POLITICAL ECONOMY OF TECHNOLOGICAL CHANGE: EXPLORING INDUSTRY-UNIVERSITY-GOVERNMENT LINKAGES IN SOUTH KOREA

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MASTER OF PHILOSOPHY

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DECLARATION

I declare that the dissertation entitled "**POLITICAL ECONOMY OF TECHNOLOGICAL CHANGE: EXPLORING INDUSTRY-UNIVERSITY-GOVERNMENT LINKAGES IN SOUTH KOREA**" submitted by me for the award of the degree of **MASTER OF PHILOSOPHY** of Jawaharlal Nehru University is my own work. The dissertation has not been submitted for any other degree of this or any other University.

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CERTIFICATE

We recommend that the dissertation be placed before the examiners for evaluation.

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Chapter I

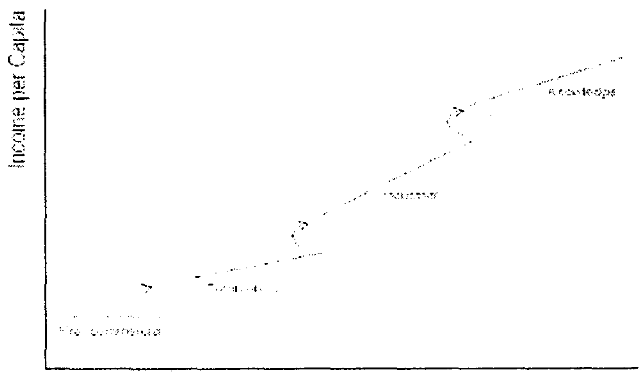
Introduction

Till recently the economists thinking of economic growth was accumulation of physical capital; machines, buildings, and highways etc. However, the evidence is that technological advance, reflecting the accumulation of knowledge, is more important. Today, new opportunities have emerged to use knowledge for more rapid development and it is acclaimed that the leading edge of the economy in developed countries driven by technology (knowledge) innovation and its effective utilization proliferated with the information and communication technology. These new technologies which emerged in the late 1950s, expanded with the proliferation of personal computers, and then surged dramatically with the widespread use of email and the Internet have considerable potential to remake the nature of work and the economy. Nevertheless, our understanding of the purported knowledge-based economy remains rather hazy, clouded by both enthusiasts and pessimists who are quick to offer labels and assessments without much attention to evidence.

1.1. Knowledge-based Economy (KBE)

Economists consider three transformations economies go through as countries moves from extreme poverty to wealth. These transformations involve restructuring of economies at different levels of economic development and pose different challenges for economic policy and strategy. The three stages are the commercial stage, the industrial stage, and the knowledge-based stage. Economies can get trapped at each of those steps of development, either at a pre-commercial level of development, a pre-industrial level, or a pre-knowledge level of development. The countries with highest income are all now knowledge economies; they very much driven by innovation, which is in turn driven by a high input of science and technology.

Fig. 1.1 Stages of Economic Development



The broad label "knowledge-based economy" covers a wide array of activities and interpretations. The oldest approach, with its origins dating back to the early 1960s, focuses on the rise of new science-based industries and their role in social and economic change. Some analysts include professional services and other information-rich industries such as publishing in this category, noting the marked growth in employment in these sectors of the economy over the past three decades (Machlup 1962). The core idea unifying this strand of work is the centrality of theoretical knowledge as a source of innovation. With some stretching, the new growth theory in economics (Bell 1973), could be included here as this work stresses the importance of knowledge in economic growth, noting that discoveries differ from other inputs because they are non-rivalrous and fuel further innovation.

A comprehensive definition Knowledge-based economy is yet to codify. But the concept could be made clear by identifying and providing a variety of definition available which deals with various aspects of the concept.

> "A knowledge-driven economy is one in which the generation and exploitation of knowledge play the predominant part in the creation of wealth"(DTI 1999:5).
>
> "...(KE) one in which the generation and exploitation of knowledge has come to play predominant part in the creation of wealth. It is not simply about pushing back the frontiers of

knowledge; it is also about the most effective use and exploitation of all types of knowledge in all manner of economic activity" (DTI 1998:2).

"The idea of the knowledge driven economy is not just a description of high tech industries. It describes a set of new sources of competitive advantage which can apply to all sectors, all companies and all regions, from agriculture and retailing to software and biotechnology" (Brinkley 2006).

It is not a new idea that technological knowledge plays an important role in the economy, nor is it a new fact. All economies, however simple, are based on knowledge about how, for example, to farm, to mine and to build; and this use of knowledge has been increasing since the Industrial Revolution. But the degree of incorporation of knowledge and information into economic activity is now so great that it is inducing quite profound structural and qualitative changes in the operation of the economy and transforming the basis of competitive advantage.

The Knowledge-based economy is emerging from two defining forces: the rise in *knowledge intensity* of economic activities, and the increasing *globalization* of economic affairs. The rise in knowledge intensity is being driven by the combined forces of the information technology revolution and the increasing pace of technological change. Globalization is being driven by national and international deregulation, and by the IT related communications revolution.

1.2. Economic Development of South Korea

South Korea's (hereafter Korea) rapid and sustained economic growth from the time when it was starting out as a low income country was an outcome of the knowledge economy approach, even though an explicit knowledge economy development strategy was not laid out. During this time from 1950 to 1997, Korea's economic development hinged on the critical interactions among the four pillars of the knowledge economy, which have evolved together with the various stages of economic development. In particular, the pragmatic development strategies focused on achieving sustained productivity growth by consistently increasing the value added of output.

These strategies involved intensive learning processes consisting of active technological capability building and complementary human resources development. At the same time, the Korean government assumed the very necessary proactive leadership role of supporting the market and providing an environment that would foster and sustain the transformation.

In the 1960s, Korea embarked on the promotion of both export and import substitution industries, starting with subsistence agriculture (rice) and labour-intensive light manufacturing sectors (textiles and bicycles). Considerable capital accumulation and investment in primary education during this period allowed a gradual shift up the value added chain toward more sophisticated commodities. Key to this shift was also the use of technologies obtained through foreign licensing and adapted for domestic production.

In the mid 1970s, the government's use of a well targeted industrial policy resulted in a major shift to the development of heavy industries (for example, chemicals, shipbuilding). Along with industrial targeting, policies were enacted to further improve technological capabilities, together with improving access to and quality of technical and vocational training.

In the 1980s, Korea undertook efforts to ensure a market conducive environment by deregulating various sectors and liberalizing trade. Concurrently Korea expanded her higher education along with investing in indigenous research and development through the establishment of the National Research and Development Program. Korea continued to pursue high-value-added manufacturing in the 1990s by promoting indigenous high technology innovation. Domestic wage hikes and the appreciation of the Korean won had resulted in current account deficits, which sparked a series of reforms, including the reform of the financial market. Together with the setting up of a modern and accessible information infrastructure, there was continued expansion of research and development capabilities in Korean industries, which drew on the skilled labour force that had resulted from the government's aggressive expansion of the higher education system.

1.3. Transforming Capital Intensive to KBE of Korea Economy

The recent development trend of knowledge-based industries in Korea basically mirrors the overall trend observed in most OECD economies as they move toward a knowledge-based economic structure. As in most other OECD economies, knowledge-based industries have been substantially outpacing the growth of other industrial sectors in Korea in terms of real value-added and employment. In short, Korea has been transforming toward a knowledge-based economic structure, just as other OECD countries. The importance of knowledge-based industries as a major driving force of economic growth is expected to accelerate over the next decade. Knowledge-based industries are projected to grow substantially faster than the remaining industrial sectors in every major aspect of the economy including output and employment (KIET 1998).

In the evolving knowledge based economy, high-tech industries such as information technology, biotechnology, nano-technology, precision materials and new basis materials industry are becoming the core source of economic development. During this transition the linkages between Industry-University-Government are identified as the key sources of technological innovation fostering the development of venture industries and high tech industries through clustering of science and technology environment facilitated by the establishment of technology parks, science parks, techno-poles, industrial clusters etc. In Korea the attention towards the Industry-University-Government synergy is a recent phenomenon. Korea also embarked on a full-scale construction of techno-parks, with the designation of a sample one in late 1997, to establish and foster venture firms under close IUG cooperation with a view to replicating the success of 'science park' cases in advanced nations. It is expected that recent S&T policy orientation and projects like BK21 will bring a change the local industrial structure into a high-tech one and foster technological innovation through IUG cooperation.

1.4. Research Questions and Motives of the Study

There are two major problems identified by the researcher which needs to be answered to understand the dynamics of knowledge based economy. First, how the process of technological change facilitated the evolution of a knowledge-based economy in South Korea?. The process of technological change in Korean case is closely associated with the stages industrialization, which cannot be independently studied with out considering the Korean government's S&T policies at various stages of industrialization. The answer to the above question will be intended to provide historical analysis of how institutions and institutional arrangements carry certain functions and the evolutionary analysis focuses on the functions of selection environments in terms of outputs. The second problem is, what is the nature and scope of Industry-University-Government linkages and how this synergy contributing to the process of technological change in Korea in the post developmental era. Which will provide an assessment of how and to what extent the co-evolution of institutional arrangements enhances synergy among different selection environments and also the differentiation and integration among the above three functions in Korea's National Innovation System.

A nation's economic growth, industrial might, military capability etc. are directly influenced by the technology capability of that nation (Mokyr 1990; 2002, Krugman 1986, Romer 1986; 1990, Kim 1997). There for relative national technological capabilities necessarily influence domestic standard of life, economic adjustments etc. Also innovation driven economic growth both attracts investments and produces surplus capital. The experience of Korea demonstrated that the technological capability was the major drive for Korean economic growth. The proposed study is an endeavor to understand the process of technological development and the evolution of knowledge economy in Korea. The study also tries to map the political process of technological change and S&T policies of developmental state in promoting 'techno-nationalism' in Korea and major shifts in the post developmental paradigm. Thus the study revisits the developmental state discourse in South Korea, emphasising how the S&T policy helped Korea during the catching up period to develop a technological base and what were the major shifts during post-developmental paradigm. The study also explores the state-market-university linkages in the technological innovation in Korea.

1.5. Methodology

The Study shall be using analytical research methods to understand the process of technological change and the emergence of Knowledge-based economy in South Korea. The research method followed in this study shall be based on the existing literature available in the form of books, journal articles official documents and related literature. The data set used in this study shall be obtained from the online databases USPTO, MOST Korea, National Statistical Office Korea, National S&T Council Korea, Korean Patent Council, Korean Institute for Economic Policy (KIEP), Science and Technology Policy Institute (STPI), Korea Advanced Institute of Science and Technology, OECD, UNSTATS and the information provided at various websites of Korean universities and S&T institute are also employed.

The hypothesis; *the Korean government's role from regulator to facilitator paved the emergence of a 'techno-scientific state*, shall be tested by mapping and detailed analysis of the Korea's S&T polices and their impact on technological change both in the developmental and post developmental paradigm. The analytical frame work for 'techno-scientific state' shall be based on the works of Schmandt and Everett Katz (1986), Gilpin (1968) and Uttam (2006).

Etzkowitz's (1998; 2003), Etzkowtiz and Leydesdorff (2002), and many others place much value on the relationships within the "Triple Helix" paradigm, claiming that industry and government are joined by universities in knowledge-based economies, necessitating new social arrangements and channels of interaction. The Triple Helix is built upon the claim that innovation and research efforts are more productive where the efforts of the government, universities, and firms overlap. Second hypothesis; *the institutional arrangements and channels of interaction in state-market-university R&D collaboration have predictive power,* will be tested by using data collected from the above mentioned sources with in the analytical frame work of triple helix model.

1.6. Review of Literature

Even before the East Asia currency crisis economists argued that the East Asian economic growth in general and Korea in particular was achieved through mere capital accumulation and they elucidated that 1997 crisis as the end of East Asian Economic growth (Krugman 1994). But the rapid recovery and the high economic growth in the post crisis period in South Korea demonstrated that the miracle was not merely a short phenomenon through high investment, rather anticipated a long term growth becoming a knowledge based economy achieved through the process of technological learning in the earlier period of catching up and followed by becoming an innovator through rapid technological innovation towards the end of 20th century. The reports of Knowledge for development (K4D) project of the World Bank documents that Korea has recently established itself as an emerging knowledge-based economic powerhouse. (World Bank 2006; 2004; 2000)

Amsden (1989) explains the rapid industrialization of Korea in the early decades of economic growth based on the process of *technological learning*. These learners do not innovate and compete on the combined basis of low wages, state subsidies and incremental quality and productivity related to existing products and they relay heavily on foreign technology to narrow the gap (Amsden 1989). In Korea the absorption of foreign technology initially was through the process of copying and self teaching and later through investing in foreign licensees and technical assistance, Amsden explains this change in mode as imitation to apprenticeship (Amsden and Kim 1985). And it viewed as a means to achieve technological independence. Jinjoo, Lee and et al (1988) and Young Lee (1997) identify the three stages of technology development during the course of industrial development: the imitation stage, the internalization stage, and the generation stage. The three stages mentioned above are consistent with the stages introduced by Kim and Dahlman (1994), who theorize, that the evolutionary path of technology in developing countries follows three stages: the mature stage, the consolidation stage, and the emergence stage. Technological development in Korea has occurred almost exclusively on the basis of nationally owned rather than foreign owned enterprises (Amsden 1989, Amsden and Kim 1985) and the philosophy has become, "invest now in in-house technological capability, even if out side expertise is cheap, to reap the rewards of self reliance later" (Amsden 89:21).Kim and Westphal (1986 and 1999) define industrialization as the process of acquiring technological capabilities and translating them into product and process innovations in the course of continuous technological change. Technological capability refers to the ability to make effective use of technological knowledge and it is the major determinant of industrial competitiveness (Lall 1990, OECD 1996, Kim 1999, Schacht 1997). To analyze the process of technological development Westphal (1985) and Kim (1999) developed a conceptual model focusing on technological capability distinguished by the function they served.

Many economists attribute Korea's success to the Korean governments developmental role, concluding that economic miracle stemmed from the policy miracle (Kim 1997, World Bank 1993, Leipzinger and Kim 1993, Amsdon 1989, Woo-Cumings 1999, White and Jack Gray 1988, Wade 1990). Korean technological catching up process was successful only with an effective national system of innovation. Korean technological development during the catching up phase falls with in the developmental state paradigm, where the state played the role of a regulator and directed the technological development through the learning process during the catching up phase through its S&T policy. Since the early 1990s when the Korean government initiated the process of liberalization, the Korean state has been reduced to the role of a facilitator from the earlier role of regulator. This shift has been remarked as the developmental to a post-developmental paradigm (Plein and Hahm 1997, Weiss 2003, Kim 2005, Boyd and Wing Ngo 2005). The early post-developmental S&T policies in the 1990s were characterized by the promotion of high-technology innovation, develop information infrastructure, strengthen market-oriented technological innovation, and accelerate import liberalization. The post crisis government policies were oriented towards the transition of Korea to knowledge based economy through industrial strength based on restructuring, continued investment, advancement into new markets, upgrading towards higher industrial value chains.

Linsu Kim (1992) provides an analytical discussion on different facets of government directly or indirectly related to the technological learning and development process in Korea at the micro and macro level. His analysis on the process of technological change was based on three perspectives; market mechanism, technological flow and time. On the demand side of the technological learning the state created and fostered the growth of large Chaebols as a vehicle for effective technological learning through various policies and incentives. On the supply side the state restricted FDI and through various policies forced the firms to acquire and assimilate foreign technology and also established S&T infrastructures and GRIs to promote indigenous R&D. With the change in environment in late 1980s, the Korean government's role from regulator has been shifted to facilitator, the shift in polices were designed to introduce market mechanism, anticipated the private sector to play a major role in technology innovation through industrial R&D and also to undertake structural change towards relatively more knowledge-based industries.

South Korea's economic growth in the early phases through rapid industrialization can be attributed to its strong system of national innovation (Kim 2003). It has been argued that earlier strengths of the Korean system of national innovation became major liabilities as Korea failed to adjust with the changing political economic condition and it along with mismanaged financial sector and foreign investors panic, led to the onset of the crisis in 1997 (Kim 2003). It has been widely reported that the crisis also turned out to be a "blessing in disguise" which pushed to the policy makers to initiate various policies to transform Korea's out-of-date economic and innovation system to competitive enough to face the challenges of the 21st century. The post-developmental national innovation system is characterized by effective linkages among the institutions and actors participating in the system and has been transformed from a system based on the catching up model which was quite effective in achieving Korea's developmental goal in a short period of time in the earlier phases of economic development (Word Bank 2000, Suh 2000, Kim 2003, Yim 2006). The quick recovery from the crisis was achieved (along with other systemic reforms) through the evolution of a new system of national system of innovation characterized by a strong innovation base realized by state-market-university synergy becoming the new source of South Korea's enduring technological change.

The National System of Innovation (NSI) concept became more widely diffused through Christopher Freeman's book on Japan (Freeman 1987), through a publication edited by Freeman and Lundvall on small countries (Freeman and Lundvall 1988) and not least through the publication of the Dosi et al. book on technical change and economic theory with contributions on national innovation systems by Freeman, Nelson, Lundvall and Pelikan (Dosi et al. 1988). More recent standard references on national systems of innovation are the three books edited by Lundvall (1992), Nelson (1993) and Edquist (1997). The national Innovation System concept to explain the national technological innovation rate starts with the recognition that innovation be it performed by firms or individuals occurs with in the context of broader political and economic institutions and policies. NIS further posits that these institutions and policies together form a system which determines a countries rate and direction of technological innovation (Lundvall 1992, Nelson 1993, Freeman 1995 and Taylor 2006).

The research university plays an important role as a source of fundamental knowledge and, occasionally, industrially relevant technology in modern knowledge-based economies (Mowery 1993). Universities are going through a second academic revolution: the economic function of the university is increasingly institutionalized in addition to the differentiation between higher education and research (Etzkowitz 1994)

Koreans' innovation system related to industrial innovation, which influences a great extent the direction and pace of technological capability development that's in turn leads to industrialization (Kim 1993). Kim argues the rapid changes in economic and political environments in the late 1980s have not given enough time to make and consolidate a major shift in designing an appropriate national system of innovation. Korean innovation system has largely been shaped by overall economic development strategies, the catch-up model, though the Korean economic miracle could made possible because of this model but couldn't made adjustment with the change in political economic dynamics and it became a liability and negatively affected the economic growth of Korea (Suh 2000). Catch-up model was quite effective for short term economic development and wasn't effective for long term innovation as the fundamentals were weak.

The knowledge-based system can itself be considered as an outcome of interaction among different social coordination mechanisms-markets, knowledge production, and (public or private) governance at interfaces-the Triple Helix model of university-industry-government relations provides with a heuristic for studying these complex dynamics in relation to developments in the institutional networks among the carriers. The coupling to the layer of institutional networks, that is, the knowledge infrastructure of a knowledge-based system, reduces the complexity because the historical conditions limit the range of possible options (Leydesdorf and Mayer 2006). The emerging communication among the above three functions can be codified in new institutional settings; the institutional sectors (public, private and academic) that formerly operated at arm's length are increasingly working together, with a spiral pattern of linkages emerging at various stages of the innovation process (Etzkowitz & Leydesdorff 1995).

1.7. Organization of the Dissertation

The study is organized in to five chapters. Having reviewed briefly three broad areas of literature related with technology development, S&T Policy and the synergy of IUG in a knowledge-based Economy and the methodological issues, the next chapter will analyze the process of technological development in Korea in macro perspective and trace the evolution of knowledge-based economy in conjunction with the process of technological development. The second chapter includes a brief discussion on development mechanism of Korean, which is highly contested in the academic circles, mainly between the classical economist who argues the Korea development is market led and on the contrary the orthodoxy economists argument of developmental state in Korea. The framework of technological capability has been employed in conceptualizing the technological development process in Korea through different stages of industrialization. The chapter also tries to conceptualize the transformation of Korean economy towards a knowledge-based from a capital intensive economy and also provides a dynamic picture of the current knowledge-based Korean economy.

The third chapter examines the political process of technological change in Korea.. The technological development process in Korea in the early phases of industrialization has attributed to the industrial policies of the strong government at the centre. Thus this chapter revisits the developmental state discourse in understating the S&T policies in promoting technological development process, where the Korean government plays the key role of a 'regulator'. Towards the end of the 1980 through the liberalization policies, the role of the Korean state has limited the role of a 'facilitator', leveraging the market to play a critical role in technology development. The post crisis technology policies of the Korean state illustrates the logic of the evolution of the "techno-scientific state" which adopts a development pattern based on science and technology innovation, which is fundamentally different from the economic growth through rapid industrialisation based on reverse engineering promoted by the developmental state.

In a knowledge-based economy strong university-industry relationships along with the government support and high-technology clusters are the keys to development. The Korean experience in the earlier phases suggests that the contribution of universities to economic development was not through the transfer of research results, rather it was indirect and through the preparation of high-quality graduates. The role of the universities and research institutes in Korea is changing to an entrepreneurial focus. The Korean case is interesting because its economy grow rapidly, despite limited direct interaction between industry and the universities and little clustering in the vicinity of universities. But recently the focus has turned to commercialization of university research and the establishment of clusters of entrepreneurial firms, as a strategy for creating economic growth. The fourth chapter analyzes the Korean National Innovation System during the catching-up period and the post-crisis period. The post-crisis NIS shows a major shift from the earlier phase which is characterised by an increased institutional arrangements and channels of interaction in industry-university-government, which is having predictive power in technological innovation. In the final chapter an overall summary is provided with the results of the hypothesis testing and the concluding remarks.

Chapter II

Technology Learning, Economic Growth and the Evolution of Knowledge-based Economy in South Korea

2.1. Introduction

Korean economy has achieved one of the fastest rates of economic growth in the world between 1960 and till the end of 1990s, its per capita income grow by an average of 6.8% annually, from 68 US$ in 1960 to 19,700 US$ in 2007 at market exchange rate and became a member of the OECD in 1996. Korea is the 10th largest economy with a GDP of 981.9 billion US$ at official market exchange rate (Bank of Korea 2007). The rapid economic growth has been referred to as the "Miracle on the Han River". This "Miracle" is continuing to this date and South Korea is still one of the fastest developing developed countries, with an average GDP growth of 5% per year the most recent analysis report by Goldman Sachs (2007) shows that South Korea will become the world's 9th largest economy by 2025 in terms of GDP and 25 years later, is to surpass all countries in the world except the United States to become the worlds 2nd richest country in terms of per capita GDP with US $81,000.

