# From Capacity-building to Innovating: The Role of International Linkages in Korean Science and Technology Development

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## 1. INTRODUCTION

Starting from nowhere in the early 1960s, Korea has now become a global player in science and technology (S&T) – the 7th largest R&D investor and the 4th largest producer of patents in the world.[1] Indeed, Korea has achieved in four decades what it took more than a century for other developed countries to accomplish.

The question then is how Korea has been able to make such a development. Many agree that the Korean achievements owe much to the well-educated human resources, the outward-looking development strategy of the government, and the strong commitment of the government to the development of indigenous R&D capability. Without the human resources, Korea would not have been able to learn, absorb and successfully implement the technologies brought from foreign sources. The outward-looking development strategy – or export-oriented strategy – of the government drove Korean companies out into international market from the early stages of development and exposed them to harsh international competition. In other words, the outward-looking development strategy put Korean companies under severe pressure for competitiveness, to which they have responded by actively engaging in R&D and innovation. The Korean government has also implemented well-structured policy programs to build up indigenous S&T capability, while at the same time, promoting inward transfer of technology. The government created the Ministry of Science and Technology (MOST) in 1967 as the central body responsible for S&T policy formulation and implementation, created the government R&D institutes in the 1960s and 1970s to help industries acquire, learn and absorb foreign technologies, and launched various policy programs to promote and facilitate R&D and innovation in the private sectors. These factors combined together have enabled Korea to achieve the development.

Yet, there is another aspect that has been left somewhat ignored in the discussion. Throughout the development period, Korea has relied very much on international linkages as a means for S&T devel-

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[1] In terms of GERD/GDP, Korea ranks 4th among OECD countries (2008). Here, patents include PCT applications, triadic patent families, and US patents granted.

opment. In the early stage, when Korea was nowhere in S&T, it relied on international linkages not only for building S&T capacity but also for learning and acquiring technologies for industrialization. The technological achievements that made the structural transformation possible during the period of 1980s-1990s were also the results of R&D drawing upon new original technologies from foreign sources. As such, international linkages have always been an important factor behind the S&T developments in Korea. So, for a better understanding of Korean S&T development, it is critical to examine how Korea utilized international linkages for S&T development, which is what this paper aims to do.

## 2. INTERNATIONAL LINKAGES AND S&T DEVELOPMENT

### *Why international linkages?*

Korea relied very much on international linkages for S&T development from the very beginning. But as a matter of fact, the strategy was not what Korea chose among various options but what Korea was forced to accept because of the geo-political and geo-economic constraints that excluded other options. Geo-economically, Korea is a small, densely populated country with a very poor resource base. Furthermore, it is so mountainous that only one fourth of the land is arable, which set a limit to economic growth during the pre-industrial period. Due to geographical remoteness, Korea had very limited cultural, economic and technological interactions with the Western world, and remained a hermit land until late in 19th Century when the peninsula was forced to open to the outer world. So, Korea had long been shielded from the influences of the Industrial Revolution, and therefore was very late in industrialization.

When the Republic of Korea was founded in 1945, it was one of the poorest countries in the world suffering from all the problems that afflicted poor countries of the world in those days. To make things worse, the Korean War (1950-53) flattened even the poor industrial base that Korea had inherited from the past. So, the economic situation in the early 1960s in Korea was more than what the word miserable means: Korea's GNP in 1961 was only US$ 2.3 billion or US$ 87 per capita (in 1980 prices). At the time, the main source of income was the primary sectors with the manufacturing sectors accounting for only 15% of GNP. Even bleaker was the S&T situation. There were only two public institutions for scientific research and technological development: The National Defense Research and Development Institute, which was created right after the end of the war and the Korea Atomic Energy Research Institute which was founded in 1959 (MOST 1962-97). On this institutional base, Korea invested US$5 million in R&D or 0.2% of its GNP in 1964, employing approximately 2,000researchers.[2] As far as global S&T landscape was concerned, Korea was nothing but a barren land.

In a nutshell, when Korea launched the development drive in the early 1960s, it had neither resources nor technologies to support industrialization. The only asset that Korea could avail for industrialization was its relatively well-educated human resources, suggesting that the only feasible strategy for Korea was to take advantage of its human resources to learn and acquire technologies required for

[2] Data on researchers for 1964 is not available. The number here is an estimate based on the number for the year 1966 which was 2,286. (MOST, 1962-97)

industrial development. Given the situation, Korea had no option but resorting to international linkages for S&T capacity building, technological learning, and technological catching-up.[3]

But Korea could not pursue the strategy as freely as desired. Being a small peninsula country bordering with super powers – with China and Russia in the north and surrounded by the Japanese Islands in the South - Korea has always been under the strong influences of those countries, and the major historical changes on the Korean peninsula have largely been the results of either rivalries or alliances among those countries. It is also the result of the interventions of those powers that the Korean peninsula was divided into two different countries after the end of WW II and still remains a Cold War front. Up until the early 1990s, when Korea rehabilitated diplomatic relationships with its former socialist neighbors, Russia and China, Korea had been an isolated island which was totally disconnected from the neighboring countries not only politically but also economically and technologically. Interactions with Japan had also been limited. To Koreans, due to the unfortunate historical experiences[4], Japan has always been a country close geographically but distant politically, and such emotional tension has kept the two countries from fully harnessing the potential opportunities for mutually beneficial exchanges and cooperation in S&T. It was due to such geo-political constraints that Korea had to go without active S&T linkages with its neighboring countries which otherwise could have been an excellent source of technological learning. As such, the geo-political and economic features have been an important factor underlying Korea's international S&T policy.

