Science and Technology Human Resource Capacity for Economic Growth: The Case of Korea

Myungsoo Park *

ABSTRACT

This paper presents the policies Korea adopted to educate and train scientists/researchers and technicians/skilled workers. The Korean policies for the increase of human resources in science and technology that stimulated an upgrading of skills in industry and adapted to technical advancements are identified. An important factor is that the supply and demand mechanism created a virtuous circle so that the science and technology education and training policies were responsive to economic demands. In addition, policies to foster a human resource capacity have enhanced the contribution of human resources in science and technology for innovation and economic growth.

KEYWORDS: economic development plan, manpower policy, human capacity building, brain drain, repatriation

1. INTRODUCTION

In the beginning of the 1960s, Korea barely managed to maintain its economic activity, after a civil war that was preceded by five decades of colonial exploitation. International assistance and aid was a part of a lifeline that sustained the Korean economy. Korea found that economic development was achieved with the appropriate mix of both natural and human resources as it revived the economy.

The economic competitiveness of a nation depends on a science and technology base that is defined by the ability of knowledge creation and creative human resources. It also requires a consistent system of development, diffusion, and application of knowledge that evolves through constant communication between science and industry. Human resources in science and technology should have the highest priority for a substantial and positive contributing factor to economic growth in order to develop a scientific capability that can continuously absorb innovative technology.

The development strategy of Korea in 1960s was naturally directed toward effective education,

* Senior Researcher, Korea Employment Information Service, myungsoo@hanafos.com

training, employment, and utilization of human resources. The attitudes of policy makers in human resource development (especially in science and technology) have been an integral and consistent part of economic development policy.

Economic development has continuously generated demand for highly qualified personnel in science, technology, innovation, and skilled labor. Accordingly, the increase in public and private demand for human resources in science and technology requires the continuous supply of human resources with knowledge in advanced science and technology. The enhancement of the ability to build a human resource capacity in proper quantity as well as quality has been a policy priority for Korea.

Government-led economic development policies have been concerned about ensuring an adequate supply of human resources in science and technology that have focused on the expansion of the investment to produce human resources. Governments are cognizant of the supply of science and technology personnel along with skilled workers with the proper balance of supply and demand. In addition, the government has implemented programs that attract more individuals into scientific and technical careers. Awareness of the necessity of investing in science and technology research and development, along with the education and training of human resources has become a crucial part in development policy.

2. PURPOSE OF THE PAPER

The significance of human resources development has become a critical element of economic development for policy makers in developing countries. Human resources are crucial to scientific, technological, and industrial success, particularly in terms of innovation. The lack of skilled scientists and engineers is a main concern of many economies as they try to boost their innovation performance.

This paper shows what Korea has done to enhance human resource capacity and knowledge resources in the economy to meet the challenges of strong economic growth in a relatively short period. This paper explores ways to achieve this goal by shaping the agenda for future actions and policies for the acceleration of human resource capacity. The economic development processes of Korea are presented in this paper that include the education and training system along with an overview of the human resource development policy that focused on science and technological human resources.

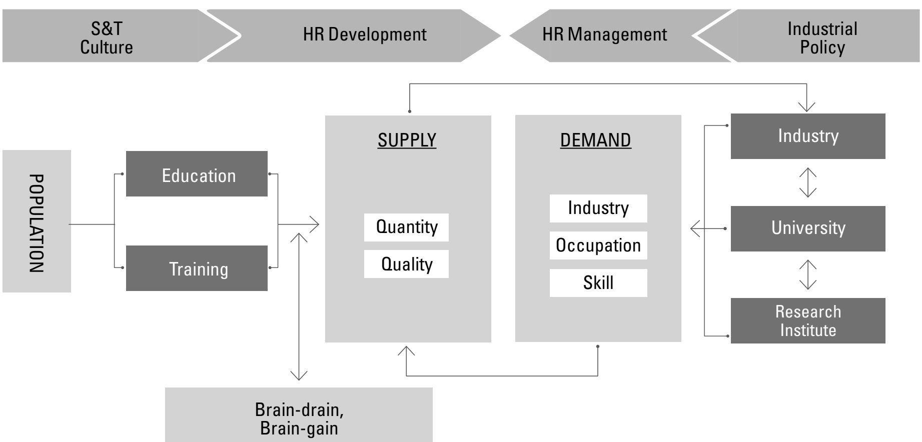
This study analyzes the issues of economic growth through the scientific and technological development of Korea. With the Korean experience of technological development examined, it probes how Korea has been able to accommodate the role of technology in development efforts as well as how it has fostered human resource development programs. It also probes what new demands the goal of a sustainable growth places on national education and training policies and suggests recommendations to fulfill the requirements.