The rapid industrialisation is the key factor in Korea's miraculous economic growth, which is out standing not only in its remarkable pace but also in other respect also. Economic development through industrialisation is the process of acquiring technological capabilities and translating them in to products process. The process of industrial and technological development in Korea is an interesting case that offers many useful implications for other developing countries. Korea began as a poorest country among the Newly Industrialized Countries (NICs) with a far lower technological base. As late as 1960s, Korea was a very poor country, it was poorer than many African countries, but has achieved phenomenal industrial growth. Beginning in 1962 Korean economy grew at an average annual growth of almost 8% over thirty years Korean exports exploded to the international markets. Korea exported textiles, apparels, toys wigs and other labour intensive mature products in the 1960s. Ten years later ships, steel consumer electronics and construction services from Korea challenged established suppliers from advanced countries. In the following decade Korean exports were dominated by computers, semiconductors memory chips, automobiles and other technology intensive products. Since the 1990s Korea started challenging the advanced countries in the next generation technology intensive products like multimedia, advanced semiconductor chips, consumer electronics, computers, mobile and telecommunication goods. Such a phenomenal growth and structural changes may be attributed to many social, economic, political economical and technological factors, but the most important of all these may be the extent of technological learning and innovation in its industries.

This chapter is an attempt to study of technological development process in Korea and to present the current status of S&T technology in Korea. The next section emphasis on the debates in the political economy research which are concerned with the sources of East Asian economic growth. The third section will be focusing on the development mechanism in Korea, which will review the major academic debates on Korea's economic development. The next part will focus on Korean technology development in conjugation with the process of industrialisation in the last four decades. The technological development in Korea can be divided in to three stages on the basis of the process of technology learning and capability acquisition. The stages of technological development in Korea are evaluated in the following section. Seventh section is an assessment of the current status of Korean technology providing various S&T technology indicators, which would be followed by an assessment of Korean technology development and the prospects of Korean economy.

2.2. Technology Change and East Asian Miracle: Debates

The technological change and its role in the "miracle growth" of East Asian newly industrializing countries (EA-NICs) have generated a great deal of interest in the academic and policy making circle in the last few decades. Everyone agrees that the NICs, have grown spectacularly over the past generation, but the debate still exists on why and how they achieved the success. The debate over why they have grown so well in the past raises difficult questions about regional growth in the future and about the aspiration of countries elsewhere to replicate the East Asian success. The debates at the centre to answer why are; the accumlationist argument and the technology augmented economic growth thesis.

Young's (1992, 1994, 1995) studies on the sources of economic growth finds that the impressive growth in EA-NICs can be explained mostly by measurable factor inputs of capital and labour, education and structural change, than by efficiency or technical progress measured by the growth residual of total factor productivity. Young finds this component to be zero or negligible for most EA-NICs. Krugman (1994:67), in his article *The Myth of East Asian Miracle* building on the works of Young, drawing a comparison of EA-NICs with the erstwhile Soviet Union;

> "The newly industrializing countries of Asia, like the Soviet Union of the 1950s, have achieved rapid growth in large part through an astonishing mobilization of resources. Once one accounts for the role of rapidly growing inputs in these countries' growth, one finds little left to explain. Asian growth, like that of the Soviet Union in its high growth era, seems to be driven by extraordinary growth in inputs like labour and capital rather than by gains in efficiency."

Likewise, in explaining the extraordinary post-war growth of the Four Tigers, Young (1994) concludes that

> "...one arrives at total factor productivity growth rates, both for the nonagricultural economy and for manufacturing in particular, which are well within the bounds of those experienced by the OECD and Latin American economies over equally long periods of time. While the growth of output and manufacturing exports in the newly industrializing countries of East Asia is virtually unprecedented, the growth of total factor productivity in these countries is not."

In the same vein, Kim and Lau (1994:235), comparing the sources of economic growth in these countries with those of Germany, France, Japan, the United Kingdom, and the United States, found that

> "...by far the most important source of economic growth in these countries [the Four Tigers] is capital accumulation, accounting for between 48 and 72 percent of their economic growth, in contrast to the case of the Group of Five industrialized countries, in which technical progress has played the most important role, accounting for between 46 and 71 percent of their economic growth."

The idea of very low technical progress in East Asia is so hard to reconcile with the manifest reality that others reject it out of hand. Stiglitz (1998) point out that ".. any visitor to the cities and factories of East Asia comes away impressed by the enormous technological progress in the last few decades. The Young, KIM and Lau et al. results are simply not very robust. When a country is accumulating capital rapidly, small changes in the estimate of the capital share can result in large shift in estimates of the contribution of TFP".

The East Asian technological progress has been established by a number of ways. First, a cursory perusal of the coverage of East Asian technological progress in business and technical journals reveals a story of achievement, which establishes the technological advancement of the EA-NICs. The technological achievements inclusive of Japan were covered in great deal in 1991 in the *IEEE Spectrum* (1991), which is the flagship journal of the U.S. Institute of Electrical and Electronics. The survey found that the Korea, Taiwan, Singapore, Hong Kong had made tremendous economic progress in a number of areas.

More detailed description of the technological progress of East Asia is given by Hobday (1995). Hobday not only catalogue the various technologies mattered, but also describes the institutional framework and business alliance, through which the stepwise ascent up the technological ladder was realized. Hobday's account of technical progress through extended learning by forms is consistent with generalized accounts of the process of technological capability acquisition (Nelson 1981; 1993; 1997, Lall 1990; 1992).

According to Nelson (1993), Korea and Taiwan in terms of technological capability are at the apex of achievements in the developing world. He remarks that they are the models for emulation for less developed countries and deservedly so. Nelson posit that the trajectories and strategies of these countries for technological acquisition even bear some broad similarity to the development paths of the United States and Germany in the late ninetieth and early twentieth century, when they borrowed heavily from Britain (Nelson and Wright 1992, Nelson 1993).

The culmination of these evidences indicates that four EA-N ICs are well head of most other developing nations regarding the acquisition of technological capabilities and they are already integrated with the advanced countries in terms of technological innovation. The 1997 East Asian financial crisis which swept through these economies was considered as the culmination of the problem associated with the factor augmented economic growth and chunk of economist argued the crisis marked the end of East Asian economic growth. More miraculous was the pace at which these countries recovered from this crisis and the economic growth of EA-NICs still is respectable. Since by all means they started off at the bottom, their present state must represent sustained technological progress in any meaningful sense of the term. Some how this reality is not reflected in the TFP measures of technological progress. As Danny Quah (1997; 2007) argues the conventional understating of TFP is insufficient in measuring the state of technology or knowledge in an economy as it doesn't incorporate the direct measures of science and technology in an economy which gives a greater picture. Paradoxically in Young's (1994) study the technical progress is highest in Hong Kong among the EA-NICs against the consensus that the technical advance in Hong Kong is the least. It is ironical that according to the study there are other countries that match or exceed Hong Kong's TFP, Malta, the Congo, Botswana, Pakistan, Egypt and Syria, which are not held up as paragons of technological excellence.

2.3. Development Mechanism in Korea

Theoretically there are several paths that an economy can take in order to achieve economic development. The first step involves a choice between industrialization and agricultural development. The industrialization pattern may be of a domestic market-led or export-led type. In addition, there is also a choice between whether final, intermediate, and capital-goods markets will be developed together or in some sort of time succession. No economic development will be realized if there is no one to decide an economy should choose which path and to lead along this path. The objective of this section is to understand the developmental mechanism of Korea by analyzing the two existing debate on Korea's developmental mechanism, they are the market led development mechanism and the government led developmental model. Under a market-led development mechanism, households and private enterprises make economic decisions based on the principles of market-based competition; on the contrary a government-led development mechanism, political leaders make the choice of which path they will take and attempt to directly and indirectly mobilize resources to the cause of development and growth.

2.3.1 Market-Led Economic Development

According to the market development hypothesis, the government of Korea was restrained from intervening in the economy, resulting in a smoothly functioning market mechanism helping to achieve high-level economic growth. This hypothesis is supported by economists affiliated with the World Bank and the IMF, such as Bela Balassa (1978; 1971; 1982) and Anne O. Krueger (1997). Concerning restricted government intervention, since the publication of Balassa (1971), a "transition" from import-substitution policies to export-oriented policies in Korea has been emphasized. Korea implemented import-substitution measures together with other developing economies beginning in the early 1950s and from the early 1960s instituted various export-promotion policies, such as devaluating their foreign exchange rates, relaxing some quantitative restrictions, and reducing tariffs. According to the market-led development hypothesis, this policy transition is interpreted as the liberalization of the two economies needed to realize the high levels of growth that followed.

Empirical work done by Balassa (1978) includes periodical analysis of export incentives carried out in eleven different countries, including Korea. Balassa showed that the best performances have been achieved by Korea, Taiwan, and Singapore, all of which have continuously implemented export-oriented measures. In a joint research project with economists from several countries (Balassa 1982), compared effective protection rates and found them to be at their lowest in Korea. In response to criticism from supporters of the government-led development hypothesis, the World Bank revised its position somewhat by introducing such concepts into the market-led development hypothesis as contest-based competition and financial restraint (World Bank 1993); however, in its continuing denial of any sector specific intervention by government, it has not changed its original position that Korean or the other NICs governments have not guided their respective economies toward prosperity.

2.3.2. State-Led Economic Development

On the contrary the conceptualization of economic development mechanism regards the economic development realized in Korea as the result of active intervention by their governments in economic affairs or other wise known as 'developmental state'[1] mechanism. Chalmers Johnson (1982), Alice H. Amsden (1989), Peter Evans (1995), Dayo (1987), Skocpol (1982), Robert Wade (1990), Woo-Cumings (1999) etc. are typical supporters of this hypothesis, who offer a rich body of factual information in support of government intervention being conducted after the 1960s, a time when, according to the market-led development hypothesis, economic liberalization was being implemented.

Amsden (1989) has attempted to show that choices in Korea concerning where capital will be invested are not made by private business, but by the government. In support of her claims, she cites the passage of the Electronics Industry Promotion Law, which played an active role in the R&D planning, fund procurement, and the establishment of a research institute for semiconductor-related development. She also analyzes the development of the shipbuilding and steel industries, concluding that the government played an important role there as well (Amsden 1989).

The research finding of Amsden and Wade which argues widespread government intervention of both the economies of Korea and Taiwan is difficult to refute. In particular, the discovery of intervention policy directed toward specific industries has cast doubt upon the market-led development mechanism hypothesis. At the present time, the focus of the debate has been shifted to the problem of whether or not such industry-specific policy was really effective. Nevertheless, from the empirical research that has been done to date, there is no easy way to disprove one side or the other, therefore no apparent end to the market-led vs. government-led development debate. The market-led development side in the debate has set upon the task of denying the effectiveness of government intervention through quantitative analysis, but has not met with much success.

[1] *Developmental state* can be defined as interventionist state that was neither 'plan-irrationalist', where ownership and management remain in the hands of the state as in the former socialist economies, nor free-market, but something different: the 'plan-rational' capitalist developmental state, conjoining private ownership with state guidance. See Johnson (1982).

2.3.3. Beyond Developmental State

No sooner was the statist theory accepted as the new development orthodoxy that it was discredited. The Asian financial crisis, which started in 1997 and quickly spread like a contagion, prompted skeptics to discount the model. Whereas earlier admirers championed the East Asian developmental state for other developing nations, today's critics warn against "moral hazard" and other undesirable collusive practices, especially financial sector weakness (Kaminsky and Reinhart 1998, Goldstein 1998). In fact, the developmental state is probably neither as omnipotent nor as guilty as adherents of both sides portray. In this regard the financial crisis alarmed Korea's systemic vulnerabilities in her development model and forced to restructure the economy. The crisis also made it clear that in the new global political economic paradigm where one cannot separate the national economies from global market, development is attributed to "more than the market, more than the state" (Gereffi 1998).

In this context many political economists (O'Riain 2000, Uttam 2006, Hahm and Plein 1997, Suh 1998, Pirie 2007) argues the post crisis Korean development logic can be considered as *post-developmental state* or *flexible developmental state*, which nurtures post-Fordist networks of production and innovation, attracts international investment and promotes development by linking these local and global technology and business networks. This is made possible by the multiple embeddednesses of state agencies in professional-led networks of innovation and in international capital and by the state's flexible organizational structure.

2.4. Technology Learning and Capability Development

The role of technology in economy growth or industrial growth has seriously studies since Solow's (1956) classic economic growth theory. Studies show that more than 50 percent of economic growth in advanced countries stems from technology innovation (Grossman 1991). Further, industrial development is the process of building technological capabilities through learning and translating them into products and process innovations in the course of continuous technological change (Pack and Westphal 1986). While, technological capability is the knowledge, skills and experience necessary in firms to produce, innovate, and organize marketing functions (Lall and Wignaraja 1998, Ernst et.al 1998). More research has begun to examine the nature of industrial technological development in market-oriented developing economies (Lall 1992, Bell and Pavit 1993). These researches suggests that industrial technological development should not be viewed as a process that can be promoted easily and quickly by investing in new equipment or buying imported technology. It requires conscious investments by firms in their own technology capability. Technology capability being defined above refers to the skills, knowledge and experiences need to operate imported technology efficiently. It is also argued that enterprises in newly industrialized countries in East Asia had built up relatively good technological capabilities in a spectrum of industries compared to international standards and that this was a major factor in their rapid export growth and technological upgrading (Pack and Westphal 1996, Aw and Batra 1998, Ernst, Ganiatsos and Mytelka 1998).

Technological progress in newly industrialized countries has achieved through a learning process consisting of borrowing, adapting, and improving upon foreign designs rather than through frontier innovation involving formalized R & D (Amsden 1989, Cumings 1987, M. Hobday 1995, M. Hobday 2001, Kim 1980). The NICs choose the path of export promotion industrialisation. The theory argues, as external markets provided competitive incentives and required fiscal discipline of the producers. Industrialisation is the process of acquiring technological capabilities and translating them into product and process innovations in the course of continuous technological change (Kim 1999, Pack and Westphal 1986). Technological capability refers to the ability to make effective use of technological knowledge and it is the major determinant of industrial competitiveness (Lall 1990, OECD 1996, Kim 1999, Schacht 1997). Kim Linsu (2000) sets a much broader definition of technology capabilities. Technology capability refers to the ability to make effective use of technological knowledge in production, engineering, and innovation in order to sustain competitiveness in price and quality. Such capability enables a firm to assimilate, use, adapt, and change existing technologies. It also enables a firm to create new technologies and to develop new products and processes in response to the changing economic environment. Technological learning is the process of building and accumulating technology capability. To achieve industrial growth, both government and firms should be concerned with capability building (Linsu 2000).

To analyze the process of technological development Westphal (1985); Kim (1999) developed a conceptual model focusing on technological capability distinguished by the function they served. They divided technological capabilities broadly in to three categories. First the production capability which is for operating productive facilities and proficiency in this reflected efficiency and ability to adapt operations to changing market circumstances. Secondly proficiency in investment capability is reflected in project cost and the ability to modify projects in accordance with the circumstances of the investment. Finally proficiency in innovation reflected in the ability to develop technologies which are cost effective and more efficient (Westphal 1985).

An elaborate taxonomy of technological capabilities was proposed by Lall (1982), which breaks them down into investment, production and linkages as follows. Investment is represented by project execution activities including feasibility studies, equipment search, assessment of equipment, employee training during start-up and involvement of the firm in detailed engineering. Production is sub-divided into process technology and product technology. Process technology includes quality control, maintenance, plant layout, inventory control, and various improvements in equipment and processes. Product technology covers copying imports, improving existing products, introducing new products and licensing product technology. Linkages are considered under supplier firm linkages, subcontracting linkages and linkages with institutions that provide trouble-shooting, testing, training and product design assistance.

The micro-level analysis of technology in developing countries has drawn inspiration from the "evolutionary theories" developed by Nelson and Winter (1982) and explained in Nelson (1981; 1987) and Dosi (1988). The starting point of these theories is that firms cannot be taken to operate on a common production function. Technological knowledge is not shared equally among firms, nor is it easily imitated by or transferred across firms. Transfer necessarily requires learning because technologies are tacit, and their underlying principles are not always clearly understood. Therefore, simply to gain mastery of a new technology requires skills, effort, and investment by the receiving firm, and the extent of mastery achieved is uncertain and necessarily varies by firm according to these inputs. Furthermore, firms have more knowledge of their "own" technology, less about similar technologies of other firms, and very little about dissimilar alternatives, even in the same industry. They operate, in other words, not on a production function but at a point, and their technical progress, building upon their own efforts, experience, and skills, is (to varying degrees) "localized" around that point (Atkinso and Stiglitz 1969). The extent to which firm-level differences in technological effort and mastery occur may vary by industry, by size of firm or market, by level of development, or by trade/industrial strategies pursued.

Bell (1984) contributed to the evolution of technology capability framework by making a clear distinction between learning by doing and many other learning mechanisms that contribute to acquire skill and knowledge at individual and organizational level. Bell has contributed to the understanding of how firms learn over time, how learning contributed to accumulate technological knowledge, and how firms can progressively undertake new activities and acquire new capabilities as a result. Bell and Pavitt (1995: 76) highlighted the importance of the organizational/ institutional dimension when they defined technological capability as;

> ".... domestic capabilities to generate and manage change in technologies used in production, and these capabilities are based largely on specialized resources, [which] .... need to be accumulated through deliberate investment - a management problem -".

The Bell and Pavitt's (1995) taxonomy is a useful analytical framework for understanding the technological capability building process in industrial firms. It suggests an idea of sequences of the accumulation stages could be easily understood as firms have to learn to carry out activities of minor complexity in terms of innovativeness to be capable of developing advanced innovation activities, as those associated with R&D. It also allows identifying the profile of technology capability at the firm-level, at the industry level or for different types of firms.

2.5. Technology Learning and Industrialisation in Korea

The modern industrialisation in Korea began in the colonial period under the Japanese, when the Japanese managed the Korean economy as an integral part of the empire. There are diverse arguments on how much technology and human capital was developed during this period. Suh (1978) emphasis on the 'imposed' enclave nature of the colonial bequest of the colonial period and concludes that the colonial bequest of human capital was negligible (Suh 1978). But according to Mason and others "the demonstration effect" of exposure to technology and forms of organization and argues that the colonial bequest was considerable (Mason 1980). Korean economy faced tremendous disruptions after the WW II and followed the economic collapse during the Korean War.

Since 1948 with the American assistance, access to raw materials, replacement parts, and technical help, South Koreans were operating facilities to produce wide varieties of manufacturing goods. Because of the adjustments and dislocations caused by the Korean War there was not much industrial expansion happened until mid 1950s. During the second half of the 1950s with the import substitution in place, a respectable rate of industrial expansion was achieved featuring light manufacturing and nondurable consumer goods. A more important development during this period was the tremendous expansion of education.

Korea's rapid and sustained economic growth from the time when it was starting out as a low income country was an outcome of the knowledge economy approach, even though an explicit knowledge economy development strategy was not laid out. During this time from 19650 to the 1990s, Korea's economic development hinged on the critical interactions among the four pillars of the knowledge economy, which have evolved together with the various stages of economic development. In particular, the pragmatic development strategies focused on achieving sustained productivity growth by consistently increasing the value added of output. These strategies involved intensive learning processes consisting of active technological capability building and complementary human resources development. At the same time, the Korean government assumed the very necessary proactive leadership role of supporting the market and providing an environment that would foster and sustain the transformation.

In the 1960s, Korea embarked on the promotion of both export- and import-substitution industries, starting with subsistence agriculture (rice) and labour-intensive light manufacturing sectors (textiles and bicycles). Considerable capital accumulation and investment in primary education during this period allowed a gradual shift up the value-added chain toward more sophisticated commodities. Key to this shift was also the use of technologies obtained through foreign licensing and adapted for domestic production.

In the mid-1970s, the government's use of a well-targeted industrial policy resulted in a major shift to the development of heavy industries (for example, chemicals, shipbuilding). Along with industrial targeting, policies were enacted to further improve technological capabilities, together with improving access to and quality of technical and vocational training. During the 1970s, the government provided most of its financial benefits to the large conglomerates called chaebols in HCI, as this sector required huge amounts of investment. However, the promotion of the HCI sector by the government resulted in over-investment, low capacity utilisation and big losses in the late 1970s (Kim 1993). What is noticeable here is that the first Korean R&D promotion policy, the Technology Development Promotion Law, was introduced to support technological learning and universities. The policy did not play a significant role in R&D promotion, because R&D was simply not significant when Korean industry was imitating technologies (Sakakibara and Cho 2002). Consequently, many Korean industries reversed the common sequence of research-development-engineering into engineering-development-research or the reverse engineering process (Kim 1993).

In the 1980s, the situation altered substantially as policies were adapted to reflect external and internal demands. There was a growing recognition that, in order for Korea to compete internationally, it needed to deepen its science and technology capabilities, especially as new technologies assumed greater significance (Ursacki and Vertinsky 1994). It was recognised that the heavy dependence on foreign, especially Japanese, component production was leading to increased trade deficits in Korea (Lim 1999). In addition, developed countries and international firms that had been investing in Korea were increasingly reluctant to transfer their technologies due to a growing recognition of the significance of patent and intellectual property rights. The outcome was that core technology development and innovation were required and, in addition, an upgrade of the industrial structure was necessary (Kim 1993; Lim, 1999). Internally, rapidly rising wages in the 1970s eroded price competitiveness, which made government officials believe the importance of more technology-intensive industries rather than labour-intensive industries (Amsden 1989), and resource allocation inefficiencies arising from excessive investment in the HCI in the 1970s made restructuring of industries essential in long-term economic development.

During this phase Korea undertook efforts to ensure a market-conducive environment by deregulating various sectors and liberalizing trade. Concurrently, it expanded higher education while investing in indigenous research and development through the establishment of the National Research and Development Program. Korea continued to pursue high-value-added manufacturing in the 1990s by promoting indigenous high-technology innovation. Domestic wage hikes and the appreciation of the Korean won had resulted in chronic current account deficits, which sparked a series of reforms, including the reform of the financial market. Together with the setting up of a modern and accessible information infrastructure, there was continued expansion of research and development capabilities in Korean industries, which drew on the skilled labour force that had resulted from the government's aggressive expansion of the higher education system.

