Korea's National System of Innovation– An Overview

Country Report on Korea for the ESF/Eurocores Project
National Systems of Innovation in a Globalising, Knowledge-based Economy: A Comparative Study of Small Countries in Europe and Asia

Chaisung Lim
(그리스도신학대학 교수)

1. Introduction

The national system of innovation (NSI) is one of a catching up country. Under the rapid industrialization which has occurred since 1960, Korea has been building institutions and technological capabilities out of those typical of a poor, agricultural country, which was exploited by Japan during the 36 years of colonization and devastated by the Korean war.

The Korean NSI has been driven mainly by central government and domestic large firms affiliated to the chaebols which are conglomerate groups. The strength of the Korean NSI lies in firms' capability to produce manufactured goods based on their production engineering and product development capabilities. The support for firms' innovation activities, received from knowledge generating institutions such as universities and governmental research institutes(GRI) is still weak.

Korea's main manufacturing industries are electrical and electronics production, machinery (including automobiles and shipbuilding) and the chemical industry (including petrochemicals. The service sector occupies a large share of production in the Korean economy, although in terms of competitiveness it is weak.
After the financial crisis in 1997, Korea has been undergoing the most traumatic reform process in its history of industrialization. The process has been targeted at establishing a Korean NSI led by efficient market mechanism in the context of the open global environment.

2. History

2.1 background

Although some Korean historians would argue that there was a crude accumulation of

capital forming the basis of capitalist production even before colonization, industrialization in Korea is generally presumed to have started after the 36 year period of Japanese colonization.

Japan wanted Korea to remain an agricultural country; as a result its progress towards industrialization was very poor in comparison with that of Japan. South Korea could not benefit from even the poor level of industrialization achieved because most of the production facilities were concentrated in the North Korea. Korea was divided into North and South Korea in 1945 when the nation was liberated. The Korean war broke out in 1950 and the few production facilities in South Korea were destroyed. Colonization resulted in a generation of Koreans that were Japanese speaking and adherents to Korean nationalism. As a result of their facility in the Japanese language, this generation found it easy to access Japanese technology and learning through frequent visits to Japan, which is only a two hour flight away. The Koreans who had been bitterly oppressed by Japanese colonization had great determination to overtake Japan. They had strong motivation to achieve successful industrialization as the first goal in building a future for Korea.

After the end of colonization in 1945, the land reform in the second half of the 1940s brought about a re-distribution. The Korean war 1950-1953 led to the destruction of the land owners, which had been leading class in the traditional agricultural society. This aspect differentiates Korea from other developing countries where land-owners are influential and hold political and economical power. Most Koreans, who were generally poor, were starting from the bottom and had to grab the opportunities resulting from the industrialization process.

Before launching further into the industrialization process, it is helpful to outline the geographic conditions which are presumed to have provided the starting point of industrialization. Korea is not a country with rich natural resources. Its main industry was agriculture until the 1950s. Korea is one of the most densely populated countries in the world. Its land area (99,000 kilometres) is scarcely larger than Indiana or Hungary, but it has a population of 46 million in 2000. Korea ranks third in terms of population density in 2000. Korea is located between China and Japan, both of which countries put great value on learning, following the tradition of Confucianism. These aspects provided the basis for the future trajectory of industrialization.

Because of its lack of natural resources, Korea was forced to adopt policies towards

industrialization aimed at the production of manufactured goods based on imported components and materials, and its ample workforce. The domestic market could not consume more than a small proportion of the relatively 'expensive' goods that were produced from equally expensive imported components, materials, and capital goods, thus, the produced goods went mainly to the export market (Nakaoka, 1990). At the beginning of industrialization Korea's only resources seemed to be human resources and an appreciation for the value of learning. The people, which had managed to survive in an agricultural tradition, were diligent (Kim 1996: 71). In lines with the Confucian tradition, government and firms emphasised the importance of education and training and invested heavily in them. Parents made enormous sacrifices – even their lives to support the education of their children (Kim, 1996: 68). This tradition of hard work and investment in learning provided the capacity to learn about and absorb imported technologies in the course of Korea's rapid industrialization process.

<Table 1> Typical technological capability building process

Period	The process of development	Technology imports	Production and R&D
1960s-1970s	Goal: establishment of Production base Characteristics: heavy Dependence on imported technologies	Packaged technology: turn-key based plants Assembling technology	Knock down OEM-dominated Almost no in-house R&D
Early 1980s	Goal: promotion of self-reliance Characteristics: import substitution, localisation of parts/components Production	Unpackaged technology: parts /components Technology Operation technology	OEM/own brand: high ratio Product development
Late 1980s-1990s	Goal: export promotion by means of expansion of domestic market Characteristics: beginning of plant exports, learning advanced and core technologies	Materials-related technology Control technology Design technology High-quality product Technology	OEM/own brand: low ratio Product innovation Process improvement

Source: STEPI. 1995 as cited in OECD (1996).

