea ranks thirteenth among the world's top economic powers in terms of total GNI and sixth in terms of manufacturing value-added (World Bank Database). As table 4-1 shows, Korea has also achieved phenomenal growth in its exports, which increased from a mere $55 million in 1962 to $ 466 billion in 2010. Ezra Vogel concludes, "No nation has tried harder and come so far so quickly, from handicrafts to heavy industry, from poverty to

[10] Korea's GNI per capital (constant 2000 US$ term) was $1,420. That of Lao PDR, Malawi and Mali was $1,528, $2,265, and $2,529 respectively (World Bank Database).

[11] Lao PDR's GNI per capital in 2010 (currency US$ term) is $1,010. That of Malawi and Mali is $330 and $600 respectively (there are no constant 2000 US$ data) (World Bank Database).

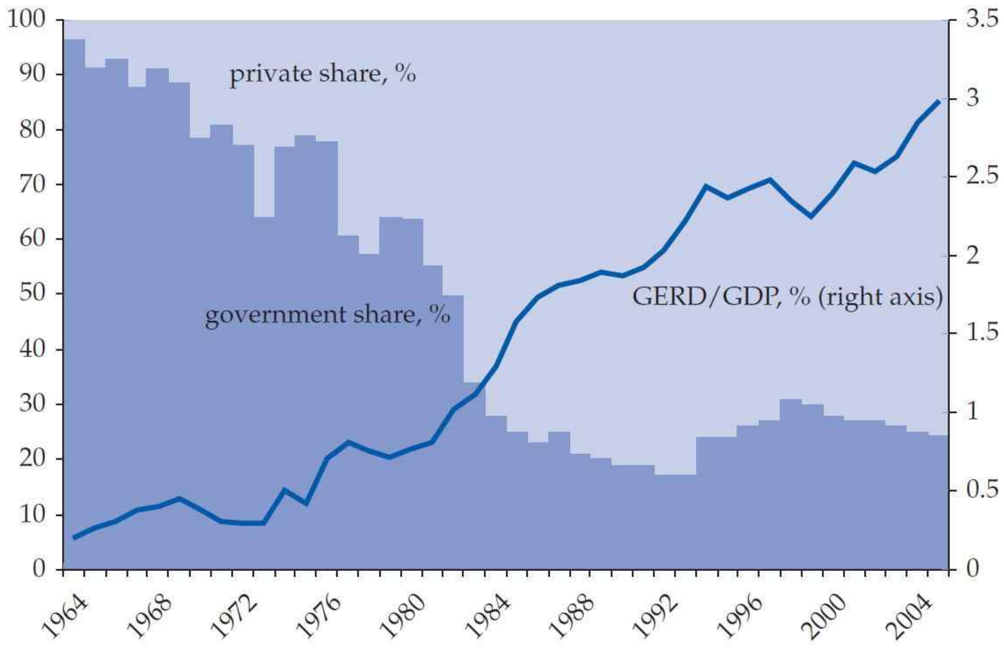
prosperity, from inexperienced leaders to modern planners, managers, and engineers (Vogel, 1991)."

How have Korea and Korean firms managed to achieve such an unexpected growth in industrialization in only three decades? What are the major factors behind the growth? The answer is technological change. There are several driving forces underlying the dynamic process from imitation to innovation in Korea: 1) Korean War shook traditional Confucianism country of Korea to a rather flexible and classless society; 2) strong government intervention with incentive mechanism; 3) large conglomerates (*chaebols*) which served as engines; 4) talented but hard working Koreans who empowered these engines; 5) export-oriented strategy that forced Korean firms out into higher global competition; 6) frequent crisis occurrence as a major means of hasty technological learning, 7) interplay between government and market.

From the technology perspective, rapid industrialization of Korea in 1960s and 1970s stemmed largely from imitative activities such as products on a large scale knockoffs or clones of mature foreign products or original equipment manufacturing (OEM) products. Those imitative efforts fortunately were neither patent infringement nor pirating proprietary know-now (Kim, 1997). A study shows that 60 percent of patented innovations were imitated legally within four years of their introduction (Mansfield, 1984).

In 1980s, Korea started to increase its creative imitation activities (it was called creative Japanese-style imitation in many literatures). Especially when Korea's science and technology policy focused more on R&D activities in the middle of 1980s, Korea transformed itself as an innovator as well as a creative imitator. Newly launching national programs such as National R&D Program in 1982 and Highly Advanced National (HAN) Project in 1992 could become a momentum of the role interchange between government and private sector. The private R&D has been turned to key activities for technological learning and progress. 1982 was the starting point of turning around the ratio of R&D expenditure in GDP between government and private sector (Figure 4-1). Several industries such as semiconductors, electronics, and biotechnology could accomplish in the results of increasing R&D expenditure.

Figure 4-1 Gross Expenditure on Research and Development in Korea, 1964-2005



Source: Suh *et al.* (2007)

From the late 1980s and 1990s, Korea's creative innovation in selective industries started by intensified in-house R&D activities and participation in global networks. And finally Korea's aspiration to become one of global leading industries has been actualized gradually.

With above discussion, this study will try to find answers on how Korea acquired the technological capability to undertake duplicative imitations – by reverse engineering – in the 1960s and 1970s. Also the following chapter will analyze how Korea accumulated enough capability to conduct creative imitations and innovations in the 1980s and 1990s.

Table 4-1 Major Economic Indicators of Korea

	1962	1970	1975	1980	1985	1990	1995	2000	2005	2010
Population (millions)	26.5	32.2	35.2	38.1	40.8	42.9	45.1	47.0	48.1	48.9
GNI (US$ billions)		8.2	21.4	63.3	96.1	270.2	529.2	530.8	843.9	1,014.6
GDP growth rate (%)	2.2[a]	4.6[b]	7.3	-1.9	7.5	9.3	8.9	8.8	4.0	6.2
GNI per capita (US$)	87[c]	255	607	1,660	2,355	6,303	11,735	11,292	17,531	20,759
Exports (US$ millions)	55	835	5,081	17,505	30,283	65,016	125,058	172,268	284,419	466,384
Structure of GDP										
Primary (Agriculture, mining, etc.) (%)	40[d]	28.1	26.5	16.2	13.7	9.2	6.7	4.9	3.6	2.6
Manufacturing (%)	18[d]	21.0	25.9	28.2	29.3	29.2	26.7	28.3	27.5	30.6
Utilities (%)	4.7[d]	6.6	5.9	10.1	10.6	13.7	12.1	9.4	9.9	8.5
Service (%)	32.1[d]	42.2	41.7	45.5	46.5	47.9	54.6	57.3	59.0	58.2
Structure of Manufacturing										
Light Industry (%)	68.6[d]	60.8	52.1	46.4	41.5	34.1	23.6	16.7	9.0	6.4
Heavy & Chemical Industry (inc. IT) (%)	31.4[d]	39.2	47.9	53.6	58.5	65.9	76.4	83.3	91.0	93.6

Source: Author's compilation from Korea Statistical Information Service (KOSIS) and Korea International Trade Association (KITA)

Note: All currency is in current U.S. dollars.

a = GNP growth rate, b = GNP growth rate in 1972, c = GNP per capita, d = 1965 data

4.2. Government Incentives: Role of Government from an Organizer to a Facilitator

During the catching-up period, the role of the government was crucial and compulsory in Korea. The Korean government made a significant impact on the process of technological learning through both direct and indirect measures such as industrial, trade, and science and technology policies. The industrial policy was designed to create market needs for technological learning and to strengthen the demand side of technology continuously[12]. The science and technology policy was implemented to catch up the market needs by increasing national S&T capabilities (Figure 3-3).

