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**Monitoring and analysis of policies
and public financing instruments
conducive to higher levels of R&D investments
The "POLICY MIX" Project**

Country Review Korea

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Introduction and Policy mix concept

The policy mix project

This report is one of the 31 country reviews produced as internal working papers for the research project "Monitoring and analysis of policies and public financing instruments conducive to higher levels of R&D investments" (Contract DG-RTD-2005-M-01-02, signed on 23 December 2005). This project is a research project conducted for DG Research, to serve as support for policy developments in Europe, notably in the framework of CREST activities. It does not form part of the ERAWATCH project, but the working documents are made available on ERAWATCH webpages for the purpose of steering a debate on the policy mix concept.

The "Policy Mix" project is run by a consortium of 7 partners:

- UNU-MERIT (The Netherlands), consortium leader
- Technopolis (The Netherlands)
- PREST – University of Manchester (United Kingdom)
- ZEW (Germany)
- Joanneum Research (Austria)
- Wiseguys Ltd. (United Kingdom)
- INTRASOFT International (Luxembourg).

Each country review is produced by an individual author, and provides expert's view on the policy mix in the country. This report is not approved by the Commission or national authorities, and is produced under the responsibility of its author.

The role of country reviews is to provide an exploratory analysis of the current policy mixes in place in all countries and detect the most important areas of interactions between instruments as well as new modes of policy governance that are particularly adapted (or detrimental) for the building of policy mixes. They provide analytical material for the analysis of the policy mix concept and its implementation in Europe. This material will be used as background for further reports of the project and for the construction of a tool for policy-makers (to be made available in late 2007 and 2008).

The policy mix concept

The country reviews are based on the methodological framework produced by the consortium to frame the "policy mix" concept. They have been implemented on the basis of expert assessments derived from the analysis of National Innovation Systems characteristics and policy mix settings, using key information sources such as Trendchart and ERAWATCH reports, OECD reviews, and national sources, among which the National Reform Programmes.

In this work, the "policy mix for R&D" is defined by the consortium as: **"the combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors."**

In this definition, policy instruments are: "all programmes, organisations, rules and regulations with an active involvement of the public sector, which intentionally or unintentionally affect R&D investments". This usually involves some public funding, but not always, as e.g. regulatory changes affect R&D investments without the intervention of public funds.

Interactions refer to: "the fact that the influence of one policy instrument is modified by the co-existence of other policy instruments in the policy mix".

Influences on R&D investments are: "influences on R&D investments are either direct (in this case we consider instruments from the field of R&D policy) or indirect (in that case we consider all policy instruments from any policy field which indirectly impact on R&D investments)".

Structure of the report

The report is structured along the following questions.

First, in section 1, and in order to place the policy mix in context, the general challenges faced by the National Innovation System (NIS) are analysed by the expert. The view is here not restricted to the challenges with regard to raising R&D investments, but rather encompasses all the conditions that directly or indirectly affect the functioning of the NIS and R&D expenditures. These context conditions are very important for the discussion of the relevance of the policy mix later on.

Second, the stated main objectives and priorities of R&D policy in the country are spelled out in section 2, as well as their evolution over the last ca. five years. This discussion is based on White Papers and official documents, i.e. on published policy statements. The reality of these objectives compared to actual working of policy instruments will appear in section 5.

The third section provides an expert assessment and critical analysis of a possible gap or convergence between the NIS challenges and the main policy objectives and priorities stated before.

Section 4 presents the policy mix in place, following the above definition, i.e. policy instruments affecting R&D activities in the private and in the public sector, either directly for instruments from the R&D policy domain, but also indirectly for instruments outside the R&D domain which are of particular relevance to R&D activities. A typology of instruments is used, to categorise the R&D-specific and non-R&D specific instruments. A short description of each instrument is provided: aim, nature, target group, budget.

Then, section 5 discusses whether there is a gap between the main policy objectives and priorities stated in section 2, and the instruments in place. This is done by comparing the set of objectives with the set of instruments at work. When individual evaluations of programmes or policy instruments are available, their results are used if they shed light on contribution of these instruments towards the policy objectives.

Section 6 discusses the orientation of the policy mix, indicating priorities amongst various possible routes to increase R&D investments. Policy instruments are categorised under 6 different routes according to their relevance, and this categorisation is followed by a discussion on the range of instruments affecting each route, missing instruments, routes that are not addressed by instruments, possible redundancies or overlaps, etc.

Section 7 provides another view on the policy mix, focusing on the relative importance of each types of instruments. The aim is to get a picture of the policy mix, the balance between (sets of) instruments, and the relative weight between them.

From section 8 onwards, the review turns to the crucial question of policy governance. That section discusses the emergence of the policy mix through examination of the following question: how did the set of R&D policy instruments arrive ? What is the rationale behind them, what were the driving force behind their establishment, and how is this evolving recently. A crucial question relates to the existence of some consideration of possible interactions when establishing new or suppressing existing instruments. The section tries to establish whether the policy design process is incremental or radical, analytical or non-analytical. From this, that section discusses if the policy mix is a “construct” or an “ex post” reality.

The next section, section 9, focuses on the governance of the system of R&D policy instruments take place. It examines the key question of interactions, i.e. whether there is a form of co-ordination between R&D policy and policy instruments from outside the R&D domain, and the existing mechanisms that favour or hinder such interactions.

The final section, section 10, deals with the core question of the policy mix concept: it endeavours to discuss interactions between policy instruments to affect R&D expenditure. The section discusses possible positive, neutral and negative effects of R&D policy instruments; both within the R&D policy domain, but also with instruments from other policy domains. In most cases, this takes the form of hypotheses rather than hard evidence.

Feedback welcome

Feedback on this report is gladly received. Individual country reports will not be updated but discussion on policy mixes is welcome during the timeframe of the study (2006-2008). Please send your comments to:

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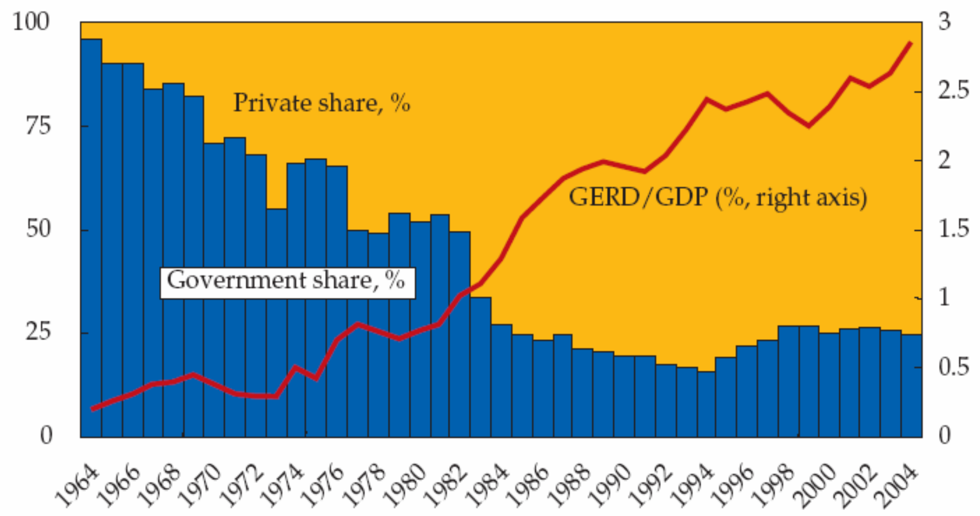
1 National Innovation Systems Challenges

Over the last 40 years, South Korea (hereafter Korea) has achieved remarkable growth—at an average of 7.2 per cent between 1970 and 2002. How has Korea achieved such phenomenal growth in only four decades? Although there are many factors responsible, many researchers have pointed out to a strong Korean national innovation system (NIS) as one of such factors. They argue that private industries and government-sponsored research institutes (GRIs) have played important roles in Korea's economic development and they emerged as strategic partners in the local R&D "policy mix".

Korea increased its R&D intensity steadily, but it was not until in the 1990s when Korea finally reached the level of advanced countries (Table 1). The growth rate of R&D intensity by Korea surpasses that of Japan and Taiwan, with the Korean growth rate being especially high in the 1980s and the 1990s. However, it is only in the 1990s when Korean R&D efforts finally became comparable to developed countries, including Germany and France. At the same time, Korea's R&D performance, in terms of output, is still lagging behind major advanced countries, including US and Japan.