2.2 Industrialization

Dynamic performance in the industrialization drive began to emerge in the 1960s when

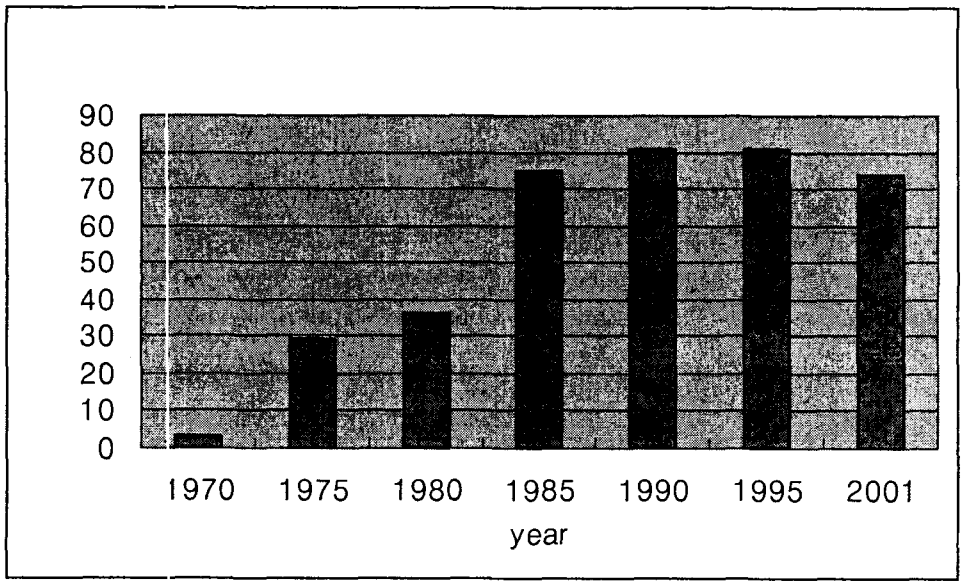
the first five year economic plan was initiated. In this period, the Korean economy grew quickly on the basis of its export promotion policy. The export promotion policy was driven by performance criteria which were applied in the form of rewards or penalties for subsidized industries. There has also been a continuing drive towards import substitution. The major manufacturing industries were labour-intensive, mature industries, for instance textiles, footwear, plywood production and electronics assembly. Domestic firms were small and their technological capabilities were poor. Research and development (R&D) expenditure was controlled by government. Policies were established to stimulate the import of foreign technology and to build scientific and technological infrastructures and initiate science education.

From the mid 1970s, the Korean economy moved into the heavy and chemical industries, including machinery, shipbuilding and petrochemicals. The policy drive was directed towards nurturing these heavy and chemical industries. Large firms, which formed chaebol groups, emerged because current policy encouraged their growth to take advantage of economies of scale (Ahn and Kim 1997: 372). This entry into the heavy and chemical industries, caused an expansion in technology imports. Import substitution policies were announced for components and machinery which had been imported abroad. There was expansion in government science and technology research infrastructures, which included establishment of a number of government research institutes (GRIs) and initiation of the Daeduk Science Town. The Technology Development Promotion Law and the Engineering Services Promotion Law were enacted. The export subsidies, which had been one of the measures used to promote export, were reduced in the 1970s (Kim 1997: 36).

The 1980s saw liberalization in trade , foreign direct investment and technology imports. The liberalization ratio of trade, that is, the number of unrestricted items to the total, rose from 51 per cent in 1973 to 95.2 per cent by 1988 (Kim, 1997: 36). In relation to foreign direct investments (FDI), government shifted from a "negative list" system to a " positive list" system by allowing foreign investment in industry. The approval system for FDI was replaced by a reporting system in which licensing activities were approved with few exceptions (OECD 1996: 28). This liberalized domestic market, in the face of challenges from other developing countries with lower wage rates, produced a transformation in the industrial structure which expanded technology intensive industries and improved productivity. In the middle of the 1980s, the share of heavy and chemical industries in exports was more than half of total exports (OECD 1996: 22) There has been an increase in overseas training programs and graduate education

(OECD 1996, 19). Government policy aimed at enhancement of functional incentives and the phasing out of industrial targeted policies. The best example of science and technology (S&T) policy was the financial incentives offered for R&D activities, which include tax credits and policy loans to finance R&D activities. With this encouragement of R&D activities and pressure to upgrade product quality, the investment by private firms increased and the number of research institutes multiplied. Private expenditure in fact overtook government investment on R&D in this period (see Figure 1). A National R&D Program (1982) and the Industrial Generic Technology Development Program (1987) were launched. The policy measures for supporting R&D activities were rearranged and Daeduck Science Town was opened.

<Figure 1> Share of Private Sector in Korean total R&D expenditure



Source: MOST (1994) as cited in Kim (1997, 54-55) MOST (2001), MOST data as cited in KITA (2003)

3. Main institutions and recent innovation policy in the 1990s-2000s

Over the ten years to 2002, successive governments that had previously been the regulators and drivers of the industrialization process have been abolishing regulations. In the three years between 1998 and 2001, 8,121 of the 14,186 regulations in place were abolished and 6,065 regulations were improved (MOTIE 2002: 42). Government was left with greatly reduced direct policy control and has been experimenting with the role as a facilitator. Government has also been driving economic reform process after the financial crisis in 1997. After the establishment of local autonomy in 1995, the role of local government has grown although it is still small.