In addition, those policies with appropriate incentive programs play a critical role of compelling the firm to intensify its activities to learn foreign and advanced technologies for technological advance in the early stage of industrialization. It means that the government incentive could create such an eco-system of interaction between government and market in a sound way (Figure 3-2).

In this vein, this part introduces the classification of government intervention into demand and supply side and explains how those interventions are correlated and are forced by incentive mechanism.

[12] In fact, the role of industrial policy in Korea has been changed. Korean government deployed the industrial policy as an anchor of creating demand on technology from the market until early 1980s. However, economic environment of Korea had become unfavorable because of global protectionism and liberalization, and rapid expansion of market needs and dynamism. After all, the government changed its position from rule- and target-setter to market supporter. Together with the change, the role of industrial policy has also become changed to support both demand and supply of technology such as R&D targeting with financing support.

4.2.1. Demand of Technology: Industrial Policy and Incentives

Many developing countries, especially low-income nations still remain to be in the condition of no resource, no industry, and even no modern market. Under this condition, in order to create new dynamics of industrial growth, the government needs to use a package of direct and indirect policy instruments to define growth targets and discipline businesses. These instruments have largely been employed toward the following objectives: first, intentional creation or promotion of business entities (bigger is better in the early stage of industrialization because of economics of scale); second, ambitious export-oriented industrialization (EOI), achieved by pushing the private sector into crisis situation; third, the promotion of highly advanced target industries (heavy and chemical industry (HCI) was promoted in case of Korea); and fourth, generalizing culture of mutual understanding in economic growth and appropriate response to the external environment.

Business Agent Promotion

In order to overcome the disadvantage from having an immature (and/or a small) domestic market and to build up international level of competitiveness in a short period of time, it is important to create large and proactive firms. It is because of its market domination and influence, conglomerates in developing counties can upgrade economic wealth of their countries rapidly. In case of Korea, to satisfy the above conditions, the government supported creation of multi-conglomerates (*chaebols* in Korean) consisting of corporate enterprises engaged in diversified business fields and typically owned and managed by one or multi-interrelated family groups.

Within this format, the government could help capital formation as well as the subsequent diversification toward the created business agents. Selling selected local enterprises or giving various big import-substitution projects that expects higher profit on favorable terms, providing preferential financing and foreign currency[13], the government guaranteed foreign loans in 1960s and 1970s were one of good examples of the Korean government.

These efforts led to the creation of world-class multinational corporations. Samsung, Hyundai and LG started to rank among *Fortune* magazine's 100 largest industrial corporations in the world since1990s. In 2011 Fortune global 500, Korea with 14 MNCs is ranked 6th among the countries with the most Global 500 companies (Fortune Magazine, July 2011).

In the process of promoting *chaebols*, the Korean government effectively disciplined the *chaebols* by penalizing poor performers and rewarding only good ones (or stick and carrot approach). Good performers were rewarded with further licenses to expand in more lucrative sectors. This is a unique and different approach compared to other developing nations.

Despite those weakness and side effects such as main culprit of Korea IMF period, *chaebols* played a crucial role in the rapid technological upgrading in the early stage and in the attaching world talents as well as drastically expanding and deepening R&D activities in 1980s and 1990s.

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[13] The government's preferential loan was given with about half or less interest rates compared to the real market rates. Also, after the currency devaluation in 1964 in order to make sure of comparative advantage of Korea export products, foreign debt burdens resulting from the currency devaluation were compensated with increased low-interest loans, further reducing the risks for *chaebols'* businesses.

Export-oriented Policy

Even though import-substitution policy helps to create demand for technological progress via foreign technology transfer, the export-oriented strategy is a more effective policy[14]. The most well-known success stories of four Asian tigers demonstrate and support this argument. In case of Korea, the government considers export as a life-or-death struggle in order to achieve its economic growth goals. The Korean government designated strategic industries for import substitution and export promotion (1960s: plywood, textiles, consumer electronics, automobile, and 1970s: steel, shipbuilding, construction services, machinery).

Because some strategic industries were created in violation of their comparative advantage, those efforts had to suffer infant-industry growing pains from high costs and risks to lack of technology. To overcome the problems, the government sheltered the domestic market from foreign competition.

The government introduced a concept of the export promotion from the revised first five-year economic development plan in 1964. To assess industrial performance, annual targets on each industry were assigned to related divisions of Ministry of Trade and Industry in Korea as well as related industrial associations. Monthly report on monitoring export performance was submitted to the monthly export promotion meeting led by the president himself. Cabinet members, heads of major financial institutions, business association leaders and business leaders all attended the meeting and 177 meetings from 1963 to 1979 were held.

The meeting was a platform for the stakeholders to share ideas and remind of export targets and to identify and solve facing problems of export related issues. If a project was

[14] The average annual economic growth rate for EOI countries was 9.5 and 7.7 percent, respectively, for 1963-1973 and 1973-1985 compared with 4.1 and 2.5 percent for ISI countries. The real per capita income growth rate was 6.9 and 5.9 percent for the same periods for the former as compared with 1.6 and - 0.1 for the latter, as the ISI group had a higher population growth rate (Kim, 1997).

delayed compared to the original planned schedule, the causes were analyzed and a decision on corrective action was taken, often on the spot by the president's decision.

The stick and carrot approach was carefully and effectively used for the meeting. Sticks in the form of administrative guidance forced firms to reach its goals. If a firm did not respond as expected to particular goals, its tax returns, government credit guarantees, preferential bank loans and any other government support were subject to be suspended without hesitation.

In the meantime, government also provided massive incentives to the firms with great export performance. Borrowing tremendous loans from domestic banks with lower market interest rates, tariff and value-added taxes exemptions, duty-free imports of raw materials and spare parts had been given into export-oriented investments as a carrot. These incentives constituted the Korea's export promotion system. With these incentives, *chaebols* could grow even larger and faster due to their greater organizational, financial, and political leverage and its combination.

The monthly meeting also provided a venue of beauty contest for government bureaucratic. Working-level officials could report to President Park directly and high performing officials who accomplished ahead of the planned export-targeting could award a fast promotion.

While it created new business opportunities, however, it also created crises for firms to invest heavily in technological learning to acquire foreign technologies and improve them in order to survive in the highly competitive global market.

Strategic Industry Promotion

In order to achieve industrialization, the Korean government understood the necessity of restructuring the economy from labor-intensive and light industries to more technology-intensive and heavy industries. And they realized the importance of technological capability to do so.

Especially, the change of international political regime prompted the Korean government to massively invest for the heavy and chemical industry program. Because of anti-war movement after the virtual defeat of Vietnamese War, Nixon announced (so called Nixon Doctrine) not to commit its military forces in Asian future conflicts, and the Nixon administration withdrew one of two U.S. Army divisions from Korea in 1971.

President Park became obsessed with acquiring a self-reliant national defense capability by developing heavy and chemical industries (HCIs) at a far greater intensity and in a far shorter time than previous plans in his mind. The HCI plan included six industries: steel, nonferrous metal, machinery (including automobile), shipbuilding, industrial electronics and petrochemical.

According to Lee (1991), the Korean government invested 906.3 billion Korean won from 1973 when the government formally announced the new lunching HCI promotion plan to the public to 1981 and it was about 13% of economic development budget (Table 4-2)[15]. As a result, accumulation of HCIs investment and "three lows" – low oil price, low interest rate, low US dollar value against Korean won (won depreciation) and high US dollar value against Japanese yen and deutsche mark (appreciation) – in 1986 led to reboost Korean

[15] HCI investment share within total manufacturing investment of Korean government from 1973 to 1979 was more than 75 percent (Kim, 1997).

economy. Table 4-3 shows demonstrate the double-digit economic growth was led by HCI industries.