3. VIRTUOUS CIRCLE OF SUPPLY AND DEMAND

Human resources are like any other good or service traded in the market back can be viewed from the aspect of supply and demand. First, in the supply side, the population of a nation provides the base for the human resources. A portion of society would be educated and trained to be scientists and technologists. While most of these resources are employed in domestic organizations, some travel with abroad for education and employment. The problem is, in most cases, these emigrants are highly qualified individuals and represent a brain drain. The second one is the demand side. When we think of a case of the industry, firms mobilize the capital and labor to produce goods and services. In the process, industry can produce better products more efficiently if there is enough high-skilled labor. The industry also employs R&D researchers for innovation. R&D researchers absorb imported foreign advanced technologies, assimilate them, and adopt them to produce new products. If there are inadequate human resources to perform these processes, the desired industrialization process cannot be accomplished. As firms grow, they need additional and higher-skilled human resources to help them advance further. That is how industry generates and induces the demand for human resources. The interactions of the two sides show the basic mechanism of how the whole system of demand and supply for human resources that makes it possible for industry to grow. In addition, industry employs the human resources, generates the demand, and induces the supply.

The supply of better-qualified human resources increases the production and technological capacity of industry. Industry and the economy then reinforce the demand for human resources. The type of feedback loop decides whether the economy enters a virtuous or vicious circle. The beginning of the Korean economic development started with the successful initiation of the feedback loop that transformed the economy to a higher stage in the next circle.

FIGURE 1 Supply-demand Mechanism of Human Resources

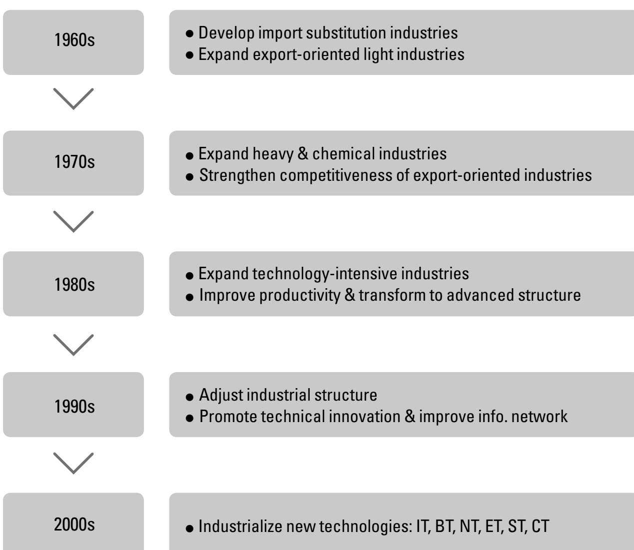


4. STEPWISE APPROACH OF ECONOMIC GROWTH AND HUMAN RESOURCE DEVELOPMENT

The task of accomplishing an instantaneous process of industrialization would be a formidable or impossible job. A systematic approach should be taken to create the capacity for industrialization. A necessary strategy for a country is the selection of the fields to be developed along with the extent of industrialization. The decision would be based on a clear understanding of the national potential and the constraints it faces, along with diverse socio-political, cultural, and economic factors.

Korea's modern industrialization started in 1960s, through successive government-led economic plans. When the First Five-year Economic Development Plan (1962-66) went into effect, Korea strategically opted for the development of light, labor-intensive industries along with absorbing the labor force from the primary sector. However, the demand for industrial products in the primary sector was insufficient and made it necessary to look outward for capital, markets, and technology. Korea then chose to develop on import-substitution industry that was accompanied by export-promotion policies. The Plan was to benefit the textile industry and make Korea self-sufficient in basic necessities. Successfully accomplishing the goal set in the First Plan, the next stage of the Plan emphasized the development of the heavy and chemical industries through the absorption and adaptation of imported technologies. Emphasis was also given to shifting major export items from consumer goods to durable goods. The Plan targeted the development of industries of shipbuilding, machinery, electronics, and petrochemicals. With the initiation of a successful virtual circle, the economy evolved into a higher stage. The economy has expanded into technology-intensive industries since the 1980s and adopted new technologies (e.g., information technology, biotechnology, and nanotechnology) in the beginning of the 1990s.