The government's expenditure on science and technology increased after 1985. The government promoted science and technology by pursuing large national research projects. These expanded in the 1990s with a plan for Highly Advanced National (HAN) Projects, or the so-called "G7 projects," in recognition of its aim to propel Korea into the world's top group of seven countries. Korea's G7 Planning Committee selected projects based on the criterion of how well they advanced strategic industries. In addition, the governmental emphasis on science and technology in the 1990s involved more centralised co-ordination to avoid duplication by competing Ministries (Amsden 2000). Recent governmental efforts to raise the country's technological capability to OECD levels have been supported by the enactment of the Special Law on Innovation of Science and Technology in 1997. However, Korean R&D efforts have tended to be concentrated in a few selected industries; for instance, R&D projects in electronics and machinery industries accounted for 73% of all R&D consortia in 1993 and 60% in 1997 (Sakakibara and Cho 2002).

When the private companies had little risk-taking experience, government-sponsored research institutes proved indispensable. They collected and disseminated critical information, and thereby reduced risks and uncertainties that the private sector faced (Lim 1999). The Electronics and Telecommunications Research Institute (ETRI) can be regarded as the leading case of a government-sponsored research institute in charge of R&D. ETRI, one of the best performing government sponsored research institutes, was established in 1985, as a consolidation of the Korean Institute for Electronics Technology and Korean Electronics and Telecommunications Research Institute. It is currently affiliated with MoST, and has been involved in many major national R&D projects such as an 8-bit computer for education (in 1986), the electronic telephone exchanger TDX-1 (in 1986) and TDX-10 (in 1991), 4M DRAM (in 1986), CDMA (in 1991), ATM exchange machines (in 1996), and DMB and WiBro (in 2004). ETRI held 1,280 international patents and its royalty income was 364.8 billion won ($US364 million) in 2004. In addition, government-sponsored research institutes played a significant role in co-ordinating the public and private sectors in new, high-tech industries.

2.6. Stages of Technological Development in Korea

Although Korea experienced a major economic crisis in 1998 due to some mismanagement of macroeconomic matters and insufficient regulation of the financial sector, it was proved to be a temporary problem. Korea has a strong industrial base developed during the catching-up phase and is determined to make major reforms to manage its modern industrial sector efficiently (Pack 1999). How have Korean firms managed to achieve such phenomenal growth in building technological capability in only three decades? This section is discussing the how Korea developed the technological base with in the framework of technological capability acquisition. The technology development process has been studied in three different stages in terms of the technological functions. To study the process of technological development in Korea Yongwon Lee's (2004) categorization of the technological stages are been used they are; imitation stage, internalization stage and the generation stage.

2.6.1. The Imitation Stage

Kim (1997) observes rapid industrialisation in Korea stemmed largely from imitation and identifies two kinds of imitations in the Korean case. Korea's 1960s and 1970s strategy was largely associated with duplicative imitation, producing on a large scale knockoffs or clones of mature foreign products, imitative goods with their original equipments manufacturer's brand names at significantly lower price. During the 1980s industrialisation increasingly involves creative imitation. In the Korean case most of the duplicative imitation were legal products were its own right, closely copying the pioneering products in the absence or expiration of patents copyrights and trademarks but markets with their own brand names at far lower price (Kim 1997). A significant study by Mansfield (1984) shows that 60% of patented innovations has been imitated legally with in four years of their introduction.

The three most important sources of building the knowledge base for Korea imitation technology stage were education, foreign technology transfer and the mobility of experienced technical people. First, education to develop human resources was one of the most conspicuous efforts Korea made in industrialisation. Korea was unique in her well-balanced expansion at all levels of education early enough to support its economic development. Using data from the late 1950s for 73 developing countries, Harbison and Myers (1964) found three nations; Korea, Taiwan and Yugoslavia with levels of educational achievements far above what would be expected, given their levels of economic development. This finding reflects the high commitment to education within Korean society. The availability of educated human resources laid an important tacit knowledge base for the subsequent development of the economy, which soon absorbed the surplus.

Second, lacking technological capability at the outset, Korean firms relied heavily on foreign sources for both explicit and tacit knowledge. The majority of important or crucial tacit and explicit knowledge needed to solve technical problems in the imitative technology stage could, however, be obtained free of charge through non-market-mediated informal mechanisms. This mode of technology transfer has clearly prevailed in innovative small firms (Kim 1999). Large Korean firms, however, resorted to turnkey plant transfer or technical licensing agreements with foreign suppliers. Given the scale of the large investment required and the lack of technological capability and experience in the early years, large firms relied on foreign suppliers to ensure swift construction, smooth start-up of their production processes, and manufacturing of goods to meet stringent OEM (Original Equipment Manufacturer) specifications (Kim and Lee 1987). Informal technology transfer has, however, been most significant in further broadening the capabilities of both large and small firms (Westphal et al. 1985, Kim 1997).

Third, the mobility of experienced technical people was one of the most effective ways for late entrants to acquire the necessary tacit knowledge base. The majority of consumer electronics producers in the 1970s entered the industry by hiring experienced managerial and technical people from existing firms. For instance, the first four large black-and-white television set producers entered into foreign licensing to acquire the initial knowledge base, but the remaining relied on the mobility of experienced personnel from the first four firms (Kim 1980). State-owned large chemical and machinery companies in the 1950s and 1960s relied completely on turnkey transplant and foreign engineers for the initial knowledge base, but engineers who accumulated modern production experience in these firms spun-off later to private enterprises to provide the crucial knowledge base there. Many studies show that a quantum leap in technological capability in small firms is commonly associated with the arrival of technical personnel recruited from other firms (Kim and Kim 1985, Kim 1997).

2.6.2. Internalization Stage

Eroded competitiveness in low-wage-based mature technology industries forced Korean firms in the 1980s to shift their emphasis from strategies focusing on mature technologies to those focusing on intermediate technologies. This required a significantly higher level of existing knowledge base than that in the previous stage to bring about creative imitation rather than duplicative imitation.

There are five major sources of building the existing knowledge base in the intermediate stage, they are; formal technology transfer, reverse brain-drain, corporate R&D, universities and government research institutes (GRIs). First, foreign technology transfer continued to serve as a major source of building the existing knowledge base in Korean firms. While mature technologies were readily available and could be obtained free of charge through informal mechanisms, sophisticated technologies could be obtained only through formal mechanisms, making it increasingly expensive for Korean firms to obtain necessary technologies. This is evident from statistics. FDI increased from $218 m. in 1967-71 to $1.76 b. in 1982-86, while royalties associated with foreign license increased from $16.3 m. to $1.18 b. during the same period.

Another important source of external knowledge was the reverse brain-drain of the high-caliber Korean manpower pool abroad. The Korean government took a relatively liberal policy with regard to the brain drain at the mature technology stage. As of 1967, 96.7% of Korean scientists and 87.7% of engineers educated abroad remained there, mainly in the USA, compared with the corresponding world comparisons of 35 and 30.2% for all countries (Hentges 1975). When industrialisation progressed rapidly in the 1970s, the Korean government made systematic efforts to repatriate Korean scientists and engineers from abroad. The state-led reverse brain-drain program was quite successful, as few repatriates went back to advanced countries. The program also became a model for the private sector, which began in the 1980s to assertively recruit high-caliber scientists and engineers. These scientists and engineers played a pivotal role in both emerging GRIs and corporate R&D centres.

Third, the emergence and increasing intensity of corporate R&D activities was one of the most remarkable characteristics in the intermediate technology stage to give rise to bargaining power in formal technology transfer, assimilation of imported technologies, and generation of new knowledge through knowledge conversion and creation by research. The number of corporate R&D laboratories increased from one in 1970 to 966 by 1990, reflecting the seriousness with which Korean firms were pursuing intermediate technology development. The total R&D investment increased from W10.6 b. ($28.6 m.) to W3.35 tr. ($4.68 b.) and the share of R&D in GNP (R&D/GNP) increased from 0.32 to 1.95% during the same period. This growth rate is the highest in the world. The private sector accounted for only 2% of the nation's total R&D expenditure in 1963 but 81% by 1990, which is one of the highest among both the advanced and NICs (Kim and Yi 1997). The average annual growth rate of business R&D per GDP is also the highest in Korea (31.6%) compared to 23.8% in Singapore, 16.5% in Taiwan, 14.0% in Spain and 8.8% in Japan (DIST 1994).

Fourth, the intermediate technology stage required universities to produce well-trained scientists and engineers and to have more sophisticated basic capabilities than ever before. But the poor quality in university education and research was a major bottleneck in building Korea's knowledge base. Frustrated in its efforts to reform the undergraduate teaching-oriented universities, the government founded the Korea Advanced Institute of Science and Technology (KAIST), a research-oriented graduate institution specializing in science and engineering.

Fifth, in the absence of university research, the government took the initiative in establishing several GRIs by recruiting overseas trained Korean scientists and engineers. These GRIs were highly industry-oriented, focusing on such sectors as chemicals, machinery, electronics, ocean science, standardization, nuclear energy, biotechnology, system engineering and aerospace to serve the growing needs of the private sector. These GRIs produced many experienced researchers who spun-off to corporate R&D centers.

2.6.3. Generation Stage

Having mastered intermediate technologies, some Korean chaebols began to challenge emerging technologies. For instance, in semiconductors, Samsung developed the 256 MB and 1 GB dynamic random access memory (DRAM) chips ahead of Japan (Kim 1997). Although a core patent was licensed from the USA, Korea was the first country that succeeded in commercializing code division multiple access (CDMA) mobile telephone technology.

In the previous two stages, relevant knowledge was readily available elsewhere and Korean firms could copy or purchase them. In the emerging technology stage, however, Korean firms must generate them. Four mechanisms-basic research in universities, mission-oriented applied research at GRIs, intensity of corporate R&D activities, globalization of R&D and the recruitment of high caliber personnel from abroad.

First, recognizing the importance of basic university research, the Korean government began to transform a dozen or so universities into research-oriented graduate schools. As a result, university research almost tripled in five years from W244.3 b. ($345.5 m.) in 1990 to W770.0 billion ($999.5 m.) in 1995. The number of university researchers also more than doubled from 21 332 to 44 683 during the same period. In addition, emulating the US experience, the government introduced in 1989 a scheme to establish Science Research Centres (SRCs) and Engineering Research

Centres (ERCs) in the nation's leading universities. The number of SRCs and ERCs increased from 13 in 1990 to 35 in 1995. Another program introduced by the government in 1997 to enhance Korea's basic capability is the Creative Research Initiative Program.

Second, in parallel with the increased investment in university research, GRIs played a role in developing some of the significant research results (such as 4 Mbyte DRAM memory chips, electronics switching system, CDMA mobile telephone system) which have subsequently been passed on to the private sector. The government introduced in 1992 the Highly Advanced National R&D (HAN) Project, also known as the G-7 Project, which is aimed at lifting Korea's technological capability to the level of the G-7 countries by the year 2020. A total of $5.7 b. is proposed to be invested in this period jointly by the government, universities and industries, about half of which comes from the private sector. Nevertheless, in the face of the rapid expansion of private R&D activities and increasing intensity of university R&D, reform of GRIs to redefine their roles has been discussed for the future. Organizational inertia and the labour union in GRIs have, however, made it difficult to implement these reforms.

Third, in light of the increasing difficulty in obtaining technology from abroad and the growing importance of innovation capability in sustaining Korea's international competitiveness in recent years, the private sector drastically stepped up its R&D efforts, from W2.37 tr. ($3.36 b.) in 1990 to W6.90 tr. ($8.95 b.) in 1995. It maintained its proportion to the nation's total R&D at 81% during the same period. This rate is among the highest for both advanced countries and NICs. The number of corporate R&D centres increased from 966 in 1990 to 2270 in 1995, reflecting the seriousness attached to R&D by private firms in the recent years.

Fourth, although investment for university and GRI research increased significantly, Korean firms are also devised other alternatives to build their existing knowledge base for emerging technologies in the face of rising reluctance from foreign technology suppliers. One of the alternatives is the globalization of R&D, which includes R&D outposts, merger and acquisition (M&A) and strategic alliances. Chaebols established a number of R&D outposts in the USA, Japan and Europe in order to monitor technological change and undertake frontier R&D. Samsung's leapfrogging into semiconductors is a good example of how Korean firms used outposts to acquire the necessary knowledge base (Kim 1997). Korean firms are also acquiring the necessary knowledge base through M&A of R&D-intensive foreign venture firms. Hyundai acquired Laserbyte Corp. in Sunnyvale, California to gain access to magneto-optical disk drive technology; Metaflow in La Jolla, California to develop SPARC-compatible microprocessors; and Image Quest in San Jose, California to develop flat panel displays (Kim 1999). However, the globalization of R&D is so new to Korean firms that they are going through a trialanderror process in managing acquired foreign firms. A few leading chaebols at advanced stages have begun to enter into strategic alliances with foreign firms to develop future technologies. Samsung has teamed up in semiconductors with rivals such as Toshiba, Mitsubishi, NEC, Fujitsu, General Instrument, Micron Technology, ISD and Array (Kim 1997). But the triad-Japan, the USA and Europe-accounts for 95.6% of the total number of such cases. The strategic alliance with NICs, including Korea, accounts for only 2.3% of the total (Freeman and Hagedoorn 1993). Korea is on the way to develop its own technologies to share with rival firms in order to expand its global technology network.

Fifth, reverse brain-drain becomes even more important for Korean chaebols to upgrade their existing knowledge base in the 1990s to 'leapfrog' into state-of-the-art technologies. Many chaebols in such industries as automobiles, electronics and semiconductors have lured away some of the best Korean-American scientists and engineers. Korean chaebols gave them challenging jobs and attractive compensation packages with considerable independence. Government statistics show that the number of scientists and engineers recruited by corporate R&D centres from abroad was 427 in 1992 alone (MoST).

2.7. Innovation Driven Knowledge-based Economy of Korea

Evidence of the growing importance of technology and innovation in wealthy countries is signaled by several key developments that are broadly associated with the growth of the knowledge economy. First, there has been a shift in the structure of value added and trade amongst OECD countries involving a decline in the share of low and medium-low technology industries and an increase in the share of high technology industries. The share of medium-high and high technology industries in international trade increased from 18 to 25% during the 1990s and their share of domestic value added was 9% amongst the OECD countries by the end of the 1990s. The fastest growing sectors in international trade are pharmaceuticals, electronics and communications equipment and computers, all of which are regarded as high technology industries. Second, there has been a growth in knowledge intensive services activities, such that knowledge-based services now account for around 15% of business value added in the OECD countries. Third, the ICT sector constitutes an increasing component of total economic activity amongst the OECD countries with its share of value added increasing from around 8 to 9.5% between 1995 and 1999. The ICT sector therefore accounts for almost 10% of business sector value added in the OECD countries and an increasing component of international trade.

As a consequence of these trends, information and knowledge resources have been recognized as being critical to competitiveness. On this basis, it is possible to expand existing understandings of the institutional foundations of industrial competitiveness, which have tended to focus on the development of engineering and manufacturing competences in traditional industry sectors to incorporate a concern with knowledge activities. With the growth of high-technology industries and knowledge intensive services, debates on competitiveness have progressed from a broad concern with the processes of industrialisation to a more focused analysis of the factors explaining cross-national variation in the level of participation in knowledge industries.

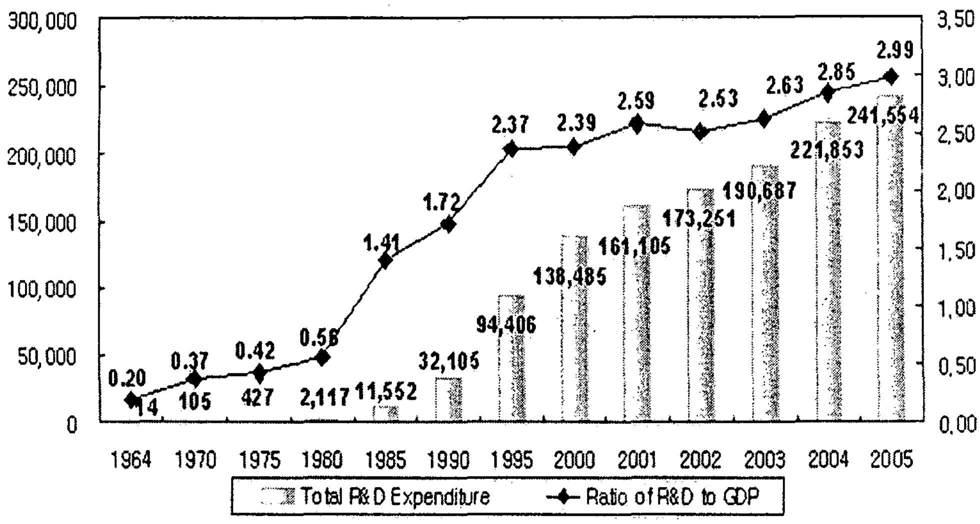
The notion of the science technology and industry infrastructure (STII) is designed to describe an important component of the environmental context of technology development and innovation in the knowledge economy. As such, the idea of the STII draws on several key bodies of research on national systems of innovation, technological systems, national innovative capacity and competence blocs.

The rapid Korean economic recovery after the financial crisis of 1997 came as a surprise for many observers who declared the crisis as the end of Korean miraculous economic development. Korea made a remarkable recovery from the crisis and grew at 10.7% in 1997, 8% in 2000 and at average of 5 % in the recent years. The World Bank (2000, 2004) studies give a different but an optimistic picture of Korean economy and its growth prospects in the coming years. The report evaluates the transition of Korea to a Knowledge-based economy. This section is an attempt to provide the dynamic picture of current Korean science and technology and also trying point out "knowledge accumulation" as one of the major engines of growth in the Korean economy by evaluating the S&T indicators such as R&D trends, Patents, Science and Technology Publications and Human Resource in S&T

2.7.1 R&D Trends in Korea

Fig. 2.1 Trend of R&D Expenditure and the Ratio of R&D to GDP

Source: MoST, 2006



It is well-known that increased spending on R&D can lead to discovery of new technologies or development of new products that contribute to higher productivity. The overall trend in R&D expenditure in the case of Korea shows a remarkable upward trend both in terms of absolute amount being put in and the relative share to GDP as shown in Figure 1. Korea's national R&D intensity continued to rise and reached a level of almost 3%, which is one of the highest in the world, in 2004. This further rise not only in absolute, but also in relative investment into R&D can be deducted to two factors. First, the country's industrial firms, in order to improve their international competitiveness further and to take and maintain the global technological lead in various fields, continued to increase their R&D investment. Second, Korean government also placed higher emphasis on R&D and upgraded the country's research infrastructure significantly.

Fig. 2.2 Status of Total R&D Expenditure in Major Countries

Source: OECD, 2006

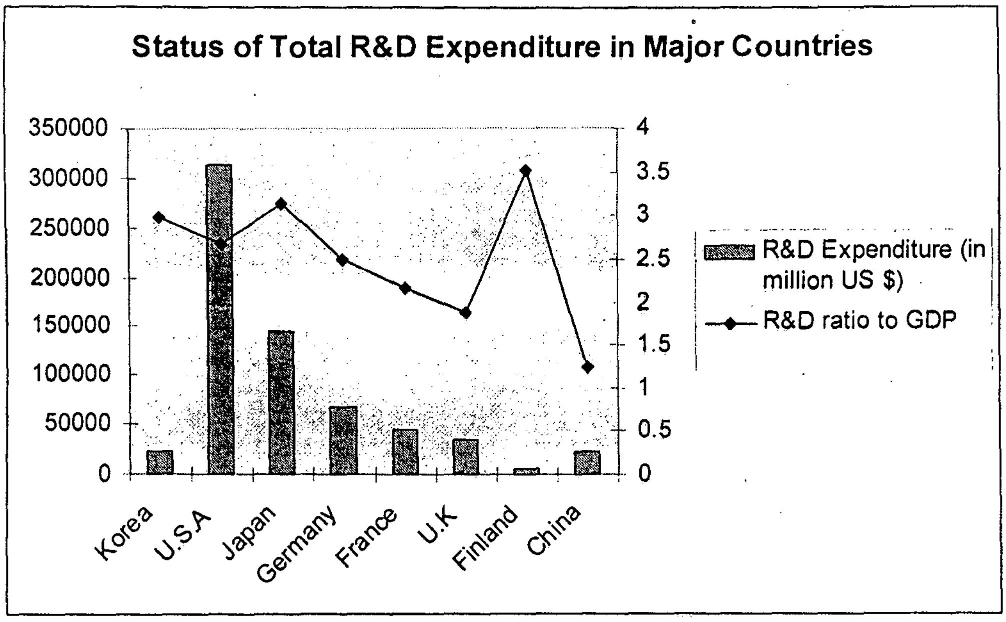


Table 1, is an aggregated data on Korea's recent technological position is summarized in comparison with the world's largest and technologically most advanced economies. In terms of input, the density of R&D personnel is still somewhat lower than in other leading countries for which data are available. As regards R&D intensity, which can be regarded as the most comprehensive input-related indicator, however, Korea has surpassed the leading European countries and is now trailing Japan only among the world's major economies. In other words, Korea is now one of the countries in the world which devote relatively most of their resources to technological learning and technological progress.

As regards output, whereas Korean firms have captured a significant share of the global market in some R&D intensive industries, the country's technological level still appears to be somewhat below the world's most advanced countries in certain aspects, such as scientific publications, patents and the position in international technology trade. Thus, at a first glance, it seems that the efficiency of Korean R&D is lower than in the other countries, given the relatively high amount of its input and the relatively low level of its output.

This interpretation of the data needs to be qualified in two ways, however. First, some of the indicators are biased towards other countries and therefore tend to understate Korea's relative position. Second and more importantly, the data in Table 1 give only a static picture and do not take the time lag between input and output, which tends to be very significant in the field of R&D, into account.

Table. 2.1 Science and Technology Indicators for Korea and Leading OECD Countries

Source: OECD, 2003

Indicator	Korea	US	Japan	Germany	France	UK
Input-oriented indicators:						
R&D expenditures / GDP (%)	2.63	2.68	3.15	2.52	2.18	1.88
R&D personnel / 1000 heads of population	3.89	n.a.	6.91	5.73	5.60	n.a.
Output-oriented indicators:						
Scientific papers / 1000 heads of population	0.39	0.94	0.59	0.84	0.81	1.21
Triadic patent families* / million heads of population (2002)	13.2	63.6	103.5	88.1	39.8	34.4
Technology exports / technology imports	0.25	2.48	2.68	0.98	1.60	2.32
OECD export market share (%) in						
electronic industry	12.46	19.76	19.01	9.29	4.33	5.64
office machinery / computer industry	8.60	19.50	11.50	9.29	3.32	7.59
pharmaceutical industry	0.35	10.21	2.06	12.18	9.45	9.88

Taken together, the historical review of Korea's technological development and an aggregate assessment of its current position indicate that (1) Korea has successfully caught up technologically to the world's leading countries within only a few decades, (2) the country's relative level of R&D investment is now one of the highest in the world and (3) its technological output is also rapidly increasing, but still appears to be somewhat unbalanced and partially below that of the leading countries.