Table 1: Long term GERD and private sector R&D investment in Korea

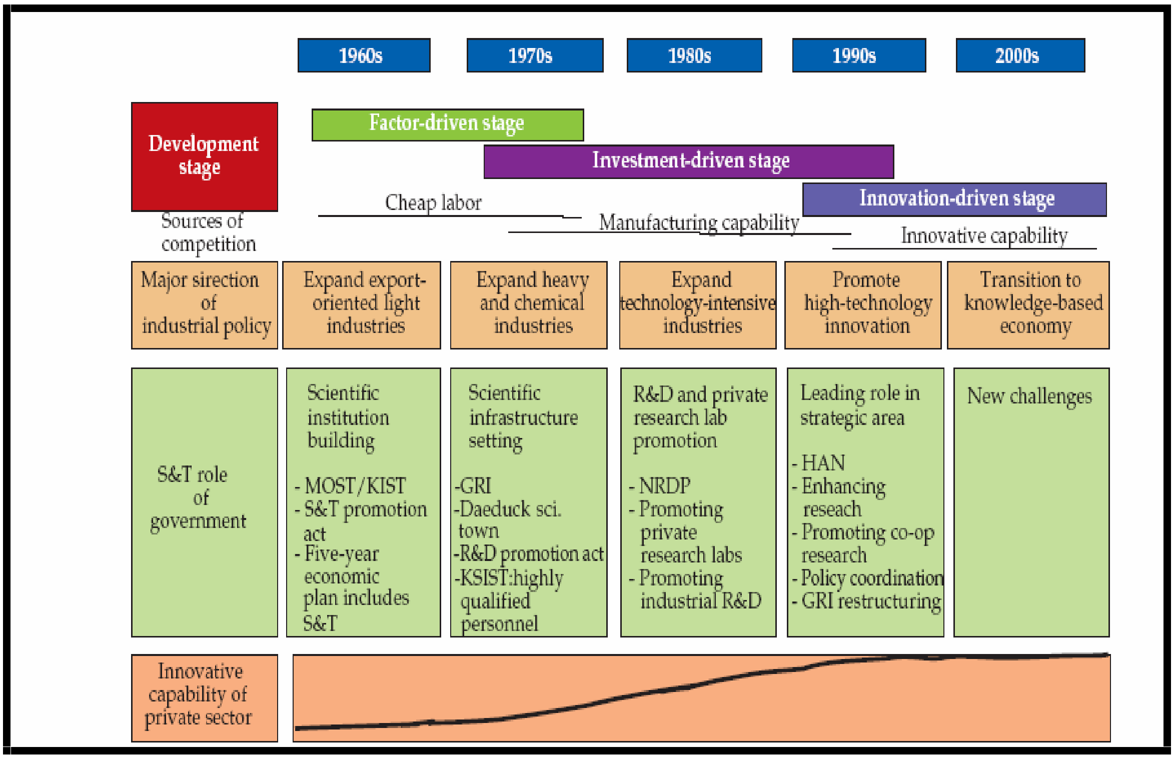


Source: Ministry of Science and Technology (MOST).

Korea followed a model of technological development which draws on the prominent role of national champions in selected industrial sectors. An important dimension of this model has been the creation of backward linkages and long-term production networks with local SMEs. This model worked fairly well in the period of catching up. Korea's relatively low performance in the generation of new knowledge reflects the fact that its NIS has remained largely based on a "catch-up" model, which favours the acquisition of advanced technologies from abroad, in selected sectors rather than a broader strengthening of its knowledge base. Indeed, in some sectors, Korea has reached the limits of the catch-up model as Korean firms approach the technology frontier. At the same time, large Korea firms were becoming global players and changes in the global economic environment, forced them to embark on intensive investment in indigenous R&D.

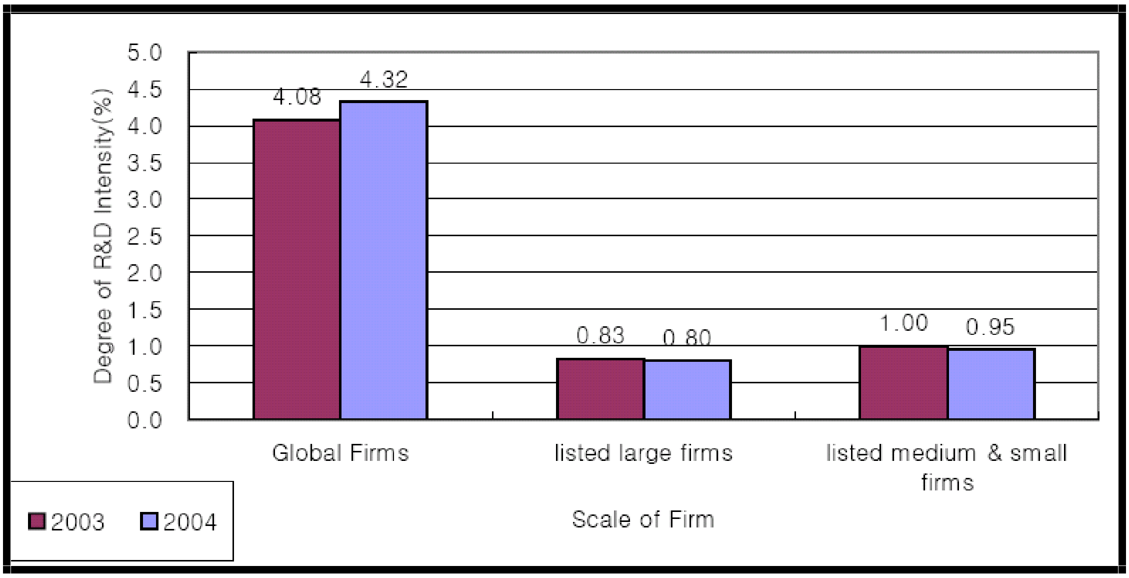
Thus, an interesting puzzle emerged. On the one hand, Korean industrial development had reached the stage at which domestic industries found it more difficult to be competitive in the international market because they were reliant on imported technologies and employed domestic labour that was becoming more and more expensive. On the other hand, a small number of large Korean firms had grown to become potential competitors in the international market, making foreign companies increasingly reluctant to transfer technologies to Korea. Thus, it was inevitable that Korea would have to develop an indigenous base for research and innovation. Meeting these challenge required highly trained scientists and engineers as well as financial resources to support R&D activities, which are by nature uncertain and risky. That was a new environment for them and they had to reconsider their networking strategy when they were forced to adjust to continuous technological change and bottom-up pressure from China and other Asian industrialising countries. Table 2 elaborates on the fascinating experience of the evolution of Korean technological development priorities, from imitation to innovation, in response to different phases of the industrialisation process.

Table 2: Patterns of Innovation Policy in Korea, 1960s-today



During this process, Korea's R&D resources and outputs remained highly concentrated in a small number of industries. Overall, about three-quarters of business-sector R&D is in high and medium-high technology manufacturing industries. In 2003, 80% of this R&D was concentrated in two sectors: ICT and automobiles. In addition, a small number of firms play an important role: the top five companies accounted for 37% of business R&D expenditures and 28% of researchers employed in industry, while the top twenty companies accounted for 52% and 48%, respectively. The concentration of innovation activities is also reflected in patents. The top five ICT companies hold 57% of all Korean patents in the United States, led by Samsung Electronics (35%). Thus, **the first challenge for the Korean R&D system is the increasing concentration of R&D investment in a small number of firms and the diverging patterns of firm-level commitment to R&D as a percentage of sales** (Table 3).

Table 3: R&D intensity in Korea



Recent firm level data confirm these trends. The Science and Technology Policy Institute (STEPI) report on the Korean R&D Scoreboard 2005, revealed the following structural weaknesses:

- The ten big firms, including Samsung Electronics, are investing 75% of all R&D investment expenditures, and the degree of R&D investment concentration is very high.
- The degree of R&D intensity of global firms is the highest at 4.32 per cent of sales, but the degree of R&D intensity of the listed large firms is rather lower than the .95 per cent of the small and medium size firms and the degree of R&D intensity of the listed large firms is the paltriest at .80 per cent.
- Contrary to the further increase in R&D investment, in the cases of industries and firms whose degree of R&D intensity is high overall, industries and firms whose degree of R&D intensity is low have a conspicuous declining trend: large firms are growing and small and medium size firms are shrinking.

The second challenge for the Korean R&D system is the low level of efficiency of the management and utilisation of R&D investment. Despite its relatively high level of R&D intensity, Korea's output of codified knowledge, in the form of patents and publications, is relatively weak as measured by the number of "triadic patent families" - patents filed in the United States, Japan and Europe. Korea is well below the expected level given both its income level and its amount of R&D spending. To some extent, this may be a legacy of focusing on catch-up rather than on the creation of new knowledge. In addition, there is some evidence that Korean firms prefer alternative protection methods, such as secrecy and lead-time, to patents, which may be less favourable for the diffusion of knowledge than patents. On the top of all that, many experts agree that the current governance structure remains rigid, with vertically integrated financial processes and limited opportunities for flexibility/interfaces.

The third challenge is the persistent weaknesses of the Korean R&D system in basic research and university research competences. Until very recently, research had not been a primary concern in most Korean universities and quality of research received limited weight in recruitment and promotion. In addition, Korean universities do not specialize in basic research. Their superficial involvement in R&D activities may suggest better networking capabilities with other innovation actors. However, this is really the *ex post* outcome of the weaknesses of the domestic knowledge base. In fact, this problem is closely linked to the direction of flows of R&D funds. Compared with the GRIs, public funding for university research in general remains at low levels, with the exception of a few research universities. Consequently, universities tend to seek other sources of funding, notably from private enterprises, which may also serve as a diversion away from enhancing their knowledge base.

