Korea's National Innovation System and the Science and Technology Policy

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[Abstract]

Over the past 40 years, Korea has shown a remarkable economic growth with drastic changes of its National Innovation System (NIS). In order to find out how the Korea's NIS has changed according to its industrial development, Korea's National Innovation System is evaluated by analyzing R&D investment, manpower, technological achievement and the individual innovation actors. In addition, the S&T policies of Korea are reviewed. It is argued that the changes in KNIS are in fact evolutionary responses and the outcome of Korean government's S&T policies. In the early stage of Korea's development, Korea's Government Research Institutes (KGRIs) led the development of Korea's science and technologies, but gradually the private companies began to take the leading role in the development. Recently, as the economy grew and industries were developed, the lack of basic technology became the weak point of Korea's NIS. Realizing this, the government again takes new initiatives in basic S&T and selected ten strategic technology areas to prepare for the next 10 years. In addition, new S&T administrative system was set up to coordinate overall national S&T policy, investment and evaluation. Korean case imply that the government of developing countries should make every effort to make appropriate NIS according to the development status of its own economy, society and culture.

I. Introduction

1. Background of Research

Korea is a country, which does not have enough natural resources. In addition, it has experienced really difficult times recently such as Korean War and Japanese colonization in recent history. However, Korea has achieved high economic growth over the past four decades. The annual real GDP growth averaged 7 percent or more during 1962-1994 and exports have increased from 2 billion dollars in 1960 to 557 billion dollars in 1996.[5] In 1997, with the Asian financial economic crisis, the GDP growth rate showed first minus 6.7 percent. But the economy has recovered rapidly to the previous level (over $10,000 of GDP per capita) for the following

6 years (see Table 1).

<Table 1 > Major economic indicators

	1960	1970	1980	1990	1996	1998	2003
Population (thousand)	25,012	32,241	38,124	42,869	45,526	46,287	47,925
GDP ($ billions)	2	8	62	253	557.4	346.1	605.7
Growth rate of GDP (%)	2.2	17.2	21.8	20.6	6.8	- 6.7	3.1
GDP/per Capita ($)	80	248	1,632	5,900	12,243	7,477	12,638
Balance of payment in trade($ mill)	-65	-597	-4,384	-2,004	-20,624	39,031	14,991
Export ($ mil)	32	660	17,214	63,124	129,715	132,313	193,817
Import ($ mill)	97	1,256	21,598	65,127	150,339	93,282	178,827

Sources: Choi (2003) for the period of 1960 to 1990, MOFE (2004) and NSO (2004) for 1996 to 2003.

In 2003, Korea was ranked 37th in overall performance among 60 countries and regional economies with GDP per capita of 12,638 and total GDP $ 605.7 billion in 2003. The development of Science and Technology is also remarkable. In 2004, Korea was ranked first in the information technology infrastructure such as broadband subscription rate and third in S&T achievement index that indicates patent productivity and patents granted to residents. In was also ranked eighth in technological infrastructure competitiveness performance among 60 countries and regional economies.[3]

There has been much debate that Korea would experience difficulties in further growth because of its structural and inherent problems such as Chaebol companies and technological gaps. However, it seems that Korea is moving forward whilst other Asian countries are showing stagnant growth rate. How has Korea achieved such a growth in only four decades? Although there can be various factors for Korea's growth, many researchers have pointed out Korea's strong National Innovation System (NIS) as one of the development and growth factors.[13] It is argued that private industries and Government-sponsored Research Institutes (GRIs) have played critical roles in Korea's NIS and contributed to the economic development.[15] , [16]

In order to understand the development of Korea's National Innovation System (NIS), it is required to understand the basic socio-economic environment. Then, the NIS can be analyzed in the perspective of actors, input, throughput, output and policies. The role of the actors and their relationship can be known well by analyzing the R&D expenditure. For instance, the amount of R&D expenditure by each actor and the flow of R&D expenditure between actors show the characteristics of NIS. Then, the S&T manpower needs to be evaluated to understand the base of NIS. The final output can be measured in terms of economic growth as well as specific technological achievements. In addition, it is necessary to review the industrial policy as well as the development of NIS.

2. Theoretical perspectives: National Innovation System

It is quite clear that National Innovation System (NIS) plays important role in the development of national economy. The outstanding feature of NIS concept is that it deals with system itself rather than individual innovation actors. However, it is also true that the NIS concept is rather vague and has some difficulties to use in real policy making. In this context, NIS concept is revisited and the changing roles of individual innovation actors are reviewed.

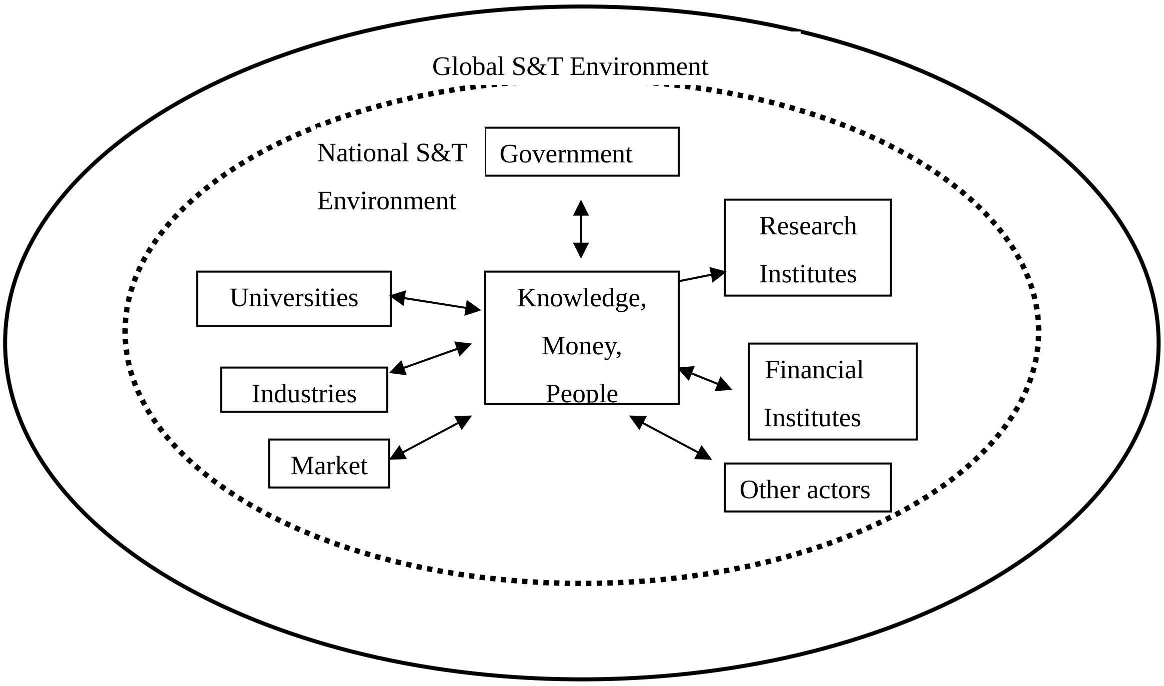
2.1 Innovation system and knowledge cluster