The financial crisis led to reform of the financial system. The financial system, which had been liberalized and opened to entry by foreign organizations and inflows of short term overseas borrowings, were not compatible with an economy led by large firms affiliated to the chaebols. Financial resources were biased towards large firms who tended to expand in size but were less attentive to profitability. After the financial crisis, financial institutions tightened their conditions for lending money to firms. A new supervisory framework for the financial sector was established to scrutinize the behavior of financial institutions and avoid another financial future crisis (OECD 2000: 29). Financial institutions have been learning to build their own lending system on the basis of credit information and estimated risks. Several of Korea's major banks succeeded in attracting foreign investment which is expected to make Korean banks follow the 'global' standard (OECD 2000, 15).

Another sector that has had to undergo a reform process as a result of the events of 1997 is the corporate sector, which was dominated by large firms affiliated to the chaebols. Government drove reformations to corporate governance so that large firms were made to focus on profitability and shareholder value, rather than size expansion (OECD 2000: 29).

As a result of the financial crisis, a significant proportion of the labour force was laid off and life long employment has become an 'old story' in Korea.[1] In 1998, there came into force a policy for enhancing the flexibility of labour markets. Layoffs for "urgent managerial needs" including mergers and acquisitions were allowed and the creation of temporary work agencies to dispatch workers to other companies was allowed (OECD 2000,191).

In the 1990s, several policies designed to enhance market competition were introduced. Trade liberalization which progressed dramatically in the 1980s, was continued in the 1990s.[2] After the financial crisis, trade barriers were reduced and non-tariff barriers were dismantled: the import diversification program which restricted certain items was completely abolished in 1999. The 220 quotas in place in 1994 were reduced to nine by 2000 (OECD 2000: 175). Second, FDI policy has been changed greatly to lure foreign investors. Investment of foreign capital was regarded as not only good for stimulating competition in Korea where oligopoly by 3-4 large firms is most common in the

[1] The unemployment rate, which was around 2% before 1996, rose to 6.8% in 1998.

[2] There was continuous opening up of the market in the 1990s with a liberalization ratio of 98.6 per cent in 1994. The government average tariff rate fell from 18 per cent in 1988 to 8 per cent in 1998 (OECD 2000: 174).

markets of main industries, but also desirable for stabilizing the newly liberalized Korean economy suffering from the lack of foreign currency as a result of the financial crisis. FDI reached its highest level of investment in the period between 1998-2002.[3] Third, to encourage fair competition, there has been strengthening of the fair trade policy. In 1996, the Korean Fair Trade Commission (KFTC) was given ministerial status. After the financial crisis, its role was further reinforced by its being awarded more investigative power (OECD 2000: 21). The Fair Trade Commission has tried to control the structure of chaebol investment in other firms through direct intervention (OECD 2000: 173)

All of these changes, which took place over a ten year period, are oriented towards building institutions to put in place a framework of efficient market mechanisms and to provide a supportive environment for a market based economy.

Under the liberalized and increasingly competitive environment, domestic firms could not find shelter from domestic and international competition. Firms found it necessary to focus more on innovation. To this end, domestic firms have been investing in R&D and rapidly accumulating technological capability. In Korea, the share of Korean patents in applications surpassed that of foreigners in the 1990s(see Figure 2). The share of Korean patents registered in the US rose from 0.2% in 1990 to 1.9% in 2000.[4]

Policy towards small firms, which had become increasingly important for competitiveness of the nation in the 1990s, has been to stimulate their development. The new government that came into office during the financial crisis regarded small firm policy as crucially important for the revitalization of economic growth. The focus of policy relating to small firms was on encouraging the development of new technology-based small firms(NTBFs).

In 1997, the law for promoting new ventures was enacted and brought financial incentives and provision of physical facilities which produced an increase in the number of newly established ventures to 878 in 1999 from 422 in 1996 (OECD2000: 150). During the financial crisis, the growth of venture business absorbed the work force that had been laid off as a result of the restructuring of larger firms. Of the venture

[3] 59.3 billion dollars between 1998-Sept. 2002, compared with 24.6 billion dollars 1962 -1997 (MOFE 2002: 162)

[4] USPTO data base : www.uspto.gov

businesses created between 1995-1999, two-fifths were in the computer or telecommunication equipment sectors which led to the boom in the information technology industry (OECD2000: 152). Korea, not being at the world frontier in science and engineering, had not had much technological opportunity from new discovery in science and engineering. Therefore, the policy towards venture companies had a combined effect of stimulating the growth of 'venture' business and technology based small firms.

Government has been investing in the information technology (IT) infrastructure. Investment in the IT infrastructure, which started before the financial crisis, has been emphasized as a possible means to overcome the financial crisis by creating new industries and market. Korean investment in information infrastructure was 1.9% of GDP, higher than that of the US (0.5%), Japan (0.3%), and Singapore (0.6%), between 1996-1999 (OECD 2000: 257).

There has been reform in the government research institutes (GRI). In 1998, the new law on GRIs made it clear that all the GRIs would be under the control of the Research Councils which would allocate funding and carry out evaluations. This meant that GRIs were no longer under the control of government ministries. Also the funding from the Research Councils did not cover all the costs of the GRIs and they were obliged to compete with other GRIs and even private firms in securing research projects.