Table 4-2 Trends in size of government budget support for HCD programs: 1970-81

Year	Total central government budget (A) (billion KRW)	Budget for economic development expenditures (B) (billion KRW)	Budgetary support for HCI (C) (billion KRW)	Percentage of total budget devoted to HCI support (C/A) (%)	Percentage of economic development expenditures devoted to HCI support (C/B) (%)
1970	446.3	121.8	17.2	3.9	14.1
1971	555.3	153.0	29.4	5.3	19.2
1972	709.3	209.0	80.6	11.4	38.6
1973	659.7	143.5	13.6	2.1	9.5
1974	1,038.3	222.8	40.6	3.9	18.2
1975	1,586.9	397.0	80.8	5.1	20.4
1976	2,258.5	576.5	123.0	5.4	21.3
1977	2,744.6	654.7	91.3	3.3	13.9
1978	3,517.0	716.1	137.0	3.9	19.1
1979	4,905.7	1,431.9	93.2	1.9	6.5
1980	6,118.2	1,338.8	222.0	3.6	16.6
1981	8,040.0	1,493.9	104.8	1.3	70.0

Source: Lee (1991)

Table 4-3 Trends in growth rate between GDP and HCI

	1980	1982	1984	1986	1988	Average 1986-88
GDP growth rate	-1.9	8.3	9.9	12.2	11.7	12.1
Manufacturing growth rate	-0.7	6.7	17.3	18.4	13.0	16.5
HCI	-2.9	8.9	20.4	20.9	17.0	20.2
Others	1.4	4.4	13.6	15.0	7.1	11.4

Source: Author's compilation from Korea Statistical Information Service (KOSIS) and Lee (1991)

The concentrating effort toward HCIs triggers several crisis situations in technological learning. Due to their limited technological capability, the *chaebols* had to rely only on foreign (and advanced) technology. They had to acquire and assimilate imported technology simultaneously in a short period time. Furthermore, in order to meet government intention, they had to upgrade their own technological capacity and capability in succession. The *chaebols* had to survive from a life-or-death struggle forced by government.

The heavy investment toward HCIs, however, created several problems. Under a desperate situation, government utilized the HCIs promotion strategy more for military purposes than for economic rationality. It resulted in a rapid rise in foreign debt from $2.2 billion in 1970 to $27.1 billion in 1980 (Bello et al., 1990). It also caused misallocation of resources (mainly financing support), rapid inflation and wage increase compared with the productivity gain, and absolute dominance of few *chaebols* in Korea society.

Economic Environment Change

Since the global economic environment had been changed significantly in 1980s, Korean government had to change its strategy in order to maintain sustainable economic growth. There were several structuring issues: 1) the global economy had began to downturn in the 1980s and countries like Korea had been seriously affected because of its export-dependent economy; 2) Attempt to overcome the economic recession, advanced countries initiated protectionist policies and it also led Korea in difficult situation; 3) rapid increase of inflation and wage resulted Korea in losing its comparative advantage in low-wage and labor-intensity (or light) industries[16]; 4) other developing countries (especially countries like

[16] Real annual wage growth rose to 5.8 percent in the 1960s (annual term) and 7.5 percent in the 1970s (annual term) (Kim, 1997).

Thailand, Malaysia and China influenced by remarkable economic transform of Korea) with much lower wage and cost were rapidly catching up with Korea in the industries; 5) Since Korea got becoming a bigger player in the global society and tried to, industrialized countries, particularly Japan, started to be unwilling to transfer their technology to Korea; 6) international society became to require Korea to change its law of Intellectual Property Right (IPR) that Korea internalized imitative reverse engineering foreign technology.

Under unfavorable circumstances, the Korean government had to set out on a major policy shift. It attempted to reduce government intervention, introduce market mechanism and develop more technology-required industries. Also, antitrust legislation, trade liberalization, financial liberalization, promotion of small and medium-size enterprises, foreign investment liberalization, and shifting emphasis on innovation-related activities had been introduced.

In short, the focus of industrial policy related to creating the demand for technological learning had shifted significantly. Whereas remarkable heavy government intervention was made in the early stage of development, government turned it to the introduction of market principles in order to enhancing international competition and particularly government started to control *chaebols'* privileges from the 1980s. Even though government's role as an interventionist has substantially weakened, but the government still remains to be relatively powerful in Korea compared with other countries.

4.2.2. Supply of Technology: Science and Technology Policy and Incentives

For economic development, government intervention for creating demand for technology through industrial policy cannot alone attain the goal; instead the government also needs to stimulate the supply of technological capability and capacity through science and technology policy. This section introduces Korea's experience of policy instrument for technological upgrading. Technology transfer, technology diffusion, and indigenous R&D provide insight into understanding how developing countries catch up with advanced countries.

Technology Transfer

In order to fill the lacking technological capability, Korea had no choice except to rely on foreign technology. Whereas many NICs such as Singapore, Hong Kong and even Taiwan acknowledge the importance of foreign direct investment (FDI), Korea tightened its FDI control[17]. Korea promoted technology transfer through other sources such as capital goods, reverse engineering, and turnkey package, instead of restricting itself to FDI. Foreign loan was received to acquire capital. As for foreign licensing (FL), Korea restricted to associate with technical assistance of turnkey plant package. We surmise Korea's policy on FDI may prefer to defend Korea's independence from MNCs because of Korea's historical invasion from strong neighbors.

The preference of the importation of capital goods, reverse engineering and turnkey package led Korea to massive imports of foreign capital goods through foreign borrowings.

[17] Korea's stock of FDI in 1983 was only 7 percent whereas that of Singapore was about 23 percent and less than half that of Taiwan and Hong Kong. Also, the proportion of FDI to total external loans was only 6.1 percent in Korea compared with 91.9 percent in Singapore, 45 percent in Taiwan (Kim, 1997).

Also, various factors stimulated the inflow of foreign capital goods to Korea. Depreciation of Korean won against US dollar, tariff exemptions on imported capital goods and financing support with lower interest rates generated a favorable environment for capital goods imports.

However, Korea which had high tendency to rely on capital goods faced new challenges in 1980s. In order to acquire and assimilate more sophisticated foreign technologies for maintaining its international competitiveness, Korea had to open up more its market to FDI and FL. Responding to the complaints about bureaucratic redtape, the Korean government introduced automatic approval system and launched diverse tax reduction and incentive programs. Also, Korea established Korea Trade-Investment Promotion Corporation (KOTRA) aiming as a one-stop service center. Also, FL has been completely open for all industries and for all terms and conditions. The approval system for FL has been changed to reporting system. As a results, FLs increased rapidly from 247 in 1981 to 707 in 1993 (KIM, 1997). However, FDI had not come to Korea as expected because big FDI players like Singapore has been settled down.

For technology transfer Korea relied on both Japan and the United States intensely. According to Kim's finding (1997), eighty percent of FDI, seventy percent of FLs and capital goods took part in Korea from 1962 to 1993.

Technology Diffusion

From the national economic perspectives, technology diffusion is as important as the learning from foreign technology in the form of technology transfer. On the basis of recognition of the importance of technology diffusion, the Korean government initiatives and established various specialized diffusion agents such as Korea Institute of Science and Technology (KIST) and Korea Scientific and Technological Information Center (KORSTIC).

However, these agents turned out to be less effective in diffusing technology due to their limited experiences on commercializing technology and absorptive capacity.