The fourth challenge for the Korean R&D system is the very low participation of local firms in global research networks. Foreign sources financed only 0.4% of R&D activities in Korea in 2003, the lowest share along with Japan. In terms of the cross-border ownership of inventions, *i.e.*, the share of foreign ownership of domestic inventions or the reverse, Korea also ranks as one of the lowest in the OECD area.

The Korean trajectory, with respect to levels of aggregate R&D investment, is very similar to the EU target of 3 per cent. Table 1 provided background information on the rapid expansion of the Korean innovation system in the last 20 years, in terms of R&D investment. In 2005, Korea reached 3 per cent of annual GDP on R&D, and a solid increase of private investment has taken place in the last 5 years. That, indeed, makes Korea an interesting case to study in the context of European innovation policy debates. First, it would be interesting to find out how they managed to succeed. And, second, it will be useful to examine the impact and the side effects of this policy.

2 Objectives and priorities of R&D policy

The first Korean R&D promotion policy can be found in the Technology Development Promotion Law of 1972. The role of government in R&D promotion was limited to the establishment of national research to support industrial technological learning, and funding university R&D. The Korean government, however, did not play a significant role in R&D promotion until the 1980s. Among the 18 industrial policies initiated by the Ministry of Science and Technology (MOST) between 1967 and 1993, only three were recorded before 1980 (see Table 3). The 1981 amendment of the Technology Development Promotion Law facilitated various tools to promote private R&D. Compared to the previous industrial policy of the 1970s, the new policy was geared towards both direct and indirect promotion of technology-intensive industries in their R&D also allowed the Korean government to help establish industrial technology research consortia, and enabled the government to promote specific R&D projects through these consortia.

Table 4 summarizes and compares the timing of the introduction and abolition of various R&D-related industrial policies in Korea. There are several important observations one can make from this table. First, Korea followed a “targeted” innovation policy. Korea did not “graduate” from protective policies until the 1990s. This means that there has been a prolonged existence of protective policies and the promotion of “targeted” industries in Korea. These trends may be partially attributed to the fact that Korea’s industrial policies in general do not include graduation dates, although it is hard to determine the causality between these two facts.

Table 4: Evolution of Korean Innovation Policies

	1960s		1970s		1980s		1990s		2000s	
Population (million)	25		32.2		38.1		42.9			48.4
R&D budget as % of GDP			0.39%	0.42%	0.56%	1.52%	1.87%	2.37%	2.39%	2.99%
Development stage (sources of competition)	Imitation or factor-driven stage (cheap labour = 55% of growth)									
			Internalisation or investment-driven stage (manufacturing capability)							
							Generation or innovation-driven stage (innovative capability – technology = 55% of growth)			
Major industrial policy direction	Expand export-oriented light industries		Expand export-oriented heavy industries		Expand technology-intensive industries		Promote high-technology innovation, develop information infrastructure, strengthen market-oriented technological innovation, accelerate import liberalisation		Transition to knowledge-based economy. Industrial strength based on restructuring, continued investment, advancement into new markets, upgrading towards higher industrial value chains	
Science and Technology (S&T) policy and role of government	Scientific institution-building – MOST/KIST – S&T Promotion Act – five-year economic plan includes S&T		Scientific infrastructure-setting – GRI – Daedeok science town – R&D promotion act – highly qualified personnel		R&D and private lab promotion – NRDP – promoting private research labs – promoting industrial R&D		Leading role in strategic areas – HAN – promoting cooperative R&D – policy coordination – GRI restructuring		New challenges. Head of MOST is made deputy prime minister. OSTI is created to coordinate across departments, promoting indigenous innovation (IPR emphasis)	
Macroeconomic policy framework	Prepare legal and institutional bases to support industrialisation		Maximise growth and increase government intervention into the markets		Stabilise macroeconomy and enhance private autonomy and competition		Liberalise trade and FDI and reform financial markets and restructure the economy		Encourage FDI, encourage transparency, FTA with the US and others, Vision 2030 plans	
Human resources	Decrease illiteracy		Increase vocational training		Expand higher education system		Develop: – highly skilled human resources in strategic fields – lifelong learning systems		Literacy rates: – 98% (2002) HR innovation, increasing: – market influence – productivity – international	
Education policy	Plan education for economic development – improve teaching quality – increase number of college graduates with engineering major – develop medium-skilled HR				Enhance lifelong learning and non-traditional education – government-led, partial market approach – develop highly skilled HR in strategic fields – increase research funds in R&D				Improve quality of education and research: Brain Korea 21 (BK21) encourages R&D research. Phase 1: 1999–2006. Phase 2: 2006–2013, NURI (regional education)	

Notes: FDI, foreign direct investment; FTA, free trade agreement; GRI, government research institute; HAN, highly advanced national R&D programmes; HR, human resources; IPR, intellectual property rights; KIST, Korea Institute of Science and Technology; MOST, Ministry of Science and Technology; NRDP, national R&D programmes; NURI, New University for Regional Innovation; OSTI, Office of Science and Technology Innovation; S&T, science and technology; SERI, Samsung Economic Research Institute

Source: Webb (2007), p. 7.

The role of the Korean government in R&D promotion has been limited, compared to R&D promotion through policies that have broad objectives. For example, in the 1990s, government R&D funding accounted for 20% of total Korean R&D expenditures, while the rest of the R&D projects were financed by the private sector, mostly affiliates of the chaebol groups. These companies enjoyed monopoly rents in the Korean market that were protected by the government from imported products and entry threats. Though the Antitrust Law was enacted in 1980, the enforcement was not effective enough to preclude the chaebol affiliates from exchanging personnel within the group, and underwriting R&D expenditures for new businesses attempted by other group firms. Korean R&D was, therefore, driven by chaebol-affiliated companies, especially in the period before the Asian financial crisis.

The current Korean government's policy directions for S&T are aiming at a major step forward of national S&T capabilities in line with national social, cultural and economic developments, in order to satisfy the following goals:

- Realize a knowledge, information, and intelligence-based society
- Pursue a society that focuses on a healthy life
- Realize a sustainable society
- Realize a value-creating industrial structure
- Enhance national security and prestige.

In September 1999, the government launched a long-term strategic initiative: the Long-term Vision for S&T Development Toward 2025 (Vision 2025). This initiative includes a series of 40 tasks and 20 recommendations designed to guide the transition to an advanced and prosperous economy through the development of S&T. The goals are grouped in three time frames, spanning a 25-year period. Each time frame is defined by a unifying theme that characterizes the primary focus of activity for that period. First Step (by 2005): Place the Korean scientific and technological capabilities at competitive levels with those of the world's leading countries by mobilizing resources, expanding industrialized infrastructure, and improving relevant laws and regulations. Second Step (by 2015): Stand out as a major R&D promoting country in the Asia-Pacific region, actively engaging in scientific studies and creating a new atmosphere conducive to the promotion of R&D. Third Step (by 2025): Secure a scientific and technological competitiveness in selected areas comparable to those of G-7 countries.

The Vision 2025 plan has several major features including the following:

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

Box 1: The Government's programme to restructure the Korean innovation system

1. Measures to upgrade the innovation capacity of industry, universities and government research institutes

- Boost R&D spending to 3% of GDP by 2007 by providing effective tax incentives to the business sector.
- Foster 10 000 innovation-driven SMEs through technical and financial assistance, subsidies for employing R&D personnel, and an easing of regulations (*e.g.*, on land use, environment) on start-up companies.
- Increase basic research from 20% of the government R&D budget in 2004 to 25% by 2007, and raise the share of R&D that is performed in universities from 10% to 15% of total R&D over the same period.
- Enhance organisational flexibility and labour mobility in the GRIs, and expand their autonomy.
- Implement deregulation of such measures as the ceiling on chaebol shareholding and building controls in the capital region to promote business innovation activities in high-technology areas.

2. Measures to raise the efficiency of R&D investment and to secure highly qualified workers

- Raise the allocative efficiency of R&D investment by concentrating national R&D programmes on basic/generic research areas and by minimising the overlap between public and private spending.
- Nurture S&T manpower and minimise mismatches in the job market for skilled workers by strengthening the monitoring of demand and supply.
- Make engineering and vocational education more responsive to technology and business demand.
- Secure talented science and engineering students by expanding incentives at the tertiary level and reforming science education in the primary and secondary levels.

3. Measures to develop technology and to upgrade the diffusion mechanism

- Develop certain technologies to act as growth engines for the Korean economy. *[Ten strategic industries were identified in August 2003 as future growth engines: bio-medical products, next-generation computer displays, next-generation semiconductors, next-generation batteries, future automobiles, intelligent robots, digital TV and broadcasting, next-generation mobile communications, intelligent home networks and digital content and software solutions]*
- Help the material and component-related industries improve their competitiveness.
- Develop technology in key areas such as future core technologies (*e.g.*, biotechnology and nanotechnology), mega-science (*e.g.*, space and marine technologies), energy, and public welfare (*e.g.*, health, transportation).