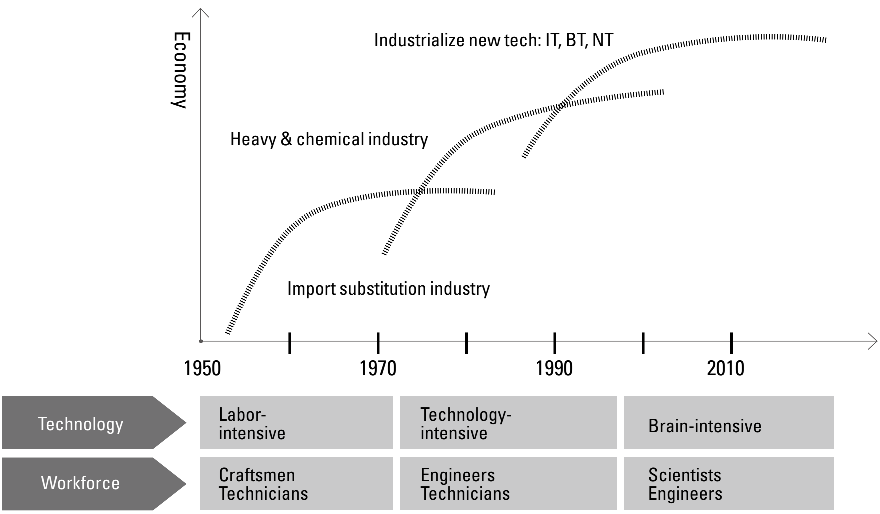
FIGURE 2 Stages of Industrialization



In the 1960s and 1970s, the acquisition and assimilation of labor-intensive and mature foreign technologies was the focus of industrial efforts. The level of technology progressed toward acquiring and assimilating increasingly knowledge-intensive foreign technologies in the 1980s. Some selected industries (semi-conductor, auto, and shipbuilding) competed directly with leading advanced countries. Industries faced a different environment than that of the first two stages of development and the concept of innovation became more important.

From the viewpoint of the virtuous circle, the process of industrialization is important because it gives impetus to the supply side of human resources. The educated and trained want to retrieve their investment of time and money in education and training through employment and higher income. Increased employment opportunities motivate individuals to acquire higher levels of education and skills.

FIGURE 3 Development of Human Resources



The development stages can be classified into three phases when the process of the required human resources is scrutinized. The Korean industrialization process shown in Figure 3 requires proper human resources for each stage. The initial stage denotes the development of the import-substitution industry and adopted labor-intensive technology for the production process. At this stage, the major human resources consist of craftsmen and technicians. As the light industry developed into the competitive stage, and as heavy and chemical industry occupies the main role of the industries, the leading human resources required are engineers and technicians. Currently, major leading industries are being replaced by high technologies that need the leading role of scientists and engineers to provide innovation to survive in competitive markets. In addition to scientific and technological progress, to make this virtuous circle a successful economy must find ways to provide adequately trained human resources to the demand side of industry, academia and research institutes.

5. SCIENCE AND TECHNOLOGY HUMAN RESOURCE CAPACITY SINCE THE 1960S

Since the start of the economic development plan in 1960's, the Korean government recognized the importance of making science and technology a national priority for the base of economic growth. The government has been involved in strengthening and expanding the domestic technological innovation, in addition to generating the demand for the new technology. For this objective, the creation of human resource capacity is both a process and a goal. To policy planners, building human resources is an end in itself. The goal is maximizing the potential of individuals to enhance the level of science and technology to contribute to economic growth by having them participate in all production activities. The capacity building is also composed of systematic approaches to learning aimed at acquiring knowledge, skills, understanding, attitudes, and values. With these goals in vision, the policy initiatives have been; 1) meet industrial demand, 2) improve education and training capacity, 3) enhance the application of technology, 4) tighten the linkage of industry-science. Since 1960s, the goals have directed the science and technology human resource development system towards sustainable growth. In the realization of the importance of human resource as a key growth factor, the government implemented various policies to meet the demands of industry for quality scientists and engineers. The question was where to look for the supply of human resources in science and technology; the sources of supply were both local and global, as suited the type of human resources.