***Korean strategy: A stepwise approach***

Korea has been using international linkages in diverse ways in order to make up for deficiencies in the requirements for S&T development. In the beginning stage (1950s-1970s), what was most desperate was building S&T capacity, for which Korea relied on foreign assistance. During the industrialization period (1960s-1980s), the policy was focused on promoting inward transfer of mature technologies from foreign sources through various channels. This was the stage where Korea pursued industrialization by imitating and assimilating foreign technologies that passed the test of market. Kim (1997) dubbed this the stage of "duplicative imitation."

In the early 1980s, Korea was emerging as a newly industrializing economy, trying to make another transition toward a high-technology-based industrial economy. In order to achieve the transition, Korea directed the focus of international S&T strategy toward securing access to new original technologies. At this stage, Korea concentrated its resources and strategic efforts on building up indigenous R&D capability, while at the same time, implementing the International Joint R&D Program designed to help scientists and engineers develop and maintain international networks for S&T cooperation. The strategy was to combine domestic R&D capability with new original technologies from foreign sources to create new innovations that would fuel the structural transformation of the economy. This is quite similar to the "fast second" strategy of Geroski and Markides (2005), and also to "creative imitation" in the framework of Kim (1997).

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[3] Ernst (2000) also emphasized the role of international linkages by saying that "Korea's success has been based on a development model that combines international linkages with a dense, almost symbiotic relationship between the government and the Chaebol…"

[4] Korea was under the colonial rule of Japan for 36 years from 1910 to 1945.

Korea now is entering the stage of "original innovation"[5]. At this stage, the tasks of international S&T policy become complex, such as (1) how to make original innovation possible through international linkages; (2) as a S&T power, how to expand influences in the international S&T community; and (3) how to fulfill the responsibility as a leading member of the international S&T community. At this stage, Korea needs to have S&T capacity to make original innovations as well as moral capacity to serve the world community through S&T. And international S&T strategy should be designed in a more coherent manner, taking into account various aspects of the consequences that would result from the policy.

TABLE 1 Evolution of International S&T Strategies

| | 1950s-1970s | 1960s-1980s | 1980s-2000s | 2010s- |
|---|---|---|---|---|
| Economic development goal | Capacity building | Industrialization | Structural transformation | Advanced knowledge economy |
| S&T policy goal | S&T capacity building | Acquiring and learning mature technologies<br>- Duplicative imitation | Innovation based on R&D drawing upon new original technologies<br>- Creative imitation | Developing new technology based on fundamental R&D<br>- Original innovation |
| International S&T strategy | Utilization of ODA and international assistance for capacity building<br>- Institution building<br>- Human resources development<br>- R&D system | Promotion of technology transferr<br>- DFI, FL<br>- Technical training<br>- Capital importation, etc | Securing access to new technologies, and S&T resources<br>- International joint R&D<br>- International S&T exchanges<br>- Off-shore R&D | International S&T resource mobilization<br>- R&D DFI, off-shore R&D<br>- Mobility of researchers<br>Participation in multilateral S&T programs<br>-I ssues of global concern<br>- Contribution to the scientific advances of the world<br>Development assistance<br>- Contribution to the balanced growth of the world |

## 3. INTERNATIONAL COOPERATION FOR S&T CAPACITY-BUILDING

After the end of the Korean War, the United States and international agencies provided Korea with massive economic aids for the rehabilitation of the war-torn economy. The major donors of Official Development Assistance (ODA) in the early post-war period (1953-) were the United States, United Nations agencies (UNDP, UNESCO, etc.) and the Colombo Plan member countries. Korea received US$12.7 billion from the United States alone during the period between 1945 and 1975, which constituted the bulk of foreign aid to the country from all sources (CBO 1997). In the early years (1945-48), the United States was the sole provider of ODA which was directed to preventing hunger and diseases, increasing agricultural productivity, and supplying consumer goods in the form of emergency relief. United States aid was then shifted toward national security and economic reconstruction (1949-60) (CBO 1997). Foreign aid to Korea peaked around the end of the 1950s and began to decline. After 1961, donor support for Korea was diversified as the IBRD loan was first signed in

[5] This term was borrowed from Kim (1997), but the notion is a little different. Kim appears to say that Korea was already at this stage in the 1990s, while this paper argues that Korea is now entering the stage.

1962, and the diplomatic relationship with Japan was normalized in 1965(CBO 1997). As the inflow of foreign aid began to decline in the 1960s, the proportion of loans in the foreign aid increased (Kim and Lee 2011) and the Korean government began to claim stronger ownership of the ODA programs, trying to link the programs closer to local needs. The Korean government used ODA as a means to develop S&T capacity, including human resource development and institution building.