- Strengthen the diffusion mechanism by creating intermediaries between technology invention and diffusion, improving technology evaluation schemes, and strengthening the intellectual property rights system (*e.g.*, providing patent information and streamlining patenting procedures).
- Foster Daedeok Science Town as a R&D Special Region and develop regional innovation clusters.

4. Measures to upgrade the performance of the innovation system

- Strengthen linkages among business, government and universities.
- Fortify international collaboration, and establish an East Asia regional R&D hub in Korea.
- Construct a national information system for S&T by 2008.
- Establish a performance-oriented evaluation and management system.
- Strengthen the roles of the NSTC and MOST in co-ordinating S&T policies and allocating their budgets.

5. Measures to upgrade innovation infrastructure

- Create job opportunities through a virtuous circle of innovation, diffusion and employment.
- Improve the social compensation of highly qualified workers by reducing the burden of the alternative military service obligation, raising the share of science and engineer career tracks in the government, and expanding the reward system for scientists and engineers.
- Promote a S&T-friendly culture and social environment by national agenda-setting and diverse activities.
- Guarantee the social and ethical responsibility of S&T.

In recent years, Korea recovered from the financial crisis in the late 1990s and the formulation of an innovation policy for the long-run has re-emerged in Korean policy debates. In line with their previous experience (see challenges in section 2) and with careful monitoring of comparative policy lessons from advanced countries, Korean policy makers have scrutinized failures and future trends and they are trying to formulate an integrated strategy, which will deal with all these challenges for the local NIS. That has proved to be a difficult task. In the past, the Korean strategy was clearly defined: more R&D inputs for higher growth in an export-oriented catching-up trajectory of economic development, which eventually is expected to trickle down to the production system. When a country reaches the level of development of advanced countries, however, the returns of R&D investment depend on the ability to adjust to generic technological change and on the efficiency of learning and diffusion processes. The creation of this learning environment remains a major challenge for the Korean Innovation System.

3 Coherence between NIS challenges and R&D objectives and priorities

Korea does not appear to be getting the full benefits possible from its high level of R&D spending. In 2003, the government placed S&T at the top of its policy agenda to promote economic growth. On a number of occasions, international organisations working on the governance of the Korean NIS system, have criticized the structure and the internal efficiency of the Korean NIS. Box 2 summarises the arguments in favour of a policy of reforms for the restructuring of the Korean NIS.

Box 2: A World Bank assessment of the main weaknesses of the Korean Innovation System

- § Encouraging greater interaction among firms, universities, government research programs and GRIs.
- § Clearly justifying the rationale for public intervention, and providing subsidies in a transparent and non-discriminatory manner.
- § Providing support to R&D in large companies on stricter conditions, assisting only when they would not have undertaken the concerned projects, and stimulating partnership with other actors (enterprises, university and public laboratories).
- § Increasing the effort in basic research; this should be done principally in universities, which should receive larger resources. This also implies changing various forms of regulations and practices that discourage research activities.
- § Reorienting the Government Research Institutes (GRIs) as their activities tend to duplicate those of industry. The GRIs have to be re-positioned to do more upstream research or to become more focused on research of collective interest (e.g. health, transport, etc). A larger part of their budget has to be secured in the form of institutional funding.
- § Developing better forms of support to innovation in SMEs with emphasis on effective networking and clustering, and the involvement of local authorities.
- § Strongly encouraging contacts of all actors with foreign counterparts-academic and research exchanges, technological co-operation, industrial joint ventures, participation in international regulatory bodies, etc.
- § Enforcing co-ordination procedures involving key ministries.
- § Implementing evaluation exercises, including an international review of the basic research capacities of the country.

World Bank (2000) Republic of Korea: Transition to a Knowledge-Based Economy.

To this end, and in response to some of these recommendations, the administrative system for S&T was fundamentally restructured:

- The role of the Ministry of Science and Technology (MOST) was strengthened by making it the central agency for planning, co-ordinating, and evaluating S&T policies, in co-operation with other ministries, particularly Commerce, Industry and Energy and Information and Communication, while abolishing its R&D programmes that compete with other ministries. The minister of MOST was named as a third deputy prime minister.

- The National Science and Technology Council (NSTC), which includes the president and the minister of MOST as chairman and vice chairman, was granted full authority to allocate the government's R&D budget, which is targeted to double between 2003 and 2007.

The Ministry of Science and technology (MOST) has been seeking to establish a more balanced innovation system that encourages a simultaneously cooperative and competitive tripartite partnership among industry, academia, and public research organizations. As a part of these efforts, the Korean government elevated the position of the Minister for Science and technology to that of Deputy Prime Minister in October 2004 and established the Headquarters of S&T Innovation in MOST to provide a more balanced, innovative administration system. This system is designed to facilitate drastic domestic and international changes on the horizon, and to plan, coordinate, and evaluate national R&D programs. The government announced a plan, which was summarised in Box 1, to restructure the national innovation system. The plan emphasises shifting from a catch-up model to a more creative approach, increasing networking among players and shifting towards performance and demand-oriented paradigms.

When it comes up to policy priorities, many experts suggest that a re-orientation of the Korean NIS is a pressing need. R&D investment incentives are needed for traditional manufacturing industries. For example, R&D activities need strengthening in the slumped chemicals, assembled metals and machinery, industries and the automobiles and transportation industries. Among the four large industries that the value added in the manufacturing industry is high: 1) electric and electronics, 2) automobile and transportation equipment, 3) chemicals, and 4) assembled metal and machinery industries, the degree of R&D intensity of all major industries, excluding the electric and electronics industries, is lower than 2.53%, the degree of intensity of major industries. R&D investment of the textiles industry, one of the four large export industries, needs to be strengthened. Finally, there needs to be concern for technology innovation in the high value service industry, along with the innovation strategy of the manufacturing industry and balances needs to be sought in resources distribution; for example, growth through venture firm financing in knowledge intensive sectors.

4 Composition of the policy mix for R&D

The National R&D Program was first initiated by the Ministry of Science and Technology in 1982 with the aim to strengthen technological capabilities and competitiveness. In the last 25 years, Korea established a portfolio of policy instruments supporting innovation and technological applications. What is unique in the Korean case is the broad coverage of policy instruments and the vertical integration of these initiatives in the structure of different ministries (see Table 6 for a presentation of policy instruments and Box 3 for a list of the legal documents which created the framework for the introduction of this comprehensive set of policies).

Table 5: Korea's Innovation policy portfolio

	National R&D programs	Infrastructure and diffusion	Institutional support	Incentives
Objectives	To develop core industrial technologies	To enhance intermediary functions and to fill the gaps among innovation actors	To nurture GRI and to strengthen GRIs' research capabilities	To induce or assist private enterprises' technology development activities
Tools	Ministries' R&D programs	Research personnel, technical information, cooperative R&D facilities, regional R&D centers, spin-offs, etc.	Funding for GRIs' operational expenses and basic research	Tax-exemptions, financial support, subsidy for technology development
Effects on industry	To expand knowledge and the technology pool for industrial use	To facilitate diffusion and to make better industry use of technologies	To bring up helper or partner for industry's technology development	To strengthen industry's own technological capabilities

Table 6: Government R&D programmes

Ministry	Year initiated	Major program	Management agencies
Ministry of Science and Technology	1982	Specific R&D Program	Korea Institute of Science & Technology Evaluation & Planning (KISTEP) Korea Science & Engineering Foundation (KOSEF)
Ministry of Commerce, Industry and Energy	1987 1988	Industrial Base Technology Development ProgramAlternative Energy Development Program	Korea Institute of Industrial Technology Evaluation & Planning (ITEP)
Ministry of Information and Communications	1989	IC Technology Development Program	Institute of Information Technology Assessment (IITA)
Ministry of Environment	1992 1996	Environmental Engineering Technology Development Program Environmental Basic Technology Development Program	National Institute of Environmental Research (NIER)
Ministry of Construction and Transportation	1994	Construction Technology Development Program	Korea Institute of Construction Technology (KICT)
Ministry of Agriculture and Forestry	1994	Agricultural Technology Development Program	Agricultural R&D Promotion Center (ARPC)
Ministry of Health and Welfare	1995	Health and Medical Technology Development Program	Korea Health Industry Development Institute (KHIDI)
Ministry of Education	1983	Basic Scientific Research Support Program	Korea Research Foundation (KRF)

Box 3: Korea's Innovation Policy mix profile – the legal framework

This Box describes South Korea's legal framework upon which RTD and S&T policies are based. These operate within the National Innovation System: the network of organisations that stimulate and control R&D activities, which is described in section 2.2.

The Science and Technology Framework Law (Law No. 6353, 2001) is the main law covering systematic promotion of S&T at the national level. Important provisions of this law include the establishment of policies and plans for S&T and the overall support mechanism for related projects and agencies. It also aims to provide the legal mechanism for inter-ministerial coordination of R&D activities and to establish an institutional system to foster an innovation-prone culture in South Korean society. The law replaces two previous S&T laws, which were the Science and Technology Promotion Law (Law No. 1864, 1967) and the Special law for Scientific and Technological Innovation (Law No. 5340, 1997).

The Technology Development Promotion Law (Law No. 2399, 1972) provides financial and tax incentives to encourage and facilitate the technological development activities of private enterprises.