Like other things in the nature, science and technology policies have been evolving through the times. In the past days, the policy-makers gave their attentions to the issues such as technology-push model, demand-pull model, university-industry cooperation, and so on. The theoretical perspectives of those models were rather simple ones compared to recent theories. Nowadays, the science and technology are understood in the context of innovation system, which means that there are many related actors and the development and utilization of science and technology take place through complex processes. The research at R&D laboratory does not lead to market automatically. To utilize the research results, we need more actors like technology transfer center, venture capital, bank, managerial consulting company, entrepreneur, and so on.

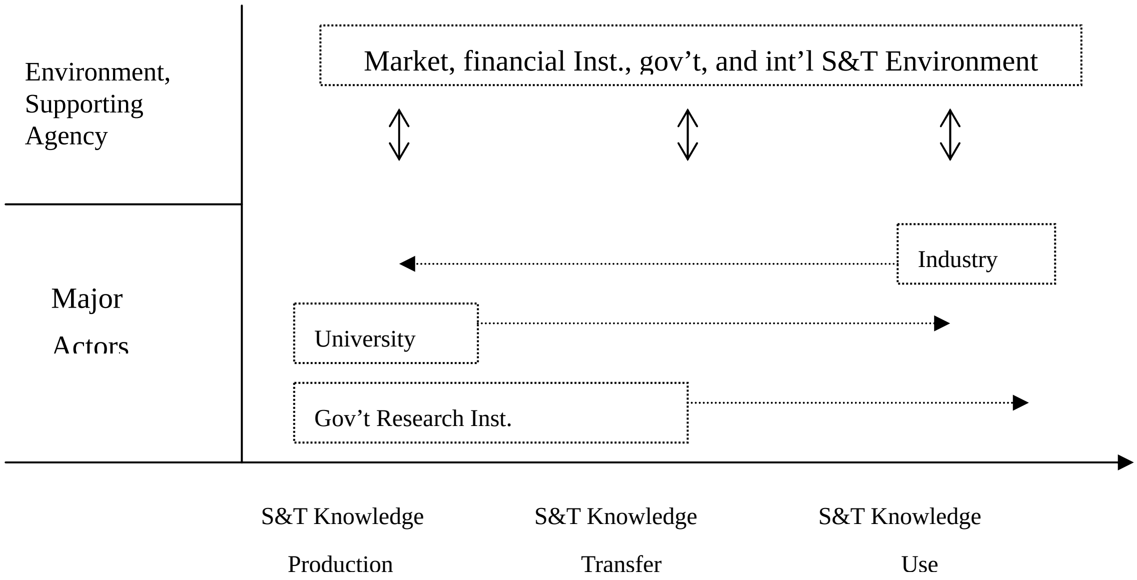
In 1990s, the theory of National Innovation System (NIS) attracted the attention of many policy-makers. The NIS model started to focus more on relationships and processes between various innovation actors. In the meantime, the globalization and regionalization of S&T has emerged as a big agenda in S&T policies as well. In addition, many people from various backgrounds started to study the innovation cluster. Not only the researchers in S&T policy but also in Economic Geography, Urban Planning, and Sociology adopted the perspective of innovation cluster. For example, Saxenian (1994, 1999) compared the Silicon Valley with Route 128 area and concluded that the culture and organizational network in the Silicon Valley is the most important factors for its prosperity.

While the NIS model is a rather abstract concept, the innovation cluster model can give practical guidelines. It is important to note that the innovation takes place around a certain area under the interaction between market and innovation actors. In this sense, innovation cluster can be said a reduced National Innovation System. The innovation cluster theory includes multi-disciplinary perspectives from sociology, economic geography, network theory, and industrial organization theory and it can be applied regardless of area. This systematic perspective implies that policy makers should emphasize not only the quantitative aspect of S&T policy such as S&T investment, number of R&D personnel, but also the management of S&T resources.

<Figure 1> National innovation system



<Figure 2> The extended roles of the actors in national innovation system



In order to have a practical implication from the theories of national innovation system and innovation cluster, it is necessary to define the innovation actors according to their generic roles in system. The main elements in innovation cluster or system are Knowledge, Money, and People. The main activities are knowledge creation, transferring and utilization in the market. For this purpose, all the innovation actors interact with each other and exchange knowledge, financial and human resources. In traditional S&T policy, university is regarded as the actor that produces scientific knowledge only. However, there are many universities, which also make some business out of its research. We can see that the industries and GRIs also extend their roles. In addition, the financial institutes, consulting companies are becoming very critical agencies for the commercialisation of R&D.

II. Innovation Actors and Technological Achievements

1. R&D Expenditure

As mentioned before, the interaction among innovation actors in NIS can be shown well by analyzing the R&D expenditure.

1.1 Total R&D Expenditure

First of all., Korea is constantly increasing its R&D expenditure over the years. According to the survey '2004 R&D activities in the fields of Science and Technology' [9], the total R&D expenditure in the field of science and technology for the year 2003 in Korea was 19,687.0 billion won. R&D expenditure as a percentage of Gross Domestic Product was 2.64 percent, which is an increase of 0.11 percent from the last year. As shown on <Table 2> the trend of R&D expenditure in Korea, the R&D expenditure has been constantly increasing, and the ratio of the R&D expenditure to GDP has been continuously increasing as well. As shown in <Table 3>, the R&D expenditure in Korea shows 1/10 of the U.S., 1/4 of Japan, 1/2 of Germany, but the ratio of R&D to GDP shows 2.64 percent, which is higher than other major countries. (Note: Average of R&D expenditure of OECD countries is 2.26 percent)

<Table 2> Total R&D expenditure/ratio to GDP

(Unit : thousand dollar, %)