United States technical assistance in the early stage was mainly used for human resource development. During the period of 1956-62, Korea sent 1,565 students to the United States for technical training and advanced education, with a focus on training technical personnel for industrialization and the modernization of agricultural sector (MOST 1962-97). In fact, many ODA programs in the 1960s and 1970s were geared to building S&T institutions and human resource development. Excellent examples are the Korea Institute of Science and Technology (KIST) and the Korea Advance Institute of Sciences (KAIS). KIST was founded in 1966 based on the technical and financial supports of the United States. At the summit meeting in 1965, United States President Johnson and Korean President Park reached an agreement on the terms and conditions of Korean military involvement in the Vietnamese war, and made an announcement in their joint statement that the United Stated would provide Korea with financial and technical assistance for the establishment of an industrial research institute. Even though it was not formally stated, it is now widely known that the idea of KIST was on the shopping list that President Park brought to the meeting. The agreement was immediately translated into action and KIST was born in the next year as the first R&D institute in modern sense in Korea.

In order to operate KIST, the Korean government launched a program to bring back overseas Korean scientists and engineers with Ph.D. or equivalent degrees in the areas of mechanical engineering, metallurgy, electronics, chemical engineering, food science, and so on. During the period of 1968-79, 238 scientists and engineers returned home under the program, and played key roles in laying the foundation for S&T development in Korea (MOST 1962-97). KIST made remarkable contributions to the industrialization in the early stage of development by helping private industries identify, acquire, and assimilate foreign technologies for domestic use. KIST later spun off many R&D institutes in specialized areas, such as electronics, chemistry, bio-engineering, food science and so on.

Another example is KAIS. On the basis of the successful development of light industries in the 1960s, the government launched another ambitious plan that was geared to developing heavy machinery and chemical industries. In order to meet the human resource requirement for the development of heavy machinery and chemical industries, KAIS was created in 1971 by President Park on the advice of Dr. K. Chung as an institution for advanced education and research in S&T. For the creation of KAIS, the Korean government worked with the United Stated Agency for International Development (USAID) which sent a team of experts on engineering education for a feasibility study. As a result of the field study, the team concluded that although the booming Korean economy desperately needed well-trained scientists and engineers, local universities were not prepared to deliver them, and recommended the Korean government to establish an independent graduate school devoted to advanced education and research in science and engineering. The USAID co-financed the creation of KAIS, which opened in 1971. KAIS, later renamed the Korea Advanced Institute of Science and Technology (KAIST), brought in the United States graduate education system and has made critical impacts on the graduate education system in Korea. Over the past four decades, KAIST produced about 8,000 Ph.D.s and 20,000 Masters in science and engineering who are now leading science and technology activities in various sectors of Korea.

Korea also benefited very much from UN agencies in developing S&T capacity – both institution-building and human resource development. The ODA programs of the UN agencies made notable contributions to the development of public research system by providing technical assistance in setting operational systems as well as financial assistance to upgrade the research facilities of the public research organizations. Among many programs, the following programs stand out (MOST 1962-97):

- Technical Extension Center for SMEs: UNIDO (1967-75)
- Fisheries skill training program: FAO (1964-76)
- Precision Instrument Center: UNIDO (1966-67)
- Meteorology Research Institute: WMO (1972-76)
- Food Research Institute: FAO (1971-77)
- Shipbuilding Institute: IMCO (1973-77)
- Oceanographic Institute: UNESCO (1973-77)
- Korea S&T Information Center: UNESCO (1973-74)
- Electric Technology Institute: ITU (1963-68)
- Central Vocational Training Center: ILO

What is more notable is the fact that these ODA programs were later further expanded and institutionalized as government research institutes or other forms of public agencies that played essential roles in S&T development in the early stage, and have grown as key organizations in their fields.

Bilateral ODA programs financed by countries other than the United States also made significant contribution to S&T capacity-building. Interestingly, it has been found that the donor countries focused their aids on certain areas rather than spreading the financial assistance over diverse sectors (MOST 1962-97). For example, Japan's ODA program in S&T was concentrated on helping institution-building in the areas of medical research and education. The cancer center at Yonsei University, the industrial medical center at the Catholic University, and the endemic research center at the Seoul National University Medical School were the major beneficiaries of Japan's ODA. German ODA programs for Korea were very much geared to skill training. The Inchon Korea-Germany Vocational School, the Busan Public Vocational Training Center, and several others were established and operated on the technical and financial assistance from Germany. French ODA for Korea in S&T was very much focused on engineering education as evidenced by the Korea-France Technical College which was founded with financial and technical assistance from France. The Korea-France Technical College has now grown into Ajou Univsrsity which is one of the major four-year universities in Korea. Australia, New Zealand, Belgium and other countries also provided Korea with financial and technical aids for S&T capacity building. (MOST 1962-97)

From the above, we can see that Korea relied very much on foreign aids for building up the foundation for S&T development – R&D institutions, graduate education, skill training, and so on. In this sense, Korea owes much of its progress to foreign aids for what it has achieved in S&T, but as noted in several studies (Steinberg 1984, CBO 1997), Korea used ODA very wisely and also deserves credit for the success of the ODA programs. First of all, As Steinberg (1984) states, "Korean position prevailed whenever there was disagreement with the US…", and thus US support generally followed Koran government policies and priorities, which means that the ODA programs were well tuned to the needs of Korea. Second, the ODA programs, being linked to local S&T development requirements and policies, were highly result-oriented. And third, not only did Korea work very closely with donors in formulating and implementing the ODA programs but the government also expanded and institutionalized the programs, making them sustainable even after the expiration of the programs.