The Korean government planned to develop domestic capital goods sector but it was not workable until 1970s. In order to emerge local engineering service firms and to provide opportunities to learn foreign experiences, the government promoted the Engineering Service Promotion Law in 1973 and Korea Engineering and Consulting Association (KENCA) was renewed to support the government intention. However, domestic capability to provide engineering service was far behind to realize. Also, government founded KORSTIC in 1962 to disseminate technical information but its usage was quite limited because firms could easily acquire and assimilate advanced (but not hi-tech) technology directly from foreigners. In 1966, Korean government established the first centralized and integrated government research institute (GRI), KIST[18], to support private firms about technological barriers. KIST played such an important role in 1960s and 1970s such as Preliminary feasibility study on POSCO, semiconductor technology transfer to Samsung and others. Unlike dominance on pure and basic research projects in major GRIs of developing countries, KIST (and other GRIs in Korea at that time) was designed to provide, commercialize, apply, industrial-oriented research works. However, researchers in KIST, mostly from academia or R&D centers in advanced countries, faced difficulties in playing their role as a technology diffusioner due to lack of experiences in commercialization and transferring of technologies to private sector and had no management know-how.

Only from 1980s, Korea could formulate a certain network framework among government, public and private (but nonprofit) institutes. The new network framework could

[18] KIST is a key agency for technological consulting in Korea. In 1960s and 1970s, KIST made significant contributions to the industrialization of Korea by helping industries identify, adopt, and assimilate new technologies. It also played a role of seed-bed of the Korean S&T as many government-financed have spun off from KIST since the 1970s.

support and stimulate private firms to intensify their business activities. Government itself plays a role as a secretariat to coordinate with different agencies related to the technology diffusion. National Industrial Technology Institute together with regional industrial technology institutes and the Small and Medium Industry Promotion Corporation provide services on industrial technology. The Korea Academy of Industrial Technology together with GRIs collaborates to diffuse their R&D activities. Private but nonprofit organizations such as the Korea Standard Association and the Korea Productivity Center provide education and training programs on quality control, value engineering, physical distribution and factory automation.

Indigenous Research and Development

Since Korea's industries became technology-intensive, the government had to adjust its policy with no R&D plan to policy with R&D programs. As a government, there are two well-known policy instruments: 1) direct R&D investment program; and 2) indirect R&D incentive program. Provision of R&D infrastructure and fund to R&D agents are examples of direct intervention. In case of indirect supports, tax reduction and preferential finance are representative examples.

As a result, total R&D expenditure by Korean government was only 10.5 billion Korean won in 1970 to 37.9 trillion in 2009 (see Table 4-4). As for the R&D share of GDP increased dramatically from 0.38 percent to 3.57 percent during the same period. Korea is now ranked 4th in term of R&D/GDP share in the World[19] and its growing rate is faster than that of GDP during the same period. The government's effort to induce investment to R&D

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[19] 1st: Israel (4.86%, 2008), 2nd: Finland (4.01%, 2009), 3rd: Sweden (3.75%, 2008) (Ministry of Education, Science and Technology)

activities in private sector contributes to rapid increase in number of researchers and number of corporate R&D centers.

Table 4-4 Research and Development Expenditures

	1965	1970	1975	1980	1985	1990	1995	2000	2005	2009
R&D Expenditure (billion KRW)	2.1	10.5	42.7	282.5	1,237.1	3,349.9	9,440.6	13,848.5	24,155.4	37,928.5
R&D/GDP[a] (%)	0.26	0.38	0.42	0.77	1.58	1.95	2.50	2.30	2.79	3.57
Researcher/10,000 Population	0.7	1.7	2.9	4.8	10.1	16.4	28.6	23.1	37.4	50.1
No. of Corporate R&D Centers	0	1[b]	12	54	183	966	2,270	7,110	11,810	18,775

Source: Author's compilation from Ministry of Education, Science and Technology and Korea Industrial Technology Association (KOITA)
Note: a = R&D/GNP date up to 1995, b = 1976 data

Direct R&D: Infrastructure

Countries like Korea that had no culture in R&D had to create an R&D environment and they started with infrastructure investment. In case of Korea, in order to support the industry’s technological learning, KIST had been established in 1966. As Korea’s first multidisciplinary and integrated research and technology center, KIST covered broad activities in applied research in the early stage of development in Korea. As market needs for technology have been sophisticated and complicated, several GRIs have been rapidly emerged from the KIST as a form of spin-off. Each GRI specialized in a specific research topic upon market prioritizing industries. Commercialization of semiconductor and telecommunication technology could be realized under the intensive collaboration between those spin-off GRIs and private endeavor.

Together with foundation of KIST, the Korean government created two major science parks: Seoul research valley and Daedeok Science Park. Seoul research valley was created in 1966 with three R&D institutes including KIST and three economic research institutes including Korea Development Institute (KDI). However, the research valley was weakening in attracting private R&D centers.

Another science park, Daedeok Science Park, was created in Daejeon city, located approximately 200km away from Seoul, in 1974. It aims to create eco-system of technological progress through close interaction among GRIs, private sector, and universities. The Daedeok Science Park succeeded in attracting not only GRIs but also private R&D labs and universities. Its reputation is however not as strong as Tsukuba in Japan as a world-class science park nor Hsinchu in Taiwan as a world-class hi-tech SMEs' town.

The government has also created research-oriented graduate school in science and technology in 1971. The Korea Advanced Institute of Science and Technology (KAIST) was an aim to rear S&T gifted students who would play an important role for national technological progress. In order to attract young and talented students, government provided unprecedented incentives to students such as scholarship with full tuition exemption and living allowance including housing and the most attractive carrot was the exemption of military obligation.

Direct R&D: R&D Promotion Program

The Korean government has started massive R&D programs in order to upgrade national R&D capability and capacity. On the basis of specialty, government required university to conduct basic research activities and ordered GRIs and private firms to concentrate applied and commercialized research efforts.

With enactment of the Basic Research Promotion Law in 1989, government invested targeting basic research topics regarding to the national R&D priorities. Just like the United States, government introduced a separated plan of promoting science research centers (SRCs) and engineering research centers (ERCs) in the universities. By 1993, fourteen SRCs and sixteen ERCs had been established and they received almost 20 billion Korean won ($24.2 million) from the government in 1993 (Kim, 1997). The limited research capacity and capability of universities are still a bottleneck in national development as well as training university researchers.

In order to fill this missing capability, GRIs have played a role of the backbone in Korea R&D. National R&D Project (NRDP) in 1982, Industrial Generic Technology Development Project (IGTDP) in 1989, and Highly Advanced National (HAN) R&D Project (or G7 Project) in 1991 had been announced and implemented by Korean government and most of the research grants awarded to GRIs in conjunction with private anchors.

IGTDP focused on facing problems. Even in late 1980s, Korea firms relied heavily on Japanese technologies. Substitution of Japanese parts in the electronics and machinery industries was a prime job for the IGTDP program. Government supported 11.5 billion Korean won in 1989 and 88.7 billion Korean won in 1993 but the amounts was not enough to solve facing critical problems.

The concentration of NRDP projects was different from IGTDP program. The NRDP projects focused on future problems that Korea would face in near or long-term future. Since investment to the future technology has a high risk of failure, it would be necessary to have government involvement. With government sophisticated analysis, target areas such as new materials development, energy conservation technology and nuclear energy fuel localization were chosen. The government spent 112.1 billion Korean won from 1982 to 1983.

The most ambitious government vision was HAN Project (or G7 project)[20]. The HAN project contained both product technology development projects which are close to applied technology development such as high-definition television (HDTV) and next-

[20] HAN project was also known as G7 project due to government goal was to lift up Korea's technological capability to the level of G7 member countries by 2020.

generation vehicle, and fundamental technology development projects that are basic research and technology such as renewable energy, new functional biomaterials and environmental technology. Total amount of the project was 5.7 billion US dollars and about half of the money came from government and universities and remaining half budget contributed by private firms.