Year	R&D Expenditure	Ratio to GDP
1970	105	0.39
1975	427	0.42
1980	2,117	0.56
1985	11,552	1.52
1990	33,499	1.87
1994	100,098	2.44
1995	121,861	2.37
1996	128,857	2.42
1997	86,107	2.48
1998	93,862	2.34
1999	104,084	2.25
2000	109,935	2.39
2001	121,488	2.59
2002	144,328	2.53
2003	159,198	2.64 [p)]

Note) [p)] means provisional
Sources: MINISTRY OF SCIENCE AND TECHNOLOGY & KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY EVALUATION AND PLANNING (2004)

<Table 3> R&D expenditure in major countries

	R&D expenditure (Million PPP dollar)	R&D expenditure based on the figure '1'of Korea	Ratio to GDP (%)	R&D expenditure per one person (PPP dollar)
Korea (2003)	25,999.7	1.00	2.64	542.8
U.S.A. (2003)	284,584.3	10.95	2.62	964.0
Japan (2002)	106,838.2	4.11	3.12	838.4
Germany (2003)	54,283.6	2.09	2.50	657.8
France (2002)	36,618.0	1.41	2.20	598.0
U.K. (2002)	31,037.4	1.19	1.88	524.2
Finland (2002)	4,761.1	0.18	3.46	915.4
China (2002)	72,014.4	2.77	1.23	55.6

Sources: OECD, Main Science and Technology Indicators, 2004/1

1.2. The Flow of R&D Expenditure

Like many other countries, the major players are central/local governments, public research organizations, universities and industries. As shown in <Table 4>, the government and the public sector provided 24.5 percent of total R&D expenditure whereas private sector and foreign sector did 75.1 percent and 0.4 percent respectively. It is interesting to see the shares of government and public R&D expenditure in advanced countries were higher than that of Korea. The ratio of foreign source of funds in Korea was 0.4 percent which is very lower level than that of France (7.2%), U.K.(20.5%) showing similar size of R&D expenditure.

<Table 4> R&D expenditure by source of funds

(Unit: Thousand dollar, %)

	1996	1997	1998	1999	2000	2001	2002	2003
o Total	128,857	86,107	93,862	104,084	109,935	121,488	144,328	159,198
o Government &Public	28,402	20,143	25,267	27,965	27,402	31,577	37,891	38,931
- growth rate	34.7%	18.9%	7.1%	5.0%	7.8%	21.3%	8.6%	2.5%
o Private	100,293	65,880	68,525	76,058	82,458	89,340	105,801	119,608
- growth rate	10.5%	10.1%	-11.2%	5.3%	19.2%	`14.1%	7.2%	12.8%
o Foreign	161	83	70	61	75	571	636	659
o Government: Private	22:78	23:77	27:73	27:73	25:75	26:74	26:74	25:75

Sources: MINISTRY OF SCIENCE AND TECHNOLOGY & KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY EVALUATION AND PLANNING (2004)

<Table 5> R&D Expenditure by source of funds in major countries

(Unit : %)

	Korea (2003)	U.S.A. (2003)	Japan (2002)	Germany (2003)	France (2001)	U.K. (2002)
Gov & Pub	24.5	36.9	25.8	32.5	38.6	32.8
Private	75.1	63.1	73.9	65.1	54.2	46.7
Foreign	0.4	0.0	0.4	2.4	7.2	20.5

Sources: OECD, Main Science and Technology Indicators, 2004/1

<Table 6> shows detailed figure of R&D expenditure among the actors. Public research institutes receive R&D funds mostly from the government and public sectors and private companies do from themselves. The universities receive some R&D funds from private sources though. The R&D expenditure flow indicates that there is not strong relationship between private and public sectors and also with foreign countries. Especially the government supported research institutes are less active in partnership with private sectors than universities.

<Table 6> the flow of R&D expenditure

(Unit: thousand dollar)

Source \ Use		**Public research institutes**			**Universities**		Companies		
		Gov. Public Institute	Gov. supported research institute	other non-profit institute	National public univ.	Private univ.	Gov. -invested company	Private company	Total
Gov & Pub	Gov.	412,857	1,653,956	115,108	553,309	626,706	83,281	470,609	3,915,828
		98.3%	88.0%	53.3%	73.0%	57.3%	14.6%	3.5%	21.4%
	Gov. Supported research institute	6,258	96,289	12,065	66,817	74,909	2,275	183,610	442,223
		1.5%	5.1%	5.6%	8.8%	6.8%	-	1.4%	2.4%
	Non-profit institute	-	3,699	24,123	8,908	20,466	276	10,037	67,510
		0.0%	0.2%	11.2%	1.2%	1.9%	0.0%	0.1%	0.4%
	National public univ.	33	309	29	34,281	5,688	-	1,666	42,005
		0.0%	0.0%	0.0%	4.5%	0.5%	0.0%	0.0%	0.2%
Private	Private univ.	-	193	251	2,051	199,380	55	2,114	204,044
		0.0%	0.0%	0.1%	0.3%	18.2%	0.0%	0.0%	1.1%
	Gov.-invested institute	80	20,674	80	4,822	17,095	26,021	8,126	76,899
		0.0%	1.1%	0.0%	0.6%	1.6%	4.5%	0.1%	0.4%
	Private company	683	104,024	64,159	85,360	144,020	460,000	12,586,219	13,444,464
		0.2%	5.5%	29.7%	11.3%	13.2%	80.4%	94.4%	73.6%
For	Foreign	-	1,244	34	2,274	5,477	96	66,422	75,549
		0.0%	0.1%	0.0%	0.3%	0.5%	0.0%	0.5%	0.4%
Total		419,910	1,880,388	215,850	757,824	1,093,740	572,004	13,328,803	18,268,521
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

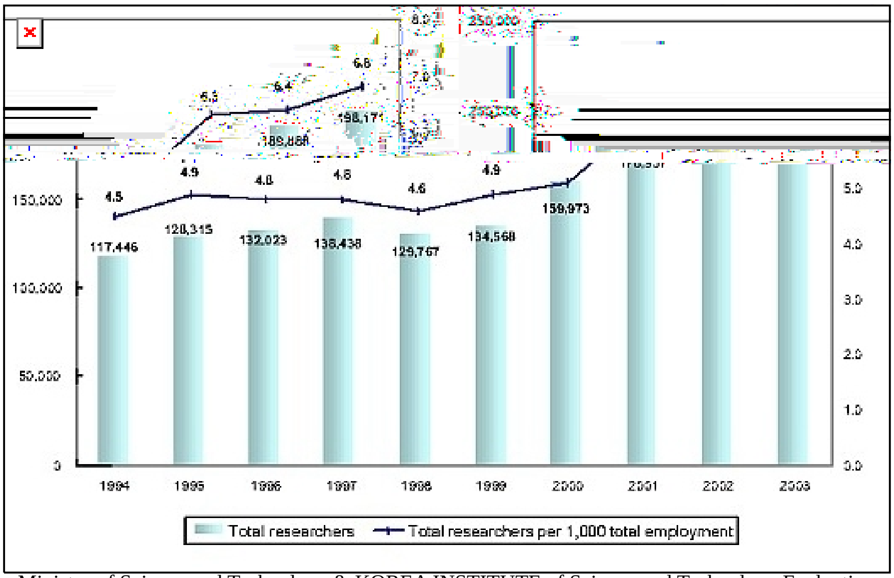
Sources: MINISTRY OF SCIENCE AND TECHNOLOGY & KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY EVALUATION AND PLANNING (2004)