FIGURE 4 Stages of Human Resource Development

- Initial Stage

Vocational Training System in 1967
- Provide technicians to meet industry demand

KIST 1966
- First multi-disciplinary scientific research institute, providing a jumping board for high-technology

- Intermediate Stage

KAIST in 1971
- Post-graduate school to educate high caliber scientists and engineers

Science high schools in 1982
- Science-oriented education for the specially-gifted youngsters

KIT in 1985
- Four-year public university for the talented in S&T

POSTECH in 1986
- Private school for world-class research university

- Current Stage

"Brain Korea 21" since 1999
- Convert universities in engineering and natural sciences into the graduate-school-oriented universities

Reinforcing regional universities
- Cooperating with industries through Regional Research Centers

5.1 Initial Stage

There were two main goals for the industrialization policy during the 1960s. First, it was imperative to develop basic industries for import substitution and expand export-oriented light industries that met the basic needs of individuals as a way to create the foundation for future economic growth. For this purpose, fertilizer, cement, oil refining and steel industries were targeted for import substitution, while textiles, plywood, and other consumer goods industries were designed for export promotion. However, there was no domestic technological capability for establishing manufacturing facilities and operating plants. Therefore, packaged technologies were imported from overseas, (assembly plants, production expertise, and technical personnel) to provide an initial base for the technological development of Korean industries. Although the capital part of production should inevitably be imported, the government wanted to mobilize an adequate domestic labor segment in production. The government initiated plans to meet the demands of industry for engineers as well as quality scientists.

Development of Technicians: To supply the human resources required for the planned developing industries, the government started a labor force education and training program to transform the labor in the agricultural sector into employees that could work in the manufacturing sector. At that time, the ratio of the size of engineers, technicians, and craftsmen in the economy was 1:1.3:33, which showed that there were too small number of technicians to support the nascent manufacturing industry. Government set a goal to increase the ratio to 1:5:25. To meet this need, an organized vocational training system was established in 1967 with the enactment of the Vocational Training Law. Vocational training programs were divided into public and private categories. Public vocational training programs were conducted by the Korea Vocational Training & Management Agency, as well as central and local government organizations. Private programs were in-plant vocational training by industry. In-plant training was emphasized in this stage to help employers recognize the importance of training and to make vocational training more effective. Under the Vocational Training Act, enterprises with more than 300 employees in the industrial sectors of mining, manufacturing, electricity and gas, water supply, and transportation were required to train at least 10% of their total employees or (if the firms choose) consign them to training institutes

Repatriating Korean Scientists: A strategic adaptation and assimilation of foreign technology was demanded for the industrial take-off; however, there were insufficient technicians to achieve the goal. The situation showed that there was a severe shortage of quality personnel, lack of research equipment, and substandard facilities. The government established the Korea Institute of Science and Technology (KIST) in 1967 to solve this problem. As more skilled scientists and engineers were required to perform research and development, the government devised a strategy to attract ethnic Korean scientists and engineers educated and trained abroad. They were enough to serve as core members of high-level personnel for the initial stage.

In order to recruit top quality Korean researchers from abroad, KIST offered an unprecedented remuneration package with substantial financial support from the government. Many top quality researchers have returned from abroad with the promise of an exceptionally high salary, subsidized housing, and a research environment that includes leading-edge facilities. For example, the monthly salary of KIST researchers was 10 times the GDP per capita. In the first round of recruitment, the selective screening of applications and interviews selected 18 scientists. By the end of 1970s, the government attracted 410 individuals through the program. Under such work and employment conditions, KIST researchers were able to concentrate on research. The contributions made by these returnees to the industrial development at the infancy stage were a significant factor in the economic success of Korea.

KIST played an essential role in strengthening the pool of researchers, engineers, and technicians that contributed to the scientific and technological progress of the nation. This role of human resource development was crucial to a country that had an inadequate system for training experts in advanced scientific and technological areas. KIST acted as a conduit for the introduction of new technology to industry and the economy. It served as the intermediary for acquiring and transferring new technology from abroad. This role was an important instrument for locating technologies from global science and human resource development or providing it to where it was needed. It also made a successful contribution the assimilation and transfer of technology to industry. The industrial technology remained at a basic level of routine operations and maintenance because firms were incapable of absorbing adopted foreign technologies. That was why industry depended on foreign sources for new production processes. KIST helped reduce this high dependency by undertaking commissioned research from industries and allowed the domestic industry to independently generate the necessary technology.