<u>Indirect R&D</u>

Alike the above mentioned, R&D oriented policy was rarely existed in the 1960s and 1970s. Government supported preferential R&D loans but the interest rates were higher than other government programs due to lower priorities within government. In addition to that, private firms had fewer interests in R&D promotion activities because of requirement of low-tech technology in their business. However, the situation turned around in 1980s. Preferential R&D loans became a key incentive to conduct intensive R&D activities in the firms. According to Kim (1997)'s calculation, preferential financing reached to 671.6 billion Korean won in 1987 and it meant about 94 percent of total corporate R&D financing was funded by the government.

Tax incentives were another form of indirect R&D support. In order to promote corporate R&D investment, tariff reduction on imported R&D equipment and supplies, deduction of annual noncapital R&D expenditures from tax income, real estate related to R&D purpose tax exemption were introduced as tax incentives. Also, Korean government created the Technology Development Reserve Fund that a corporate can reserve 3 percent (4 percent in hi-tech industries) of sales and it would be permitted to use the reserve to its R&D activities for next 3 years. Other types of incentives such as specific industry support program, technology-based SMEs promotion program and various cost reduction on R&D related activities were provided by the government. Government also gave certification to the firms that commercialized new technologies, called Korea Technology (KT) or New Technology (NT) award under the New Technology Commercialization Program implemented in 1993. The last, government encouraged private firms to spin off its small labs into separate young companies and institutes as a part of spin-off support program in 1992.

Overview of Korea's Incentive Schemes for Industrial Technology Development

Korea has designed and implemented a variety of incentive policies to promote technological capability in target industries (Table 4-5). From the early 1960s, corporate tax deduction and exemption programs for FDI firms that satisfied technology requisite were introduced. After the incentives, government also implemented diverse incentive systems in 1970s. However, those incentives in 1960s and 1970s were targeted to technology transfer activities rather than that of R&D. It was because that domestic capability and capacity for R&D efforts were not built yet. Only 1980s and late years, government expended its incentives for indigenous R&D activities. National R&D program initiated from 1982 was a flare that government's focus has been reshaped from imported technology transfer oriented to internal R&D activity oriented.

Also, the change of government incentive system from vertical approach to horizontal approach or functional support was formalized by the enactment of the Industrial Development Law in 1990 because of rapid expansion of private R&D activities on the basis of economic of scale and technological complexity.

Table 4-5 Chronology of Major Technology Policies

	Before the 1970s	*1970s*						*1980s*				*1990s*	
		1973	*1974*	*1976*	*1977*	*1978*	*1979*	*1981*	*1982*	*1984*	*1986*	*1991*	*1992*
R&D investment promotion		Technology development reserve funds system											
			Tax credit or special depreciation for investment in equipment to develop technology and human resources										
					Duty abatement or exemption on goods for academic research								
								Tax credit for technology and human resources development expenses					
								Tax exemption for real estate of private enterprises' affiliated research centers					
									Tax exemption for research devices and samples				
												Duty abatement or exemption on goods for research	
Technology transfer promotion	Deduction and exemption of the corporate tax for the foreign investment accompanied by the technology requisite												
						Reduction and exemption of tax amount on technology transfer income							
								Income tax exemption for foreign technologists					
Technology commercial-ization promotion									Provisional special consumption tax rate for technology commodities				
										Reduction and exemption of tax for start-up venture SMEs			

Source: Sub *et al.* (2007)

4.3. Market Response: Enhancing Absorptive Capacity and Intensity of Efforts

As we mentioned in chapter 2, the foregoing government intervention and incentive, such as policies to promote both demand for innovation and supply of capabilities in case of Korea, cannot explain the different growth rates among catching-up countries and among firms within a nation. This is because one-way government provision cannot contribute to the national growth and it means intimated linkage not only between demand and supply policies but also between government and market are a key for attaining higher economic growth. Therefore, market and technological environment promoted by government incentive or manipulated by government intervention are crucial and it affects to a significant extent not only the behavior of market, especially firms as basic economic agent units including all actors such as suppliers and customers, but also interactions among them (Figure 3-4).

Once the government incentive gains the summit, it compels the firm to intensify its efforts to strengthen internal activities for enhancing technological capability. It also compels the firm to intensify its efforts internally and externally to strengthen technological capability and to deepen its knowledge from outside sources and its interplay with other stakeholders (players) in advance.

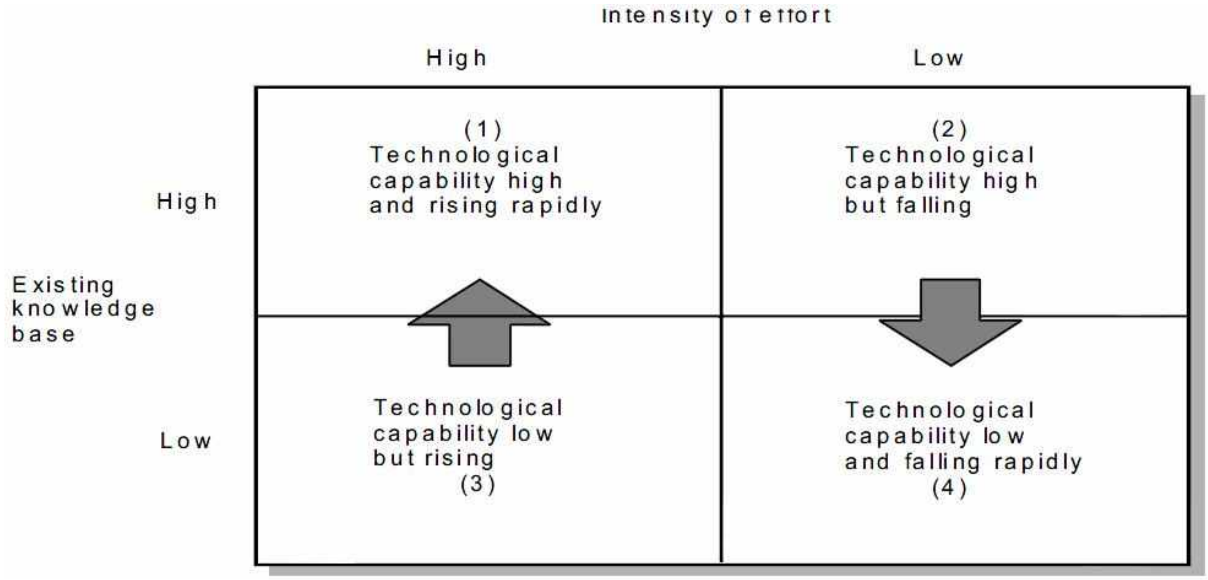
In this section, the study introduces firms' continuous innovation for serving qualified goods and services with low cost in order to meet the needs of customers. The innovation efforts are the following items: first, firms' devotion for acquiring knowledge and intensity of efforts; second, activities of technology transfer and diffusion; third, in-house R&D efforts for enhancing technological capability; fourth, human capital empowerment; and fifth, crisis management and upgrading organizational structure within firm based on Korean case.

4.3.1. Initial Stage: Acquiring Knowledge and Intensifying Efforts

The level of knowledge and intensity of effort are key determinant factors for technological progress regardless of the level of technology. On the basis of current knowledge gains, firms can upgrade their technological advance. Without continuous intensifying efforts, technological progress is difficult or slower. In this section, we would like to emphasize the importance of acquiring knowledge and intensity of efforts in the initial stage in order to build up eco-system.