## 4. TECHNOLOGICAL LEARNING THROUGH INTERNATIONAL LINKAGES

The first Five-year Economic Development Plan (1962-66) and the subsequent plans created huge demand for technologies that could not be acquired from domestic sources. Lacking in technological capability, Korea had to rely almost entirely on foreign sources for technologies. Korea pursued the strategy of promoting inward transfer of foreign technologies for imitation and assimilation.

Developing countries acquire technologies through various channels, such as direct foreign investment (DFI), foreign licensing (FL), importation of capital goods, turn-key plant importation, and so on. Of these, DFI is very often cited as the most effective means for developing countries to acquire production technologies, management skills, and other business knowhow, such as in the case of Singapore. Unlike the experiences of other developing countries, however, the role of DFI as a channel for technology and capital acquisition was very limited in the early stage of industrialization in Korea. Two reasons underlie this rather unusual phenomenon: first, the government took a very restrictive policy toward DFI, such as restriction on ownership and repatriation of profits, technology transfer, and export requirements. The Korean government in the 1960s could not afford to take an open stance toward DFI, because Koreans in those days held a view that multinationals might perpetuate economic and technological dependence, thus reinforcing the asymmetric relationship between the developed and developing countries (Koo 1986, Vernon 1977, Stewart 1978). Second, regardless of the Korean government's policy on DFI, foreign investors might not have invested actively in Korea, because Korea was still under a state of ceasefire and thus appeared, in many respects, much less stable and riskier than other developing countries. So, Korea relied much more on combinations of arm's length methods, such as reverse engineering, original equipment manufacturing (OEM), and turn-key plant importation.

TABLE 2 Channels of Foreign Technology Transfer to Korea: 1962-1981 (US$ million)

| | DFI | Foreign licensing | Capital goods importation |
|---|---|---|---|
| 1962-66 | 45.4 | 0.8 | 316 |
| 1967-71 | 218.6 | 16.3 | 2,541 |
| 1972-76 | 879.4 | 96.6 | 8,841 |
| 1977-81 | 720.6 | 451.4 | 27,978 |

*Source: National Statistical Office cited in Chung and Suh (2007)*

Instead of relying on DFI for capital and technology, Korea resorted to long-term foreign loans to finance industrial developments. The government brought in large-scale foreign loans and allocated them to finance the development of selected strategic industries, which led to massive importation of foreign capital goods and turn-key plants. The purchase of technology through FL was also of modest importance in the early stage because of the government's imposition of foreign exchange controls. Being a poor agrarian economy relying on primary sectors for a large share of national production, Korea in the 1960s simply could not afford to buy technologies from foreign sources, which often may entail long-term financial commitments.

The responses of private companies to such restrictive policies varied across industries. Industries acquired necessary technologies by reverse engineering the imported capital goods or through technical training as part of turn-key plant importation or through learning by implementing the imported technologies. In the case of light industries, such as shoes, clothing, textiles, and some intermediate goods for import substitution as well as export, the major sources of technological learning were

OEM (original equipment manufacturing) production arrangements. Korean firms benefited most from such arrangements because they offered opportunities to work with foreign buyers who provided everything from product designs and materials to quality control at the end of the process. This was especially so in the case of garment and electronic industries (Hobday 1995). In the 1970s, Korea's development target shifted to more capital- and technology-intensive industries, and the government implemented massive investment projects to build up machinery and chemical industries. For the development of chemical industries, Korea relied largely on the importation of turn-key plants, which offered technical training programs as part of the package. In the case of heavy machinery, foreign licensing was an important channel for technology acquisition (Chung and Branscomb 1996). To help industries to adopt new technologies, the government created government R&D institutes in the fields of heavy machinery and chemicals, such as the Korea Institute of Machinery and Metals, the Electronics and Telecommunications Research Institute, the Korea Research Institute of Chemical Technology, the Korea Research Institute of Standards and Science, the Korea Institute for Energy Research, and the Korea Ocean R&D Institute. These institutes worked with private industries to build technological foundation for industrial development.

As a result, DFI had a minimal impact on the Korean economy, accounting for only 4 percent of Korea's cumulative total long-term foreign capital over the period of 1962–82 ($9 billion). According to a United Nations report, DFI in all developing countries in the early and mid-1970s accounted for 10–20 percent of their total foreign capital inflow (Ahn 1991). Over the period of 1962–71, DFI inflow in Korea remained at US$264 million, while imported capital goods reached US$2.9 billion. In short, Korean industries acquired technology more from informal than formal channels.

Through such strategies for technological learning, Korea was able to achieve industrialization and economic growth earlier than planned. The government set the target of achieving per capita GDP of US$ 1,000 and annual exports of US$ 10 billion by the year 1980, which was attained in 1977, three years earlier than planned. During the period of 1960s-80s, the Korean economy grew at an average annual growth rate of over 9%, and had undergone a remarkable transformation from being a stagnant agrarian economy into being a dynamic industrial one, which was based on low- and medium-technology.[6]

In fact, the Korean strategy for inward technology transfer was successful because of both internal and external factors. Domestically, Korea had technological absorptive capacity — well-educated workforce, S&T institutions, and so on — that were built in part through international cooperation (as described in the previous section). As informal channels involve less market mediation, they are less costly but require recipients to have higher capacity, not just in identifying and selecting technologies, but also in absorbing, assimilating, and improving upon the transferred technologies.