The Promotion of Engineering Services Law (Law No. 2474, 1973) deals with the improvement of the engineering industry, which contributes to manufacturing enterprises and expedites the commercialization of R&D results.

The Promotion of Basic Science Research Law (Law No. 4196, 1989) provides financial support promoting innovative research in basic science at R&D institutes and universities to encourage innovation.

The Dual-use Technology Programme Facilitation Law (Law No. 5535, 1998) was enacted upon the recommendation by four ministries, namely: MOST, the Ministry of Information and Communications, the Ministry of Commerce, Industry and Energy, and the Ministry of National Defence. It aims to strengthen the nation's industrial competitiveness and military readiness by facilitating dual-use research and development and promoting technology exchange between the private sector and the military.

Box 4: Korean Policy mix profiles – the sectoral dimension (biotechnology)

The driving forces

Both demand-side pulls and supply-side pushes fuel South Korea's biotechnology ambitions. Unlike many developing countries, the urgency for health biotechnology development in South Korea is not in addressing so-called 'developing world diseases'. The expansionary pressures of the domestic drug market are also driving biotechnology demand. This is a reflection of South Korea's public healthcare system, which features universal access and relatively low out-of-pocket payments. On the supply side of, R&D spending in South Korea has skyrocketed in recent years. During the early 1970s, total R&D spending in the country was just 0.31% of GDP, but by 2001 South Korea's R&D expenditures had increased tenfold to nearly 3% of GDP—equaling Japan's (2.98%) and surpassing the United States' (2.70%) and the United Kingdom's (1.86%)2. Health-based R&D accounted for 12% of all university research spending in 2001 and almost 20% of all university researchers were engaged in biomedical science R&D2.

Government Policies

The government has ploughed funding into both basic and applied research. From 2000 to 2007, the government is expected to invest over 5.2 trillion South Korean Won ($4.4 billion) in the field. Significantly, it has also recently started financing mechanisms for technology transfer from the country's excellent academic institutions to the private sector. Recent progress has also been made in providing a legal framework that gives greater intellectual property (IP) protection to companies, encouraging the growth of IP dependent biotech enterprises. The Ministry of Science and Technology (MOST, administers the 21st Century Frontier R&D Program, of which seven of 19 designated projects are in the biotechnology field. Working with South Korea's elite research universities and publicly funded laboratories, such as the Korea Research Institute for Bioscience and Biotechnology (KRIBB; Daeduk Science Town, South Korea) and the Korea Institute of Science and Technology (KIST, Seoul), MOST has financed new R&D laboratories specifically designated for adult and embryonic stem cell research.

Implementation Dynamics

In the past, the South Korean government collaborated with its industrial allies the chaebols (predominantly large conglomerate firms) to orchestrate technology commercialization in the country. The emerging biotechnology sector faces a different environment. Centralized government control over the commercialization process has waned, the influence of the chaebols has diminished because of the 1997 Asian financial crisis, and small and medium sized firms increasingly dominate the industrial terrain in South Korea. The 1999 Technology Transfer Promotion Act sparked the creation of new technology transfer centers to facilitate the commercialization of cutting-edge technology ventures throughout South Korea. A wide range of public and private sector actors are actively involved, including government ministries, major university and public research laboratories, business associations and private sector R&D consortia. In the past, the overwhelming majority of R&D spending came from government coffers, but by 2001, private sector sources accounted for nearly three quarters of R&D expenditures2. This is due, in part, to the availability of private sector capital resources. For instance, an important source of biotechnology financing is South Korea's burgeoning venture capital (VC) market. The liberalization of South Korea's financial markets began during the mid-1990s, and the process was accelerated after the 1997 financial crisis. VC funds exploded onto the industrial technology scene.

Policy lessons

Three major lessons are apparent for encouraging startup activity in countries with a relatively well-developed educational, research, financial and industrial infrastructure: (a) Create a mix of small and large firms, (b) Exploit existing competitive advantages and (c) Go global for R&D development

Source: Wong, Joseph. et. Al (2004)

The current National R&D Program includes 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, and the Space Technology Development Program. A brief summary of each of these projects is provided below.

The 21st Century Frontier R&D Program was initiated in 1999 with a vision to develop core technologies and to secure leading-edge technologies in promising areas by 2010. Technologies selected for development are those that will be able to produce prototype products to improve national competitiveness within 10 years of the start of development. The government plans to support 20 projects at a total cost in excess of US$3.5 billion under the program. Eight projects in the areas of biotechnology (BT), three in nanotechnology (NT), and five in environment and energy are currently underway, for a total of 16 projects. The governmental support for this program in 2006 was KRW 144 billion.

The Creative Research Initiative (CRI) Program, which was launched in 1997, symbolizes the policy shift in S&T development in Korea "from imitation to innovation." It aims to strengthen the national potential for technological competitiveness through creative basic research. Therefore, it focuses on exploring various phenomena that occur in nature, developing new fields of scientific research, and making technological breakthroughs. Grants are awarded to researchers on the basis of creativity and originality of their proposals. Thirty-seven CRIs are already under way, and ten new CRIs were selected this year (US$600,000-700,000 per year for 10 projects through 2016). The ten new CRIs include Artificial Bio Muscle research, Micro Electromechanical Systems (MEMS) Astronomical Telescope research, Three-dimensional (3D) Nano Optical Imaging System research, Immunity Control research, Functional Molecular Memory research, etc. Five CRIs that showed remarkable achievements were renewed in 2006 (US$500,000 per year for five projects through 2011). The five renewed CRIs include Nano Particle Control Technology research and Superconductor Research, among others. A total of KRW 32.5 billion has been allocated for this initiative in 2006.

The National Research Laboratory (NRL) Program, launched in 1999, aims to explore and foster research centers of excellence, which will play a pivotal role in improving technological competitiveness. Annually, the government will fund US$250,000 per laboratory for a maximum of five years, with special emphasis on strengthening core technology in relevant fields. From 1999 to 2006, a total of 666 NRLs were funded at a total of US$580 million. Basically, the selected NRL receives funding for five years, and depending on the NRL's research achievements, it can be funded for an additional five years. About 175 NRLs are expected to receive funding in 2006, totaling KRW 37.4 billion. The NRLs have produced over 12,300 technical papers and over 3,600 patents.

The Nano-Bio Technology (NT-BT) Development Program was established in 2001. The Korean government declared 2001 as "The Year of Nano-Bio Technology," and plans to put available S&T resources together toward building "Nano-Bio Korea." **The Nanotechnology Development Program** will work on core research in nanomaterials, electronic devices based on miniaturization technology, computer memories and molecular-logic devices. The increase in funding over previous years was a result of the government's recognition of the importance of nano-technology. As a result, a National Nano-Fabrication Centre was constructed in December 2004. The Centre is a silicon based and compound silicon-based device fabrication R&D Centre, with class 1000 to fabrication rooms. An amount of KRW 5.7 billion has been allocated for four projects in 2006.

The Biotechnology Development Program aims to make Korea a high-level biotechnology power at an international scale comparable to Korea's IT economy. The Government formulated "Biotech 2000," which is the basic plan for the development of biotechnology. The plan was put into action under the co-sponsorship of seven government ministries including MOST. Through the plan, Korea aims to attain technological competitiveness in the areas of biotechnology, with a view to joining the ranks of the G-7 by the year 2010. MOST allocated KRW 47.6 billion for 33 projects in 2006. Box 4 summarises the context, policy initiatives and the outcome of the policy driven expansion of research on biotechnology.

The Space Technology Development Program, which runs from 1996 to 2015, aims to acquire core and fundamental technologies for the peaceful utilization of space. Under this program, the government has successfully launched four scientific satellites and, more recently, one civil-military common communication satellite. In 2007, the Science Technology Satellite 3 will be launched by Korea’s internally developed rocket, and plans to launch a total of nine satellites by 2015. The national strategy also includes the construction of a space centre with launch facility, development of a space launch vehicle (projectile), the first Korean astronaut program, and participation in the Galileo project. Korea successfully launched a 13-ton class liquid fuel sounding rocket in 2003 and expects to launch its first satellite from its own centre in 2007, utilizing an indigenous launch vehicle. The total budget for the space development program in 2006 is KRW 250 billion for seven projects.

Atomic Energy R&D Program: Korea invested KRW 1.86 trillion into this programme during the period 1992-2005 for the R&D of future nuclear reactor, proton accelerator, nuclear fusion, nuclear fuel, nuclear safety, radioactive therapy, and radioactive waste management technologies. For 2006, the government has budgeted KRW 188.7 billion for this program. As natural energy resources are scarce in Korea, it is essential for the country to develop alternative energy sources and to increase energy efficiency. An estimated 41% of Korea's energy comes from atomic sources; hence, nuclear science and engineering have been a major focus. Korea would also like to develop basic technology for fuel cell and fuel cell vehicles by 2010. Superconductivity and super thin-film solar battery projects are also receiving attention. From 2006, Korea will also begin developing a hydrogen production system using atomic energy.