Kim (1997, 1999) created an absorptive capacity framework through the following two key ingredients: knowledge base and intensity of effort. Current knowledge is a fundamental asset to tomorrow's knowledge because current knowledge affects knowledge learning process and it creates better and advanced future knowledge. The intensity of effort is an engine to solve facing problems. Without the effort, the existing knowledge cannot contribute to enhance absorptive capacity of a firm. According to the Figure 4-2, technological capability is high and rising rapidly when both existing knowledge base and intensity of effort are high (quadrant 1). On the other hand, technological capability is low and falling rapidly when both intensity of effort and existing knowledge base are low (quadrant 4). In case of quadrant 2, firms with high existing knowledge but with low intensity of effort may have a possibility to lose its gained knowledge gradually (move down to quadrant 4) because technology is rapidly improved. In contrast, firms with low existing knowledge but with high intensity of effort (see quadrant 3) may have low technological capability now but will rise it rapidly in future due to their energy based on intensity of effort lead them to move up to quadrant 1 through continuous technological learning activities. In short, he argued that the intensity of effort is more crucial than existing knowledge base for long-term prospect.

Figure 4-2 Absorptive Capacity Framework



Source: Kim (1997, 1999)

In 1960s, Korea had neither capital nor technology in order to be industrialized countries. Also, there was no domestic market to do business activities. Therefore, the Korean government had to opt for an export and outward-oriented strategies with its only strengthen -- relatively well-trained human capital with strong will to overcome current poverty. The government set up two main goals in this respect: transfer of foreign technologies and developing domestic absorptive capacity of the transferred technology. Reverse engineering, original equipment manufacturing (OEM) and foreign licensing have been critical role to transfer foreign technologies but foreign direct investment (FDI) was not a main aim for technological learning[21].

Under the government regime, private firms propelled appropriate strategies according to industries. Firms in light industries such as garment, wig, and shoes received benefit from OEM business and training program of turnkey plants package. Especially,

[21] The reason is mentioned in the followed section: "3.2.1.2. Supply of Technology: Technology Policy and Incentives."

OEM provided them to understand the whole business cycle from planning and design to quality control and marketing. For the HCI industries, firms depended on turnkey plants with operational training program and foreign licensing as a tool of acquiring foreign technologies. Because of the Korean government policy on business agent promotion, big corporations (would become *chaebols* afterward) utilized various benefits fully from financing support to domestic market monopoly ownership[22]. Also, technologically weakened industries were compensated by GRIs' technological supports. Those technological learning through informal channels enabled Korea to acquire technologies at lower costs and to maintain domestic firms' independence from MNCs. However, Korea experienced difficulties in acquiring sophisticated technologies that could be imported by FDI channels and the speed of technological progress was relatively slower than other countries like Taiwan at the early stage of development (Lall, 2003).

4.3.2. Period of Technology Catch-up: Technology Transfer and Diffusion

As this study depicts in figure 3-4, three main sources interplay in the process of technological progress: international community, domestic community, in-house efforts at the firm level. First, international source is a very important source of technological learning in catching-up countries. Learning new technologies, using expertise (or experts), and upgrading absorptive capability of technology are the benefits gained from the international community. Therefore, intimate relation with the international community is necessity to upgrade firms' technological ability. Domestic source is another way of enhancing

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[22] Korean government compensated *chaebols*' effort on massive investment of HCI industries based on export first strategy as domestic import substitution business that could easily collect money and other capitals.

technological capability at firms. Joint research project among domestic players from public, private and university is the most predominant way of collaborating domestically. The last is firm's self-effort. It is a stepping-stone of upgrading technological capabilities. Interaction of diverse ingredients within firms such as existing technological capability, production experience and trial and error, and R&D activities are main factors for technological progress.

As we mentioned above, international community is the most important source for technology transfer in the early stage of development. Even though many literature on technology transfer points out the important role of FDI, other literature with empirical supports emphasizes that informal channel of technology transfer and diffusion is much greater than that of formal channel during early stage of development in catching-up countries (Kim, 1990 and 1997). According to Kim's finding, he described the activities of technology transfer in two dimensions: market-mediation and attitude of foreign suppliers (Figure 4-3). In case of market-mediation, it relates to whether formal agreement and payment needs between foreign suppliers and local buyers. Also, attitude of foreign suppliers means whether the suppliers may participate technology transfer activities actively or passively. FDI, FLs and turnkey package can be quadrant 1 (market-mediated and active role of foreign suppliers) and capital goods can be classified in quadrant 2 (market-mediated and passive role of foreign suppliers). Literature review, journals, observation and reverse engineering are classified in quadrant 4 (non market-mediated and passive role of foreign suppliers) and quadrant 3 is included such as technical assistance. In case of Korea, it preferred to non active participation of foreigners such as quadrant 2 and 4 instead of quadrant 1 and 3. It is because that Korean had an allergy to direct involvement of foreign firms, as we pointed out already.

Figure 4-3 Evolution of Technology Transfer in Catching-up

The Role of Foreign Suppliers

	Active	Passive
Market Mediated	Formal mechanisms (Foreign direct investment, foreign licensing, turnkey plants, consultancies) (1)	Commodity trade (Standard machinery transfer) (2)
Nonmarket Mediated	Informal mechanisms (Technical assistance of foreign buyers and vendors) (3)	Informal mechanisms (Reverse engineering, observation, trade journals, advanced reverse engineering, etc.) (4)

Source: Kim (1990, 1997)

Increasing royalty ceiling for technology transfer from foreigners, GRIs foundation for facilitating the acquiring technology transfer, deregulation of prior approval of technology transfer contract, technology development promotion law in 1972 and diverse technology localization promotion plans during 1970s, and tax exemption for imported capital goods were incentives to create an active business environment for domestic firms.

4.3.3. In-House R&D Efforts for Enhancing Technological Capability

As Korea can take advantage of neither light-and-labor-intensive industries nor one-way technology transfer from foreigners, Korea had to reshape its strategy for hi-tech industries with enhancing empowerment of domestic players. Simultaneously, increasing viewpoint that technologically advanced countries started to regard Korea as a future competitor in the global market hindered Korea to acquire foreign technology transfer, even though Korea had to do a lot for achieving industrialization. As a result, Korea had to do with building up indigenous R&D capability.

However, given context of Korea in terms of R&D, there was only a very limited experience within and without domestic firms. No experience at the universities was almost same as that of private sector. Therefore, government designated GRIs as a R&D supporter. According to Lee's finding (2010), the late-industrializing countries in Asia including Korea have shown a tendency to rely on formal collaboration channels such as joint or contract-based research because those catch-up countries do not usually have enough technological capability to take a lead for a collaboration project without government support and drive. KIST and its spin-off GRIs that specialized each target industries and technologies led R&D activities and they spend a large proportion of the total national R&D budgets until early 1980s. In order to upgrade firms' technological capability in a short period of time, government organized joint research team and joint consortium among *chaebols*, GRIs in charge and even university later on.

Even though several attempts were failed to transfer the results, as time goes by private firms could improve their capability to indentify prospective technologies and foreign suppliers and accumulated experiences and know-how from those joint activities helped firms to assimilate and adapt imported technologies rapidly. Joint collaboration between private firms and GRIs reached diverse success cases from polyester film to semiconductor and telecommunication after all. Also, Kim (1990, 1997) pointed out those joint collaboration was helpful for generating experienced researchers and they would play a pivotal role in private R&D centers later on.