In the 1990s, Korea, with a need to increase its capability in R&D, has put in place policies to stimulate R&D activities with scientific creativeness, R&D activities on a level with those in advanced countries and R&D relevant to private sector innovation. The Highly Advanced National Project (so-called "G-7 project"), aimed at upgrading Korea's technological capability equivalent to advanced countries, was launched in 1992 (Kim 1997: 51), the enactment of the Special Law for Scientific and Technological Innovation, the establishment of the Five-year (1997~2002) Plan for Science and Technology Innovation were also put in place. There has been emphasis on cooperative R&D in implementing national R&D programs and S&T policies for stimulating R&D activities. The National Science and Technology Council was established in 1999 to coordinate decisions among ministries. However, this coordination has not gone according to plan.

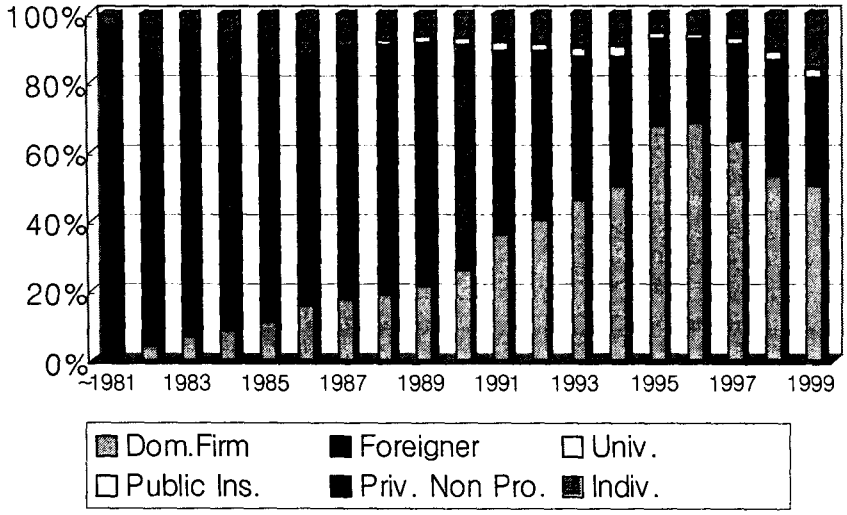
In the 1990s, there were policy initiatives to stimulate innovation activities at regional level. Techno-parks, regional research centers, technology incubator centers, etc. were

established as regional R&D centers and for the commercialization of R&D activities. A consortium for cooperative R&D between small firms and university & GRIs at regional level was set up. Recently various policy initiatives designed to stimulate growth of clusters of specialized industries in several regions were introduced. These policies were originally initiated by central government but local government has been increasingly involved with these policy initiatives to foster local clusters.

Intellectual property rights (IPR) laws have been reinforced. Korea became a party to the Paris Convention for the Protection of Industrial Property in 1980 and tried to abide by the principle of giving equal treatment to nationals and foreign nationals alike. Reinforcement of the intellectual property rights regime began in the late 1980s when Koreans became active in patenting activities. To enhance the protection of inventions and expand the scope of protected inventions, a product patent system was introduced in 1987. The term of patent right protection was extended from 12 years to 15 years. Punishment for the infringement of patent rights was strengthened. As a result of a series of negotiations between Korea and the US, the patent law was amended to protect IPRs in computer software and materials in 1987. In the 1990s, Korea joined the World Trade Organization (WTO) Agreement on Trade-Related aspects of Intellectual Property Rights (TRIPs) (1995). The Korean share in patents registered being greater than those of foreigners in Korea.[5] IPR protection became an important issue for encouraging the innovation activities of domestic firms. Korea has been establishing and enforcing laws relating to intellectual property rights.

[5] 65.6% in 2000

<Figure 2> Patent applications in Korea



Note: The lowest part of the bar is 'Dom. Firm'. The second lower part is 'Foreigner'... The top part of the bar is 'Indiv.'

Source: Data from KIPO (Korea Intellectual Property Office)

<Table 2> Policy Changes and Changes of Institutions>

Policy changes in the 1990s-2000s		
Promotion of Competition Deregulation of governmental policy Reform of financial system Reform of corporate governance Enhancement of labour flexibility Promotion of technological innovation - Frontier technology R&D program - Promotion of university research - Promotion of cooperative research - Reinforcing coordination of policies - Launch of research council - Promotion of local cluster - Investment on information technology infrastructure		
Changes in institutions		
	Early 1990s	Latter 19990s - 2000s
Competition	-Organized market influenced by the chaebol affiliation	-Organized market less influenced by the chaebol affiliation, -More product competition
Main actors in private sector	Large firms affiliated with the chaebol	Large firms, technology based small firms, FDIs
Government	-Regulator -Central government	-Driver of economic reform -Little room for direct policy means -Early stage of Functional Facilitator -Central government and local government -Local government: weak, becomes more important
GRIs	Driver of governmental projects	Complementary research to private firms
University	Mainly education	Streghthened role of R&D and education

Linkages among actors	-Close among chaebol affiliated firms and subcontracting firms -Active GRI-industry linkage -Not-active university-industry linkage	-Close among large firms and subcontracting small firms -Horisontal network of small firms -Active GRI & university –industry linkage

Accompanying the policy changes above mentioned, there have been changes in the following aspects expected to bring about a radically new model of economic growth in Korea. The Korean market used to be an organized market influenced by the chaebol affiliation and are now the market less influenced by it. Main actors in the economy have been changing. The role of small firms' innovation activities has been growing with increased share of total industrial R&D expenditure and with increased R&D intensity.[6] Foreign firms who rushed in after the financial crisis became important actors in the economy.