Externally, the international economic order, including IPR (intellectual property rights), trade and investment regimes, in the 1960s and 1970s was more lenient towards developing countries than it is today, and so Korea could rely on protectionist policy for development while seeking inward technology transfer through informal channels. But this policy had both positive and negative effects. On the positive side, it enabled Korea to acquire technologies at lower costs, and precluded the constraints often imposed by multinationals on local firms' efforts to develop their own capability. Korea's approach was effective in maintaining independence from the dominance of multinationals. Negative effect is that Korea had to give up an important access to new technologies that might have been possible through direct equity links with foreign firms.

[6] For more discussion on this, see Kim (1997) pp.100-102.

Learning through technical training: POSCO

In the late 1960s, POSCO acquired technologies required to build and operate steelworks from Nippon Steel Corporation and Nippon Steel Pipe Corporation. The Japanese companies provided POSCO with not only technologies but technical training to help the recipient implement the technologies. POSCO engineers also developed personal relationships with Japanese engineers who later transferred tacit knowledge which could not be acquired through on-the-job training. POSCO also hired Japanese technicians as consultant to obtain knowhow on the maintenance and operation of the steel mill. POSCO then accumulated technical knowhow and developed capability to improve upon the imported technologies through learning by operating, and two decades later, it built a new steel mill on its own technologies and knowhow. It is now one of the major steel mills, producing high-quality iron and steel.
(Taken from MEST (2010) p.64)

Technology acquisition through FL: LG Electronics

LG licensed TV technology from Hitachi in 1965 as a package that included not only assembly processes but also product specifications, production knowhow, parts, components, technical training, and technical consultancy. In the process, LG sent seven engineers to Hitachi for intensive training, and also invited Hitachi engineers to supervise the installations and start-up of the production system to minimize trial and error time. It did not take long time for LG engineers to grasp the knowhow and the utility of the Hitachi engineers diminished in less than a year. LG was able to internalize the TV technologies and apply the technologies to the assembly of other consumer electronics, such as cassette recorders and simple audio systems without foreign assistance. LG's case shows how Korean electronics companies absorbed and internalized technologies borrowed from foreign sources.
(Taken from Kim(1997) pp. 135-136)

## 5. INTERNATIONAL LINKAGES, TECHNOLOGY CATCH-UP, AND STRUCTURAL TRANSFORMATION

As the growth and structural changes continued into the 1980s, the technological requirements of Korean industries became increasingly complex and sophisticated. The Korean economy reached a stage where mature technologies could not generate further growth. The rapid growth of Korean exports also gave rise to increasing concerns among advanced countries that Korea might emerge as a new competitor in the international market, making it more difficult for Korean companies to engage in technological interactions with their foreign counterparts. To promote international technological interaction of private industries, the government loosened the regulations on DFI and liberalized FL during the 1980s. However, the deregulation and liberalization did not lead to noticeable increases in DFI inflow and FL. To make the situation more difficult, the high growth phase of the Korean economy was coming to an end toward the end of the 1980s, due partly to the exhaustion of the latecomer advantages[7] in growth, and partly to the changing socio-economic environments, such as the changes in trade environments, rising union movements, and increasing wages which resulted in the serious erosion of growth potential of the economy.

In a word, Korea had to find new sources of growth in order to sustain the development. The government viewed this as a signal that Korea had to build indigenous R&D capability to meet the changing technological demand, and launched the National R&D Program in 1982, which was the first national program designed for industrial technology development. In parallel with this, it took a series of measures to promote industrial R&D, including tax and fiscal incentives. Since then, R&D expenditures in Korea have been increasing at an annual rate of around 20% (KOITA). However, being weak in R&D infrastructure and limited by poor knowledge stock — R&D stocks, know-how, research experience — these domestic R&D efforts did not suffice to meet the new technological challenges. Korea had to tap into the global reservoir of knowledge to make up for the deficiency. The challenge was how to secure access to new original technologies. Yet only a negligible portion of R&D expenditures was used to utilize overseas S&T resources. Thus, in 1985, MOST launched the International Joint R&D Program, which was designed solely for international R&D cooperation. This program aimed to promote and facilitate international cooperation by providing funds for small- and medium-size research projects, through which researchers could develop and maintain international R&D networks.

Over the period of 1985–1997, the Korean Government spent 52 billion Korean Won (approximately, US$50 million) on this program, of which 17% was for collaboration with the United States, 24% with Japan, 17% with Russia, 13% with Germany, and so on. Only 2% of the total fund was used for cooperation with developing countries. So Korea devoted more than 70% of the program funds to collaboration with the four major countries that are the top technological leaders of the world today (Chung, 1999). The allocation of the funds to technology areas in the later part of the 1990s (1995–1997) shows that the lion's share was spent on collaborative research on new materials (20.8%), machinery and electronics (16.3%), information and communications (12.9%), and biotechnology (13.8%). This implies that the International Joint R&D Program was used by Korean scientists mainly as an avenue for catching up with new developments in high technology areas in the advanced countries (Chung, 1999). Following MOST, the Ministry of Industry and Commerce and the Ministry of Communications also launched similar programs to promote and facilitate international cooperation in the areas under their purview, increasing the annual budget for international cooperation programs to 41.4 billion Korean Won or US$ 400 million in 2001.