Box 2. Korea's ICT Industry Development

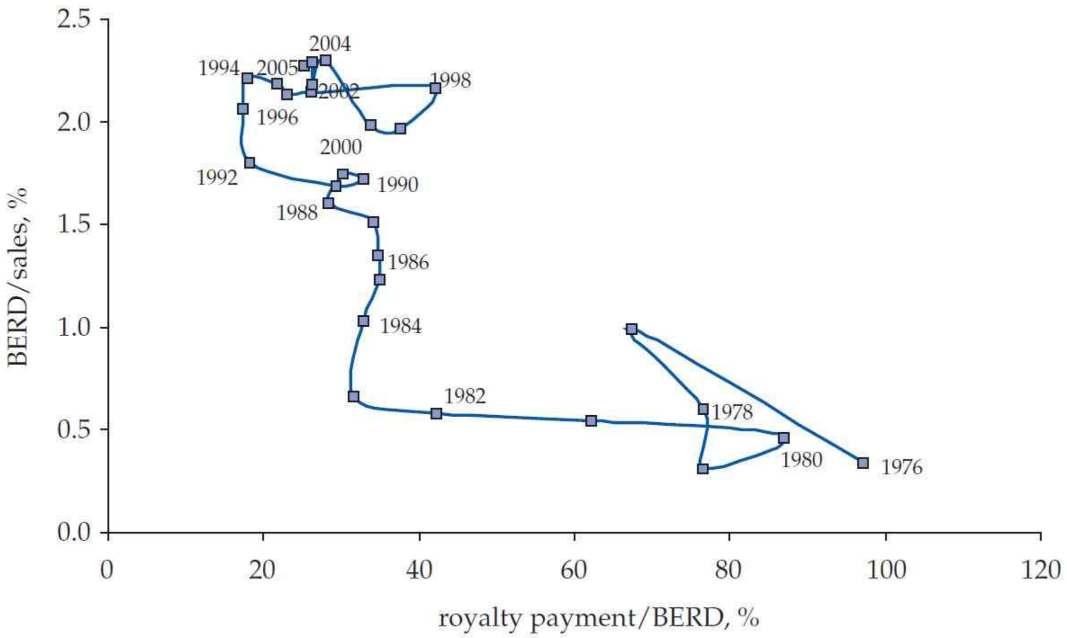
In case of Information and Communications Technology (ICT) industry for example in Korea, Korea government started to recognize the urgency of localization of ICT technology as a country's next growth engine next to HCIs from late 1970s. The government formulated a consortium under the scheme of public-private-partnership. Electronic and Telecommunications Research Institute (ETRI), Korean Telecommunications Authority (KTA[23]), and four *chaebols* (Samsung, LG, Daewoo, and Hanwha) joined the consortium. Enormous government incentives such as import restriction of foreign ICT equipment and technology, provision of domestic market share to above four *chaebols*, and sequencing massive financial support were provided to the ICT industry promote programs. From the first success of developing a proprietary digital switching system, called TDX (Time-Division eXchange), the consortium had developed various switching systems and its indigenous capability could advance to wireless and mobile telecommunication. In 1992, the government designated Code Division Multiple Access (CDMA) as the national standard for mobile communications[24] even though national competence remained in the analog communication technology at that time. With cooperative efforts between public and private endeavors for years, the first commercial CDMA service was launched by Korea and spread to the rest of the world. In addition, the success of CDMA could lead to strengthen mobile phone industry of Korea. In 2010, CDMA service was used by 577 million people in 95 countries (Statistics of CDMA Development Group) and

[23] KTA became an independent public corporation with the name of Korea Telecom (KT) in 1990.
[24] The reason for choosing CDMA as a national standard was to preoccupy the global ICT market because GSM (a rival standard against CDMA) was chosen as an European standard at the same.

two Korean *chaebols'* (Samsung and LG) global market share reached to 29.4 percent according to International Data Corporation (IDC). Most importantly, private firms were the main actors for the process of the development of ICT industry. Without their intense efforts on acquirement, assimilation, adoption, development, and commercialization, the government incentives could not have led to the great success.

Beginning of launching National R&D Project (NRDP) in 1982, Korea government took various policy instruments to promote and facilitate private R&D activities. Private sector's response was to make massive R&D investment. In consequence, technology imports had been declined sharply, whereas private R&D expenditure had been increased rapidly contrastively (Figure 4-4).

Figure 4-4 Changing Relationship between Royalty Payments and Business Expenditures on R&D, 1976-2005



Source: Suh *et al.* (2007)

Also, main anchors of R&D activities turned from public GRIs to private firms (Figure 4-1). From 1982, R&D expenditure ratio between public and private sector turned around and nowadays, government R&D budget is 10,889 billion Korean won and it is about 28 percent of total national R&D expenditure in 2009[25].

Since Korea has been grown up, the Korean government cannot take care of all targeted industries because of increasing economic of scales and technological complexity. After all, government quitted intervening to industries directly, instead it involved indirectly such as industrial infrastructure designing and long-term plan implementing. As a facilitator and promoter, the government however is intervening to the market and industries continuously. At the same time, the government initiated R&D programs in basic and fundamental scientific research and technology in order to maintain its technological potential in the future.

4.3.4. Human Capital Empowerment

In fact, education is also one of key determinants for economic growth together with technological progress as many literatures mentioned. However, the importance of education is excluded in this study that focused on the relation between government incentive and technological learning and the importance of technological progress for national growth. Nevertheless, this part would like to convey the role of education as a key factor for enhancing technological capability at the firm level due to necessity of educated and skilled human capital for technological progress.

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[25] Private R&D expenditure is 26,961 billion Korean won and it is about 71 percent of total national R&D expenditure in 2009 (Ministry of Education, Science and Technology).

Initially, the Korean government was a main actor for providing and expanding the education system based on the market needs successfully. Strong demand for education based on Confucianism and homogeneity of Korean society[26] also contributed to planning and implementing the education policy. The government established a compulsory primary education in 1954. After achieving the universal primary education, the government shifted its focus to secondary education in the 1960s and 1970s and then to higher education in the 1980s to satisfy the market needs in HCIs.

There are two main contributions to supply and to train well-educated and skilled works continuously: provision of on-site and after-work vocational school and specialized vocational training school.

First, the on-site and after-work vocational school was established by *chaebols* from 1977 and small and medium size firms gradually sent their young employees to evening classes nearby the firms after Korean government enacted in-plant training compulsory law for all companies that retained more than 300 employees and vocational training promotion fund, which was financed by fines imposed to the firms that did not fulfill government requirements on employees' training in 1976 respectively (Gill *at al*, 2000). This free on-site school benefited both employers and employees. Low turnover rate, higher productivity and loyalty were one of benefited from the program and especially the passion for higher education led them to gear to work hard with higher loyalty. The number of such schools increased from 5 in 1977 to 42 in 1980 and those schools became to provide high-school program to the workers who completed the middle school program. By the early 1980s, more than 70,000 young workers completed their secondary education while on the job (Kim, 1997).

[26] It was ironic that Japanese colonial period, land reform after the independence from the Japanese colonization, and Korean War contributed to cultivate such an equitable social structure and mindset.

Another contribution was to provide specialized vocational training school. With enactment of the Vocational Training Law in 1967, vocational high schools were established[27] by Korean government right away to provide skilled workers to the growing light industries. Junior colleagues and polytechnic or vocational colleagues were also designed to supply technicians to the fast growing HCI industries. Establishment of Kum-Oh National Technical High School in 1972 for example was appropriate provision of skilled manpower to the strategic industries. Kum-Oh high school provided state-of-the-art equipments that did not exist in Korea for practical training and employed Japanese teachers who had technical know-how and experience in a practical way. Also, various incentives to the students of the Kum-Oh high school were provided such as full tuition fee exemption and living allowance including housing. Especially, students who successfully graduated the Kum-Oh had a privilege to work at the most prestige *chaebols* with a higher salary and a chance to work overseas. Those incentives attracted many young talented students from poor families in particular to enroll the school. By 1990, the number of graduate at Kum-Oh high school was 6,164 and the high school won 18 medals (gold medals were 14) at the Vocational Olympics in the same period[28]. The success of Kum-Oh high school led to establish enormous specialized technical high school in Korea. Consequently Korea won 9 times in a row from 1977 to 1991 at the Vocational Olympics[29].