2.7.2 Business Sector R&D

Data on the concentration of Korean industrial R&D (Fig: 3) reveal that large firms play a much bigger role here than small and medium-sized firms. Korea does not constitute an exceptional case in this respect. The concentration of R&D on large firms is even stronger in some other advanced and bigger countries, such as the US, Japan and Germany (OECD 2004). As the lower part of Figure shows, however, the majority of Korea's industrial R&D is not only concentrated on large firms in general, but also on a small number of large firms. In fact, the R&D expenditures of Samsung Electronics alone amounted to 4.79 billion Won in 2004 (Samsung Electronics 2005), which was equivalent to 28.1% of Korea's total industrial R&D expenditures in this year. These numbers starkly illustrate that the dominating role which the big chaebol firms played in the formation of Korea's industrial R&D base still prevails.

Fig. 2.3 Korea's R&D Expenditures by Performing Sector
Source: MoST (2005)

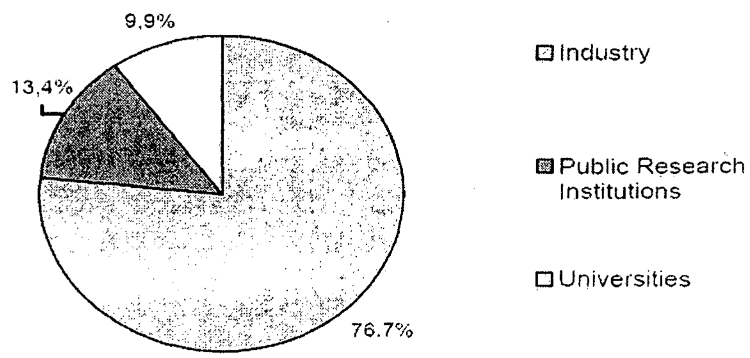
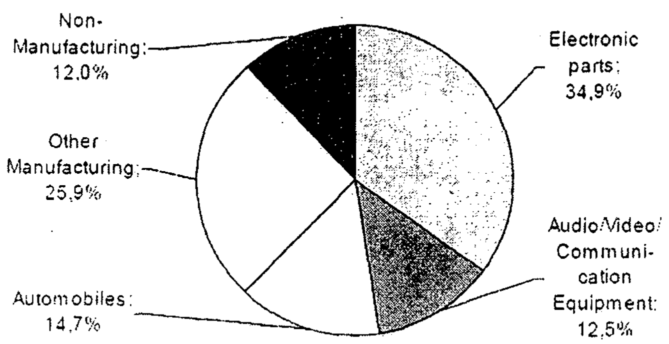


Fig. 2.4 Composition of Korea's Business R&D by Industries
Source: MoST (2005)



Furthermore, the R&D investments of Korea's large industrial firms were also rewarded with remarkable competitive achievements in recent years. Again, the performance of Samsung Electronics is particularly eye catching, as this firm maintained a dominant position in the global memory chip industry for the last 15 years (Shin and Jang 2005). However, other large Korean firms also established themselves as technologically leading competitors during the last decade.

2.7.3 Patents

According to NSF (2004), Korea's performance in U.S. patent applications has been significant, especially since 1996. Samsung Electronics, a Korean company, ranked fifth among companies receiving U.S. patents in 2001. Also, Korea is the second-largest buyer of U.S. intellectual property next to Japan (The TR Patent Scorecard 2004). In 2001, Japan and Korea paid 38.7 percent and 15.3 percent, respectively, of total U.S. receipts of royalties and fees.

Twelve Korean companies were listed in the TR Scoreboard of 2004. Five of them were ranked in the top 20 technologically strong companies in each technology category. All five are in electronics and semiconductors. As shows, Samsung Electronics and Samsung Group ranked 4th and 6th in semiconductors and electronics, respectively. Hynix ranked 13th in semiconductors, LG ranked 14th in electronics, and LG-Philips ranked 18th.

Table. 2.2 U.S Utility Patents Grated to Selected Countries, 1998-2003
Source: US Patent and Trade Mark Office (2004)

	1998	1999	2000	2001	2002	2003	% of Total, 2003	Rank in 2003
Total foreign-origin patents	67,229	69,580	72,426	78,432	80,361	81,127		
Japan	30,840	31,104	31,295	33,224	34,859	35,517	43.8%	1
Germany	9,095	9,337	10,235	11,259	11,280	11,444	14.1%	2
Taiwan	3,100	3,693	4,667	5,371	5,431	5,298	6.5%	3
Korea	3,259	3,562	3,314	3,538	3,786	3,944	4.9%	4
France	3,674	3,820	3,819	4,041	4,035	3,869	4.8%	5
UK	3,464	3,572	3,667	3,965	3,837	3,627	4.5%	6
Canada	2,974	3,226	3,419	3,606	3,431	3,426	4.2%	7
China	72	90	119	195	289	297	0.4%	29

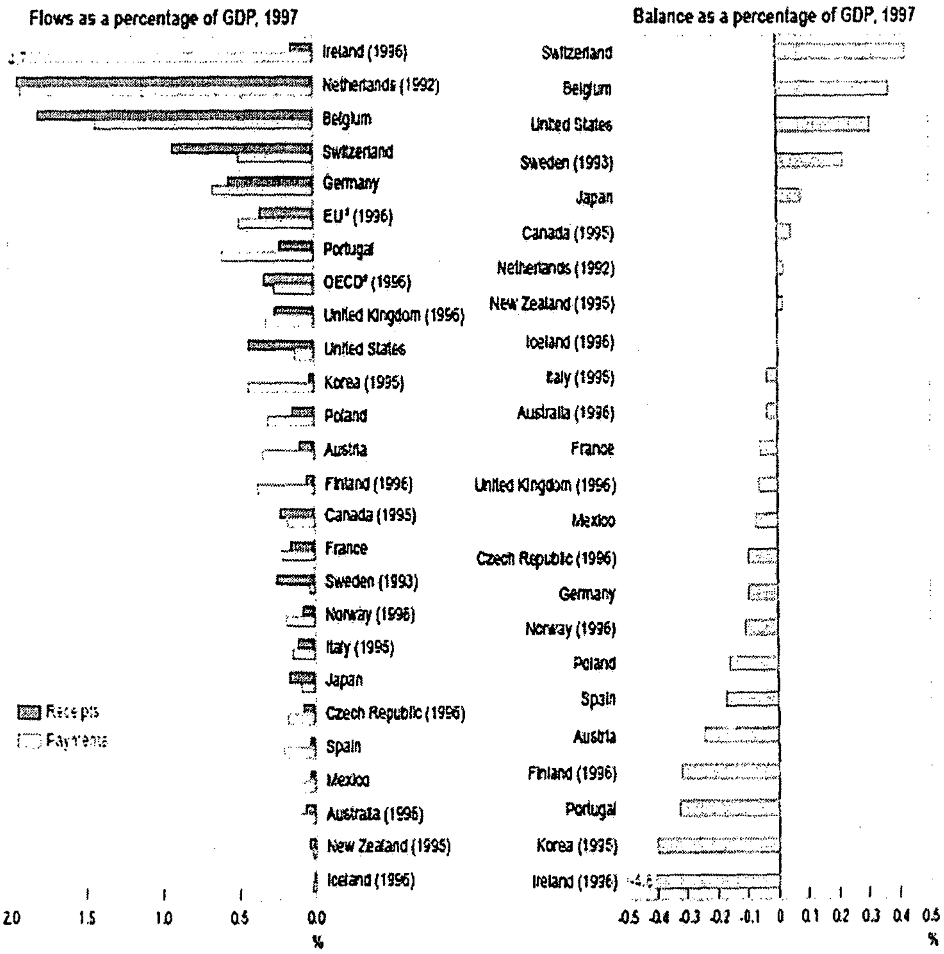
Table. 2.3 Technological Strength of Selected Companies
Source: Technology Review and CHI Research (2004)

	Tech Strength Rank	Company	Country	Number of U.S. Patents	Science Linkage	Technology Cycle Time
Semiconductors	1	Micron Technology, Inc	United States	1,712	2.39	6.6
	2	Intel Corp.	United States	1,608	1.01	5.3
	3	Advanced Micro Devices, Inc.	United States	908	0.65	4.4
	4	Samsung Electronics	Korea	1,363	0.25	5.3
	13	Hynix Semiconductors, Inc.	Korea	443	0.40	5.0
Electronics	1	Hitachi Ltd.	Japan	2,189	0.55	6.5
	2	Matsushita Electric Industrial	Japan	1,944	0.46	6.0
	3	Canon, Inc.	Japan	2,051	0.64	7.1
	6	Samsung Group	Korea	1,577	0.25	5.3
	14	LG Electronics	Korea	465	0.15	5.2
	18	LG Philips LCD Co., Ltd.	Korea	227	1.01	5.3

2.7.4 Technology Balance of Payments (TBOP)

TBOP measures the international transfer of technology: licenses, patents, know-how and research, and technical assistance. These are payments for production-ready technologies. Although a deficit position in TBOP does not necessarily indicate low competitiveness, it does show the characteristics of a country's technology and innovation activities. Figure 5 shows that, for TBOP, Korea has one of the highest deficits of all the OECD countries, exceeded in this group only by Ireland. However, the sources of the deficits in Korea and in Ireland are quite dissimilar. The high magnitude of Ireland's technology payments is due to the strong presence of foreign affiliates, which import technology extensively from their countries of origin. In the case of Korea, technology payments are mostly related to the arm's length licensing fees of domestic firms, whereas foreign affiliates maintain only a very low share of technology payments.

Fig. 2.5 Technology Balance of Payment
Source: OECD, STI Scoreboard, 1999



2.8. Conclusion

The analysis of technological development pattern provides a dynamic picture of Korean economy development and documents that the economic growth in Korea was not merely stemmed from factor accumulation rather it was through the process of rapid industrialisation in conjugation with technological capability acquisition through learning and industry innovation with other supporting factors. The process technology development in Korea has been studied through the process of achieving technological capability in three different stages; the imitation stage, the internalisation stage and the generation stage. Imitation stage features technology learning through the process duplicative reverse engineering and companies were dependent on foreign technology, acquired through technology licensing agreements with foreign suppliers, transferring of turnkey plants and through the mobility of experienced technical people. During the 1980s loosing competitiveness in low-wage-based mature technology industries forced Korean firms to shift their emphasis from strategies focusing on mature technologies to those focusing on intermediate technologies. The main sources of technological development during these stages were formal technology transfer, reverse brain-drain, corporate R&D, government research institutes (GRIs). In this stage the effort was to developing local technological base through assimilation of foreign technology and adopting it to the Korean context. During 1990s Korean companies mastered the intermediate technologies and challenged major competitors in high-end technologies. This period shows a paradigm shift in the process of technology development from reverse engineering mode to an innovation based technology development. The mechanisms employed in this phase were basic research in universities, mission-oriented applied research at GRIs, intensity of corporate R&D activities, globalization of R&D and the recruitment of high caliber personnel from abroad. The current state of Korean science and technology competitiveness documenting different S&T indicators shows that Korean economy is a knowledge-based economy where the economic growth is happening through the knowledge acquisition through technology innovation.

Chapter III

Political Economy of South Koreas' Technology Policy

3.1. Introduction

Korean government's call to transform Korea to be the innovation hub of East Asia came with no surprise. The call infers two things; alarms the danger that Korea facing with the rapid growth of China and the developing Asia and also a policy shift towards the next stage of industrialization which is industrialisation based on innovation in science and technology. Korea deserves to be taken seriously because it has ambitious plans. The future, not the past, is where Korea's science and technology (S&T) begins. Nearly every government department, university, research institute or company has a vision for the future. Korea is used to setting itself ambitious targets but even if Korea delivers only a share of what it has set out to achieve, it will still be a significant force in science and technology. Ten next generation growth engines were identified in 2003, designed to drive The Ministry of Information and Communications (MIC) 'Ubiquitous Korea' or 'U-Korea' IT839 Strategy is designed to help Korea realize a digital welfare state, at a cost to government and private industry of US$70 billion by 2010. The Korea IT Industry Promotion Agency (KIPA) is promoting open source to turn Korea into international software 'powerhouse' with 40 per cent of servers running open source operating systems by 2010. The Korea Bio-Vision 2010 aims to push South Korea's biotech ranking from 13th in the world in 2003 to seventh by 2010. Government plans are for Korea to have ten cutting-edge nanotechnologies and 12,600 nanotechnology experts by 2010 (MoST 2006).

Korean development in the 1960s and 1970s characterized as the 'imitation phase' where the state directed industrial policy kicked off Korea's growth. Korean firms were contracted as suppliers to US and Japanese companies. Gradually, these firms internalized and redeveloped technologies from the West to become competitors in their own right. The government facilitated investment in R&D by sharing risk through government research institutes that helped companies to develop key technologies. Korean scientists who returned from the US were enlisted in national projects. The 'internalization phase' of the early 1980s took a slowdown in the world economy, combined with rising costs, as the prompt for further investment in R&D. Private sector R&D investment increased from 0.21 per cent to 1.17 per cent. Companies like Samsung started making branded goods in their own right. Korean analysts have dubbed the 1990s the 'innovation phase', with Korean companies less dependent on foreign designs and intellectual property and more capable to explore emerging technologies. In 1998, the Korean government set out to turn the country into a knowledge economy, committing to doubling investment in R&D and increasing the R&D labour force from 180,000 to 250,000 by 2007. R&D spending was almost 3% of GDP in 2005, about 75% of it from private industry. Public funding for R&D in 2006 was US$8.65 billion, a 15 per cent increase over 2005. Korea is ranked 15th in the world in terms of scientific publications. Between 2000 and 2004, Thomson Scientific indexed 81,057 papers with at least one author in South Korea. Korea has the highest annual growth in patent families which is more than 20 per cent and the highest growth in US patents from 1986 to 2003. In many areas, Korean infrastructure for science and its technological capability is world class.

In short, a country that was on its knees at the start of the 1960s, with few natural resources, a limited higher education system and little or no research, has succeeded through a mixture of brainpower, hard work, state direction of large companies and the political economic context, to become one of the most technologically adept and best-educated societies in the world.

The main arguments and explanations in this chapter are organized as follows. The next section argues the evolution of a techno-scientific state in Korea which is the new growth model to understand Korea's future development based on science based innovation. The fourth section provides an analytical framework to understand the S&T policies in Korea based on the model developed by Westaphal and Kim (1992). Korean technological development in the catching-up phase was heavily depended on the industrial policy, the fifth section tried to elucidate the major policy measures that helped the Korean industries to acquire the technological capabilities. It was only in early 1970s the Korean government has really given attention to develop its technological base, till then the market demand for supply science and technology was very less. The sixth section maps the supply side technology policies over the three stages of technological development. The 1997 economic crisis can be considered as breach in the Korean economy which forced economic restricting. In the post crisis period the Korean state gives primary importance to the growth of science and technology and has been identified it as the future driving force. The detailed evaluation of post crisis S&T policy in the section seven illustrates the logic of Koreas' "techno-scientific state".

3.2. Evolution of Koreas' 'Techno-scientific State'

The evolution of the "techno-scientific state" towards the end of twentieth century features a new phase of the developmental pattern in South Korea with deteriorating developmental state model. Uttam (2006: 257) argues the logic of "'techno-scientific state is states' preoccupation with inventing distinct techno-scientific sphere which is qualitatively different from the techno-industrial sphere". This transition from a techno-industrial to techno-scientific state is characterized by the shifting attitude of the Korean state towards its growth pattern which is focusing on science based innovation industries from the earlier development model of imitative reverse engineering. This shift features the importance of S&T technology policy which was overshadowed by the industrial policy during the early phases of Korean technology catching up. The current Korean development policy regime gives predominance to S&T policy to develop a strong national science base to compete with the technologically advanced countries. The current technology policy illustrates Korean governments' preoccupation with techno-scientific sphere, featuring investing heavily on R&D, human resource development in science and technology, institutional restructuring to facilitate university-industrial collaboration, tax and fiscal incentives for corporate R&D, international collaboration in technology development, liberalized FDI regime, mission oriented programs towards future technologies like BT, IT, Robotics etc. and also to develop science culture in Korean.

The reasons for transformation of Korean states development pattern has been identified by Uttam (2006) as follows. Firstly the structural changes took place due the collapse of Cold War dominated global political economy, which weakened Korean developmental states' capacity to develop national capital at the expense of international capital. Secondly, the 1997 financial crisis which swept away the nation, demonstrated the incompetence of the Korean economy to adjust with the evolving post cold war political economic order. This also questioned Korea's 'high-debt high-growth' developmental model and the efficiency of the economy. The major cause which forced Korea to rethink on its development pattern is the changing intra-regional division of labour with the emergence of China and other East Asian countries.

3.3. Korean Technology Policy: An Integrate Framework

Korean government identified export industrialization as the driving force for economic development in 1960s. As industrialization is the a process of acquiring technological capabilities in the course of continuous technological change, the toughest task for Korean government was how to facilitate this process of technological capability acquisition. Over the years Korean government has adopted an array of policy instruments designed to facilitate technological learning in industry and in turn strengthen the international competitiveness of the economy. The growth and the competitiveness achieved by the Korean economy over the years have attributed to the pivotal role of the Korean government and its policy instruments in facilitating technology development. The following framework will be used in evaluating the Korean technology policy.

Kim (1991) developed an integrate frame work to study the technological policy in the developing countries. This framework looked at the technology policy from three perspectives. They are; the market mechanism, technology flow and time. The market mechanism perspective includes policies related to technological development in to three major components: the demand side of the technology development that creates the market need for technological change which is often referred as the industrial policy; the supply side of the technology development that's strengthens the technological capability and referred as the Science and Technology policy and the policies designed to provide effective linkages between the demand side and the supply side, attempting ensure that the innovation activities are both technically and commercially successful. A competitive market is necessary to ensure that the firms to innovate products and services to sustaining and rising market competitiveness. Strong links to the market are necessary to make sure the public

R&D efforts are efficient and effective. Kim argues S&T policies should be an integral part of overall industrial policies that shapes market structure and industrial development. Even though there is a high market demand for introduction of new products and process, countries with out indigenous technological capabilities cannot be expected to grow industrially. On the contrary some economies with indigenous technological capabilities still couldn't grow as because their technological capabilities were not coupled with the right business capabilities.

Despite the presence of high demand for innovation and adequate technology capabilities, few innovations can be materialized only if there is good R&D management system in place, to link the demand with supply effectively. Kim (1991) argues the absence of this linkage explains why in some industrialized countries little innovation happening. Some linkage instruments such as institutions to bridge the demand and supply side of the technology and it also evident that tax and financial incentives for R&D efforts in developing countries are not effective in stimulating technological activities in the absence of demand and supply of technology.

Kim (1991) integrates policies related to technological flow also included in the framework. This perspective is mainly concerned with three sequences in the flow of technology from abroad to catching up countries: transfer of foreign technology, diffusion of imported technology and indigenous R&D assimilation and improve imported technology and to generate its own technology. The first sequence involves technology transfer from abroad through such formal mechanisms as foreign direct investment (FDI), the purchase of turnkey plants and machinery, foreign license and technical services which facilitates the acquisition of technological capabilities. The effective diffusion of imported technology with in an industry and across the industries is the second sequence in upgrading technological capability of an economy. The third is the effort of to assimilate, adapt and improve the imported technology and eventually develop one's own technology. This ability can be achieved through indigenous technological efforts.

The dynamic perspective is added as the third dimension to indicate time. The relative impact of the individual sequence of technology flow and the impact of different type of market mechanisms- demand, supply and linkage change as industry advances through different stages of industrialization over time. Stages of technology development in Korea has been proposed by Kim and Dahlman (1992), Jinzoo Lee

(1988) Yongwon Lee (2004) which provides a framework to analyze technology policy with regards to the function they serve. The technological development in Korea can be categorized in three; imitation stage, internalization stage and the generation stage.

3.4. Linking Industrial Policy and Technology Development in Korea

Korean government's commitment towards developing technology cannot be understood with out looking at the industrial policies which it pursued during the early phase of catching up, which has greatly influential in the development of technology in Korea. Broadly speaking, industrial policy of Korea over the past four decades can be divided into four distinct phases of evolution. The first phase covers the period from 1953 to 1961, during which easy import substitution policy was adopted. The second phase is the period of export drive policy covering the years from 1962 to 1971. The third phase, which began in 1972, can be characterized by the promotion of heavy and chemical industry, which continued until the end of the 1970s. The fourth phase of industrial development began in the early 1980s when the technology-oriented industrial policy was pursued. Since no technology policy efforts were made during the first phase of industrial policy it is important to examine the key features of the industrial policies which triggered technological capability acquisition.

3.4.1. Export Driven Policy

The import substitution policy played an important role in creating demand for foreign technology transfer in Korea (Chang 1994). Since there was no local capability established and operate production system, local entrepreneurs has to completely depend up on foreign sources for production process, production specifications, production know how, technical personals and components and parts. The Korean government made export as the vital component of economic growth goal. Korean government designed the strategic industries for import substitution and export promotion In the 1960s the government pushed the firms with ambitious goals, the export targeting system was used as an instrument to assess industrial success.

Through strict administrative guidance the Korean government forced the firms to achieve the target. The firms which didn't reached the target were severely punished curbing incentives on tax returns, bank credits etc. The role of the Korean government was much stronger than the Japan or other NICs during 1960s and 1970s. The government also wheedled the firms with incentives, borrowing heavily from abroad and channeling the funds into export oriented investments below market interest rates. Firms were granted unrestricted and tariff free access to imported intermediate inputs and automatic access to bank loans for working capital for all export activities, even when the domestic money supply was being tightened. These firms also have unrestricted access to foreign capital goods and were encouraged to integrate vertically in order to sustain international competitiveness. The incentives operated automatically and constituted the crux of the Korean export promotion.