2. R&D Personnel

2.1 Total Number of R&D Personnel

In year 2003, 297,060 people have engaged in R&D activities (researchers, research assistants, other supporting personnel), which represents a 6.2 percent increase from the previous year figure. Among the total research personnel, the number of researcher was 198,171, showing a 4.4percent percent increase from the previous year. Accordingly, the number of researchers is 6.8 people per 1,000 total employments. <Figure 1> illustrates the total number of R&D personnel and the number of researchers per 1,000 total employments in major countries.

<Figure 3> Number of researchers



Sources: Ministry of Science and Technology & KOREA INSTITUTE of Science and Technology Evaluation and Planning (2004)

As shown in <Table 7>, the R&D expenditure per one researcher (171,900 dollars) was lower than those of other advanced countries.

<Table 7> R&D expenditure per one researcher in major countries

	R&D expenditure (million PPP dollar)	R&D expenditure based on the figure '1' of Korea	Ratio to GDP (%)	R&D expenditure per one person (PPP dollar)
Korea (2003)	25,999.7	1.00	2.64	542.8
U.S.A. (2003)	284,584.3	10.95	2.62	964.0
Japan (2002)	106,838.2	4.11	3.12	838.4
Germany (2003)	54,283.6	2.09	2.50	657.8
France (2002)	36,618.0	1.41	2.20	598.0
U.K. (2002)	31,037.4	1.19	1.88	524.2
Finland (2002)	4,761.1	0.18	3.46	915.4
China (2002)	72,014.4	2.77	1.23	55.6

Source: OECD, Main Science and Technology Indicators, 2004/1

2.2 The Number of Researchers by Sectors

Of the total number of researchers (198,171 people), 124,030 people, which accounts for 62.7 percent of the total, were employed in the companies. A total of 59,746 people corresponding to 30.1percent of the total, worked in the universities, and 14,395 researchers (7.3percent) were from public research institutes. The growth rate of the number of researchers in the companies was increased by 5.1 percent over the last year, which presents higher growth rate than total growth rate of the number of researchers, 4.4percent. On the other hand, the growth rate of the number of researchers in the public research institutes and universities remained as 2.1 percent and 3.7 percent.

As <Table 8> shows, the number of researcher rate in companies was decreased to 50.9 percent in 1998 due to the impact of Asian financial economic crisis, but has been increasing since 1998. On the other hand, the number of researchers, and growth rate of the number of researchers in the public research institutes and universities is decreasing now.

<Table 8> Trend of number of researchers by sector of performance

(Unit : No. of people, %)

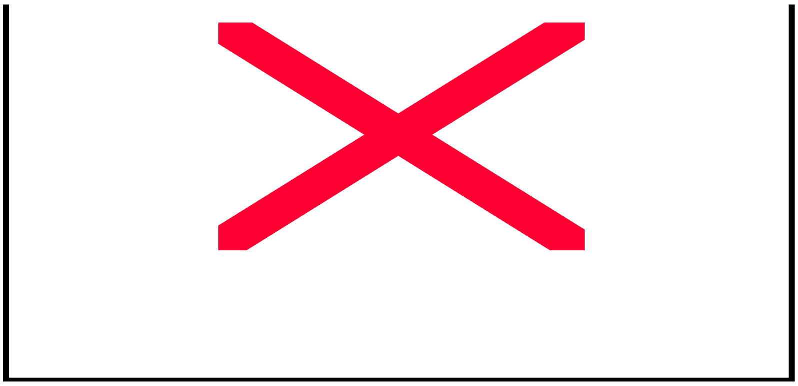
	Total			Pub. Research Institute			Universities			Companies		
	researcher	ratio	growth rate	researcher	ratio	growth rate	researcher	ratio	growth rate	researcher	ratio	growth rate
1994	117,446	100	18.9	15,465	13.1	-4.8	42,700	36.4	49.2	59281	50.5	9.6
1995	128,315	100	9.3	15,007	11.7	-3.0	44,683	34.8	4.6	68625	53.5	15.8
1996	132,023	100	2.9	15,503	11.7	3.3	45,327	34.3	1.4	71193	54.0	3.7
1997	138,438	100	4.5	15,185	11.0	-2.2	48,588	35.1	7.2	74665	53.9	4.9
1998	129,767	100	-6.3	12,587	9.7	-17.1	51,162	39.4	5.3	66018	50.9	-11.6
1999	134,568	100	3.7	13,986	10.4	11.1	50,151	37.3	-2.0	70431	52.3	6.7
2000	159,973	100	18.9	13,913	8.7	-0.5	51,727	32.3	3.1	94333	59.0	33.9
2001	178,937	100	11.9	13,921	7.8	0.1	53,717	30.0	3.8	111299	62.2	18.0
2002	189,888	100	6.1	14,094	7.4	1.2	57,634	30.4	7.3	118160	62.2	6.2
2003	198,171	100	4.4	14,395	7.3	2.1	59,746	30.1	3.7	124030	62.7	5.1

Sources: MINISTRY OF SCIENCE AND TECHNOLOGY & KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY EVALUATION AND PLANNING (2004)

2.3 The Number of Researchers by Degree

Researchers are classified by degree; the number of people who received doctorate degree amounts to 52,595, making an increase of 5.9 percent (2,928 people), master's degree 67,695, increasing by 5.6 percent (3,574 people), and bachelor's degree 69, 892, raising by 3.4 percent (2,280 people). The composition of the researchers by degree is as follows: doctorate 26.5percent, master's 34.2percent, bachelor's 35.3percent, and other 4.0 percent. <Figure 4> shows the distribution of researchers by degree. The difference of researchers' degrees by sector of R&D performance is remarkable. For example, of the total number of researchers with doctorates, 72.1 percent (37,928 people) was affiliated to the academic sector, whereas 96.8 percent (67,671 people) of the researchers with bachelor's degrees worked in the companies.