Venture Capital programmes: The government introduced a number of programmes for venture businesses in 2004 to boost entrepreneurship and to overcome the weaknesses in the risk capital market:

- The Korea Technology Credit Guarantee Fund (KOTEC) has shifted the target of its credit guarantees towards start-ups and technology companies.

- Corporate credit bureaus have been established and the disclosure system for venture businesses was tightened.

- A private equity fund (PEF) law was introduced in December 2004. As of April 2005, five funds (with a total of 0.8 trillion won) had been established.

- Venture capital firms were allowed to acquire more than 51% of shares in their invested firms, allowing them to fully realise the upside potential.

- Reforms in the KOSDAQ and the "over-the-counter" market were introduced to induce viable start-ups and to restore trust among investors.

In contrast to the policies in the late 1990s that contributed to the bubble in the venture business area, this package should help improve the framework for this sector. Some of these measures, such as the establishment of credit bureaus, will strengthen market orientation. However, there is a risk of mismatches in the demand and supply for venture capital if the entrepreneurial sector provides insufficient investment opportunities, resulting in an excess of venture funds chasing too few start-ups. Private equity would then be concentrated on later-stage investments and traditional industrial sectors, with far less impact on potential growth. Thus, a key priority is to create an environment that encourages the supply of investment-ready SMEs. In addition, it is important to boost the private sector's role in venture funding. Government programmes should focus on leveraging and diversifying private sources of venture capital and moving small firms away from dependence on public debt guarantees and public funding.

Public R&D through government R&D activities and subsidies to business R&D significantly and effectively influence the private R&D investment in the same direction. The effects are greater in the long-term than in the short-term, and the effect of government R&D is greater than that of subsidies. In particular, the effect of government R&D, which influences the firm through spillovers and improvement of the R&D environment, is important and long-lasting. Government subsidies, in contrast, seem to have little effect on the long-term behaviour of business R&D.

In order to train scientists and engineers of top quality, the transformation of current teaching-oriented universities into research-oriented universities is critical. 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.

The Korean Advanced Institute of S&T (KAIST) serves as a good example of the type of research-oriented university that Korea is pursuing. KAIST was established by the Korean government in 1971 in order to producing world-class, quality engineers. Since its inception, KAIST has been receiving preferential funding from the government, and 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. Based on the KAIST model, the government founded the Gwangju Institute of S&T (GIST) in 1995, and recently established the Daegu-Gyungbuk Institute of S&T (DGIST) in 2004, to promote balanced regional development. Likewise, the Pohang University of S&T (POSTECH) was founded with similar aims by the Pohang Steel Corporation in 1986. POSTECH represents the first private sector initiative of its kind in Korea.

From our review of the literature we have observed two interesting characteristics in Korea's medium term S&T strategy. First, Korea is taking an IT-focused strategy (more than 30 per cent of Government R&D expenditures goes to ICT applications; see, Table 7). At least six out of the ten growth-engine industries fall into the IT product category. Two other industries—future automobiles and intelligent robots—are also highly correlated with IT applications in the industry. Only two industries—next-generation batteries and biotechnology (BT) new medicines and organs—are not in the IT category. Second, the emphasis is still on tangible products rather than intangible knowledge goods. In other words, Korean companies are still earning money by selling commodities rather than by providing intangible goods such as knowledge and services as other world technology leaders.

Table 7: Sectoral Allocation of Government R&D Investment

Technology Area	% of the Total Investment 997.5 billion won	
	1997	2002
Bio-science	18.9	20.9
Transportation	15.2	6.3
Information/Communication	13.7	33.5
Nuclear Energy	9.7	6.3
Machinery	9.3	7.8
Chemicals	8.1	4.7
Energy and Resources	7.2	35.
Environment	6.4	4.0
Materials	5.1	4.3
Others	6.4	

Source: World Bank (2006)

5 Coherence between main policy objectives and priorities, and policy instruments

In this section we will focus on the interaction of different institutions in the Korean R&D system. While collaboration among R&D players has gained in significance across OECD countries, the industry-academia-government interface in Korea has remained weak because of inherent structural problems. The innovation system is characterised by only limited reliance of industry on scientific research and low responsiveness of the non-business sector - government research institutes (GRIs) and universities - to demand from the business sector. In a number of recent surveys, GRIs and universities point to an absence of technological and absorptive capability in the business sector and its lack of interest in technology diffusion, while firms complain about the inability of the GRIs and universities to solve business' technical problems. In 2003, 97% of business-financed R&D was performed by the business sector itself, while GRIs and universities performed only 1% and 2%, respectively. About half of government-financed R&D spending was channelled to GRIs, with smaller amounts granted to universities and the business sector. In sum, the limited interaction between the suppliers and users of technology hinders the effectiveness of Korea's R&D spending.

The major criticisms related to GRIs, in a number of OECD and World Bank reports, is that because of poor R&D project management, extensive duplication of research takes place and that leads to low R&D productivity. These problems were mainly attributed to the lack of consensus on their institutional missions among related government authorities and top managers of GRIs, excessive monitoring and controlling by the government, and the government's unstable budgetary support . As a first step towards dealing with these problems, the government changed its research funding system from the lump-sum system to the project-based system (PBS) in order to increase research productivity in 1996. Before the introduction of PBS, manpower costs of researchers of GRIs were supported from 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 research of the NRDP. 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. However, there is also some criticism for the PBS. First, researchers of GRIs have been forced to shift their research priorities from basic research projects to short-term application-oriented projects to make more research contracts and to secure their manpower costs. Second, the PBS made greater use of cheap temporary researchers in GRIs. Since the research budget is not enough, GRIs cannot use permanent and experienced researchers any more and have to rely on M.A. or Ph.D. students. As of 2002, GRIs have 50 per cent irregular employment, which includes temporarily hired students.

Moreover, when the financial crisis occurred in 1997, the Government, changed 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 of January 1999, a new management system, Research Council System (RCS), was created modelled on aspects of the German and

British systems in 1999. That means the status of GRIs under the related ministries were brought under the unified control of the Prime Minister's Office, giving freedom to GRIs from the excessive control of related ministries. Under the new management system, RCS, five research councils were established. Each research council acts as a supervisory body to oversee its member GRIs.

This new approach, since its introduction in 1999, has brought about quite a few positive results. By providing autonomy in operation, management, decision making and organisation of GRIs; strengthening each director's leadership through empowering from related research councils; fostering competitive climates among industries, universities and GRIs by utilising the PBS; and improving the compensation system with the introduction of an annual salary system and performance-based initiatives. But the RCS system still has many defects, especially relating to governance structure, budgetary allocation structure and internal management within GRIs. Some of the shortcomings are as follows: first, in terms of governance structure, there is excessive influence of the government over the board of directors in the research council and lack of budgetary allocation power in research councils; second, in the budgetary allocation structure aspect, introduction of excessive competitive principle by utilising the PBS and unclear allocation criteria of government budget; and last, lack of autonomy and individuality of directors within GRIs, and lack of job security of individual researchers (low job satisfaction and high turnover rate).

Since 2003, GRIs are going through two additional changes: physical location and governance structure. First, the Korean government is making a grand plan to relocate a total of about 268 public organisations among 344 (including GRIs) within the capital area, Seoul, to local areas as a part of the administrative capital relocation programme to Chungcheong province after 2005. The government plans to foster regional innovation clusters and, as a result, promote balanced national development by relocating public organisations (including GRIs) to local areas. Therefore, the contribution of GRIs in the development of regional innovation clusters is expected to increase. Second, the problems of RCS' efficiency and effectiveness have been raised since their launch in 1999. The Prime Minister's Office, the upper-level institution of GRIs, is now looking into an effective management structure and the desired future roles of GRIs. Consequently, GRIs are still in a process of transition on many different fronts and many parameters remain unpredictable.

The current wisdom among policy makers is that an undue emphasis on targeted R&D policies and picking winners could lead to a government failure or distortions. To avoid these problems in Korea, flexibility in implementing R&D programmes is required. This is especially important for the "next generation growth engine" programmes, in which the government is planning to invest 3.1 trillion won between 2004 and 2008. Perhaps more important is the level of demand provided to the private sector. The government's role in R&D should strengthen its focus on developing generic technologies and human capital in order to avoid crowding out private investment and to abide by international norms regulating government subsidies. Another risk of focusing on key high-technology products, such as semiconductors and mobile telecommunications, is a further deterioration in the terms of trade as firms in other countries also increase production in these areas. This point suggests that there are important gains to a diversified approach to R&D.

6 Balance within R&D policy mix

Three Tables (Tables 8,9 and 10) present the basic facts on the relative importance of different actors and on the direction in which the Korean R&D policy mix has moved in recent years. The importance of the private sector is increasing and the Government has a very narrow set of priorities for research.

It is worth emphasizing that almost three quarters of Korea's R&D expenditures come from the private sector, including the massive private R&D institutes operating relatively independently of their parent companies, i.e., LG-Elite, an LG group R&D Institute, and the Samsung Advanced Institute of Technology (SAIT), a Samsung group R&D institute, which employ thousands of scientists and engineers. Many of Korea's large corporations (e.g., KT Corp., SK Group, Hyundai Motors, and Hynix) also have significant internal R&D centres based within their prime business units. SK Telecom and SK Chemical, for example, have specialized R&D operations in various centres across Korea.