3.4.2 Big Business

The Korean government promoted and played an active role in the creation of large firms, the *chaebols* to over come the disadvantage of a small market and to exploit the nature of matured technologies on which initial industrialization strategy was built (Amsden 1989, Seok-ki Kim 1987). The government helped the capital formation and as well as the subsequent diversification of the *chaebols*. The Korean government managed the *chaebols* relatively effectively compared to other catching-up countries. The government effectively disciplined the *chaebols* by penalizing poor performers and rewarding only good ones proven to be a successful policy compared to other business promotion countries. The good performers were rewarded with further license to expand and also promoted entry enterprises with industrial license in more lucrative sectors, thus leading them to further diversification. On the contrary the government refused to bail out badly managed or bankrupted firms rather in promoted the healthy and better managed firms to take over the badly managed ones (Amsden 1989).

Chaebols played a vital role in the technological capability acquisition in Korea. These conglomerates were in an advantageous position to attract the cream of the best universities. They had organizational and technical resources to identify, negotiate and finance foreign technology transfer and assimilate and improve imported technologies. They also played a major role in drastically expanding and deepening R&D activities in Korea since 1980s.

3.4.3. Heavy and Chemical Industries Promotion

Entering the 1970s, Korea faced rising protectionism in developed countries for labor-intensive products, which prompted the Korean policy makers to improve the structure of exports toward capital and technology intensive products. This led to promoting the heavy and chemical industries such as steel, machinery, electronics, shipbuilding, etc., which were already designated as strategic industries to be promoted. During 1973-79 $12.7 billion was invested in promoting HCI accounted for more than 75% of total manufacturing investment (Lee, Suk-Chae 1992). As a result it took only fifteen years for the ratio of value added in light industries over HCI to fall from 4:1 I Korea, where as the same shift took twenty five years in Japan and fifty years in the United States (Kim 1997).

A series of preferential financial and tax incentives were devised in order to induce investment in HCI. The government established the National Investment Fund (NIF) in 1974 to help entrepreneurs' long-term investments in the heavy and chemical industry. The NIF, which consists of funds from government contributions, various public funds, and savings from banking institutions, was used to finance the procurement of land, fixed as well as working capital, and long-term export financing requirements. The loans from NIF were, however, mostly made for heavy and chemical industries at a preferential rate and the interest rate differences were subsidized by the government. Besides this indirect financing through the NIF, the Korean government made a large amount of direct investment, either in the form of infrastructure construction or equity investment, to key industries. The construction of five major industrial complexes was started in 1974, including a machinery industrial complex in Changwon, a non-ferrous metal complex in Onsan, the second petro-chemical complex in Ryochon, a medium-sized shipyard in Okpo, and a cement plant in Bookpyung. Aside from these investments, the government had already started the construction of an electronics industrial complex in Gumi in 1971 and the Pohang

Integrated Steel Plant in 1968. In addition to this financial support, the Korean government provided various tax incentives for the promotion of HCIs in 1974. Those who invested in so called "important industries" were exempted completely from corporate income tax for the first three years. Alternatively, they could get either 8 percent investment credit or an extra 100 percent special depreciation allowance. These "important industries" include petro-chemicals, shipbuilding, machinery, electronics, steel, non-ferrous metal, fertilizer, defence, electric power generation, aircraft, and mining (Chang 1994).

The sudden push fop HCI with out adequate preparation in technological capability how ever created a crisis in technological learning. Lacking technological capability the *chaebols* were fully dependent on foreign technology. The firms were forced to master technology rapidly and upgrade capacity utilization by expediting learning in order to survive. The Korean firms were able convert this crisis in to an opportunity in the technological learning frontier.

3.4.4. Liberalization and Technology Oriented Industrial Policy

Faced with these structural problems, the government began to reshape its development policy by introducing wide ranging macroeconomic, trade, and industrial policy reforms beginning in the early 1980s. The basic philosophy of the policy reforms was that the Korean economy should rely more on market mechanism and competition while reducing government intervention and assistance (Chang 1994).

First, the government began to overhaul the industrial incentive system, which had been characterized by industry specific support. The industry specific support system was gradually replaced by a functional support system in which all industries were, in principle, equally treated and incentives were given mostly to R&D activities and manpower development. In line with the new direction of the industrial policy, the various tax and financial incentives given to heavy and chemical industries were sharply reduced. While reducing industry-specific support, the government began to strengthen its support for technology and manpower development. The seven industry specific promotion laws were replaced in 1986 by the Industrial Development Law, which was mainly designed to promote industrial development by assisting industrial innovation. Government support was provided only to two kinds of industries, namely ailing or declining industries and infant industries with great development potential. Even in this case, government support in the form of preferential loan and tax reduction was allowed only for a given period of time.

The Korea government tried to resume import liberalization in 1978, but could not continue due to balance of payments difficulties arising from the second oil shock in 1979. As balance of payments situation improved in the early 1980s, renewed efforts were made in 1983 by announcing the multi-year import liberalization program covering the period up to 1988. The program was aimed to raise the import liberalization ratio to 95 percent by 1988. According to the program, the commodities to be liberalized were announced in advance so that the industries concerned could prepare for foreign competition. The government has also greatly liberalized its policy toward foreign investment since 1980. Two rounds of liberalization measures were undertaken in 1980 and 1982, which opened many industries to foreigners. In December 1984, the Foreign Capital Inducement Law was substantially revised in order to encourage direct foreign investment (Kim 1991).

Technology licensing was fully liberalized from 1984. The approval system was changed to the report system. The firms that want to import foreign technology merely have to report their intention to the ministry concerned. If the ministry makes no objection within twenty days, the imported technology is considered acceptable. Furthermore, the government has taken various measures to strengthen competition among domestic firms. The first policy action to this end was the enactment of the Monopoly Regulation and Fair Trade Law in 1980, aimed at supervising noncompetitive mergers, market restrictive behaviours, and entry barriers. Although the law was hampered by allowing many exceptional cases, it greatly helped to provide a competitive environment among business firms.

The trade and industrial policy reform coupled with stabilization efforts has greatly contributed to regaining the competitiveness of the Korean industry and a smooth structural adjustment, which in turn enabled the Korean economy to have a continued high rate of economic growth until the late 1980s. It is also noteworthy that the industrial policy reform greatly facilitated industrial R&D and innovative activities of private firms. The R&D/GNP ratio, which increased very slowly until the end of the 1970s, rose rapidly in the 1980s. The ratio more than tripled, rising from 0.6 percent in 1980 to 1.9 percent in 1990. The sharp increase in R&D activities was mostly carried out by the private sector, which accounted for more than 84 percent of all R&D expenditures in 1990. Although the various tax and financial incentives have been responsible for the rapid increase in industrial R&D activities, it should not be overlooked that trade liberalization and promotion of competition led many private firms to spend more money on R&D activities for their survival and continued growth.

3.5. Supply Side Science and Technology Policy

Jinjoo, Lee and et al (1988), and Kim and Dhalman (1994) identified three stages of technology development during the course of industrial development in terms of the technological capability acquisition: the imitation stage, the internalization stage, and the generation stage. During the imitation stage, foreign technology imitation is the predominant means of acquiring technological capability. The internalization stage starts when local engineers are capable of developing products or constructing new plants through indigenous efforts, or when domestically manufactured products became technically superior to products manufactured initially. Generation stage begins when the nation is capable of introducing market-leading products and state-of-art core technology. The following section will examine the science and technology policies implemented by the Korean government in each of the above stages.

3.5.1 Technology Policy during Imitation Stage

The systematic effort to promote technology development started only after the launching of the first five-year development plan in 1962, which placed great emphasis on export-oriented, labour-intensive industrial development. In recognition of the importance of science and technology in Korea's economic development, the government formulated the five-year science and technology development plan as an integral part of overall development plan. The major objectives of the plan were (i) to set up the administrative and legal framework for science and technology promotion,

(ii) to promote skilled manpower development, (iii) to facilitate foreign technology import, and (iv) to build up the technological infrastructure.

The first 5 year economic plan started in 1962 at that time, total R&D investments amount to 0.2% of GNP. There had been virtually no R&D activity in industry and universities. Only public research institutes, whose primary functions were testing and inspection, undertook small scale R&D projects. The government recognized the importance of S&T in industrial development. Following the completion of the first five-year plan in 1966, more technological manpower and research capability were needed to implement and assimilate foreign technologies. President Park Chung Hee, the architect of the Korea's early industrial development, initiated and supervised the establishment of science and technology infrastructure in the 1960's and 1970's. Korea Institute of Science and Technology (KIST), the first modern integrated technical centre, was established in 1966. Ministry of Science and Technology (MOST), whose primary function was to integrate plans for S&T development, coordinate governmental R&D, international S&T coordination and research on nuclear energy, was established in 1967. The building of S&T infrastructures continued in the 1970's. The Technology Development Law and the Engineering Services Promotion Law were enacted in 1972. The Korea Advanced Institute was set up to carry out high calibre masters and doctorate education in 1971. Many specialized research institutions funded by the government were established in the 1970's.

Korean government invested a larger portion of its budget for S&T compared to other developing countries at that time. The government budget for S&T promotion increased from 0.18% of GNP 1964 to 0.3% of GNP in 1970, and 0.37% in 1980. The proportion has remained at that level until 1990's. Korea was also the first developing country to have a ministry-level administration for S&T.

It is well known that S&T policy, the supply-side of technology, played only a minimal role during the imitation stage because private demand for R&D was almost nonexistent. Nevertheless, policy-makers including President Park had strong faith in investments in S&T. The government did not demand immediate return from Government Funded Research Institutes (GRIs), who spent most of the government's R&D funds. GRIs had full autonomy in the allocation of funds earmarked by the government. It would not have been possible without the complete trust by the government. GRI's major contribution during this period was to provide the S&T pool to be utilized for the absorption and assimilation of foreign technology and to carry out contract research for the private industries. This alone may not be sufficient to justify the efficacy of resources put reserved for GRIs. Investments in GRIs in the 1960's and the 1970's paid off for other reasons. GRIs attracted many Korean scientists and engineers abroad who otherwise would have not returned. Many of them later played a key role in the development of the heavy and chemical industries and high-tech industries. GRIs also contributed to heightening the social status of scientists and engineers. They received high salary and enjoyed high social prestige. As a result, engineering and science related departments of universities attracted the best students.

Despite strong commitment by the government on the supply side of technology, its actual role during the imitation stage is believed to have been minimal (Kim 1997). On the other hand, industrial policy, the demand side of technology greatly influenced the rate and direction of technological advance building in Korean firms. Among the many important aspects of industrial policy, industrial targeting deserves closer attention.

The main objective of industrial targeting is to expand production capacity. But it also stimulates technological capability building. The Korean experience shows that targeted promotion of industries influences technological learning in two ways. First, the interactions with foreign buyers or suppliers provide opportunity to absorb foreign technology. A survey on the source of technology of exporting Korean firms found that trade related activities such as employee training abroad, technical assistance from suppliers of parts and raw materials, and technical assistance from buyers are very important modes of technology transfer. For some product innovation, trade related contacts comprised 95 percent of source of foreign technology transfer (Westphal et.al 1981). Second, increase in production enhances technological learning, the Korean in the automobile industry and the electronics industry support this hypothesis.

Heavy and Chemical Industry Drive in 1970 was initially much criticized by many economists because it distorted market mechanism. They insisted that the nation's scarce resources will be wasted by the overinvestment in these industries. These industries indeed suffered from over-capacity and weak technological competency as predicted. In the late 1970's, the average capacity utilization rate dropped to less than 70%. These industries, however, overcame most problems by the mid 1980's, becoming the major source of export growth in the following years.

It should be noted that industrial policy and S&T policy had not been closely coupled. Industrial policy was mainly administrated by the Ministry of Trade and Industry, while S&T policy was under the control of the Ministry of Science and Technology. The two ministries rarely consulted with each other. Furthermore, the Economic Planning Board, the coordinating ministry of economic related matters, was preoccupied by other tasks.

Direct foreign investment and contractual licensing have been recognized as important channels of international technology transfer from the beginning of industrial development. Korea, however, adopted selective approach in approving the entry of foreign firms to domestic market. Experiences under Japanese colonial period had bred apprehension towards foreign ownership of domestic firms. A legal provision for regulating foreign investment was installed by enacting the Foreign Capital Investment Act. At that time, entry regulation and quality control of foreign investment were not primary concern. After normalizing diplomatic relations with Japan, measures to regulate entry of foreign investment were introduced, which lasted until 1984. Joint ventures were preferred to wholly owned enterprises. The government authorities have discretionary power to reject "undesirable investment". Performance requirements such as local contents requirement and mandatory export quotas were imposed.

Policies toward technology licensing were more lenient. Technologies licensing required approval from the government authorities but the criteria for approval were minimal. Approval process was not to intend to discourage technology licensing per se but to help the domestic licensee in reducing royalty payments or shorting contract duration. It was also possible to impose performance requirement through this approval process.

Korea's policy is characterized by restrictive policy towards FDI and lenient policy towards technology licensing. This policy as a whole is often called unpackaging strategy because foreign capital and technology is acquired through separate channels (Lee 1980). Restrictive policy toward FDI, fortunately, did not discourage flow of capital and technology in significant proportions. The supplies of foreign investors were plenty while potential recipients of these investments are scarce during 1960's and 1970's. Unpackaging also turned out to be a less costly means of finance because world interest rate at that time was low. Unpackaging also contributed to internalizing transferred technology. Study by Young (1983) shows that technological absorption level is negatively correlated with degree of foreign control.

3.5.2. Technology Policy during the Internalization Stage

Korean economy experienced negative growth rate in 1979 for the first time since Korea began active industrialization. Many industries suffered from the overcapacity. The newly installed government in 1980 realized that the extensive intervention during HCI drive create too much distortion in the market mechanism. Stabilizing measures was introduced, which include financial market liberalization, trade liberalization, and devaluation of the won. Industrial targeting was gradually phased out. Functional incentives were emphasized instead of sectoral incentives.

Tax incentives for R&D were extended. Tax credit for R&D is excluded in accounting the upper ceiling of the total tax exemption a firm can receive in the corporate taxation. Custom duties on R&D equipments were either abated or exempted. Tax credit for corporate expenditures on human resource development was introduced. Policy loans to support technological development were expanded despite the fact that policy loans in general was shrinking at the time. To assist commercialization of technology venture capital companies were promoted. The government relegated administration of policy finance to public venture capital companies. Legal foundations for private venture capital companies were introduced. This policy had significant impact since the entry of financial institutions had been very tightly controlled. From 1987 to 1992, over 50 new venture capital companies had been created.

These policies may have contributed to a fast increase in the private's R&D investment later. But it also resulted in exploitation of the incentive scheme by firms who disguised non-R&D investment as R&D investments. A popular scheme was to shift testing and quality control function to the R&D units. In Korea, R&D expenditures for tax purpose is defined as expenditures by R&D units.

Administration of the government's R&D was also changed. Most significant change in the scope and direction of governmental R&D investments was the establishment of the National R&D Programs (NRDP) in 1982 by MOST. NRDP under MOST included six research categories. Among these, the HAN project was the most unique. The main objective of the HAN project was to develop industrial technologies of strategic importance. The private participation is encouraged in the project. The private companies provide some proportion of the research funds and they can claim ownership of the research results in return. It was also the first large-scale inter-ministerial R&D program.

The introduction of the national R&D programs brought two important changes. First, universities and private firms could participate in governmental R&D programs. They could compete against GRIs in getting R&D project. Direct subsidy to GRIs on the other hand reduced substantially. Second, the government was able to pursue technology targeting of strategic importance. In the past, GRIs had autonomy with little control by the government. But in this phase the government could take initiative in planning and implementing R&D projects. The introduction of NRDP opened a whole new issue regarding the orientation of S&T policy. The introduction of NRDP and the initiation of the HAN project signal Korean S&T policy is shifting closer to mission-oriented. The shift was favoured by bureaucrats because it increases their discretionary power.

One of the most expensive S&T projects during this stage was the construction of Daeduk Science Town located near the city of Taejon. This project intended to relocate GRIs to Daeduk. Many GRIs had been located either in Metropolitan Seoul or the Changwon industrial complex. The primary purpose of the project was to encourage mutual cooperation among GRIs. But more important reason for this project was to disperse over-populated from the Seoul Metropolitan area. The project officially started in 1974 but construction and relocation were mostly carried out in the 1980's

Polices regarding FDI and technology licensing had been revised considerably during this period. The Korean government has gradually liberalized its foreign investment policy since 1980. The Foreign Capital Inducement Act, for example, was revised in December 1984 to encourage direct foreign investment. One of the most important changes was the introduction of a negative lost of industrial activities, which, in effect, made it easier to lower the number of activities that were prohibited or temporarily restricted to foreign investors.

Policies regarding technological licensing have also been much less restrictive since the revisions of 1978 and 1979. Automatic approval is given for licensing arrangements meeting the following criteria: first, the life span of the project must be less then 10 years; second, the running royalty payments must be less than 10 percent of the total sales value, and third, front-end payment must be less than one million U.S. dollars. Further liberalization was introduced in 1984. The approval system has been replaced by a reporting system. Companies that want to import foreign technology have to only report their intention to the relevant ministry. If the ministry makes no objections and requests no additional information or changes within 20 days after the report is submitted, arrangements for technological import are considered as accepted.

3.5.3 Science and Technology Policy during Generation Stage

The primary goal of S&T policy in this stage was the building of national innovation systems similar to those of highly advanced countries. Balanced development of research capability among industry, academia, and public research institutions is an important policy goal. Furthermore, net working among the main actors of R&D is emphasized. This intention was clearly reflected in the 7th Economic and Social Development Plan which covers the period from 1992 to 1997. The most important policy objective is to enhance research capability in universities. Universities primarily had been educational institutes with little research activities despite the fact that they have the largest proportion of qualified scientists and engineers. University holds about 80% of PhD's in science and engineering. Nonetheless, universities in total received 7% of government R&D funds.

To promote cooperative research, the government introduced the Cooperative R&D Promotion Law in 1993 to provide legal basis for priority funding of cooperative R&D. MOST introduced a new R&D program to support research in the universities. Science Research Centres and Engineering Research Centres were created in 1990 to help finance basic research in the universities. The Ministry of Education also introduced a new program to support research-oriented universities in

1995. Under this program, six research units in five universities receive 5 billion won for five years. The funds will be used to upgrade infrastructure for R&D and to hire more researchers.

The policy for enhancing research capability in universities did not progress as intended due to the following reasons. First, ministries in charge of government R&D were more interested in funding GRIs associated with respective ministries than funding of universities R&D. Second, the built in rigidity in allocating government budget hindered significant increase in investment for the enhancement of research capabilities in universities. In consequence, the allocation pattern of governmental R&D has not changed significantly. GRIs still received 79% of the total governmental R&D expenditures in 1994. The proportion was 90% in 1990. Third, the universities have been very slow adapting to the newer environment. Universities did not have capability nor willingness to adjust to changing environments. Korean universities are notorious for inapt management. The concept of efficiency and competition are absent in all aspects of university administration. Professorship is a guaranteed life-time job. Universities do not have to compete to attract students given the very high excess demand for university education. Too many regulation on the management of universities by the government also contributed passive management style.

Another significant change in this stage was the diversification of government R&D programs. Many ministries joined to host R&D programs of their own: the Ministry of Information, Ministry of Agriculture and Forestry, Ministry of Environment, Ministry of Health and Welfare, Ministry of Ocean and Fishery. It reflects that R&D policy now is regarded as a viable instrument in carrying out policy objectives of ministries.

Among these the R&D program hosted by the Ministry of Information is by far the largest and most important. The Telecommunication Technology Program, started in 1992, has created many successful results. R&D projects such as BISDN and CDMA are good examples. The program by the Ministry of Information has two advantages over other programs. It is possible to put a relatively large amount of money in a narrowly defined area because fund originates not from government budget but from the proceeds of the Korea Telecommunication Company. Second, marketing of the R&D results is supported by the procurement policy. The ministry, the largest buyer of telecommunication equipments, guaranteed to buy the products.

Coordination and cooperation among ministries became an important issue as the participating ministries were increased. Inter-ministerial Council on Science and Technology chaired by the Prime Minster is responsible for this task. However, it had not functioned adequately because the Budget Office, under the Ministry of Finance and Economy, do not respect the recommendation of the council. To cope with this problem, Korea established the Ministerial Meeting of Science and Technology in 1996, chaired by the Deputy Prime Minister. The budget office is under the control of the Deputy Prime Minister who is also the Minister of Economy and Finance. It is still too early to tell whether this new arrangement will produce better results. The key issue is whether MOST will have a proper role. Legally, MOST is responsible for coordination of government R&D programs and hosts the Ministerial Meeting. But MOST lost credibility as a neutral coordinator because it has its own R&D programs competing funds with other ministries.

A notable change in this stage regarding technology transfer was the globalization of Korean firms. Chaebol's have been quite active in pursuing global networking and technology outsourcing. Ernst and O'Conner(1992) concluded that the major source of rapid development of electronics industries in East Asian countries turns out to be an active acquisition of technological sources as well as successful utilization of international networking. Study on technological building of Samsung in the production of semiconductors also confirms the importance of international sourcing and networking (Choi 1994)

Government policies were responded to accommodate this new trend. "Segewha", a Korean term for globalization, has become an important slogan since 1995. The policy package for Segewha includes diverse spectrum covering almost all aspects of government policy. Segewha in S&T include the following. The Government R&D opened to foreign nationals. It is a significant departure although areas open to foreigner researchers are somewhat restricted. The role of government supported technical information centres has been expanded. Programs to support invitation of foreign scientist and engineers have been expanded with the help of these technical information centres. Cooperation with former communist countries such as Russia and China received special attention. The policy package of "Segewha" also includes a reform of laws regarding intellectual property rights protection and strategic approach to standardization.

Protection of Intellectual Property Rights (IPR) has received increased attention as the Korean technological strategy shifts from imitation to innovation. During the imitation stage, protection of IPR was not regarded as important because Korea generated few intellectual properties. The government tried instead to minimize the IPR protection to help domestic firms use foreign intellectual property. Laws and regulations were formulated in such a way to meet minimal international standards. Furthermore, enforcement of the law had been lenient. But the environment has changed in recent years. First, Foreign pressure to strengthen intellectual property protection increased. Especially, the pressure from the United State was very acute. Second, Korean innovators increasingly demanded more protection. Significant reforms have been made since the late 1980's to strengthen intellectual property protection. Material Patent was introduced in 1986. Computer Program Protection Law took effect in 1987. The new Patent Act was promulgated in 1995.