Also, the government created KAIST in 1971 as a same purpose as that of Kum-Oh National Technical High School. KAIST as an aim to nurture S&T gifted students who will devote to upgrade R&D capability. The incentives scheme of KAIST was also almost same as

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[27] The Korean government categorized 4 types of specialized technical high school as such: machinery school (precision processing engineers), model schools (oversees dispatched engineers), specialized schools (engineers for specialized industry), and general school (engineers for general industry). Number of schools was 19, 11, 10, and 55 respectively (Kang, 2011).

[28] Author's compilation from the website of Kumoh Technical High School retrieved from http://www.koths.or.kr/ (In Korean).

[29] Introduction of technical licensing and certification system in 1973 to verify competitive students also contributed to the success in the Vocational Olympics.

that of Kum-Oh high school. In order to attract young and talented students, government provided unprecedented incentives to students such as scholarship with full tuition fee exemption and leaving allowance including housing and the exemption of military obligation.

4.3.5. Crisis Management and Upgrading Organizational Structure within Firms

In catching-up period, a country plays an orchestral role for industrialization like Asian NIEs often formulates a series of crises by imposing challenging missions in prioritized industries. The picking winner approach is clearly shown to the firms that winner takes all and loser has to get out of the business. When a crisis happens, regular technological learning activities have to be quitted and firms get into trouble. Given crisis, firms have to find out a way of continuing activities for technological learning and progress in order to maintain their market competitiveness. In such a case, the only firm that invests not only human capital but also capital goods intensively in order to acquire new tacit and explicit knowledge as well as knowledge exchange can survive and take a lead in the global market. If a firm succeeds in sustaining the technological learning, the firm becomes a new (or a continuous) market leader after the crisis has been gone. In case of Korea, the government created a sequencing challenge to the market and the series of crises motivated Korean firms to become the world leading competitors at the end.

Crisis may also be happened regularly by nature. In 1980s, new crisis that created naturally faced to the firms. The global economy recession, protectionism, harsh competition among catching-up countries in the field of light and labor intensive industries, and import liberalization required firms to restructure its organization fitting into new business eco-system.

Chaebol that usually gets used to traditional chief in commander military style of organization had to transform itself into new innovative and technology oriented organization. This military type of organization requires a decentralized, self-reliance, small but strategically systematic business unit structure. Creative individuals with efficient small groups and effective and flexible coordination across the whole process of production enables to applicable. Also, the structure can be easily communicated, indentify and respond quickly to market opportunities, threats and technological possibilities. This transformation is one of the most formidable tasks facing Korean *chaebols*, even up to now. Therefore, the strategic importance of top and middle management should not be overlooked in order to attain the restructuring. Their role is vital in continuous and discontinuous coordination and communication between working level employees and executive level officials. In Korea, retraining those middle level managements is a prior job for *chaebols*.

5. Conclusion and Implications

This study explores the Korean way of development in the early stage of industrialization from the perspective of analyzing the relationship between technological learning and government incentives. As many scholars pointed out, government in late industrializing countries, especially countries succeeded in transforming from poorer countries to richer and advanced countries like Japan and four Asian Tigers, played a significant role as an environment creator and a facilitator.

변경: As many scholars pointed out, the government played a significant role as an environment creator and a facilitator, especially in countries like Japan and four Asian Tigers, which were both late-comers in terms of industrialization and succeeded in transforming from being poor to rich and advanced.

In case of Korea, the government set a national agenda with growth targets and industries and provided a package of policy instrument. Overcoming agro-based economic structure and lack of domestic market and capability, the government created a demand of technology through industrial policies and incentives. Under the umbrella of outward-looking and export-oriented national strategy, government drove to promote big business agents (*chaebols*) and to select strategic industries that enabled to sustain economic development of Korea in future. Through the government activities, technological capability can be improved in conjunction with industrial endowment. The government poured out massive incentive programs under the names of tax exemption, preferential loan, and domestic market monopoly to only performing firms selectively and continuously. At the same time, the government fully supplied technological provision to firms through science and technology policy. The government established numerous GRIs and spin-offs to support the activities of technology transfer and diffusion that market would like to have. Also, for enhancing indigenous R&D ability, the government provides massive R&D funding and infrastructure program such as National R&D program and HAN project.

However, those foregoing government interventions cannot solely boost the level of national technology. Instead, those government's efforts become a powerful mechanism only together with market's appropriate response. Firms' intensifying efforts of acquiring, assimilating, and imitating foreign technology based on talented and passionate individuals should be corresponding with the government initiation. In the initial stage of development, firms devoted to learn and assimilate foreign technologies through reverse engineering, OEM products and turnkey plants. Also, with interactive activities with GRIs and other firms for technology transfer and diffusion, firms could enhance their capability and it contributed them to start in-house R&D efforts. The Last, firms could become stronger with crisis management. Either generating crisis by government or firm itself or natural crisis caused by global recession, firms had to maintain and upkeep their technological capability to survive from the given crisis. Nowadays, they are trying to restructure their organization to be more timely appropriate to the new innovative and technological global society.

In summary, the Korean experience provides three implications for catching-up countries. First, government and market in developing countries especially with limited natural resource nations should carefully target industries and activities and all their efforts with incentive structure should focus on fostering in applied technology rather than basic and pure scientific research if they would like to accomplish rapid industrialization. As we mentioned, developing countries usually suffer from limited resources, finance in particular. Therefore, they have to focus on the role of selectivity to maximize effectiveness of limited resources in activities. There is no doubt that basic science would be a crucial backbone for long-term advancement and for knowledge and innovation economy. However, what Korea case emphasized is that the timing of fund allocation between applied technology and basic technology should be differentiated. The role of KIST, Korea's first multi-discipline research institute in science and technology, as a foreign technology transferor and diffusioner instead of basic scientific research aim can provide significant implications to developing countries. Also, the dominance of private R&D institutes in the national R&D share indicates that Korean R&D system is focused overly on industrial technology.

Second, interactive linkage between government and market is very important. As many scholars found out, one-way of government incentive cannot contribute to the national growth and technological learning and progress. As old saying goes, it takes two to tango. Systematic and close coordination between government incentive and market's intensifying efforts (or response) can play a tango. A consortium building as public-private-partnership is a good example. In case of ICT industry, Korean government supported to organize a consortium for telecommunication equipment and service. GRIs like ETRI and private firms such as Samsung and LG (*chaebols*) participated in the consortium. With government massive incentives in both direct and indirect way, the consortium could develop TDX and its success continued to launch the first commercial CDMA service in the world after all. Also, technological capability gained from those experiences and the benefit of global dominating CDMA service provider has led Korea's handset industry as a top manufacturer in the world nowadays.

Last but not least, government incentives with high pressure to stimulate market should be implemented in the early stage of development. Even though government does not intend to create crisis in the market, global recession happens regularly. Without any preparation to the crisis, domestic market and nation itself will easily collapse and lose its competitiveness. Therefore, government should create a system of incubation: that is to push into emergency situation and to provide incentives to the firms regularly. In case of Korea, monthly export promotion meeting that was held 177 times for two decades on a regular basis provided a platform to inject massive pressure as well as to provide sequencing incentive toward firms. With President's leadership, the meeting was a venue to remind (or assign) export target and to identify and solve facing problems of export related issues immediately. Also, the meeting is a place for a beauty contest not only among business anchors to dig out more government support but also government officials to be promoted and be awarded by the president.

In fact, there is no single practice to be replicated for technological development and economic growth. A number of different options are available but recipient countries should carefully implement those options upon the countries' socio-economic and political situation as well as global environment. Of course, there are common elements to develop technology as such: government leadership, appropriate strategy and commitment, well-trained manpower, effective technology supporting systems, attractive incentive mechanism, and intensifying efforts of business anchors. Therefore, we must note that the priority should be on adequate analysis of global and domestic context followed by cautious designing and implementation of national programs.. Its underlying philosophy is driven more by faith than rationality and evidence as Lall mentioned (2003).

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