In the meantime, some of the main weaknesses of the Korean NIS prevail. These are the emphasis on applied research and the focus on ICT related technologies. For the short term, going with products and technologies that will come to fruition sooner may be a lucrative strategy. Relatively strong applied technology and commercialization capability are Korea’s current strengths. Korean companies are weak in generic technologies, which are a rich source of intellectual property. Since generic and future-oriented technologies usually involve externalities that cannot be appropriated by invested parties, industries often under invest in those technologies. This is all the more so in Korea because only a few Korean firms are capable of investing in generic technologies. Smaller firms not only cannot launch such projects but also cannot utilize the results fully even if they succeed in the project. Generic technologies and technologies that will be realized in the long term are areas where the Korean government might want to play a more dominant role. It is evident, from the increase in Bio-Science spending reported in Table 7, that they are aiming at that direction.

For the medium and long term, the Korean government might want to pay more attention to technology areas where government needs to play a leading role, such as generic technologies and long-term future technologies in which the Korean industrial sector is less interested. Of course, supporting basic science is an area where government traditionally plays a leading role in advanced countries. In fact, investment in basic science has been rapidly growing in Korea during the last decade. It will take a long time for Korea to join the world leaders in basic science so that it can serve as a foundation for creating next-generation technologies and intellectual property rights. The Korean government may want to put a high priority on consistently moving ahead in basic science and generic technology.

Korea has a relatively sound capability in selected areas of information technology, although it is still quite weak in other emerging technologies, such as BT and nanotechnology (NT). For example, NT is expected to revolutionize science and consumer products over the next two decades the way computers and the Internet have over the past three decades. In the short to medium term, Korea's current IT-focused strategy may pay off better. For the long term, however, Korea may be better off to gradually diversify into such non-IT areas as BT and NT, which are the core technologies of the next wave of the technology revolution after the IT revolution of the 1990s. Given the scope of this report, we could not do a quantitative analysis of whether an IT-focused strategy is a better option for Korea than moderate diversification into non-IT areas. However, this is an interesting subject for future research.

Table 8: The Structure of R&D expenditures in Korea

	1980	1985	1990	1996	2000	2002
R&D Expenditures						
(billion won)	282.5	1,237.1	3,349.9	10,878	13,849	17,325
Government	180.0	306.8	651.0	2,398	3,435	4,557
Private	102.5	930.3	2,698.9	8,467	10,387	12,699
Gov : private	64 : 36	25 : 75	19 : 81	22 : 78	24.8 : 75	26.3 : 73.3
R&D/GNP(%)	0.77	1.58	1.95	2.79	2.65	2.91
R&D Performers(%)						
Industry	28.8	65.4	74.9	73.2	74.0	74.9
Universities	9.2	10.3	7.6	9.4	11.3	10.4
GRIs*	62.0	24.3	18.5	17.4	14.7	14.7
R&D by Nature(%)						
Basic Research	-	16.8	16.1	13.2	12.6	13.7
Applies Research	-	29.2	24.4	26.9	24.3	21.7
Development	-	54.0	59.5	59.9	63.1	64.6
Industrial R&D Intensity(%)	0.47	1.23	1.72	2.13	1.98	2.19

Source: World Bank (2006)

Table 9: Government financed R&D in Korea compared to US and Japan

Objectives	Korea	U.S.A.	Japan
Agriculture	8.4	2.4	3.4
Industrial tech	32.5	0.6	3.4
Energy	9.3	3.6	23.3
Health	8.6	17.6	3.5
Knowledge	17.5	4.1	48.6
Defence	0.6	54.7	5.9

Source: World Bank (2006)

Table 10: Evolution of Public Sector R&D priorities

	Formation stage (1982–1985)	Take-off stage (1986–1990)	Maturing stage (1991–)
NRDP objective	Internalization of foreign technologies	Development of core technologies	Creative research, future-oriented research
Planning	No planning: bottom-up	Based on loose long-term plan	R&D planning, technology foresight
Main actors	Government research institutes (GRIs)	Main: GRI Minor: Universities and industries	Main: GRI, with increased role of universities and industries

As a whole, universities have a critical role to play, in the sharing of knowledge with innovative firms. As for industry–university partnerships, increasing the ratio of university participation in various R&D programs is desirable from the viewpoint of innovation policy. However, public research institutes, another source of public knowledge stock, seem to be ineffective in cooperating with private firms. A recent study of Korean PRIs found that (1) innovative firms and PRIs each have their own idea of what the main objective should be and (2) the small gap in technology (or accumulated knowledge) that exists between the two agents can be a contributing factor to the low efficiency of public–private partnerships. In general, firms want to develop and commercialize their innovative output as quickly as possible so as to gain and maintain a superior position in the market. Therefore, for the PRIs, establishing new mechanisms for priority setting and funding that meet firms' emerging needs and tie funding to performance can be a prerequisite to improving the productivity of public–private partnerships. Undoubtedly, if they are to function as a knowledge pool in the whole society, PRIs need to enlarge their specialization more deeply.

Finally, the banking system needs to be strengthened to become an effective screening filter on innovative ideas, especially with respect to evaluating technologies and monitoring firms. Reinforcing cooperation with competitive firms is related to establishing clear rules and guidelines for intellectual property rights.

7 Emergence of R&D policy mix

Over the years, the Korean government has adopted an array of policy instruments designed to facilitate technological learning in industry and the international competitiveness of the economy. The government not only stimulates the demand side of technological learning through industrial policy instruments but also gives rise to the supply side of technological capability through technology policies.

First, Korea's experience indicates that in the early stage of industrialisation, when R&D activities are still in their infancy for the private sector and academia, GRIs can be a most powerful tool for both technological development and human resource training. For example, KIST, the first modern multidisciplinary research institute, covered a broad spectrum of industrial R&D and helped find solutions for simple and practical problems arising from industries in the absence of research in industries and universities. KIST also played an important role of training centre for researchers who would be needed at corporate R&D centres in the following stages of economic development.

Second, in parallel with facilitating GRIs in the early stage, it is also important to point out that the government offered various programmes for promoting linkages among industry, academia and GRIs. These programmes included national R&D programmes sponsored by the government that can act as a catalyst or seed for cooperative researches among innovative actors in technology development. The Korean Government, for example, launched the NRDP in 1981 in order to link the technological demand of the private sector with the R&D activities of the public sector. The programme laid the foundation for the following cooperative researches, igniting the R&D activities of the private sector.

Third, in order to manage the various programmes for promoting linkages among the innovation actors, the Government established an R&D management agency to plan and evaluate its own programmes in an efficient and effective manner. In fact, the Korean government established various R&D management agencies, like STEPI, for planning, implementing and evaluating its NRDP.

Fourth, as industrialisation progressed, it became necessary to shift its paradigm from a GRIs-centred to an industry-centred NIS. Although GRIs are useful in the early stage of industrialisation, it tends to generate inefficiency at later stages. The Korean experience indicates that though GRIs centred S&T policies were very effective early on, later, in the 1980s, GRIs led to serious inefficiencies through research duplication and their bureaucratic behaviour. Therefore, as industrialisation advanced, the government gradually handed over R&D roles in industrial technologies to the private sector and redefined the role of GRIs to the development of public and basic technologies. To what extent this transition was a smooth and efficient is an issue of heated debate among policy analysts.

At this point, it is important to recognise that there is no single best configuration for GRIs at all times. That is, the configuration of GRIs regarding their strategy, structure, and funding and management systems should fit into the national S&T and social environment. It means the features of components in GRIs can vary depending on the development stages of industrialisation. The Korean experience shows that a centralised structure with an efficiency-oriented strategy by the central government can be very effective in an early stage of industrial development. But as industrialisation progresses, the feature worked as a bottleneck, requiring empowerment to the individual institute level and competitive funding system, that is, RCS and PBS, respectively, for promoting its creativity and agility.

Fifth, but important nevertheless, there is a need for constant evaluation and reforms for GRIs. They tend to become bureaucratic and inactive organisations over time. Accordingly, the evaluation activity itself is very important because it provides the momentum to think over their performance and future direction at both GRIs' and individual researchers' level). Moderate reforms can also expedite active learning by constructing creative crisis. In Korea the government has introduced performance-based system, such as, annual salary and PBS, and made a reform, i.e., RCS for GRIs since the mid-1990s in order to promote their productivity and industry-oriented research. The introduction of new evaluation method and reforms partly contributed to move GRIs towards performance-oriented thinking.

In conclusion, Korean R&D policy instruments had successfully responded to the changing NIS by the 1980s. But since then there have emerged new criticism for the performance of specific policy instruments and the Korean government took several initiatives to redefine their roles and to restructure the organisations. For countries like Korea, with rapid development of experience, it is obvious that there will be many things to change, and time is needed for the whole NIS to be stabilised.