3.6. Post-Crisis Technology Policy in Korea

Towards the end of 1990s Korean S&T policy was geared to acquiring core competences in strategic technology areas and developing an innovation system that will enable the nation to make a successful transition toward a knowledge–based economy. To transform the Korea in to knowledge based economy the government enacted the special law for Science and Technology in 1997. This law was focused to improve the competitiveness of Korean technology through structural changes at the institutional level. The policy recommended the creation of the National S&T Council to improve the efficiency of government R&D activities through inter-ministerial coordination of R&D policy and investment. There have been tremendous criticisms that there exists duplication and overlap among public sector R&D programs because of the lack of inter-ministerial coordination. This was also pointed out in the OECD S&T policy review of 1996 (OECD 1996). For effective coordination, the council then presided over by the President. Secondly, formulation and implementation of the Five Year plan for S&T Innovation that contains specific programmes for R&D, human resource development and building S&T infrastructure. Third was to increase government R&D investment to five per cent of the total budget to support the programmes proposed by the plan. In accordance with the law, the Five Year Plan for

S&T Innovation was launched in 1997. The plan contains specific plans for action to achieve the policy goal. The National S&T Council was created and put into operation early in 1999. Government R&D investment was increased from 2.8% of the total budget in 1997 to 3.6% in 1998 and to 3.7% in 1999. The increase reflects the actual increase in R&D investment as well as an increase due to a change in the definition of R&D investment.

The impacts of the financial crisis were even larger since they came at the time of political transition. However, the financial crisis provided an environment in which the new government could carry out strong reform measures in many areas of society. Two important changes in the S&T policy framework took place in the period 1998–99. The major change happened was at the reorganization at the institutional level including upgrading the seniority of the Ministry of Science and Technology within the Cabinet, and designating it as the Secretariat of the NSTC, so that it can function as a central coordinating body on S&T within the government. Reorganized the government R&D institutions (GRI) in response to the criticisms that GRIs were not working in the interest of the nation but those of individual ministries, to which they belonged, and that the lack of inter-institutional mobility of R&D resources (flows of human resource and information, and the sharing of equipment, etc.) among GRIs caused inefficient use of scarce resources. Therefore, the GRIs have been regrouped into three research councils and put under the jurisdiction of the Prime Minister's Office. The three research councils are: (1) Korea Research Council for Fundamental Science, (2) Korea Research Council for Public Welfare Technology and (3) Korea Research Council for Industrial Technology. The Chairman of the research council reports directly to the Prime Minister's Office.

In addition, the five year Plan for S&T Innovation was revised in order to take into account the new developments, such as regulatory reform, the reorganization of the S&T system, and the increasing knowledge-intensity of economic activities. The revision was completed in December 1999. The major contents of the revisions are:

- Focusing support for industrial R&D on promoting knowledge-intensive industries, such as IT, biotechnology, and so on.
- Placing priority of government R&D on future-oriented areas of science and technology. Future-oriented R&D programs include the 21st Century Frontier

Program, which was first launched in 1999, the National Research Lab program launched in 1998, and the Creative Research Initiative launched in 1997.

- Reforming university education through the BK–21 (Brain Korea 21) programme, a seven-year programme to support post-graduate programmes at universities with excellence in advanced research and education.
- Promoting S&T activities on the regional level, and supporting the evolution of regional systems of innovation that take into account the natural, social and economic characteristics of the regions.
- Readjusting the investments for individual programmes considering the changes in the financial situation.
- Reduce the planned investment in the fund for Basic Scientific Research from KRW 300 billion to KRW 160 billion.
- Add a new program to support the university system of research and education at the graduate level – BK 21 Program (KRW 200 billion per year for seven years).

3.6.1 Reforms to Support the Science-based Industries

The post crisis Korean technology policy features the strong commitment of the Korean government in developing its science base. This shift can be characterized as the evolution of a 'techno-scientific state' in Korea. The transformation of Korean states' techno-industrial orientation to techno-scientific sphere features the end of Koreas' technology catching-up phase and the evolution of an advanced economy which competing in the high end technology through its firm commitment in scientific R&D and innovating future technology. The Korean government initiated the "Brain Korea 21 (BK-21)" program in 1999 in order to upgrade the quality of university research and graduate education. The focus of this programme is on advanced S&T particularly emerging technologies like IT, biotechnology, etc. The beneficiaries of this programme have to reduce their undergraduate enrolments and concentrate their resources more on graduate programmes and research activities. The GRIs went through massive restructuring, which included downsizing and reorganisation. GRIs reduced their staff size by 20% in 1998, and their budgets for 1999 were also cut by

20% over the previous year. In addition, they were regrouped into three research councils and put under the jurisdiction of the Prime Minister's Office. All these changes took place in 1998-1999. The restructuring was completed in early 1999. Thirteen new university research centres have been designated as Science Research Centres (SRC) or Engineering Research Centres (ERC) in 1999 in addition to the existing 35 centres. Each of the COEs receives about KWR 800 million (about USD 800 thousand dollars) of research funds every year for nine years. In addition, ten research centres at local universities have been designated as Regional Research Centres (RRC) in 1999, in addition to the existing 27 RRCs. These centres are selected based on their research performance. There has been no major change in the criteria for public funding for basic research, but owing to the financial crisis, the government has reduced the size of the "Fund for Basic Scientific Research" to KWR 160 billion from the originally planned KWR 300 billion. Despite the reduction, support for university research has been much strengthened through the BK–21 program that provides selected universities with a fund of KWR 200 billion every year for seven years.

In the effort to develop more science based industries the Korean government offered various incentives. Corporate tax deduction of 50% of the increase in R&D and HRD investments over the annual average investments of the past four years or 5% of the current expenditures for the same purposes (15% for SMEs). The firms were given incentives like 5% deduction of corporate tax of the total investment in equipment and facilities for R&D and/or human resource development, exemption of the corporate or personal income tax on incomes accruing from the transfer of IPRs, income tax exemption for foreign scientists and engineers employed for R&D, direct R&D subsidy for SMEs within KWR 100 million or 75% of the total investment and given support for individuals or SMEs with new ideas or technologies with a maximum financial support of KWR 100 million per project for either the production of test product or commercialisation of the new technologies.

3.6.2 Mission Oriented S&T Policies

The philosophy of current Korean governments' science and technology policy is the realization of the national renaissance on science and technology through the creation of a science and technology society (MOST 2000). The Korean government anticipates the evolution of a science and technology society through national social, cultural development fuelled and sustained by creative innovation in science and technology.

In 1999, the Ministry of Science and Technology launched a long-term plan to help the nation be one of the top technologically advance country. "Vision 2025: Korea's Long-term Plan for S&T Development" provides a roadmap toward becoming the world's 7^{th} power in S&T by the year 2025. The Vision 2025 plan has several major features including the following:

- Shifting from a government-led to a private sector-led innovation system
- Improving the effectiveness of national R&D investment
- Aligning the R&D system from a domestic to a global network
- Meeting the challenges of the IT and biotechnology revolutions

The goals set for each phase of development toward the long-term visions are as follows: To achieve the long-term visions and goals in science and technology development, Korean government identified certain strategic S&T areas and concentrate resources on these selected areas, namely, information technology, biotechnology, nanotechnology, environment, energy, new materials, etc. The major goal of the mission is to transform the national innovation system from the government-initiated, development-oriented system into a market-driven, diffusion-oriented system and also transform the Korean inward-looking S&T system into a globally-networked system. The mission also envisages the emergence of Korea as the R&D hub of the Asia and Pacific region. The program anticipates establishing world leadership in selected technology areas and rising as world's 7th power in science and technology. To achieve these goals the Korean government has employed various strategies.

In an effort to realize the vision by the year 2025, the Korean government formulated the Five- Year S&T Plan and National Technology Road Map. Finalized in December 2001, this plan serves as the action plan for reaching the first stage of the development goal set in Vision 2025, and supplements the Five-Year Plan for S&T Innovation. The plan had aimed to place Korea among the ranks of the top ten S&T powers by 2006, and has pursued the following strategies towards this end:

- Investment in S&T development on the principle of "selection and concentration"
- Making the best use of the creativity of scientists and engineers
- Linking Korea's domestic innovation system to the global system

Investing in basic science; In Korea, the portion of basic research out of total R&D investment is relatively low compared to that of other advanced countries during the earlier phases of technology development. The portion of basic research has been continuously increasing in the government's R&D budget. The basic research accounted for $1,005 million, equivalent to 20.4% of national R&D budget of $4,939 million in 2004. The portion has been increased to 25% by 2007 in basic research and joined the group of world's top 10 countries in basic science capabilities.

Establishment of global R&D network; Korea has made S&T cooperation agreements with 44 countries including U.S.A., Japan, the U.K., France, China and Russia on the basis of the agreements. Korea is supporting around 150 projects for bilateral joint research a year (US$ 11 million in 2003). Korea is participating in multilateral S&T cooperation projects in ITER, OECD, APEC, and others in order to contribute to global S&T development and help in solving global problems. Korea prepared so called an "International Technology Road Map," in order to effectively acquire key technologies through international cooperation.

Korea has suggested an idea to establish a Northeast Asia S&T Cooperation Organization. It includes establishments of "Northeast Asia S&T Commission" and initiation of "Northeast Asia S&T Cooperation Program" to deal with common issues such as nano-technology and epidemics frequently occurring in the region. Korea is also trying to induce North Korea to participate in the Northeast Asia S&T Cooperation Organization through expanding S&T cooperation between the two Koreas. Korea Foundation for International cooperation of Science & Technology (KICOS) was established on February 2004. To support the successful establishment of foreign R&D centres and educational institutes into Korea and to ease difficulties and reduce bottlenecks for incoming foreign R&D centres and deliver post-establishment services

The plan also tries to make Korea the R&D hub of the Asia-Pacific region by 2015 Korea has intensified its effort to position itself as the research and development hub of Northeast Asia. Korea also has sights on becoming the epicentre of regional technology and science, which would lead resurgence in the economy. In pursuit of joint international research, Korea has made cooperation agreements with 44 countries, including the United States, Japan, Britain, France, China and Russia. Korea has been supporting about 150 joint projects a year since 2003. Korea has also participated in multilateral science and technology projects with a number of international organizations, such as the Organization for Economic Cooperation and Development (OECD), the International Thermonuclear Experimental Reactor (ITER) and the Asia-Pacific Economic Cooperation (APEC). The Ministry of Science and Technology has been managing various projects to build up the nation's research and development infrastructure and network. It spent $10 million in 2004, focusing on attracting internationally renowned research institutes to Korea. Korea has increased overseas R&D investment in hopes of acquiring advanced technologies and platforms for further research. These efforts include dispatching officials to high-tech countries and establishing more. The government has embarked on transforming Daedeok Science Town into a world class innovation cluster to become a Northeast Asian R&D hub.

Promoting regional science and technology; The Five-year Regional S&T Promotion Plan (2000~2004) was established to expand local growth potential and to realize balanced development of national land with the visions of local science and technology development. It also stipulates that the MOST shall formulate the implementation plan every year. It includes 6 projects aiming at the development of local strategic and specialized technologies, the creation of local technological innovation bases, and the nurturing local S&T manpower in the strategic and specialized field. "Regional Science Promotion Division" was newly established in the MOST in August 2000 to promote regional S&T, and Regional S&T Promotion Council attended by the central and the local governments was organized in 1999. The government is promoting following policies to improve local capabilities of innovating S&T. To allocate a portion of the national R&D budget to local governments and induce local governments to invest a certain portion of their budgets in S&T. To recommend establishing a section in charge of S&T in each provincial government, and dispatch central government officials to support the local governments. To designate major high-tech science complexes as "National R&D

Special District," including Daedeok Science Town and also to execute regional R&D cluster projects aiming to support local governments which integrate research centres with industries, universities and research institutes.

3.7. Conclusion

The technology development in the early catching-up period was mostly dependent up on the demand side industrial policy as the S&T policy, the supply-side of technology, played only a minimal role during the imitation stage because private demand for R&D was almost nonexistent. During the imitative phase Korea committed relatively large amount of the government budget to build S&T infrastructure. GRIs, which spent the bulk of the government's S&T investment, was an important institutional innovation. Second, the industrial policy played a more crucial role building technological capability of strategic industries. S&T policy, however, was not closely coupled with industrial policy. Third, policy toward FDI was selective. In other words, investments that meet the various governmental restrictions are allowed to enter. The main theme of S&T policy in the internalization stage can be summarized as enhancement of the private firm's capacity for innovation. Tax and financial incentives for R&D expenditure and manpower development were reinforced to help the private firm's efforts to accumulate in house R&D capabilities. Technology acquisition through FDI and licensing contracts were encouraged. The government significantly reduced entry barrier to FDI. Also regulation measures to control the quality of FDI and technology licensing were reduced. The role of the government as a supplier of technology was less emphasized. The ratio of government R&D investment to GNP and to the total governmental budget outlay had not increased during the1980's. To be precise, the ratio had been declined in the first half of the 1980's and recovered in the latter half of the 1980's. Government R&D investment has not increased primarily because small government policy of 1980's. But it also reflects that the policy-makers' attitude toward government R&D had significantly changed. They began to pay more attention to efficacy of investment. The primary objective of S&T policy in the generating stage was to build advanced national innovation system emphasizing interactive learning among the main actors of industrial innovation, industry, academia, and GRIs. In this respect, enhancement of the university research capability was an important goal. Policy measures to increase research capability of universities had been introduced. But these efforts and only a marginal impact until now, vitalizations of university research still remains as an important task for S&T policy in the future.

The post-crisis science and technology policy of the Korean government envisages a shift in Koreans industrialization path from capital intensive economy based on reverse-engineering towards a knowledge economy based on science and technology innovation. To achieve this goal the Korean state is fully committed to make it science and technology based strong through various policy measures which concentrates in increasing basic science research, develop the pool of human resources in the science and technology, developing institutional structures to synergize the university-industry collaboration, increasing global linkages in science and technology development, creating environment to enhance the industrial R&D and to develop a science culture in the Korean society. The 'developmental state' which altered the destiny of Korea by transforming the nation in to one of the advanced economy through its interventionist state policies which controlled and directed the market, is now transmuting in to a 'techno-scientific state' which is fully committed to transform Korea in to a Knowledge-based economy.

Chapter IV

South Korea's Changing National Innovation System: Industry-University-Government Linkages

4.1. Introduction

South Korea (hereafter Korea) has achieved unprecedented economic growth and development throughout the last four decades. As a result, the country has been transformed from an underdeveloped economy dominated by agriculture into a full-fledged industrial economy and is transforming in to knowledge-based economy. Such phenomenal growth is largely attributed to a strong national innovation system (NIS), which functioned effectively from the 1960s facilitating the industrialization process. Korea's rapid industrialisation particularly in the early stage of transformation was enabled by the mobilization of domestic resources combined with the introduction of foreign technology. In other words, Korea relied to a very high extent on imported technology, including technology embodied in production facilities, during the early stage of its industrialization. International competitiveness was secured by producing commodities as well as increasingly sophisticated goods at a reasonable quality and low cost. The main function of the NIS during the catching-up phase was to facilitate the technological capability acquisition process in Korea through the dynamic process of interplay between foreign technology and indigenous R&D efforts.

Korea's catching-up NIS can be separated into two periods (Kim, 1997; Park, 2000). The initial period was government led and the later period was private sector led. During the 1960s and 1970s, while the strategic focus was on light industries then on creating heavy and chemical industries, innovation was neglected. Nearly all efforts were directed at establishing a basic industrial infrastructure built upon imported technology. At this stage, the Government Research Institutes (GRI) played the major role in assisting firms in importing, acquiring and absorbing the foreign technologies. Beginning of the 1980s, the locus of R&D performance and innovation shifted from the government to private firms. Private firms had grown significantly and believed it necessary to strengthen their own research capabilities to respond to competition in international markets. The organization of the Korean innovation system changed significantly as the chaebols rapidly increased their in-house R&D investment. In 1997, South Korea tumbled down to a serious economic crisis. Unlike previous economic disruptions, which had been evoked by external shocks such as oil crises, the 1997 and 1998 crisis that affected South Korea stemmed from fundamental structural weaknesses in its institutions that support national innovation (Kim 2001).

The Asian financial crisis has undoubtedly resulted in tremendous economic and social consequences in South Korea in terms of rising bankruptcies and unemployment and dwindling living standard. But it provided a rare opportunity for Korea to fix its structural weakness. The post-crisis NIS features Korean governments commitment towards altering its past development trajectory based on catching-up to a development paradigm based on technological innovation. It is characterised by restructuring the administrative apparatus for coordinating public science and technology efforts, put S&T at the centre stage of developmental effort, structural adjustments and entered progressively more technology-intensive industries, increased R&D investment to sustain competitiveness in international markets, greater emphasis on university research, increased technology sophistication and diversity by established several specialized GRIs, fiscal and tax incentives for industries to increase in house R&D and more over making effective mechanism for knowledge diffusion across institution through coordination, collaboration and creating new institutions.

This chapter is an attempt to examine Korean's NIS in the catching-up period and the changes brought about in the post crisis period and also the university-government-industry linkages in the changing NIS in Korea. The main arguments and explanations in this chapter are organised as follows. The next section lays the conceptual foundation of National Innovation System. The third section will brief Korea's NIS and enumerate the features of Korea's catching-up NIS. The fourth section will elucidate the shifting paradigm of Korea's NIS in the post crisis period, emphasising restructuring at the university, government/GRI and industry level. Last section provides an analysis and concludes the chapter.

4.2. National Innovation System

The concept of NIS have been discussing frequently in S&T policy and innovation researches since the late 1980s (Freeman 1987, Dosi 1988, Nelson 1993, Lundvall 1988; 1992, Patel and Pavitt 1994, Chung 1996, Edquist 1997, Chung and Lay 1997, OECD 1996). Lundvall (2007) argues the concept of national Innovation System was evolved based upon an accumulation of empirical studies at different levels of aggregation showing that innovation is an interactive process. According to Lundvall (1992:12), "innovation systems include 'all parts and aspects of the economic structure and the institutional set-up (of a country) affecting learning as well as searching and exploring". In concrete, he identifies the internal organization of firms, inter-firm relationships, the role of the public sector, the institutional set-up of the financial sector, R&D intensity and R&D organization as its basic elements. Similarly, Nelson and Rosenberg (1993) raise the country-specific allocation of R&D activity and the sources of its funding, the characteristics of firms and the important industries, the roles of universities, and government policies aimed to spur and mould industrial innovation as common features of national innovation systems. The broad definition encompasses all interrelated institutional actors that create, diffuse, and exploit innovations, while the narrow definition includes organizations and institutions directly related to searching and exploring technological innovations, such as R&D departments, universities, and public institutes. Experts in this area emphasise that effective institutional setting and interactive learning between major actors within the setting, which can be classified into knowledge producers and users (Lundvall 1988; 1992, Chung 1996), are very important for generating innovations and strengthening and maintaining national competitiveness.

Innovation means technological innovation and defines a NIS as a complex of innovation actors and institutions that are directly related to the generation, diffusion, and appropriation of technological innovation and also the interrelationship between innovation actors. The major concern in this concept is how we can formulate an effective national setting of major innovation actors and how to motivate information flows among them in order to generate and appropriate innovation effectively. A NIS consists of three comprehensive innovation actor groups, i.e. research institutes/ academia, industry and the government. Universities and research institutes are actual research producers who carry out R&D activities, the industry which commercialise the technology innovation and there are governments, i.e. the central and regional governments, which play the role of coordinator among research producers in terms of their policy instruments, visions and perspectives for the future.

Incorporating the triple helix model offered by Etzkowitz and Leydesdorff (1997) in the concept of NIS emphasizes the decline of the linear conception of basic and applied research, where theoretical and practical issues are tackled in a separate institutional sphere, namely the university and industry. The model anticipates the increasing growth of a spiral model of innovation where the theoretical and practical questions are interrelated, cross over the boundaries, or occur at the interstices of what until recently were rigidly demarcated institutional spheres. Universities, states, and industries that were differentiated from each other as a condition for the constitution of modernity are now intersecting with each other to create unique institutional configurations. Thus, universities are taking on the characteristics of firms, many firms are beginning to resemble universities, and many states function as private corporations. These developments are partly driven by the commodification of scientific knowledge, even as they reflexively contribute further to that process.

4.3. Korea's National Innovation System

Many researchers acknowledged that the Korea's strong national innovation system (NIS) as one of the major factors for the Korean 'economic miracle' (Chung 1999, Kim 1993; 2001, Lim 2000, Suh 2000, Lee and Chung 2004, Yim et al. 2003). They argued that private industries and government-sponsored research institutes (GRIs) have played important roles in Korea's economic development and occupied strategic positions in NIS. Some researchers have studied Korea's private sectors and GRIs as the contributory factors of growth (Kim 1993, 2001; Lim 2000). But most of those works have not covered the recent period beginning after the Asian financial crisis in 1997 and which illustrates a paradigm shift in Korean National Innovation System on its race towards a knowledge-based economy. The Korean NIS can be categorized in two on its evolutionary accounts; the (i) catching-up NIS; led by the government sponsored research institutes (GRI) in the 1960s and 1970s , then carried forward by the Chaebol led private enterprises and (ii) the post-catching up NIS. As

Kim argues strengths in South Korea's innovation system in the past became its most serious liabilities in recent years (Kim 1997, 2000). Korea's core competence through the 1980s has become core rigidity in the 1990s according to Leonard-Barton (1995). The crisis has resulted in numerous negative consequences in the short-term, but also provided a rare opportunity for South Korea to fix its system in the long-term. The post-crisis policy initiatives of the Korean government illustrate its efforts to restructure its NIS through various reforms in the financial sector, corporate governess, global networks, institutional level and R&D sector. The post-crisis NIS is characterised by increasing institutional collaboration between the industry-GRI/government-universities in the innovation process.

4.4. Korea's Catching-up Innovation System

The pattern and nature of the KIS has largely been shaped by overall economic development strategies, namely the catching-up model. This model has brought both limitations and advantages to the KIS. This section will briefly review the evolution of Korean NIS during the catch-up phase first led by the Government sponsored Research Institutes in the 1960s and 1970s, followed by the private companies from the 1980s onwards. The development strategies which have influenced the shape of the KIS can be summarised as follows: 1) government-led mobilisation of strategic resources for achieving development goals; 2) export promotion *cum* rapid market expansion; 3) selective industrial promotion, notably in the heavy-chemical industries; 4) governmental support for the growth of big business; 5) utilising foreign technologies; and 6) constructing S&T infrastructure, institutions and R&D programmes for industrial demands.