<Figure 4> Distribution of researchers by degrees



Sources: MINISTRY OF SCIENCE AND TECHNOLOGY & KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY EVALUATION AND PLANNING (2004)

3. Technological Achievements

The number of patent registrations has grown rapidly too. Korea was ranked 4th in the world in the number of patents and utility models applied in 1997 inventing 175,791 items that account for 3.7 percent of the world total. In addition, as <Table 9> shows, the number of patents by Koreans is consistently increasing. In 2003, the patents by Koreans reached to 22,943 of all patents accounting for 65.6 percent.

<Table 9> Number of patents in Korea

	1981	1985	1990	1995	2000
Total Patents (T)	1,808	2,268	7,762	12,512	34,956
Patents by Koreans (K)	231	349	2,554	6,575	22,943
K/T (%)	12.8	15.4	32.9	52.5	65.6

Sources: Korean Intellectual Property Office

The number of industrial property granted is also increasing rapidly and shown on <Table 10>

<Table 10> Industrial Property Granted in Selected Countries

(Unit: Cases)

	1994	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Korea	58,604	67,444	72,363	105,409	163,150	148,107	126,395
U.S.	176,674	198,688	214,770	261,553	292,158	255,650	284,454
Japan	318,424	352,864	524,327	488,484	345,291	337,056	274,646
China	101,598	136,930	165,255	268,597	166,853	214,715	258,313
Germany	181,332	155,284	184,499	205,868	191,155	215,358	202,606
France	168,966	169,367	120,337	181,031	129,891	133,366	122,480
U.K.	85,861	90,130	110,775	103,381	100,292	101,779	107,754
Spain	90,088	95,481	106,672	85,930	84,577	89,352	91,652
Argentina	52,417	38,475	40,637	32,561	64,613	55,879	48,239
Russia	34,742	46,944	42,603	50,823	45,564	43,993	45,455

Sources: Korea National Statistical Office, Intellectual Property Rights Annual Report, 2004

<Table 11> Korea's Share of Patents in U.S.

(Unit: Number of Registration, %)

		1994	1997	2000	2001	2002	2003
Total number of patents (A)		101,676	111,984	157,494	166,037	167,333	169,028
Patents by Korea (B)		943	1,891	3,314	3,538	3,786	3,944
	Rank	10	6	5	5	5	5
B/A (%)		0.93	1.69	2.10	2.13	2.26	2.33
Technology Strength Index		9	8	8	8	8	8

The patents registered in U.S. gives the clue for one country's industrial and technological competitiveness. Korea has jumped from 943 registrations in 1994 to 3,944 in 2003 and ranked 5th in the world. The share of Korea's registration has been steadily growing. The technology strength[1] index shows Korea is 8th country in the world.

[1] This index is developed by MIT based on the number and current impact index of patents to measure corporate technology competitiveness, and used by Korea Institute of Industrial Technology Evaluation and Planning (ITEP)

For the high-tech products, Korea is exporting more than it import, which indicates that the industrial structure of Korea is in the changing process into high-tech industries (<Table 12>). However, it is also worthy to note that Korea has been paying more royalty than it receives (<Table 13>).

<Table 12> Share of High-tech Products in Export/Import

Unit: US Dollar	2000	2001	2002	2003(Jan-June)
Export of high-tech products (A)	40,300,000,000	28,300,000,000	32,700,000,000	16,900,000,000
Total Export (B)	172,268,510,000	150,439,144,000	162,470,528,000	89,088,937,000
A/B (%)	23.39	18.81	20.13	18.97
Import of high-tech products (C)	29,600,000,000	22,700,000,000	24,500,000,000	13,600,000,000
Total Import (D)	160,481,018,000	141,097,821,000	152,126,153,000	85,933,988,000
C/D (%)	18.44	16.09	16.11	15.83

Sources: Korea International Trade Association, Weekly Trade Review No.67, July 2003

<Table 13> Korea's Technology Balance of Payment

(Unit: %, 100 mil $)

Year	Receipts	Payments	Ratio
1978	0.003	0.0851	0.00
1979	0.019	0.939	0.02
1980	0.060	1.072	0.06
1981	0.118	1.071	0.11
1982	0.182	1.157	0.16
1983	0.169	1.495	0.11
1984	0.168	2.132	0.08
1985	0.113	2.955	0.04
1986	0.092	4.110	0.02
1987	0.091	5.237	0.02
1988	0.089	6.763	0.01
1989	0.105	8.886	0.01
1990	0.218	10.876	0.02
1991	0.352	11.838	0.03
1992	0.325	8.506	0.04
1993	0.451	9.464	0.05
1994	1.109	12.766	0.09
1995	1.124	19.470	0.06
1996	1.085	22.972	0.05
1997	1.629	24.147	0.07
1998	1.409	23.865	0.06
1999	1.933	26.858	0.07
2000	2.010	30.628	0.07
2001	6.191	26.427	0.23
2002	6.381	27.215	0.23

`Sources: Report on the Survey of Research and Development in Science and Technology, 2004, Ministry of Science and Technology Republic of Korea, Korea Institute of S&T Evaluation and Planning

III. Major S&T Policies and R&D Program

1. Establishment of Government Research Institutes

In early 1960s, Koreas started its first modern R&D activity by establishing the government research institutes. From 1970s to 1980s, Korea had a remarkable growth in its GDP, which increased from a mere 8 billion dollars in 1960s to 62 billion dollars in 1980 and to 253 billion dollars in 1990. During that time, industries have grown so fast and increased their R&D investment with the establishment of its own R&D laboratories. Universities also began to play an essential role in providing high caliber human resources.[5]

After the late 1980s, the growing R&D activities in industrial firms and universities have led many scholars and policy makers to point out the relative inefficiency of Government sponsored Research Institutes (GRIs) and raised a question over their ineffectiveness in industrial technology development. For example, the government made an R&D investment of 207 million dollars for the period of 1982-1990 on 2,400 projects that were mainly proposed and carried out by GRIs. While the government jointly funded 30.9 percent of the projects and industries were successfully commercialized, only 4.1 percent of government-funded projects went to market successfully. The major criticisms on the GRIs at that time were duplication of research, poor R&D project management, and low R&D productivity.[6] These problems were mainly attributed to the lack of consensus on their institutional missions among the related government authorities and top managers of GRIs, excessive monitoring and controlling by the government, and the government's unstable budgetary support.