Government driven economic reform is expected to continue with the new government which will come into office in 2003. However the direct policy means of government have been greatly reduced. Government is in an early stage of becoming the facilitator of a market-led economic system. At the same time, the role of local government, though still small, is becoming increasingly more important.

4. Main organizations

Government

The Korean government has been mainly led by bureaucrats and the role of the parliament has been weak. The Korean government's science and technology policy has been driven by central government. In Korea where local autonomy was only introduced from 1995, the role of local government is still small, but is slowly being enhanced.

The Korean government has designed incentives and built institutions to encourage the process of technology catching up. Government intervention was direct in the early stages of industrialization. This direct intervention was superseded by market mechanisms in the 1980s and 1990s (Kim 1996: 34). The Korean government has been active in setting up institutions to promote technological learning. Government

[6] According to Suh(2002, 4), small firm's share in total industrial R&D expenditure was 9.5% in 1995 and up to 18.0% in 2000. R&D expenditure per sales of small firms also rose from 2.8% (1997) to 3.1%(2000).

implemented demand oriented policies to promote export and market competition. Policies have also been set in place to promote technology generation, technology diffusion, education and training. As a result of the financial crisis, which left the government with little regulating power, government is in a state of transition towards taking on the role of orchestrating conditions to facilitate innovation activities.

The chronic problems in coordinating S&T policies among ministries were revealed in the 1990s. Although National Science and Technology Council was established to solve the problems, coordination among ministries has been poor.

Large firms

In Korea, large firms have been the main actors in innovation activities. Large firms formed the chaebol. Large firms were in a very good position to attract finance either because of governments' favourable conditions or because of their assets, which were seen as good collateral by financial lending institution. These large firms were in a position to recruit the best human resources in Korea and invest in technology imports and learning and thereby were able to become leaders in technology accumulation. With their modern facilities and technological capabilities they were able to gain a share both in the domestic and international market. Some large firms became world class firms able to produce world frontier products. As a result of their easy access to financial resources, they were able to expand in size through diversification into other business. However, their aggressive borrowing was directed to enlargement and less attention was paid to profitability as discussed above. Nevertheless, the large firms led the growth in subcontracting firms by providing market and information.

Small firms

Small firms who found it difficult to borrow money and recruit well-qualified human resources were weak in their competence and became a burden on the Korean economy. However, since the financial crisis, with the boom in venture business, NTBFs have been able to get access to financial resources and employ a highly educated work force. Small firms could gain an improved position in the economy with increased share in industrial R&D investment, production and export.

GRIs

The role of government research institutes in the 1960s and 1970s was confined to

training researchers and carrying out mission oriented research for government and absorbing scientific knowledge from advanced countries. However from the 1980s when R&D activities were in demand to help. GRIs led big national research projects based on industry-university-GRI cooperation. Research was about improvement of mature technology and imitation of future technology (MOST 1997: 271).[7] In the 1990s when firms took over leadership in R&D activities in Korea, GRIs focused attention on complex advanced technologies to complement private firms' activities. Government research institutes have been carrying out core public R&D activities and have received most of the new technology R&D funding (Kim 1997: 50), R&D activities of GRIs have been mostly in collaboration with firms.

As the R&D capabilities of firms and universities have been enhanced, GRIs have been forced to take on new roles. To improve the productivity of GRIs, a new system was introduced. The Research Councils established in 1998, allocate funds on the basis of their evaluation of projects.

Educational Institutions

The education system in Korea has been expanding rapidly to support the industrialization process. In the 1970s technical and engineering education expanded and in the 1980s-1990s there were improvements to graduate education and expansion of overseas training programs (OECD 1996: 19). This expansion has resulted in the quantitative indicator of illiteracy rate[8], rate of enrollment as a percentage of the corresponding age group in elementary, middle, higher and tertiary schools[9] which are on a level with or even better than other advanced countries.

However, the educational institutions are biased mainly towards transferring documented knowledge which has been accumulated in advanced countries. The educational institutions are negligent about transferring non-documented knowledge, which requires creative thinking and experimentation. The level of education in universities in Korea is low (Kim 1997: 65). Those who aspire to become researchers of international standing apply to advanced country universities, although quality oriented universities such as KAIST and the Pohang University of Science and Technology were

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[7] as cited in Suh (2000, 42)

[8] 10.6% in 1970. The illiteracy rate after the mid-1970s were so insignificant that the government ceased to collect data on it (Kim 1997, 61)

[9] 100.5 (elementary school), 99.0(middle school), 88.7(high school) and 48.8 (tertiary school) in 1994 (Kim, 1997: 61).