Although Korea, as a late-industrialising country, has depended heavily on foreign technologies, it has also made concerted efforts to accumulate technological capabilities. At the initial launch of its economy-wide economic development plan, Korea was poorly endowed with factors necessary for industrialisation except for a plentiful labour force. Furthermore, the technological competence of Korean firms was far below world standards. Consequently, it was inevitable or natural to look toward foreign sources for technologies. After the industrialisation process launched in 1962, there was remarkable growth in imports of foreign technology. The process of technological capability building in Korea is characterised as a dynamic process of the interplay between imported technologies and indigenous R&D efforts. The catching-up Korean NIS can be broadly classified in to two on the basis of actors' role; a GRI led system in the 1960s and 1970s and later took over by the private industries since the 1980s.

4.4.1. GRI-led Innovation System

The catchphrase of this period is duplicative imitation. In the 1960s Korea was in a subsistent agricultural economy and suffered all the difficulties facing most poor countries today. Korea's per capita gross national product (GNP) in 1960 was $79; less than that of Sudan and less than about one third that of Mexico (Kim 1997). Therefore, the imperative goal of Korean government was to lay the foundation for industrialisation through the development of import substitution industries and expansion of light industries. In order to achieve this goal, there was an urgent need for technological capabilities that could operate, maintain and repair imported technologies and facilities. But in the early years of industrialisation, the industry had no capacities to import and imitate foreign mature technologies. The private sector faltered in R&D investment, accounting for only 2 per cent of the nation's total R&D expenditure in 1963 (Kim 2001). In addition, it had no private R&D institutes at all. That means the private sector played a minor role in nation's R&D activities in the early stage of economic development (Suh 2000), entirely relying on the public sector for R&D.

During this period universities also had little role in helping the industry in Korea. They remained primarily undergraduate teaching-oriented institutions, undertaking little research (Kim and Yi 1997; Lim 2000). Instead, junior colleges and vocational colleges made a significant contribution to the establishing of a skilled manpower base for making sense of mature technologies transferred from abroad in the 1960s and 1970s. In the absence of research in industries and universities, GRIs, particularly in the early years, spearheaded both technology development and human capital formation in Korea (Choi 1984, Kim 2001, Kim et al. 1999, Lee et al. 1991, Lee and Rubenstein 1980, Shin and Kim 1994). In the 1960s Korea's NIS was not yet well established, but there was an increasing demand for domestic R&D due to the rapid industrialization process. In order to meet this demand, the Korean government established the first GRI the Korea Institute of Science and Technology (KIST) in 1966. KIST, the first modern multidisciplinary research institute, covered a broad spectrum of industrial R&D and was directed towards finding solutions for simple and practical problems arising from the application of transferred technology (Lee et al. 1991). KIST also played the vital role of training centre for top-quality researchers and transferring technology to industry through reverse engineering and producing experienced researchers (Kim and Yi 1997). However, GRIs in the 1970s suffered from poor linkages with industry. Most Korean scientists and engineers recruited by KIST came from either academic institutions or R&D organisations that undertook advanced research. These researchers in KIST were unable to fully assist industries in solving technological problems in the crucial initial stages of production. Furthermore, the private sector preferred turnkey transplants or technology licensing from experienced foreign firms to technology transfer from inexperienced local GRIs such as KIST (Kim and Yi 1997)

The main task of the KNIS this period was to support the duplicative imitation of the foreign technology. That means all innovation actors, such as industries, universities and GRIs, were driven to imitate imported technologies and facilities. To facilitate the process of imitative reverse engineering the Korean government formulated and implemented policies related to building technological capabilities that could operate, maintain and repair imported technologies and facilities. Moreover, as industries and universities totally lacked research capabilities, the government was forced to take up measures for building up S&T infrastructure.

The Korean government understood the importance of the need for a ministry-level government organisations to accelerate national S&T development, and, as a result, established MoST in 1967 (Lim 2000). With the inauguration of MoST, S&T policies began to be established and coordinated on a full scale. Since then, MoST has provided central direction, leadership and coordination of all S&T activities in the country. Meanwhile, the government also established government-sponsored R&D institutes to meet the country's industrial needs because of weak research capability of private enterprises and universities. So, the first GRI KIST was founded in 1966 as an integrated technical centre. KIST, the first modern multidisciplinary research institute, covered a broad spectrum of industrial R&D, including technological feasibility studies, technological services for small and medium-sized enterprises (SMEs) and engineering studies on a pilot plant scale (Kim et al. 1999, Lee et al. 1991). And it was directed toward finding solutions for simple and practical problems arising from the application of transferred technology. KIST also played the pivotal role of training centre for top quality researchers and in transferring technology to industry. For example, as the Korean economy expanded, many KIST members left to take up new positions in the other sectors of the economy; 25 per cent of them left for academia, 31 per cent went to research institutes and 17 per cent left for industry (Lim 2000). From the early 1970s, however, the government started to designate strategic industries such as, machinery, steel, chemicals, shipbuilding and electronics for import substitution and export promotion in order to overcome the disadvantage of having a small domestic market and to take advantage of stable mature technologies on which the industrialization strategy was based (Kim 1993, Lim 2000, Yim et al. 2003). But KIST alone could not respond to the increasing demand from strategic industries. Thus, the government established many GRIs under related ministries in order to meet immediate R&D demands from such strategic industries. As a result, fourteen institutes in the S&T area were founded until the end of the 1970s; mainly having spun-off from KIST and other institutes (Lim 2000; Yim et al. 2003).

In summary, during this period, when R&D activities were still in their infant stage in the private sector and academia, GRIs spearheaded both technology development and human resource training in Korea (Choi 1984, Kim et al. 1999, Lee et al. 1991, Shin and Kim 1994). And the number of GRIs started to expand for responding to the increasing demand from strategic industries. Based on strenuous effort on import substitution and export promotion during the 1960s and 1970s in area such as machinery, steel, shipbuilding, chemicals and electronics, the Korean economy steadily grew; increasing GDP from a mere $8 billion in 1970 to $62 billion in 1980. But as industrialisation progressed and Korea lost its comparative advantage in labour-intensive industries, industries needed to upgrade their capability through transition from mere duplicative imitation to creative imitation. Therefore, private firms began to develop their own indigenous R&D by establishing their own R&D centres (Kim 2000, Lim 2000).

4.4.2. Industry-led Innovation System

Since the early 1980s, Korea's private enterprises have consistently and rapidly increased R&D spending, with large companies, notably Chaebols, taking the lead in this drive. As previously explained, rapid market expansion cum industrial widening has brought newer technological demands to the Korea's NIS. Since there has been a wide gap between the domestic knowledge base and the technological requirements of fast moving industrial and production activities, private enterprises have had to opt for in-house research. The internalization of the technology base by private enterprises has obvious advantages. Internal technological capabilities are apparently a basic requirement for business success. They enable companies to monitor market trends, to pre-empt competitors and to reap higher profits through economic rents. The problem is whether internalisation is accompanied by increased learning or technological deepening; this is where Korea seems to face serious bottlenecks.

As chaebols have been the driving forces in expanding production and exports in the 1960s and 1970s, they also played pivotal role in developing high technology industries in Korea in the 1980s. In doing so chaebols were aggressively diversified their source of technologies through adopting a number of technology strategies. First; several major chaebols have setup outposts in Silicon Valley, California to 'leapfrog' into state-of-the-art technologies by monitoring changes and acquiring advanced semiconductor and computer technologies. The Korean chaebols used this opportunity to over come their lacking experienced scientists and engineers by making use of the Korean-American scientists and engineers in Silicon Valley who were already working in leading American companies, providing them challenging jobs and attractive packages. Leading chaebols like; Hyundai, Samsung, Daewoo, LG etc established subsidiaries in Silicon Valley. These subsidiaries were mainly engaged in R&D activities for mass production in Korea. These outposts in California were served as an antenna for information on research activities in advanced countries and as training post for scientists and engineers from R&D and manufacturing plants in Korea (Kim 1987).

Secondly, the Korean chaebols successfully developed collaboration with multinationals, which provided important inputs in developing Korea's high technologies. Multinationals from advanced countries were looking at Korea form consortia for techno logy corporation though Korea has weak bases in basic science and technology but has an internationally competitive edge in manufacturing and processing technologies. Chaebols have also entered extensive licensing ties with foreign high technology forms. Third, chaebols developed closer ties with local public R&D institutions in the 1980s than the previous decades. Capabilities available at the local public R&D institutes became relevant for chaebols efforts to develop high technology industries. Fourth, the Korean chaebols have also invested aggressively in developing in-house R&D activities in order not only assimilate and adapt imported technologies but also to strengthen their own innovative activities. For example Samsung setup 12 new R&D centres in Korea in 1980s and spent around $ 900 million, LG and Hyundai spent $ 600 million each; Daewoo spent $300 million in R&D.

The costs of excessive internalisation in wide ranges of technological activities are apparent in many respects. In addition to the high financial burden of maintaining them, big research labs are not so flexible; the fixed cost for dismantling the organisational structure in order to meet new needs is often enormously high. Organisational inertia coming from large size, whether governments, international organisations, or business enterprises are concerned, is also quite high. Furthermore, there is a trade-off between industrial/technological widening and deepening, in that excessive internalisation and industrial/technological widening frequently do not allow enough time to develop a deep understanding of technology. Korea is a case in point. The internalisation of R&D activities by Korean conglomerates has not come from specialisation; rather it is the result of the diversification of business activities, which require mostly quick product development and "adroit adaptability". This system neglects learning and blocks further development of the KIS (Suh 2004).

Another limitation of excessive internalisation is that it may weaken the need for closer cooperation with other innovation actors. For Korean conglomerate groups, this was the case both domestically and internationally. This is quite contrary to the current trend for the increased externalization of R&D activities in most OECD countries. Strong internal ties between subsidiary companies weaken the incentive for cooperation with companies in other groups. Intra-group mobility of R&D resources is an advantage; but weak inter-group mobility is a disadvantage, as information mostly flows within a group, not between groups. This pattern of resource and information mobility was also typical of Korea enterprises relations with other innovation actors, particularly regarding relations with supporting SMEs. A vicious circle of self-propagating internal ties blocked further development of the Korea's NIS (Suh 2004).

4.5. Korea's Changing NIS

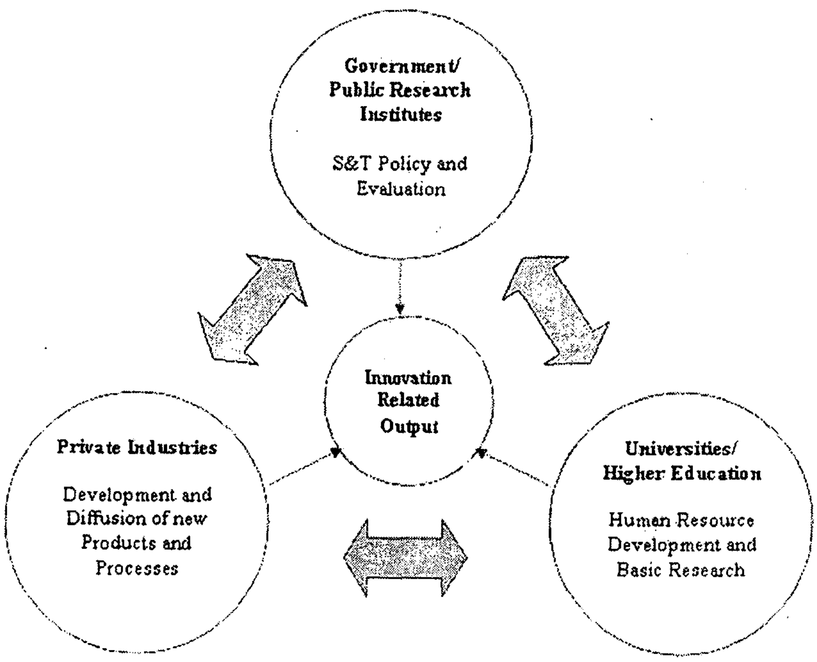
During Korea's catching-up period the innovation system was supporting R&D efforts on applied knowledge in industrial technology and relatively little emphasis was placed on more upstream R&D activities, particularly basic research. From mid 1990s onwards Korea's national R&D intensity continued to rise and reached a level of almost 3% in 2007, which is one of the highest in the world. This further rise not only in absolute, but also in relative investment into R&D can be deducted to two factors. First, the country's industrial firms, in order to improve their international competitiveness further and to take and maintain the global technological lead in various fields, continued to increase their R&D investment. Second, Korea's government also placed higher emphasis on R&D and upgraded the country's research infrastructure significantly.

The historical review of Korea's technological development and an aggregate assessment of the its national NIS during the catching-up phase and its current position indicate that, Korea has successfully caught up technologically to the world's leading countries within only a few decades, the country's relative level of R&D investment is now one of the highest in the world and its technological output is also rapidly increasing, but still appears to be somewhat unbalanced and partially below that of the leading countries. Due to their very nature, however, the aggregated data do not allow more detailed insights.

How ever in the context of 1997 financial crisis, the system was criticized for its weak systemic linkages and interfaces among innovation actors, inefficient duplication of resource allocation and uncoordinated setting of priorities among relevant ministries, in spite of the high level of R&D spending and relatively rich pool of well trained S&T human resources. Driving forward science and technology innovation as the top priority strategy for the promotion of national competitiveness, the Korean government has been in the process of restructuring its NIS then, transforming its imitative, catch-up-oriented NIS to an innovation-driven one. It intends to establish a systematic cycle of creation and diffusion of outstanding R&D outputs, which eventually result in boosting economic growth, creating more jobs, and enhancing the quality of life.

The goal of the post catch-up NIS is to promote the nation's S&T capabilities through innovation in the five major areas of actor, performance-diffusion, element, infrastructure, and system. Actor innovation strengthens the creative innovation capacity of the three major players in NIS such as industries, universities, and government-supported research institutes and promotes their linkages and interfaces. Element innovation efficiently allocates R&D resources based on socio-economic demands, bridge demand supply mismatch, and expanding the infrastructure accordingly. In line with the above, the government had taken up various policy measures to achieve the goal. In the following section will examine various changes happened at different actors level in the Korean NIS.

Fig. 4.1 Korea's Emerging NIS: Basic Framework



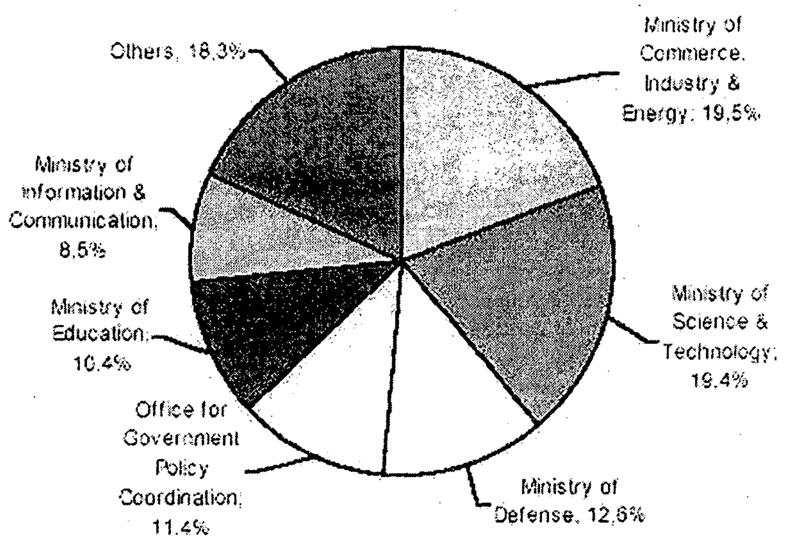
4.5.1. The Government and Public Research Sector

The Ministry of Science and Technology (MoST) which was founded in 1967 is the apex body in Korea responsible for the formulations and implementation for S&T policy. During the subsequent decades, this policy field, and thereby the MoST itself, gradually gained attention. One recent event which symbolizes this tendency was the upgrading of the Minister of Science and Technology to the rank of a Deputy Prime Minister in October 2004, which in turn signifies the importance for S&T policy in the Korea's overall development agenda. To act as the secretariat of the NSTC, the Office of the Ministry of Science, Technology Innovation (OSTI) was also newly established within the Ministry of Science and Technology. It has the responsibility of micro-economic policies, supervising not only planning, coordination and evaluation of S&T related policies (industrialization, financing, regional innovation, human resource development), but also coordinating and allocating the entire government R&D budget. As an exclusive support agency for OSTI, the Korea Institute of Science & Technology Evaluation and Planning, or KISTEP, plays a key role in planning national S&T strategies, setting priorities for the coordination and allocation of R&D budgets, evaluating and analyzing national R&D programs, and capitalizing R&D knowledge.

Among various missions and activities as above, KISTEP recently identified the following Top Brand 3S projects as its strategic focus areas; Smart NES (National Evaluation System), Silk Road 21, and Supreme Academy. Smart NES represents developing the Korean-specific S&T evaluation system, while Silk road 21 and Supreme Academy symbolize the identification of the nation's future cash-cow technologies and customized training program for researchers according to their career development path (CDP), respectively. KISTEP is also dedicated to the capitalization of R&D knowledge. It is establishing a comprehensive national R&D information system for efficient S&T planning and policy, organizing training courses for R&D planning, coordination and evaluation, and is actively promoting international collaboration.

The graph given below gives the break up of Korean government's overall R&D spending, which shows that the related activities are highly fragmented. Less than one fifth of the total governmental R&D spending falls to the MoST, and no less than five other Ministries also hold a considerable share. These data indicate that notwithstanding the rising importance and status of the MoST, its position in Korea's science and technology policy is still by no means dominant. Rather, a variety of Ministries unfold their own activities in this field. Moreover, since not all of these activities are necessarily well coordinated, the effectively fragmented structure of science and technology policy potentially results in a considerable overlap between different programs implemented by various Ministries. This situation appears problematic from an efficiency perspective.

Fig. 4.2 Composition of Korea's Governmental R&D budget by Ministries
Source: MOST 2005



Governance and funding the public research institutes is another major activity of MoST. The Korean R&D statistics distinguish between three types of non-business research institutions: governmentally affiliated, governmentally supported, and others. Though the governmentally supported public research institutes are not formally affiliated to Korean government but are funded by the government thus holds a control over them. It is this group of institutes which are biggest by average unit size that account for the majority of non-business funded R&D in Korea. Most of them are focused on engineering related R&D, thereby giving this field a dominant position in Korea's non-business R&D. Approximately 55% of the total research manpower in this sector falls to engineering (MoST 2005). This field orientation appears to be a good match with the country's industrial R&D, strongly focused on the electronics and automobile industries and therefore can be expected to have a particularly strong need for scientific engineering knowledge. The public research institutes have been criticized for their rigidity especially inflexible labour and their efficiency. After the crisis of 1997, however, employment rules, as well as managerial practices in general, have become much more flexible, resulting in a potential rise of the efficiency and effectiveness of the public research sector in Korea (Yim et al. 2005).

Another potentially important role of science and technology policy is giving direct support for the private industry R&D activities. In 2003, 5.3% of the Korean business sector's total R&D spending has been financed by the government (OECD 2005). This proportion is somewhat lower than in some leading countries such as the US where defence-related governmentally funded R&D programs play a major role, but similar to that of many European countries like Germany and much higher than in Japan where less than 1% of the business R&D is financed by the government. In other words, the financial support of the Korean government for business R&D appears neither particularly high nor particularly low when compared with other developed countries.

As regards contents, the support of venture firms was a major focus of the Korean government's R&D support policies directed at the business sector in the years after 1997 (OECD 2005). On the one hand, problems in the governance of these support programs which partially have been due to a lack of experience of the governmental agencies' staff have resulted in windfall gains, as many firms which received governmental support proved not to be very successful or innovative (Lim 2005). On the other hand, however, the governmental support programs apparently helped to create the sector of innovative new venture firms in Korea which has been discussed in the previous section, although the importance of the governmental help can be evaluated on a case-by-case basis only. Moreover, the screening process for R&D subsidies given to the venture business sector has been improved during the last years (OECD 2005).

A further important aspect of science and technology policy is the protection of intellectual property by the government. Whereas this protection was weak during the early stages of Korea's technological catch-up in order to foster technology diffusion, it has been tightened several times since the 1980s and is now regarded as quite strong by international standards (Lim 2005), thus giving relatively strong incentives for innovation to inventors. In total, notwithstanding certain problems, science and technology policy and the public R&D sector appear to have been grown up in Korea to a level which can be considered as adequate for a developed and technologically advanced country. This assessment is also supported by the fact that the country's total governmental R&D spending amounted to 0.63% of GDP in 2003, a level which is not much lower than in any of the world's leading countries and higher than in some of them like Japan or the UK (OECD 2005).

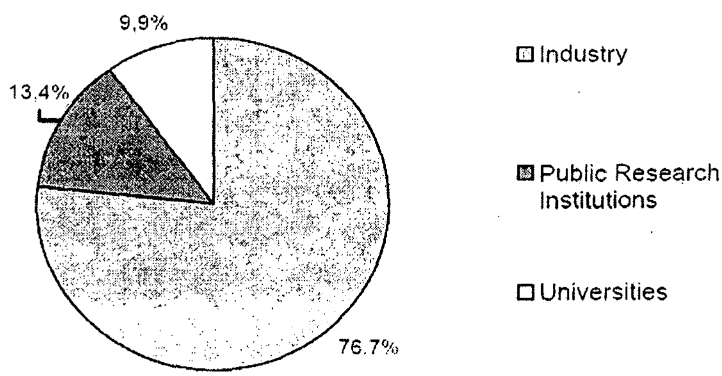
4.5.2. Industrial R&D

As shown in Fig 3, more than three quarters of Korea's R&D is conducted in the business sector, illustrating the high importance of this sector for the Korean innovation system. Whereas in most advanced countries the majority of R&D activities are conducted by the private sector, the percentage of R&D falling to industry is the highest in Korea among all major OECD countries. In terms of distribution of business R&D among industries, the situation clearly reflects the strong overall concentration of Korean firms on certain products and technological fields in particular; the electronic parts industry plays a dominating role, followed by the automobile industry and audio/video/communication equipment industry. In contrast, other R&D intensive industries, such as pharmaceuticals or instruments, are very weak in Korea.