As the first step of dealing with these problems, the government changed its research funding system from the lump-sum system to Project Based System (PBS) in order to enhance research productivity in 1996. Before the introduction of PBS, manpower costs of researchers of GRIs were supported from the governmental budget and GRIs charged only direct research costs to each project. Under the PBS, GRIs have to charge the manpower cost to research project and compete with universities and industries to get contractual. The PBS contributed to diffuse the competitive R&D funding system for creative researchers and the customer relationship and price concept in government R&D.[6] There is also some criticism for the PBS. First, the researchers of GRIs have been forced to shift their research foci from the basic research projects to short-term application oriented projects to make more research contracts and to secure their manpower costs. Second, PBS made more use of cheap temporary researchers at GRIs. Since the research budget is limited, GRIs cannot use the permanent and experienced researchers any more and have to rely on M.A. or Ph.D. students for their research activities. As of 2002, GRIs have the ratio of 50 percent irregular employment, which includes temporarily hired students.[2]

In 1977, as the financial crisis happened in Korea, the government, as a second drastic measure, took a step of changing GRIs' management system in order to deal with the issues of research effectiveness and operational efficiency in the late 1990s. Based on *the Act on the Creation, Operation, and Development of GRIs*, which was enacted in January 1999, a new management system, i.e. Research Council System (RCS), was created on aspects of the German and British system in 1999.[15] That means the status of GRIs under the related ministries were changed under the unified control of Prime Minister's Office; giving freedom GRIs from the excessive control of related ministries. Under the new management system, RCS, five research councils[2] were established. Each research council acts as a supervisory body to oversee its member GRIs.[3] Since its foundation in 1999, it has brought about not a few positive results; giving autonomy in operation, management, decision-making, and organization of GRIs; strengthening each director's leadership through empowering from related research councils; fostering competitive climates among industries, universities, and GRIs by utilizing PBS; improving compensation system with the introduction of annual salary system and performance-based system.[15] But, the RCS still have many defects as well in three aspects: governance structure (RCS itself), budgetary allocation structure, and the internal management within GRIs.[17] Some of the shortcomings are the followings: firstly, in terms of governance structure, excessive influence of the government over the Board of Directors in research council, lack of budgetary allocation power in research councils; secondly, in budgetary allocation structure aspect, introduction of excessive competitive principle by utilizing PBS, unclear allocation criteria of government budget; lastly, lack of autonomy and individuality of directors within GRIs; unstable job security of individual researchers (low job satisfaction and high turnover rate) in the internal management within GRIs aspect.

2. **National R&D Program**

The National R&D was first initiated by the Ministry of Science and Technology in 1982. The program, which aims to strengthen technological capability and competitiveness, has made significant contributions to economic growth as well as the improvement of the quality of life. Now, national R&D efforts are geared toward meeting the challenges in a move to a knowledge-based economy with a view to placing the nation among the ranks of the advanced economies by the early 2010s. In order to accomplish this goal, the government emphasizes efficient use of S&T resources based on the principle of "selection and concentration." The current National R&D Programs include the 21st Century Frontier R&D Program, the Creative Research Initiative (CRI), the National Research Laboratory (NRL), the Biotechnology Development Program, the Nanotechnology Development Program, the Space and Aeronautics Program and so on.

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[2] The five research councils are as follows: 'Korea Research Council of Fundamental Science and Technology'; 'Korea Research Council for Industrial Science and Technology'; 'Korea Research Council for Public Technology'; 'Korea Council of Economic and Social Research Institutes'; and 'Korea Council of Humanities and Social Research Institutes.

[3] The major functions of each research council are: planning, budgeting, and evaluating. That is, the research councils plan the research areas, evaluate the performances, and submit the budgets for the GRIs. In addition, the research councils are given the power to nominate the directors in concerned GRIs and to restructure the GRIs if the performances are not satisfactory.

The 21st Century Frontier R&D Program was launched in 1999 to develop scientific and technological competitiveness in newly emerging areas. The government planed to invest a total of U.S. $ 3.5 billion over a period of ten years in this program that would comprise twenty-three projects in new frontier areas, such as twenty-three projects has already been launched as of September 2003. The most outstanding features of the program are that each project director is given full autonomy in managing the program. The project director is responsible for designing the details of the research projects.

3. Basic Research and High-caliber Manpower

3.1 Basic Research in Korea

Universities in Korea retain 72.6 percent of the research with doctoral degrees, but they do not offer adequate research environments due to insufficient funds, poor research facilities, and excessive teaching-oriented environment. In 2001, only 10.4 percent of the national R&D investments was allocated to universities; whereas, the shares of the government research institutes and private industries were 13.4 percent and 76.2 percent. As basic research is essential to the strengthening of the nation's foundation long-term development, the government plans to increase its investment in basic research up to 25 percent of the government R&D budgets by 2006. The Ministry of Science and Technology and the Ministry of Education & Human Resources (MOE) via their respective agencies, the Korean Science and Engineering Foundation (KOSEF) and the Korea Research Foundation (KRF), mainly sponsor basic research.

In order to promote university research, the government designates university research groups with distinctive research capabilities as centers of excellence (COE). The COE includes Science Research Centers (SRCs), Engineering Research Centers (ERCs) and Regional Research Centers (RRCs). The SRCs and ERCs focus on cooperative research between regional universities and industries.

The SRCs and ERCs are selected on the basis of research capability and performance. In the selection of the RRCs, the capabilities to contribute to the regional economy and community are important factors. Once the centers are selected, they receive government funding for nine years provided that they survive the interim evaluation which is conducted every three years. So far, forty-three SRCs, fifty-seven ERCs, and fifty-four RRCs have been selected and funded.

In 1996, the government created the KOREA INSTITUTE for Advanced Study (KIAS) as a world-class institution for basic research. The Asia-Pacific Center for Theoretical Physics was also established in 1997 as a regional center for basic research. To facilitate basic research, the government also provided universities with modern research facilities through the Korea Basic Science Institute (KBSI), which maintain more than 300 sets of research equipment for joint use among universities.

3.2 High-caliber Manpower

Scientists and engineers are the main players in the advancement of science and technology. In order to foster scientists and engineers of top quality, it is critical to develop a system of advanced education that can nurture the creativity of the nation's youths. Therefore, the top policy task of Korea is to transform the current teaching-oriented universities into research-oriented universities. To stimulate such a transformation, the government is providing financial support to those universities with excellent research performance.