established to tackle the chronic problem of weak R&D competence in universities. The weakness in research retards the development of good researchers (Kim 1997: 30). In the 1990s, the role of the university was strengthened by government policy designed to stimulate the R&D activities of universities. The share of university R&D expenditure to total R&D expenditure in Korea rose from 8.7% in 1995 to 12% in 1999 (KITA 2001: 107). Cooperative research between university and industry has been increasing.[10] The number of papers published in SCI journals shows the recent progress made in university research.[11]

Institutions for technology diffusion

The role of technology diffusion institutions in Korea as a catching up country cannot be overemphasized. Technology diffusion is particularly important for small firms who are weak in searching for and learning from foreign sources of knowledge. However, it was only in the 1980s that Korea began to appreciate the role of technology diffusion institutions when the poor technological capabilities of small firms emerged as a bottleneck in improving the competitiveness of the nation. The technology diffusion institutions include public institutes such as Small Business Corporation, Korea Productivity Center and GRIs and industry associations. These effects and reach of these institutes, although they have branches at provincial level, are limited because their activities tend to be mainly driven by their Seoul headquarters. Since the 1990s activities at regional level have increased.

Financial institutions

The most important organizations amongst Korean financial institutions are banks. To Korean firms, finance from banks is more important than that derived from the securities market. Before the financial crisis, the lending systems of the banks relied on mortgages and their credit analysis and internal risk control mechanisms were poor. Allocation of financial resources used to follow the direction of government (OECD 2000: 28), therefore money was rarely lent on the basis of evaluation of firm performance. This lending system advantages the large firms because of their large assets and therefore money allocation tends to be biased towards large firms. However after the financial crisis, there has been some experimentation with lending based on credit and risk estimation.

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[10] The share of firm support for university R&D rose from 6.9% in 1989 to 22.2% in 1996 (Lee 1998: 602).

[11] Korea was ranked 15th(14,673 papers) in 2001 from 18th(7,852 papers) in 1997 according to the number of papers. 76.5% of SCI papers published orginated from universities (MOST, 2002).

5. Specialization of Industry and technology

Korea's industry structure is the structure of advanced countries in general. The proportion of knowledge intensive industries such as the share of electronics, machinery, chemicals is similar to those of advanced countries.

Between 1970 and 2000 there was a drastic reduction in agriculture and mining and a continuous increase in manufacturing from 22.9 to 34.1%. The service sector has occupied an even more important proportion than manufacturing from the 1980s.

In the 1960s and 1970s the major manufacturing industries were labor-intensive, mature industries such as textiles, food and beverages and printing. In the 1980s and 1990s Korean firms were increasing production of knowledge-intensive products in the major manufacturing industries such as electronics, automobiles and machinery. 1980-2000 data show that the electrical and electronics industry and machinery including transport machines (vehicles) emerge as the most important industries. The service sector has been the most important sector, with an ever increasing share. Finance/insurance/assets and community/social and personal service have been continuously expanding to occupy the largest share in 2000.

<Table 3> Industrial Structure

(unit: %)

Industry	1970	1980	1990	2000
1. Agriculture, forestry and fishing	26.9	14.9	8.4	4.6
2. Mining and quarrying	1.5	1.6	0.8	0.3
Primary Industry	28.4	16.5	9.2	5.0
3. Food, beverages and tobacco	6.1	5.4	3.7	3.4
4. Textiles and leather	4.3	5.5	3.3	1.3
5. Wood	0.6	0.3	0.2	0.2
6. paper, publishing and printing	1.2	1.1	1.3	1.3
7. chemicals	2.3	3.4	3.4	3.4
8.Petroleum	0.9	1.6	0.5	3.5
9. Rubber	0.1	0.4	0.3	0.4
10. Non-metallic mineral products	1.1	1.5	1.6	1.0
11. Metal	0.3	1.9	2.6	2.5
12. fabricated metal products	0.2	0.7	1.1	1.3
13. Machinery and equipment	0.5	1.0	1.6	1.8
14. Electricity and electronics	0.8	3.0	4.2	5.7
15. Transport equipment	1.9	1.7	3.8	4.7
16. Precision machine	0.1	0.3	0.3	0.4
17. Other manufacturing	0.7	0.7	0.8	0.4
18. Electricity, gas and water	1.6	2.2	2.1	2.8
Manufacturing	22.9	30.8	31.1	34.1
19. Construction	5.2	8.2	11.4	8.0

20. Wholesale,retail, restaurants,hotels	16.9	13.6	13.5	12.1
21. Transport, storage and communication	6.8	7.8	6.7	6.7
22. Finance, Insurance, real estate	6.3	9.4	11.7	15.2
23. Public administration, service and defense	5.1	4.9	4.2	4.3
24. Community, social and personal services	8.3	9.0	12.2	14.7
Service	48.6	52.8	59.7	61.0
All Industries	100.0	100.0	100.0	100.0

Source: data from Bank of Korea

The major exports were semiconductors which occupy 15. 1% of total exports, and computers (8.4%), automobiles (7.7%), petrochemicals (5.5%), shipbuilding (4.8%), wireless telecommunication equipment (4.7%) in 2000.[12] The industries which occupied the highest world market share in 2000 are consumer electronics (8.1%), steel (6.0%), automobiles (5.4%), petrochemicals (5.1%), textiles (5.0%) and automobile components (4.8%) (KIET, 2001). Korean firms' strength lies in manufacture/process innovation. Korean firms are weak in R&D, product design, distribution and marketing (Bessant et.al. 2002)

The technological areas in which Korean firms are strong are those relevant to the industries with dominant status in production and export amount. The largest shares of patent applications in Korea are in electronics and telecommunications (43%), machinery (19.9%), chemical (9.9%) in 1999 (KIPO, 2000) According to the report of the Ministry of Science and Technology (2002), using the ISI data base, the area where Korean scientific papers occupy more than 5% of world papers are information technology and telecommunications, materials engineering and mechanical engineering which ranks between 4th and 7th among those countries published scientific papers.