8 Governance of the policy mix

The Korean Government is trying to streamline the structure of the S&T system and to improve its effectiveness. In order to set priorities for the allocation of S&T budgets, and to effectively review and coordinate national S&T policies and R&D programs, the government established the National S&T Council (NSTC) in January 1999. The NSTC is chaired by the President of the Republic of Korea, and deputy chaired by the Deputy Prime Minister of S&T, and is composed of 13 Ministers of S&T-related Ministries and 9 representatives from the S&T community. The NSTC holds ultimate power over the coordination of R&D programs and budgets within Korea.

MOST serves as the secretariat for the NSTC through its newly established Office of S&T Innovation (OSTI), taking responsibility for the overall management and coordination of S&T policies, national R&D projects, industry and human resources policies related to S&T innovations, and regional technology innovation policies.

The OSTI, headed by a Vice Minister, will focus on the following:

- Forming a S&T R&D system in preparation for the future
- Promoting efficient investment and budget allocation
- Supporting development of future growth engine industries
- Developing a realistic long-term plan for a national R&D program
- Developing human resources in S&T and activate regional S&T

A second advisory board, the Presidential Council on S&T (PCST), is primarily comprised of non-governmental scientific experts and corporate leaders representing various areas of S&T.

In the past, the PCST was irrelevant to the centrally controlled, government-driven central planning exercise. Currently, however, it is becoming more important as the government takes a more flexible, market-oriented approach to the planning process. The government would like to have its scientific policy satisfy more of the private sector's needs and is accordingly more open to that sector's views.

MOST is responsible for implementing the national coordination of S&T efforts within the country. This includes R&D initiatives, human resource development and education, and internationalization policies, as well as coordinating activities amongst the science-based Ministries and government-supported research institutes. MOST oversees compliance with the various national initiatives. The S&T Framework Law (No. 7218) implemented in September 2004 consolidated the authority for inter-ministerial S&T policy and R&D coordination within MOST to help establish an institutional system that would foster an innovation-driven culture in Korean society. The new law contains important provisions for the establishment of policies and plans for the overall support mechanism for related R&D projects and agencies. It also replaces the basic laws covering systematic S&T promotion and education at the national level. MOST is also responsible for the Centers of Excellence (COE) in Korea, including: Science Research Centers (SRCs), Engineering Research Centers (ERCs), Medical Science and Engineering Research Centers (MRCs), and National

Core Research Centers (NCRCs). These COEs were created to implement programs encouraging basic research in major universities.

The SRCs and ERCs, founded in May 1990, focus on innovative research in basic sciences and new technologies, while the MRCs, which started in 2002, emphasize research in physiology, diagnostics, treatment, public health, neurology, and psychology. The NCRCs started in 2003 and currently have research centers on nano-application, environment and biotechnology, biodynamics, and nano-medical systems. The SRCs and ERCs are selected on the basis of creativity and research capability. MRCs are selected from medical schools and funded in three phases. NCRCs are selected to promote future-oriented S&T fusion research. Once the centres are selected, they receive government funding for five to nine years, provided that the interim evaluations demonstrate good progress. In 2006, MOST initiated a large scale financial support programme for 65 SRCs/ERCs (up to KRW 980 million per year, per center), 18 MRCs (up to KRW 1 billion), and six NCRCs (up to KRW 2 billion).

Falling under the NSTC, there are three S&T-related research councils that oversee the operation of the Government-supported Research Institutes (GRIs) - the Research Council for Industrial S&T, the Research Council for Public Technology, and the Research Council of Fundamental S&T. This new system is expected to improve research productivity, strengthen linkages between institutes, and to increase transfer and commercialization of research results. However, ten GRIs still remain directly under MOST to support or carry out specific duties relative to the Ministry's mandate.

A key challenge for Korean policy makers is to make the innovation system more efficient and interactive by strengthening linkages among the institutions active in R&D, including foreign players. Although the government has already implemented programmes to raise the responsiveness of GRIs, new approaches such as public/private partnerships may be beneficial. To overcome the under-utilisation of human resources, the compensation scheme, including the ownership of intellectual property rights, needs to be reformed to reward research achievements. However, a more effective way may be to promote joint research and manpower exchanges across sectors, including technological co-operation between domestic and foreign firms. In the past, Korean firms have relied on “arm’s length” methods to acquire foreign technologies. New modes of technology acquisition, such as foreign direct investment, joint research, cross-licensing and strategic alliances, need to be utilised more. In addition, the evaluation system for public R&D investment needs to be upgraded to improve budget allocation and its responsiveness to a diverse set of stakeholders. The current system is more centred on programme management rather than systemic performance evaluation. The evaluation of R&D programmes is entrusted to 12 management agencies, which also play a vital role in allocating R&D budgets. Recent initiatives to enact a law for performance-based evaluation are a step in the right direction.

9 Interactions between policy objectives and instruments

This section draws on several recent assessments of the Korean Innovation System. This is an on-going debate and we focus on areas where consensus has been reached among researchers. In the last paragraph, we provide our personal assessment of the relevance of the Korean experience to the European policy debate.

It has been suggested that Korean innovation policy should be more fully integrated into the overall strategy of economic development. Given that the ultimate objective of innovation is to raise living standards, government programmes should be more focused on generic knowledge and boosting productivity, rather than on upgrading technology itself. This requires greater linkages among policies for S&T, education, the product market and other areas, in part through increased co-operation among ministries. For example, securing highly qualified human capital for S&T requires greater co-ordination between the NSTC and the Human Resources Development Council (HRDC) in the Ministry of Education and Human Resource Development. The current public funding system for university R&D, which is fragmented among diverse ministries, also needs co-ordination between those two councils to improve efficiency in the allocation of funds. The recently created S&T Joint Committee for S&T Workforce Issues is an attempt to improve co-ordination between the two Councils. Another priority should be to harmonise and minimise potential conflicts between the national innovation system and the recently launched Regional Innovation System (RIS), which emphasises balanced territorial development. Regional industrial policies driven by diverse ministries focusing on S&T, business and universities have suffered from weak co-operation. It is thus necessary to strengthen regional planning, co-ordination and evaluation capabilities and to build effective firm-supporting systems.

Having said that, it is at least as important to ask whether optimal use is being made of the existing stock of knowledge as it is to ask how that stock can be expanded. Effective use of existing technology depends on its diffusion. Increasing the R&D linkages between business, GRIs and universities is one strategy that is likely to encourage diffusion. In addition, the government recently introduced programmes to bring patent holders together with potential licensees and a public-private partnership was established to support SMEs in intellectual property matters. At the same time, it is important to consider the role of intellectual property rights, regulatory features of product, capital and labour markets, and the availability of skilled human capital in diffusing technology. While policies in these areas usually aim at objectives other than innovation, they affect an economy’s capacity to diffuse, as well as to create, new technologies. In the absence of an appropriate framework, policies to stimulate innovative activities in the private sector, are unlikely to be effective.

High R&D intensity is one of Korea’s strengths. However, Korea has a long time problem of relatively low R&D efficiency. Several factors may have contributed this. The density of scientists and engineers in Korea is not as high as in other industrialized countries, while Korea’s R&D investment intensity is in the highest group. To support intensive R&D activities inside Korea, it would be ideal for Korea to have more high-quality scientists and engineers. However, developing highly qualified scientists and engineers is not a short-term project. Therefore, Korea should not neglect opportunities to build networks with others in the "global brain pool." Another major determinant of R&D efficiency is the level of existing knowledge stock. If the knowledge stock is low, R&D investment flows do not produce as much as in countries with a high knowledge stock. R&D investment is a necessary condition to increase the knowledge stock itself. In other words, to reach a certain level of R&D efficiency, Korea must accumulate knowledge stock, and this in turn will need additional R&D investment in basic research and generic knowledge.

Institutional governance and R&D infrastructure are other determinants of R&D efficiency. Compared with other developing countries, Korea has a better market system, stronger linkage between markets and technology, and a more modernized institutional structure. So Korea's R&D efficiency will be higher than China's, for example, if other things are equal. If Korea and China invest the same amount of R&D funds in the area where they have similar existing knowledge stock, R&D outcomes or productivity would be probably higher at present in Korea. To maintain this advantage and to further improve the R&D efficiency, Korea needs to make continuous improvements in organizational innovation, R&D management skills, and governance structures.

Finally, are there any useful policy messages -for European policy makers- from the Korean experience? To start with, it should be emphasized that the Korean case is a unique one. An intensive and export driven industrialisation process creates surplus for further expansion and diversification. A competent and powerful bureaucracy is co-ordinating this process with a rigid and vertically integrated governance structure. Beyond these context specific characteristics, there are some useful insights for policy analysts. Firms involved in competitive markets respond to government R&D incentives very fast. That creates dual production structures and exposes the manufacturing base to exogenous shocks. Also, the strategic orientation of the local innovation system is an important dimension. An innovation policy geared to product development is, in the long run, undermining the accumulation of knowledge stock and its ability to adjust to generic technological change. Policy implementation is a third area which offers valuable insights. A top-down process in innovation policy increases the speed of adjustment, mobilises the administration and succeeds in achieving quantitative targets. However, when it comes to learning and interaction, this rigid structure is finding it very difficult to respond to these challenges.

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