Many of the major universities in Korea have responded to the government policy by preparing and launching various reform programs that are anticipated to bring about drastic changes in university education in Korea. Those changes include changes in admission processes, undergraduate curricula, graduate programs, and so on.

The Korean Advanced Institute of Science and Technology (KAIST) serves as a good example of a model for the research-oriented university that Korea pursues. The Korean Government established KAIST in 1971 in order to generate world-top quality engineers. Since its inception, KAIST has been received preferential funding from the government, and on that basis, it has been able to recruit the nation's best students. No less important, however, is its research performance record, which attracts abundant industrial research funds. Good students and good research programs have made KAIST what it is today. Thus far, produced 26,707 graduates, of who 5,380 received Ph. D degrees. KAIST also established "the Graduate School of Management," whose roles and activities are to bring up technology executive officers. Modeled after KAIST, the government founded Gwangju Institute of Science and Technology (GIST) in 1995, which currently has an enrollment of 800 students. GIST has produced 1,130 graduates, of whom 121 received Ph. D degrees. Likewise, the Pohang University of Science and Technology (POSTECH) represents the first private sector initiative of its kind in Korea.

In short, in the early stage of industrialization there was an increasing demand for engineers outpaced the expansion of university capacities, so the focus of S&T education was more on "quantity" However, policy priority is now fast moving toward "quality" in response to the emergence of the information-based economy.

4. International S&T Cooperation

Since Korea started without modern technological base, Korea has to seek foreign technological sources. Therefore, the main purpose of Korea's international S&T cooperation was to acquire the foreign technologies and get the technical training. However, as the economy grows, Korea also tries to contribute to international scientific advancement as well. It is actively promoting both bilateral and multilateral cooperation with foreign countries and international organizations.

The International Joint Research Program, first launched in 1985, has served as a major financial source for international joint research based on bilateral, intergovernmental and inter-institutional agreements. Thus far, the program has funded 1,896 joints projects. The international joint projects have been small in scale, and have been used more as a means to facilitate international scientific exchanges as projects research and development. The international joint research projects have also been very concentrated on a limited number of countries, such as Japan, U.S.A., Germany, France, Russia, China and the U.K. The program is now being restructured so it can facilitate bona fide international joint R&D.

Multilateral Cooperation as a responsible member of the international community, Korea is committed to joining international efforts for the advancement of science and technology and to solve the issues of global concern, such as climate change, global warming, and acid rain. At the governmental level, Korea has been participating actively in international S&T activities of multilateral and regional organization, especially, the OECD and APEC.

The summit meeting between South and North Korea held in Pyongyang in 2000 has opened a new era for S&T cooperation. The main objective of inter-Korean S&T cooperation is to facilitate co-economic development through an S&T cooperation mechanism. A short-term objective is for South Korea to aid North Korea in helping to resolve such difficulties such as food and energy shortages. For a long-term goal, cooperation will increase economic benefits of S&T capabilities for both Korea. The ministry is now conducting five R&D projects, including the development of super corn, the development of agricultural medicine suitable for North Korean terrain, and joint R&D in computer software, establishing the channel of S&T for systematic and effective implementation.

Regarding the international S&T policies of Korea, there is consensus that Korea is not that much globalized to the extent that its economy is globalized. In this sense, Korean government is trying to hard to make its S&T environment more open to other international S&T community.

IV. Issues and Direction

1. New Trends and Issues in S&T

At the inauguration ceremony in 2003, President Roh declared “Arrival of óatiŸ al RenaÜssance of S&T- riented Society” emphfsizing muilding S&T oriented society.#The key featu es ofUS&T ori¦™t d society are represented 7y eocial, cultzral and economic deÕelbpmeQ5 fuèlled and sus_ainedby creÌtive innovatioó in S&T. HoweÙer, a re7ent survey of orean industries reveals th t 44 p@rcent Of indu)tries ha e "hifted thei production facilitiesÕto fÔreiÈn countries and 33 percen of them have Ãlans to shift in the near future. Sørious problems will be †ncurre% by dbindust ializatôon such as™unemploymÿnt o low skilled worke[s in shor ” term, an a=hars struct‘ral ad¶ustment˙˙inlong te=m.[14] The large compani˜s are al‰o moving into Ýoreign countries not only f*r market, production)but œlso fo² outsourcinÆ R&D activities. MHreo er, ƒhe science, technologyœand œngineering fields are not favo×ite fields for the new ýoung university students. Rqther, business and l$w arx prefeÌred majors ¯or fresh students.

Korea ‘s f ced withÃnew chall‘nges from China. China has been catching up Korea’s industrial\technology very fast. If Korea does not move faster, it would lose the competitiveness Œo other emerging countries. To be ¾eally c eative countryÑ Korea needs more accumulated knowledÀe ,n the area of basic science and fundamental technologies, which requi©e a cuÁulated investment and longer time frame. I{ this situation, Korea needs to upgrade itš national innovation system not only in quantity@but also in quality. For instance, i1 may have t increase —he R&D productivity}of universi½y as well as goíernmen‰al research nstiÛute. It has to attract morÄ peo le to sci˜nce aLd wechnology both dY estically and inteAnationally.

2. ScienŒe and Techno,ogy Po‹icy Directions for the 21st CenturÒ

2.1 Curren chaWges in S&T policy

óhe nœw government - i"augurC ed iì February 200Ð – stresse³ "balancFd nationa‰ dev lopment± and "new «oles of "cience and technologŒ," whi¤h wer/ differentêfrªm th˜ past S&T policy diuectiVn. It aims to meet socletal ònd environmen‰al needs, —nd Tho policy needs to ¤e comp tible with humanity and the natural environment. Korea wishes to play an active role in international efforts to contribute to human welfare through the advancement of science and technology. This is a drastic transition from the past policy of industrialization. In order to achieve this objective, the Ministry of Science and Technology has been seeking to establish a more balanced innovation system that encourages a cooperative and competitive tripartite partnership among industries, academia, and public research organizations. Corresponding to these new national initiatives, National Science & Technology Council (NSTC) revised the Basic Plan and also changed the period over which the plan was to be carried out to 2003-2006. The new government also created the position of Presidential Advisor for Information, Science and Technology Policy, completing the groundwork for building a "science and technology-driven society."