No doubt, the program has promoted international research collaboration. Of the total Science Citation Index (SCI) publications by Koreans over the period 1995–97, 27.6% were internationally co-authored, which was slightly higher than the OECD average (26.7%) (OECD 2001). As in the case of the International Joint R&D Program, Korean international co-authorship showed an extreme geographical concentration. Of the total SCI publications coauthored by Korean and foreign scientists over the period 1988–1994, those co-authored with US scientists accounted for 64.2%, and those with Japanese scientists 20.1% (BIE, 1996). This clearly shows how much Korea depended

[7] Cho, Kim and Rhee(1998) identifies five general categories of late-mover advantages, of which the following is more relevant in this context: Late-movers in the new technologies can free-ride on the information externality generated by the early technology pioneers in terms of educating consumers, avoiding cost of trial and error, spillover of learning curve effects from the early movers and diffusion of know-how leading to lower cost of imitation by late-movers etc.

on the United States and Japan. This orientation of S&T cooperation stems in part from Korea's geo-political and geo-economic situation. Geographical proximity is often considered as a major factor that determines international S&T cooperation. Yet, until the early 1990s, it was political distance rather than geographical distance that dictated bilateral S&T relationships among the Northeast Asian countries. During the development period (1960s–1980s), Korea could not take advantage of being a neighbor to such technological powers as Russia and China, which were then Cold War enemies. Excluding these two neighboring countries, the United States and Japan were the only realistic choices. In other words, Korea was very much bound by the geo-political constraints. Korea established diplomatic relationships with Russia and China in 1990 and 1992, respectively, and since then S&T interactions with those countries have been increasing in both quantity and quality.[8] The geographic concentration of international cooperation is also a consequence of the traditional relationships that exist between the scientists and engineers of Korea and those of the United States and Japan. Most of the leading scientists and engineers in Korea are the products of US institutions, while their predecessors were trained in the Japanese way during the colonial period. Naturally, they tend to collaborate preferentially with their former colleagues and/or mentors in the Unites States or Japan.

Private industries also changed their technology strategy from imitating and assimilating mature foreign technologies to creating innovation through in-house R&D drawing upon existing new technologies. They started to expand in-house R&D organizations and investments, including funding for international R&D and foreign licensing. In 1980, there were only 54 corporate R&D centers in the private sectors which spent a mere 76 billion Korean Won (or US$ 70 million) on R&D. Over the period of 1980-2000, the number of corporate R&D centers increased to 7,110 and the private R&D investments grew by more than 11 times to 8,585 billion Korean Won (US$ 8 billion). Foreign licensing, which remained at only US$ 564 million during the period of 1962-81, increased by more than 40 times to US$ 26 billion during the period of 1982-2001. It was also at this stage that they began to expand off-shore R&D, on which they spent 545 billion Korean Won (US$ 500 million) in 2001, operating 17 off-shore R&D centers.

This period witnessed remarkable technological achievements that include DRAM (Dynamic Random-Access Memory) chips, hepatitis B vaccine, NMRI (Nuclear Magnetic Resonance Imaging) technology, nuclear source materials, TDX (an electronic switching system), CDMA (Code Division Multiple Access: a wireless telecommunication system), automobile engines, computers and so on, almost all of which were the results of local and/or international joint R&D drawing upon foreign technologies. As an example, the Electronics and Telecommunication Research Institute (ETRI) developed TDX-1 in 1984 and TDX-1A in 1988 based on foreign technologies and successfully installed the new system to expand telephone lines in the rural areas of Korea. Then, ETRI organized an R&D consortium to develop TDX-10, a large-scale switching system to replace the old systems in large urban cities. The development of TDX-10 was completed in 1991. This was an achievement of private-public joint R&D to create new commercial opportunities using existing foreign technologies. Learning from this experience, Korea developed and commercialized the CDMA system first in the world in the mid-1990s. The development and commercialization of DRAM, TDX, and CDMA laid a foundation for Korea to grow as a major IT power in the next decade.

[8] For example, Korea brought in various new original technologies from Russia which have been translated into new innovations by Korean scientists and engineers. Korea and Russia are now working together to develop a spaceship launcher for Korea.

## 6. INTERNATIONAL S&T POLICY TOWARD AN ADVANCED COUNTRY:

### *New Challenges for Korea*

Korea has made remarkable achievements in S&T development over the past four decades, and is emerging as a major economic and S&T player on the global stage. Korea now is world's 15th largest economy and 9th largest trading country, and a member of the OECD. It has transformed itself from being a foreign aid recipient into being a donor in four decades.[9] The geo-economic situation surrounding the Korean peninsula has improved significantly over the past two decades. Similar developments are taking place in the geo-political conditions: the long disconnection between Korea and its neighbors, Russia and China, ended in the early 1990s and new geo-political environments are being created in the region.