6. Impact of globalization

Korea has been learning to adapt to globalization. Korea began opening up the trade and FDI in the 1980s. From the late 1980s, Korea also began opening up the financial market. The poor coordination of the liberalization process led to the financial crisis in 1997 (OECD 2000: 28). Over the last five years, there has been a major change in policies as a result of the financial crisis. This financial crisis led the government to focus on economic reform. The reform of the economic system aimed at transparent accountability of economic actors on the basis of market mechanism, to comply with the 'global' standard.

[12] Korea International Trade Association (2001).

Korea, as a catching up country, has been aggressive at utilizing the global opportunities arising from technical change. As Perez and Soete (1988) and Freeman (1989; 1995) discussed, Korea utilized the technological opportunities of new industries in the new technological paradigm: electronics and information industries. These industries are one of the most globalized industries in production, R&D and marketing. These industries have provided technological opportunities of catching up through stage-skipping and leapfrogging pattern of catching up (Lee and Lim, 2001). After the financial crisis, the government's investment in the information infrastructure and the information industry in parallel with supporting policies for venture businesses enabled Korea to be better placed to utilize emerging technological opportunities.

In terms of global R&D activities, Korea's first foreign R&D research institutes were established at the end of the 1980s. According to MOST (2001), these research institutes of foreign branches of Korean firms and joint ventures number 83. The research institutes originally led by the large firms in the 1980s were extended to the smaller firms in the 1990s. However, this increased number and scope of institutes is not necessarily an indication of the increased importance of foreign R&D activities. According to a recent report based on USPTO[13] data, the share of non-Korean resident in patents registered by Koreans remains stable at around 1- 4% range.

With the major increase in the inflow of foreign capital after the financial crisis, R&D activities by foreign firms have increased. According to KITA (2002, 13), half of 122 R&D centers of companies invested by foreigners in Korea were established after 1997. Half of the new R&D centers were those in electrical & electronics industry. One of the processes of R&D in which Korea is known to be weak is collaboration and cooperation in R&D activities between Korean and foreign researchers. Korea has a poor record in co-authorship of scientific articles and co-invention of patents compared to other advanced countries (Suh 2000: 46)

For production abroad, Korean large firms have been driving investment in foreign countries both advanced and developing countries in the 1980s and 1990s. Some Korean small firms have relocated their manufacturing base to developing countries. These investments were either for foreign markets or for global outsourcing for domestic market.

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[13] The US Patent Office

Korea has been utilizing opportunities from the global sourcing trend. In 1980 and the early 1990s, Korean large firms exported their products through OEM. In the 1990s, domestic large and small firms participated in OEM[14] and ODM[15] production for their export.

7. The functionality and performance of the NSI

<Table4> Indicators of technological performance (1999)

Country	R&D as a% of GDP, 1999	R&D as a% of OECD gross expenditure on R&D, 1999	Business R&D as a % of total R&D,1999	Researchers per 10000 labour force 1998	S&T articles per unit of GDP, 1995-97	External patent per million USD of GERD 1997	Productivity1999 US=100[1]
United states	2.8	43.7	68.5	74	23	7.5	100
Japan	3.1	17.8	72.6	96	16	4.2	74
Germany	2.3	8.3	61.7	60	22	10.4	94
Italy	1.1	2.4	43.9	32	15	7.2	106
United Kingdom	1.8	4.5	47.3	55	36	14.1	87
Canada	1.6	2.4	49.2	56	33	7.9	84
Australia	1.6	1.4	47.5	67	32	9.8	84
Austria	1.6	0.6	52.1	34	20	8.8	.....
Korea	2.5	3.3	72.5	48	7	1.9	40
Netherlands	2.0	1.5	45.6	50	35	14.5	109
Switzerland	2.7	1.0	67.5	55	40	15.1	91

Note: 1. GDP per hour workload
Source : OECD (2000) OECD (2001)

As one of the performance indicators of NSI, efficiency of R&D investment should be discussed. Korean R&D efficiency is low in comparison with other advanced economies From table 4 it can be seen that for scientific articles per unit of GDP and external patents per million USD of GERD 1997 and also for productivity Korea ranks lowest among the countries included in the table. According to a survey, the propensity to produce innovations is also relatively low in Korea (see Table 6). All of these are in contrast with the input indicators such as the size volume of R&D expenditures and intensity of population of researchers[16] which are comparable to those of the OECD

[14] Original Equipment Manufacture

[15] Original Development Manufacture

[16] number of researchers per 10,000 labour

countries.