Furthermore, under this new government, GRIs are expected to experience another change in two folds: physical location and governance structure. Firstly, for the physical location aspect, the Korean government is making a grand plan to relocate a total of about 268 public organizations among 344 ones (including GRIs) from the capital area, Seoul to local areas as a part of the administrative capital relocation program to Chungcheong province after 2005. The government plans to foster regional innovation clusters, and, as a result, promote balanced national development by relocating public organizations (including GRIs) to local areas. Therefore, the roles of GRIs for building regional innovation clusters are expected to increase. Secondly, for the governance structure aspect, the problems of RCS' efficiency and effectiveness have been raised since its launch in 1999. The Office of Prime Minister, the upper-level institution of GRIs, is now making research in an effective management structure and desired future roles of GRIs.[12] Consequently, the GRIs are expected to be in a little turmoil in order to take-off in the 21st century.[10]

The year 2004 was marked by efforts to bring about significant changes in Korea's S&T administrative system. The concept of "science and technology" is being expanded and developed into "technological innovation." As part of this strategy, the Minister of Science and Technology has been promoted to the higher rank of Deputy Prime Minister.

In addition, an independent Office of the Ministry for Science and Technology Innovation, headed by a vice-ministerial level official, is to be established within the Ministry of Science and Technology. The head of the Office will also serve as the secretariat to the National Science & Technology Council (NSTC). At the same time, the Science & Engineering Research Society, a group of government-funded research institutes, will be transferred to fall under the umbrella of the NSTC from the Prime Minister’s Office.

Moreover, as the economic volume enlarges and industries develop, the lack of basic technology is becoming a setback for the further advance. Thus the government is now making an investment in basic sectors. In 2004 the Korean government designated ten industries of growth engine; i) biotechnology, drug discovery, organs ii) display iii) intellectual robot iv) semiconductors for the new generation v) batteries for the new generation vi) digital TV, broadcasting vii) mobile communications for the next generations viii) intellectual home network ix) digital contents, software solution x) cars of the future. By concentrating the budget for R&D into several areas, the Korean government is trying to overcome the insufficiency of the budget and to invest in generic technologies.

2.2 The First Five-Year S&T Principal Plan

This plan made the framework for managing S&T development, including measures such as action plan for the S&T investment and national R&D, enhancement of public awareness of S&T, S&T human resource development, promotion of technology transfer and commercialization, and globalization of S&T activities. This plan, which was finalized in December 2001, 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 aims to rank Korea within the top ten S&T powers by the year 2006.

Toward this end, the plan pursues following strategies:

- Invest in S&T development on the principle of "selection and concentration"
- Make the best use of the creativity of scientists and engineers
- Link the domestic innovation system to the global system
- Enhance public understanding of and interests in S&T
- Efficient use of R&D resources

Korean government set up a National Technology Road Map (NTRM), which describes target technologies for development, timetables for development, and their anticipated effects. Approximately 800 experts from industries, academia, and research communities participated in the process of formulating the NTRM. The NTRM will be updated periodically to take into consideration the new changes taking place in science and technology.[8]

2.3 The Revised S&T Basic Plan (2003-2007)

The basic plan was revised with the inauguration of the new government in February 2003. Compared to the original Basic Plan established a year early, the revised plan lays out more broad role and status of S&T, both from a national and community perspectives. Before, the S&T could be meaningful only when it contributes to the development and competitiveness of nation. However, new perspective was introduced and S&T was viewed in broader and societal points. The specific goal is essentially the same, except for the aim that enhancing S&T competitiveness has been readjusted upward to become the world's 8^{th} best by 2007, instead of the world's 10^{th} best by 2006, as originally planned.[10]

The basic policy direction of the revised Basic Plan is as follows: [10]

- Advance the national S&T innovation system
- Select and focus on strategic future S&T areas
- Strengthen future growth engines
- Systemize regional innovation capacity
- Create new jobs matching the demands of a knowledge-based society
- Expand people's participation and spread S&T culture

2.4 The Long-term Vision for Science and Technology Development Toward

The major directions for S&T development set out in Vision 2025 include:

- Shift the national innovation system from government-led to private-led
- Improve the efficiency of national R&D investments
- Align the R&D system to global standards
- Meet the challenges and harvest the opportunities presented by new technologies

In an effort to realize the vision by the year 2025, the Korean government launched the 21st Century Frontier S&D Program and enacted the Science and Technology Framework Law that was put into effect in 1999. Based on this law, the government formulated the Five-Year Science and Technology Plan and National Technology Road Map.[7]

2.5 Regional Science and Technology Plan

Promotion of regional science and technology is essential to the sustainable development of the nation. The government has set up a Five-year Comprehensive Regional Science and Technology Promotion Plan, which consists of followings six programs:

- Development of local competences in strategic technologies
- Creation of regional centers for technological innovation

- Development of local S&T human resources
- Establishment of regional S&T information systems
- Nurturing a culture conducive to S&T innovation
- Increasing R&D investments of local governments

The plan for 2003 focuses on cultivating key technologies for regional industrial development and creating regional clusters of innovations.[8]

V. Summary and Discussion

Over the past 40 years, Korea has shown a remarkable economic growth with drastic changes of its National Innovation System (NIS). The rapid development of industries means rapid changes in National Innovation System (NIS). The dynamics of Korea's NIS were shown by analyzing the S&T policies as well as the information of S&T investment and manpower. It is true that Korea's policy on science and technology was changed in response to the economic and industrial changes of Korea. It is argued that the changes in KNIS are in fact evolutionary responses and the outcome of Korean government's S&T policies. In the early stage of Korea's development, Korea's Government Research Institutes (KGRIs) led the development of Korea's science and technologies, but gradually the private companies began to take the leading role in the development. Recently, as the economy grew and industries were developed, the lack of basic technology became the weak point of Korea's NIS. Realizing this, the government again takes new initiatives in basic S&T and selected ten strategic technology areas to prepare for the next 10 years. In addition, new S&T administrative system was set up to coordinate overall national S&T policy, investment and evaluation.

As a case study of Korea's S&T policy initiative, Daedeok Science Town (DST) has been evaluated in the perspective of an innovation cluster. As an early innovation cluster, DST has shown both strong and weak points. The accumulation of S&T knowledge led by GRIs and supported by central government reached enough level to create self-sustainable effect. However, relatively low level of commercialization is criticized. Now the government is trying to utilize such a knowledge pool by providing business-friendly infrastructure in the framework of R&D special zone law. The DST case clearly shows the interaction between university, industry, and GRIs are growing even though not sufficiently satisfied level of speed.

In a conclusion, we can say that the Korea's NIS has contributed to the development of Korea. Though, the NIS has its weakness too. Korean government is trying to reshape its NIS more productive and the NIS is still in the evolutionary process. There would be some risk to generalize Korean case. However, we can say that the government should make every effort to make appropriate NIS according to the development status of its own economy, society and culture.

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