In the Korean case in the R&D break up large firms play a much bigger role here than small and medium-sized firms. Korea does not constitute an exceptional case in this respect. The concentration of R&D on large firms is even stronger in some other advanced and bigger countries, such as the US, Japan and Germany (OECD 2004). The case is more interesting as the R&D is more concentrated in large but only in few big chaebols. In fact, the R&D expenditures of Samsung Electronics alone amounted to 4.79 billion Won in 2004 (Samsung Electronics 2005), which was equivalent to 28.1% of Korea's total industrial R&D expenditures in that particular year. These numbers illustrates the dominating role which the big chaebols played in the formation of Korea's industrial R&D base still prevails. Furthermore, the R&D

investments of Korea's large industrial firms were also rewarded with remarkable competitive achievements in recent years. Again, the performance of Samsung Electronics is particularly eye-catching, as this firm maintained a dominant position in the global memory chip industry for the last 15 years (Shin and Jang 2005). However, other large Korean firms also established themselves as technologically leading competitors during the last decade.

Fig. 4.3 Korea's R&D Expenditures by Performing Sector
Source: MoST (2005)



The relative weakness of Korea's supplier industry has been often perceived as a weakness of the country's SME sector in general. In recent years, however, an increasing number of smaller R&D intensive venture firms have entered the stage in Korea. These firms share several features: they have been founded since the mid-1990s, are relatively small with a few hundred employees at most, independent, very R&D intensive and growing fast. Their existence and success proves that notwithstanding the still dominant role of large chaebol firms in Korean industrial R&D as a whole, a new generation of innovative independent firms has established itself. When considering the fact that such firms have been almost non-existent in Korea until about 10 years ago, it seems likely that their role in the Korean innovation system will gain further importance in the future. Their growth has been supported by governmental support programs for venture firms which have been created since about 1997. Another supporting factor appears to have been the restructuring of the Korean economy after the financial crisis of 1997 that resulted in large-scale layoffs by many chaebols which also included considerable numbers of highly skilled R&D

personnel, showing a changing attitude of the Korean work force which preferred to work of big chaebols.

4.5.3. University and Higher Education Institutes

The university and higher education sector performs two main functions within the innovation system of a country: (1) skill formation through higher education and (2) contribution to knowledge creation and knowledge transfer through research activities conducted at universities. As regards the first function, Korea's position appears to be very strong, at least in quantitative terms. According to OECD data, the proportions of the population between the age of 25 and 34 years with an upper secondary school education and a tertiary (university) education in 2002 were the highest and the third highest in Korea among all OECD countries, respectively (OECD 2005). More recently, the formal level of education among young Koreans is even more impressive: in 2004, no less than 99.7% of all middle school graduates advanced to high schools and 81.3% of all high school graduates advanced to universities (KEDI 2004).

The outstanding formal level of higher education in Korea, particularly among the younger generations, can be explained with two interrelated factors: a long-term national tradition of appreciation of high education levels which can be linked to strong Confucian cultural roots and the extremely high importance which the education level, as well as the prestige of the educating institution, plays for future career opportunities of individuals. Notwithstanding these notable achievements, however, there is widespread discontent with the quality of the education system in Korea.

In recent years, the Korean government initiated various programs to improve the quality of secondary and tertiary education. Moreover, the focus of college entrance exams, which constitute a crucial point regarding the career opportunities of Koreans, is gradually shifting from testing memory and learning skills to examining problem solving skills (OECD 2005b), thereby inducing further changes in secondary education through altering incentive structures. Whereas these developments should help to raise the perceived quality of higher education in Korea, it remains to be seen how fast and to what extent improvements can be made.

As regards research activities only about 10% of Korea's R&D is conducted by universities. This proportion is one of the lowest among the OECD countries (OECD 2005a), indicating that the role of higher education institutions for research is relatively small in Korea. In fact, until quite recently, universities have predominantly been regarded by Koreans as education institutions, and their research activities met relatively little attention. This attitude has clearly changed since the 1990s, however. Governmental and private funding of university research has steeply expanded, resulting in an almost threefold increase of their R&D expenditures within less than 10 years.

Thus, Korea has invested heavily into the expansion of its academic research capabilities throughout the last decade. The still relatively low portion of R&D performed by universities reflects their low initial level as well as the fact that Korea's business R&D also rapidly increased during the last years. The recent efforts to improve the university research base are not limited to quantitative expansion through increased spending. In addition, governmental programs such as 'Brain Korea 21' (BK 21) and 'The New University for Regional Innovation' (NURI) are also aimed at improving the quality of research through the creation of centres of excellence and the upgrading of R&D facilities (Moon and Kim 2001). As a result, many universities in Korea now give much higher priority to research activities of their faculty than in the past. If these efforts are continued, a considerable increase regarding the role of university research in the Korean innovation system can be expected in the foreseeable future.

The following sections will briefly asses the objectives and achievements Korean governments' two major projects to improve the university research system; Brain Korea 21' (BK 21) and 'The New University for Regional Innovation' (NURI).

4.5.3.1. Brain Korea (BK) 21 Project

Brain Korea (BK) 21 Project is a governmental funding project introduced by the Korean Ministry of Education in 1999 for enhancing the international competitiveness of Korean universities in response to the concerns over the relatively low standing of the nation's universities and researchers. BK21 seeks to nurture globally competitive research universities and graduate programs and to breed high quality research manpower in Korea. It provides fellowship funding to graduate students, postdoctoral fellows, and contract-based research professors who belong to research groups (*sa-up-dan*) at top universities. Recipients are selected on the merit of the research groups and universities to which they belong, not on individual merit. The program has had two phases so far. In Phase I, which ran from 1999 to 2005, BK21 allocated about US$1.4 billion. In Phase II, which began in 2006 and is scheduled to run through 2012, BK21 will allocate an additional US$2.1 billion. Phase I emphasized university-level excellence, Phase II emphasizes department-level excellence. Phase II emphasizes the university- industry link more than Phase I does, and institutional reforms are emphasized in Phase I more than in Phase II.

With the announcement of the project in June 1999, in the first phase the fund has been invested in the field of science and technology, plus in the field of humanities and social science. The BK 21 money has been also allocated to regional universities and to facilities for the exclusive use of graduate schools in the BK 21 project. Eleven specialized graduate schools and 317 project teams were selected to receive financial support. These groups currently undergo annual and interim assessment. Summary of research teams selected for the BK 21 project in the first phase are as follows:

- Science and Technology: - 26 Primary Project Teams from 14universities (22 cooperative groups)
- Humanities and Social Science: - 18 Primary Project Teams from 11 universities (2 cooperative groups)
- Leading Regional Universities: - 13 Primary Project Teams and 29 cooperative groups from 38 universities
- Professional and Graduate Schools: - 11 Professional Graduate Schools from 11 universities

The BK 21 project, which is greatly different from previous governmental support for universities, has brought innovative changes in universities. The funding principle of "selection and concentration," together with the financial support closely linked with universities' own efforts to reform, has spurred universities to reform curricular, admission policies, and faculty review systems, and so on. More than anything else, the creation of research-centred environments in universities is one of the most remarkable results of the BK 21 project.

The goals of the Phase II program are (1) developing research manpower and (2) strengthening graduate programs and research universities to be globally competitive. The Phase II program, while operating through department-level research groups, seeks improvement far beyond them, both for Korean universities generally and among individuals who make up the R&D workforce. Much of BK21 is designed to modify the behaviour of young graduate students making career decisions, faculty and research workers seeking the most profitable application of their skills, and administrators of institutions.

4.5.3.2. New University for Regional Innovation (NURI) Project

The New University for Regional Innovation (NURI) Project is another innovative governmental funding project for strengthening the capability of colleges and universities located outside the Seoul metropolitan area (Seoul, Incheon, and Kyunggi-do). The NURI Project, which is aligned with the major national policy of "Balanced Development of the Nation," focuses on: 1) reinforcing capabilities of local colleges and universities and 2) linking capacity-building of local colleges and universities to promoting and facilitating the development of regional economy. Specifically, the NURI project aims to develop college curricular by specialized areas, which is closely aligned to characteristics of the regional economy, thereby improving competitiveness of colleges and universities. The NURI project also aims to promote regional development by training high quality manpower; this project will cultivate college graduates through various educational programs reflecting demands of labour market as well as needs of regional industries and these highly qualified college graduates are expected to invigorate the regional economy. Another essential purpose of the NURI project is to establish a collaboration system, called the Regional Innovation System (RIS), in which higher education institutions, local governments, research institutes, and corporations build partnerships for mutual development and improvement.

The NURI project is implemented by the following strategies. First, the project is planned and implemented in region-led, decentralized, and bottom-up manner; for instance, a project team consists of various stakeholders in the region and a project plan is reviewed by 'Regional Innovation Council.' Second, to enhance investment efficiency, the NURI fund is distributed in lump-sum package including wages, operation costs, equipment purchase fees, scholarships, and repair cost. Third, the project is managed by the performance-based management system. That is, annual and interim evaluation of the project is implemented, based on key performance indicators set by the project team. Through the NURI project $ 1.4 billion was allocated for fiver years from 2004 to 2008.

4.5.4. The Linkages between the Sectors

The linkage of the above discussed entities of the Korean NIS is important to understand to evaluate how frequently and smoothly resources and knowledge are transferred between these three parts, or, in other words, how effectively the nation's knowledge stock is utilized and increased through inter-sectoral collaboration and mobility.

Throughout the last decades, the innovation-related interaction between industry, government and universities appears to have been very limited in Korea. This applies to the mobility of human resources as well as to flows of capital and knowledge. As was discussed earlier, the industrial R&D base developed first, whereas the other parts of the Korean innovation system were upgraded mainly since the 1990s. During the initial stage of the catch-up process, industrial firms relied to a very high extent on foreign technology sources. Subsequently, this reliance was gradually reduced through the formation of internal R&D resources developing internal knowledge. In contrast, domestic external knowledge sources, such as governmental R&D labs or universities, did not play a major role in this substitution process because firms did not regard these knowledge sources as highly relevant for their own domain at that time.

The weak linkages between industry, government and universities are perceived as a major constraining factor regarding the effectiveness of national innovation systems since they limit the utilization of existing knowledge as well as the formation of new knowledge through the combination of complementary knowledge from different sectors (OECD 1999). Notably, the situation has largely improved since 1997. As was mentioned already, highly skilled human resources in science and technology, which previously have been concentrated on large business groups, have been increasingly moving to small and medium sized firms as well as to government labs and universities as a result of the economic restructuring during the crisis and of increased labour flexibility. Moreover, a venture business sector has also been created, mainly through the help of governmental support programs.

Research collaboration between industry and universities is also increasing due to recent administrative measures, such as the establishment of technology transfer offices within universities (OECD 2005), but most likely also due to the improved R&D capabilities of the universities themselves. As a result, the number of patents which are co-invented by members of different organizations has been steeply increasing since the 1990s (Lim 2006). Nevertheless, the general perception in Korea is that there is still ample room for expanding and deepening such collaborations.

Another aspect which also enhances the performance of a country's innovation system is international collaboration. Whereas Korean firms have initially built their catch-up process on the import of foreign technology and still rely to some extent on it, other forms of international R&D links have been very few in Korea until the 1990s. After 1997, the number of foreign R&D centres located in Korea doubled to 122 (OECD 2005b), and the proportion of Korean R&D financed from abroad increased from 0.06% in 2000 to 0.49% in 2004 (MoST 2005). This proportion, however, is still very low when compared with other countries, indicating that there is still a large unused potential for improvement through the formation of international R&D linkages. Moreover, most of these foreign R&D centres have no or weak linkages with local R&D organizations (Bok et al. 2006). This further suggests that the global integration of the Korean innovation system could still be improved to a high extent.

To over come the interlink between the different entities of NIS, Ministry of Commerce, Industry and Energy in late 1990s launched techno-park project with the designation of six model techno-parks in Ansan, Songdo, Chungnam, Kwangju-Jeonname, Daegu, and Kyungbuk. The main objectives of Korean technoparks greatly involve infrastructure development, firm support, and the creation of an innovation environment by developing a strong Regional Innovation System (RIS). First of all, the infrastructural development task was to secure a site and constructing facilities so that the establishment support of venture firms and R&D tasks can be carried out in harmony and the basic technological facilities of the university and research agency can be commercialized. Firm support task, concrete firm-development promotion and support for technological innovation for venture firms, can be classified into the development of firm, education training, common R&D, information distribution, equipment use and pilot production support, amongst other things. The task RIS construction is to efficiently establish a firm support system by making an integrated network of local government, universities, research institutes, and financial agencies.

Korean techno-parks were constructed through the positive initiative and support from central government in terms of their establishment and main operating bodies. But the leadership of practical operations can be classified into university-leading types and local government-leading types. In terms of a legal basis, all six of the technoparks are the Public-Private Partnership (so called as "Third Sector Type"), which involves the formation of a foundation being supplied with funds or sites by central government, local government, and universities. The expenditure for this project till 2006 by each location was 165.7 billion won for Songdo technopark, 99 billion won for Ansan, 95.3 billion won for Chungnam, 97.1 billion won for Daegu, 58.1 billion won for Kyungbuk, 67.1 billion won for Kwangju-Jeonnam. The rate of fund support by each agency was 25.8% from central government, 37.5% from local governments, 16% from universities and 20.7% from other sources. The greatest characteristic of these projects is that many universities have participated in partnerships. It diversity and vitality in the promotion of projects with the enlargement of the size of funds supplied through the participation of many universities will occur. But due to conflicting interests among participating universities, ill-side effects such as the distortion of the direction of promotion and delay in project promotion have occurred. In addition, the fact that few agencies or large enterprises concerned have supplied funds is a problem.

4.6. Conclusion

The pattern and nature of the Korea's NIS has largely been shaped by overall economic development strategies before the crisis, namely the catch-up model and in the post-crisis period there have been a significant change in the Korea's innovation system followed by the restructuring of the Korean economy. From a Korean perspective, as has been pointed out already, the most important remaining challenge to strengthen the national innovation system appears to be a stronger development of the linkages between its different parts as well as of its international linkages.

Chapter V
Conclusion

This dissertation is an effort to study the technological development in Korea and the transformation and features of the Korea's knowledge-based economy. To understand the process of technological change and the dynamics of technology innovation in the Korean economy, we approached the study in three different perspectives. First an evolutionary approach where we study the different stages of technological development in Korea, second we study the political process of technological development from a policy perspective and third, a systemic perspective where by evaluating the Korea's innovation system.

To understand the evolutionary pattern of Korean's technological development in conjunction with its rapid economic growth, we have tried to answer the question, how the process of technological changed facilitated the evolution of a knowledge-based economy in Korea? First and foremost, Korea is not a developmental failure. The Korean economy is a charter member of the "Asian Miracle" Club. Korean firms such as Samsung, Hyundai, POSCO, and LG are globally competitive in industrial fields including steel production, DRAM semiconductors, flat panel displays, and cell phone design and production. The Korean economic miracle was not a short term boom through just sheer accumulation of factors of economies (Krugman 1994, Young 1994; 1995, Kim and Lau 1994) but rather through achieving of technology capabilities and competitiveness at different stages of economic development has been elucidated through the works of Amsden (1987), Stiglitz (1998) Danny Quah (1997; 2007), Hobday (1995) Nelson (1981; 1993; 1997), Lall (1990, 1992). Korea's technological development path has been studied by conceptualising the trajectory of technological development in Korea in relation with the industrialisation process using the framework drawn from the works of Westphal et. al. (1985), Kim (1999, 2000), Lall (1982), Nelson and Winter (1982) Nelson (1981, 1987), Dosi (1988) and Bell and Pavitt (1995). The Korean technological development has be categorised into three stages on the basis of achieving technological capability; the imitation period, internalisation period and the generation period. The technological competitiveness of Korean economy has been analysed through a detailed evaluation of different science and technology indicators like R&D investment, business R&D, patents, science and technology publications, technology balance of payment, internet users, broad band connections etc.

In terms of R&D investments as a percentage of GDP Korea have been increased rapidly and is well ahead of the other developed countries reaching 3% in 2007. But Korea shows a lowest R&D share by the government, followed by Japan which means the lion share of Koreas R&D is financed by private sector and shows a high level of business sector R&D, exceeded only by Sweden. The statistics from OECD (2004) show that Korea's ratio of scientists and engineers to total higher education degree holders was 41 percent in 2003, higher than Japan's 29.2 percent and the United States' 18.0 percent. This statistic looks paradoxical because "avoidance of science and technology majors" has been often highlighted as critical economic and social problem in Korea. Korea's gross tertiary science enrolment ratio between 1995 and 1997 was 23.2 percent, which is according to UNDP (2001), only Finland (27.4) and Singapore (24.2) has higher ratios than Korea. According to NSF (2004), Korea's performance in U.S. patent applications has been significant, especially since 1996. Samsung Electronics ranked fifth among companies receiving U.S. patents in 2001. Also, Korea is the second-largest buyer of U.S. intellectual property next to Japan.

Korea's success attributes to the Korean governments developmental role, which implies the economic miracle stemmed from a policy miracle (Amsden 1987, Kim 1997, Hassinik 1994). Kim (1997) argues the crux of Koreans economic miracle as, the Korean government envisioned a miracle and provided a policy environment and rest did the industry. During the catching-up phase the technological development in Korea was dictated by the industrial policy pillared on export promotion industrialization, which played an important role in creating demand for foreign technology transfer in Korea since there was no or negligible local capability established and operate production system (Chang 1994). During the imitative phase of the technology development, Korean government paid little attention towards the supply side technology policy but rather preoccupied with the industrial policy. The major technology policy instruments during the catching-up phase was characterised by promoting technology transfer through foreign licensing and capital good import, forcing the Korean firms to acquire and assimilate the technology through imitative reverse engineering. The government efforts to establish S&T infrastructure, GRI and domestic R&D came at an instance when the private sector was faltered to invest in developing local technological base and in the wake of anticipated technology demand for Korean governments HCI drive. During the innovation phase policy instruments were more orientated towards promoting private R&D providing fiscal and tax incentives. Since the early 1990s Korean economy was slumping in to crisis as its export-led industries lost regional division of labour advantage and tough competition from the developing Asia. Following 1997 Asian financial crisis forced Korea to alter its development pattern based on industrialisation based on imitative reverse engineering towards a an science and technology based innovative economy through various reform programmes.

As Uttam (2006) rightly pointed out that the Korean governments' call to stride economy towards a knowledge-based paved the emergence of a 'techno-scientific state', which is preoccupied with further economic development of Korean economy based on science and technology innovation, in the context of a deteriorating developmental state. The post crisis Korean governments' preoccupation with science and technology innovation for national development and the priority of S&T policy was further made clear when the S& T minister was upgraded to the level of Deputy Prime Minister and the call to develop a science culture in Korea. Towards this effort the Korean state is fully committed to make it science and technology based strong through various policy measures which concentrates in increasing basic science research, develop the pool of human resources in the science and technology, developing institutional structures to synergize the university-industry collaboration, increasing global linkages in science and technology development, creating environment to enhance the industrial R&D and to develop a science culture in the Korean society.

Many researchers agreed that the strong Korean national innovation system (NIS) as one of the major factors for the Korean 'economic miracle' (Chung 1999, Kim 1993; 2001, Lim 2000, Suh 2000, Lee and Chung 2004, Yim et al. 2003). Fourth chapter is an attempt to study the technological development from a system perspective examining the various actors in the process innovation in the Korean context. Most political economist agrees that domestic institutions determine national innovation rates. The NIS approach to explaining national innovation rates starts with the recognition that innovation be it performed by firms or individuals, occurs with in the context of broader political and economic institutions and policies, and these institutions and policies determines a countries rate and direction of technology innovation. The development strategies which have influenced the shape of the KIS can be summarised as follows: 1) government-led mobilisation of strategic resources for achieving development goals; 2) export promotion *cum* rapid market expansion; 3) selective industrial promotion, notably in the heavy-chemical industries; 4) governmental support for the growth of big business; 5) utilising foreign technologies; and 6) constructing S&T infrastructure, institutions and R&D programmes for industrial demands.

The pattern and nature of the KIS has largely been shaped by overall economic development strategies before the crisis, namely the catch-up model and in the post-crisis period there have been a significant change in the Korea's innovation system followed by the restructuring of the Korean economy. The catching-up NIS was characterised by the institutional arrangements to support process of learning and acquisition of technological capabilities to fulfil the technological demands for the industrialisation process. During the early phase of catching-up the Korean NIS was led by Government Research Institutes (GRI) in the context where the Korean companies were faltered to take up industrial R&D; mainly KIST has played the role of technological functionary in responding to industrial demands for rapid economic growth and KAIS (Later KAIST) which implemented the concept of research-oriented university in to the Korean higher education system. Subsequently, several important policies have been successively enacted; among others, the establishment of specialized GRIs since the 1970s, and, since the early 1980s, full-scale national R&D programmes. Since the early 1980s, Korea's private enterprises have consistently and rapidly increased R&D spending, with large companies, notably Chaebols, taking the lead in this process. As was previously explained, rapid market expansion cum industrial widening has brought newer technological demands to the KIS. Since there has been a wide gap between the domestic knowledge base and the technological requirements of fast moving industrial and production activities, private enterprises have had to opt for in-house research. However, in the midst of 1997 financial crisis, the system was criticized for its weak systemic linkages and interfaces among innovation actors, inefficient duplication of resource allocation and uncoordinated setting of priorities among relevant ministries, in spite of the high level of R&D

spending and relatively rich pool of well trained S&T human resources. The challenges presented to the catching-up KIS require several fundamental and structural changes some are more directly related to particular innovation actors and activities; but some are, directly and indirectly, related to the much wider context of the economic system as a whole. The role of the NIS in a KBE is as the primary producer of knowledge which enables sustained economic growth; however, at the same time, the configuration and constellation of the NIS is conditioned by a much broader socio-economic context. Some of these changes are already underway in Korea, particularly in the wake of the financial crisis. Government, industry and research communities are all making painful efforts to reform. Some of these efforts are very positive, but some need to be more carefully designed

Driving forward science and technology innovation as the top priority strategy for the promotion of national competitiveness, the Korean government has been in the process of restructuring its NIS since 1998, transforming its imitative, catch-up-oriented NIS to an innovation-driven one. It intends to establish a systematic cycle of creation and diffusion of outstanding R&D outputs, which eventually result in boosting economic growth, creating more jobs, and enhancing the quality of life. The goal of the NIS is to promote the nation's S&T capabilities through innovation in the five major areas of actor, performance-diffusion, element, infrastructure, and system. Actor innovation strengthens the creative innovation capacity of the three major players in NIS (industries, universities, and government-supported research institutes) and promotes their linkages and interfaces.

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