Amidst such changes, Korea has been moving on a bumpy road toward an advanced economy.[10] To join the ranks of advanced countries, Korea should be able to produce original innovations that require highest level of R&D capability. Even though Korea has been increasing investments in R&D and human resource development, there exist two basic constraints that Korea has to overcome in order to attain an advanced level R&D capability within a reasonable period of time. First, Korea is a latecomer in the scene which started the S&T development drive only in the 1960s on a very poor knowledge base, and thus it would be very difficult for it alone to attain the desired capability in R&D and innovation without international collaboration. Second, Korea spends more of its income on S&T and human resource development than other countries[11], but its expenditures on R&D accounts for only 3-4% of the global R&D expenditures, which means that more than 95% of new discoveries and/or inventions are being made outside Korea. Under such a circumstance, it would be practically impossible for Korea to successfully compete in the global R&D race without tapping into foreign S&T resources.

To deal with the issues, the Korean government, in the early 2000s, set a policy goal to position Korea as an R&D hub serving the North East Asian region[12]. The basic idea was to attract S&T resources – financial, human, and information resources—to Korea to make up for the deficiency of the Korean S&T system. As part of the efforts, the government invited some of the world-renowned institutions to Korea in expectation that they would bring in not only institutional knowledge base but also advanced research management systems that can be transplanted in the Korean soil.[13] Unfortunately, however, the policy has not been successful mainly for two reasons: First, it requires long-term efforts to attain such a policy goal, but the policy program could not survive the changes of government, whose term is five years. Second, multinational companies do not consider Korea an attractive location for regional headquarters which usually operate regional R&D centers. According to

[9] Korea is the only country to make the transformation among the countries born after WW II.

[10] Korea was hit hard by the Asian Financial crisis of 1997, from which it recovered faster than other countries by taking bold and broad reform measures throughout the economic system, and also by investing heavily in R&D and innovation.

[11] Korea spends more than 3.5% of GDP on R&D.

[12] The Roh Moo Hyun government launched the program in 2003, the focus of which was on attracting R&D centers of multinational to Korea.

[13] One of such cases is the Institut Pasteur Korea which started operation in 2004 under the management of the Institut Pasteur with the financial support of the Korean government (ten million Euros a year for ten years).

STEPI (2003), Korea lags behind its neighbors in terms of business and living environments which are the key determinants of the location for R&D foreign investment. Korea needs to improve business and living environments along with environments for R&D and innovation to attract the inflow of foreign R&D resources.

Off-shore research, an alternative way of accessing foreign R&D resources, has been increasing among Korean companies, but the phenomenon has largely been limited to large enterprises. A survey by the Korea Industrial Technology Association (KOITA) in 2003 found that only 4% of the respondent companies operate off-shore R&D centers, while 17% of them are engaged in international joint R&D of various forms (STEPI 2006). STEPI (2003) assesses that Korean industries are not active in utilizing global technological opportunities, because of the lack of experiences in international collaboration, weak financial capability and other reasons. They simply do not know how to navigate their way to successful international technology cooperation. This is more so in the case of small and medium enterprises (SMEs). As such, the government stepped in to provide them with assistance, such as information and legal services (intellectual property, licensing contract, local tax, etc.) and others, which, however, did not turn out to be effective.

In contrast, Korean participation in international scientific activities has increased remarkably. Korea joined the OECD Committee for Science and Technology Policy in 1994 where it has been playing an active role as a non-Western, newly industrialized country, providing new perspectives on international S&T issues. Korea is also now actively involved in the activities of various multilateral programs, such as the Human Frontier Science Program (HFSP); the Intelligent Manufacturing System (IMS); the Inter-governmental Panel on Climate Change (IPCC), EU Framework Program, and others.[14] This is important because these programs offer opportunities for Korea not only to keep up with the trends in scientific research but also to make scientific contributions to devising solutions to the issues of global concern.

A new challenge for Korea as an emerging S&T player is how to fulfill its share of responsibilities for solving the global issues. Korea is expected to play a meaningful role in promoting balanced growth of the global economy. The expectation stems from the fact that Korea has come through the economic and political hardships of the developing world and is well aware of what it takes a developing country to attain economic and political freedom. Korea is expected to make contributions to the balanced growth of the world by providing developing countries with S&T assistance, such as sharing S&T development experiences, transfer of mature technologies along with technical training, technical and financial assistance for S&T capacity building, and so on. In addition, Korea needs to actively engage in international efforts to attain global sustainability. Korea has been strongly advocating green growth at various international forums, including the OECD, G-20 Summit and others, and initiated the creation the Global Green Growth Institute (GGGI), an international think-tank devoted to research and analysis of the issues related to global sustainability. This kind of international involvement needs to be further expanded. Furthermore, Korea can make unique contributions to the development of the international community by taking the role of linking developed and developing countries in S&T and innovation. This is something Korea can do better relative to other countries. As direct transfer of technologies from developed to developing countries may entail unnecessarily high learning costs when the recipients are not capable of absorbing the technologies, a country like Korea can be instrumental in facilitating the transfer.

[14] For the processes that Korea had to go through to join the multilateral programs, see Chung (2002)

At this stage, Korea is faced with new challenges. First of all, Korea has to develop broader and more effective international S&T linkages to complement domestic efforts to enhance its S&T capacity, and at the same time, as a global S&T player, it has to assume new responsibilities (1) to contribute to the advancement of world science, and (2) to contribute to the balanced and sustainable growth of the global society. In order to carry out these tasks, Korea should equip itself with not just stronger S&T capacity but also higher moral capacity to use its S&T capabilities for the causes of humanity.