<Table5> Propensity to carry out innovation

Country	Propensity to carry out innovation*
Korea	48.9%**
Netherland	75.4%
Sweden	60.9%
Finland	54.2%
Germany	78.9%
France	50.7%
UK	60.1%

Note: * Share of firms that introduced new or technologically improved product or processes on the market 1994-96 in manufacturing
**Korean data : *1996-1997*
Source: OECD (2001, 174) Yoon and Jang (2000, 34)

However, the Korean NSI has been producing dynamic performance. For example, the share of Korean's patent registered in the US rose dramatically as have been discussed in section 3. Technology exports rose faster than technology imports between 1991-1999.[17]

In terms of the functionality of the NSI, linkages among actors can be discussed. The empirical data on the overall pattern of linkages among actors are not yet available. Dominant linkages among firms before the financial crisis were those between chaebol affiliated large firms and subcontracting small firms. Since the financial crisis, the dominant linkages are those between large firms (chaebol affiliated or non-chaebol affiliated) and subcontracting small firms, and horizontal linkages between NTBFs. Linkages between university and industry are being developed as the R&D function of universities are strengthened. Linkages between GRIs and industry, used to be active, are active. There are also satellite linkages between spin-offs and parent organizations. During the financial crisis, the restructuring of large firms and GRIs resulted in employees being laid off or resigning, some of whom went on to establish spin-off companies. These spin off companies take part in the subcontracted production and R&D process for parent organization. These spin-off organizations contribute to improving the efficiency of the parent organizations.

[17] The ratio of technology export to technology imports rose from 3.0% in 1991 to 7.2% in 1999 (Web site of Korea Industrial Technology Association [http://kita.technet.or.kr])

8. Strengths and weaknesses of the NSI

The strength of Korean NSI is presence of large firms. In the 1990s, some of the large firms in Korea, for example, Samsung Electronics and LG Electronics, became major players in the world market. Korea has a strong manufacturing base in automobiles, shipbuilding, machinery, electronics, all of which are led by large firms. These large firms should be able to react to the challenges of a global environment.

Another strength of the Korean NSI is heavy investment in the IT infrastructure as discussed in section 3. The IT infrastructure provides a positive environment for internet businesses and innovative transformation of service sectors. An advanced IT infrastructure also facilitates information channeling and access to sources of knowledge.

Capability for rapid commercialization in a fast growing new industries such as electronics and IT industry is a strong advantage. Albert (1998) argues that Korean and Taiwanese patents demonstrate the fastest speed at which recently-emerged technology was utilized for commercial purposes, compared with other advanced countries.

The GRIs with accumulated R&D experience could be a source of strength. Korea has 178 government research institutes and national and public testing (experimental) institutes (Lee 1997: 619) which are being transformed to efficient operation under the supervision of the Research Councils. If this transformation process continues to be successful, the GRIs will provide strong knowledge infrastructure for industry.

Korea has a highly educated, even overqualified, population. The number of people with higher degrees in science and engineering are 163 per 100 thousand population. This is higher than Japan (84) and the US (94) (Lee 1998: 619). Many of these people are familiar with IT and therefore could be the basis for a domestic market for IT related products. They also can be trained to enter the workforce of IT related businesses. As underlined earlier, Koreans are diligent and believe in learning and will be a strength in a future led by knowledge intensive industries.

The weaknesses of the Korean NSI can be seen to be as follows. The corporate sector has not been sufficiently transformed yet. The chaebols have been following the reform plan reluctantly. If the reform plan were to fail, the large firms affiliated to chaebols would continue to be a great burden on the Korean economy.

A chronic weakness of the Korean NSI is the small firms. Although NTBFs are emerging, the smaller firms in general are laggards of the large firms and therefore have difficulty in collaborating with large firms for developing high quality products. They also have difficulty in entering the international market.

The service industry is more important than manufacturing in terms of production in Korea. However, the competitiveness of service sector is low and R&D intensity is low.

As a result of under-investment and inefficiencies in the education system, poor quality of university education is a burden to firms. This undermines the competitiveness of the nation.

Korean government officials are bureaucratic and reluctant to use a variety of channels in order to interact with firms. These officials will find it difficult to find new roles in a government that is a facilitator for firms' business and R&D activities. In addition, the problematic coordination mechanism among ministries causes inefficiency of policy implementation process.

Koreans tend to be 'clannish' and work in closed networks. Informal networks in regions, of alumni of universities, of families are exclusive of other 'clan' networks. This blocks information flow and flexible work organization arrangements.

Korea's hierarchical culture could be a burden on the emerging society. In the digital age, where flexibility of organization and efficient communication are required, a hierarchical culture hinders smooth communication and flexible organizational arrangements.

In spite of the introduction of various measures designed to attract foreign capital, FDI fell in 2001. The business environment is not regarded as stable due to the conditions in North Korea. Unless the threats and uncertainties emanating from North Korea can be eliminated, the NSI in South Korea will find it difficult to attract substantial foreign capital.

The financial system is not sufficiently well developed to channel financial resources to those firms that display good performance because there is a limited pool of accumulated experience on the credibility and performance of firms; the pool of experts knowledgeable about firms' performances and competences is small.

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