## 7. CONCLUSION:

### *International linkages and S&T development: Korea's achievements*

Korea has utilized international linkages in a very appropriate way to achieve the S&T policy goals set for each stage of development. Korea took maximum advantage of ODA to build up the foundation for S&T development – R&D institutions, graduate education, skill training, and so on. Without question, Korea owes a lot to foreign aids for what it has achieved in S&T, but as assessed by Steinberg (1984) and CBO (1997), Korea used ODA very wisely and deserves credit for the success of the ODA programs. The Korean government stubbornly stuck to the ownership of ODA projects to such a degree that Korean position prevailed whenever there was disagreement with donors. Thus ODA programs generally followed Korean priorities, meaning that the programs were well tuned to the local needs. As the ODA programs were linked to local S&T development requirements and policies, they were highly result-oriented. More importantly, Korea further expanded and institutionalized the programs after the expiration of foreign aids, making them sustainable.

During the industrialization stage, Korean strategy was focused on how to acquire and absorb the technologies required for industrial development. For acquiring and assimilating technologies, Korea also depended on international linkages. At this stage, Korea could succeed in acquiring foreign technologies mainly through informal international linkages, owing to both internal and external factors. Domestically, Korea had technological absorptive capacity — well-educated workforce, S&T institutions, and so on — that were built in part through international cooperation. As informal channels involve less market mediation, they are less costly but require higher recipients' capacity, not just in identifying and selecting technologies but also in absorbing, assimilating, and improving upon the transferred technologies.[15] Korea was well prepared in this respect and could succeed in acquiring and assimilating technologies for early industrialization. Externally, the international economic order, including IPR (intellectual property rights), and trade and investment regimes, in the 1960s and 1970s was more lenient towards developing countries than it is today, and so Korea could rely on protectionist policy for development while seeking inward technology transfer through informal channels. But this policy had both positive and negative effects. On the positive side, it enabled Korea to acquire technologies at lower costs, and precluded the constraints often imposed by multinationals on local firms' efforts to develop their own capability. Korea's approach was effective in maintaining independence from the dominance of multinationals. The negative effect was that Korea had to give up an important access to new technologies that might have been possible through direct equity links with foreign firms.

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[15] For more discussion on this, see Kim (1997) pp.100-102.

Korea had gone through a tremendous structural transformation from low- and mid- technology industries to high-technology industries during the period of 1980s-2000s. This period witnessed remarkable technological achievements that include DRAM, hepatitis B vaccine, NMRI (nuclear magnetic resonance imaging) technology, nuclear source materials, TDX, CDMA system, automobile engines, computers and so on, almost all of which were the results of local and/or international joint R&D drawing upon foreign original technologies. ETRI developed TDX-1 in 1984 and TDX-1A in 1988 based on foreign technologies which made a critical contribution to the expansion of telephone lines in the rural areas of Korea. Then, a private-public consortium organized by ETRI developed TDX-10, a large-scale switching system which replaced the old systems in large urban cities in 1991. This was an exemplary case of private-public R&D partnership that created new innovation using existing foreign technologies. The organizational processes of TDX development was later applied to the development of the CDMA system which was commercialized first in the world in the mid-1990s. The development and commercialization of DRAM, TDX, and CDMA laid a foundation for Korea to grow as a major IT power in the next decade. At this stage, Korea took advantage of international linkages mainly in the form of FL and international S&T collaboration in both private and public sectors to create new innovations drawing upon new technologies from abroad.

***New challenges***

Now, Korea has entered a new stage of development toward an advanced knowledge economy. To reach the developmental goal, it requires Korea not only S&T capacity to create original innovations but also moral capacity to serve the world community through S&T. To strengthen S&T capacity, Korea has been massively increasing investments in R&D over the past three decades, and it is now one of the major R&D investors in the world. But considering the shallow domestic knowledge base, the domestic S&T efforts, however massive they may be, do not suffice to build the desired S&T capability in the foreseeable future. Such domestic R&D efforts have to be complemented by effective international linkages, through which Korea can tap into global S&T resources. In order to enhance moral capacity as a global S&T player, Korea will have to place a greater emphasis on the social and ethical aspects of S&T development so that S&T development can serve the sustainability of human society.

***Lessons for latecomers***

Several lessons can be derived from the Korean experiences. For Korea which started the development drive on a very poor S&T base, international S&T linkages have been an indispensable means to compensate the deficiencies of the domestic S&T system. Thus, from the stage of S&T capacity-building, international S&T cooperation has been an essential component of the S&T policy. Second, what stands out most throughout S&T development process is the role of human resources. Without the well-educated, hard working workforce, Korea would not have been able to achieve what it is today in S&T. The third factor is the massive R&D investments, on the basis of which Korea has developed capabilities to tap into the global knowledge reservoir and create new innovations. Lastly, the focused strategy of the government has been very effective in putting the above factors together in a consistent manner to promote and facilitate S&T development. In a word, the combination of well-trained human resources, investments in R&D, international S&T linkages, and the government's focused strategy has enabled Korea to achieve the S&T development.

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