5.2 Intermediate Stage

As the initial Development Plans successfully achieved the set goals, the next stage of the Economic Development Plan emphasized the development of the heavy and chemical industries through the absorption and adaptation of imported technologies. Emphasis was also given to shifting major export items from consumer goods to durable goods. Under this policy direction, shipbuilding, machinery, electronics, and petrochemicals were strategically chosen as major target industries.

The demand for technology by industries has changed. They increasingly require more sophisticated technology and the demand for post-graduate level technical human resources has increased tremendously both in quantity and quality. Rapid wage increases have made some labor-intensive industries uncompetitive.

Government drastically expanded science and engineering university and graduate school education, with special emphasis on fields such as mechanical, electrical and electronic engineering to meet the conditions of the heavy and chemical industry that government emphasized. KIST had succeeded in satisfying the short-term demand for the economic development and technical innovation of Korea. Education at the graduate school level (the prime means for cultivating scientists) needed to be reinforced and expanded in order for Korea to flexibly deal with the increasing demand for human resources in science and technology.

Developing Scientists: A changing industrial environment makes it imperative to develop self-reproducing domestic technological capabilities. Increased local R&D efforts have become necessary for Korean industries to improve imported technology, but also conceive independent ideas. This showed that research and development is critically important at this stage. With this industrial background, human resource development policy is given special emphasis in the training of high-caliber technological human resources needed to meet the rapidly increasing demand.

Although qualified individuals were recruited from abroad and the amount of investment in educational facilities was increased, it was also imperative that an efficient education and training system be established. A major graduate school, the Korea Advanced Institute of Science (KAIS), was established by the government in 1973 and later renamed as Korea Advanced Institute of Science and Technology (KAIST). With a special mission of to develop an indigenous scientific capacity to generate and expand an internal technological base, strategic measures have been taken to cultivate a core of qualified human resources that will lead the future of Korea in the global economic arena. Full financial support and leading-edge education opportunities were provided to recruit the best students. Approximately 40% to 50% of the total domestic Masters and Doctorate degree holders in S&T studies have been conferred by this institution alone.

With the number of graduates from domestic institutions increasing along with the repatriation of foreign-educated scholars, government-sponsored research institutes emerged to accommodate and utilize the power that provided opportunities and favorable working conditions.

Along with KAIST and graduate programs at other universities, a science high school was established in 1983 to provide an early education program for students gifted in mathematics and science. As a free boarding school, the programs emphasized creative scientific exploration and experimentation. Beginning with 60 students in 1983, the enrollment grew to 1,300 in the 1990s with the establishment of twelve schools. In addition, the Korea will Institute of Technology (KIT), a free boarding undergraduate program, was established in 1986 to accommodate graduates from science high schools and other gifted students. Highly competitive KIT admitted only those in the upper 10% of academic standings. KIT is located in Daeduk Science Town, enhancing its educational effectiveness through the active interchange and cooperation with government-funded or privately-supported research institutes. The government has made efforts to link KAIST, KIT, and science high schools to provide an integral educational program for science-gifted students.

Encouraging Technicians and Craftsmen: Major emphasis was also stressed on engineers, technicians, and craftsmen. From the view of Confucianism, skilled individuals in the fields of technology have been undervalued in Korea, which traditionally valued scholars. The Technical Qualification System was designed to change this tradition and assign the qualified individual status and recognition equivalent to professionals. The ultimate objective of the system was to help bridge the social status gap between engineers, Ph.D. holders, and craftsmen and change the traditionally dismissive attitude toward technical personnel by Korean society. The authority of the National Technical Qualification Act promulgated in 1973, designated all categories of engineers and craftsmen with the equivalent status of college graduates. With detailed plans for preparing, issuing, and scoring qualification tests, the policies and procedures for assuring the recognition of individuals successfully qualified were made and executed.

5.3 Current Stage

Since the 1990s, a fast development towards a knowledge-based economy has put the scientific and technological capacity as the source of national competitiveness for the economy, which is defined by the capability of knowledge creation and the creative human resources. Efficient exploitation of knowledge, information, and technology is fundamental to economic performance. It is important to develop a scientific capability that can absorb innovative technology. The transition of the core competence of an economy has moved from skill to technology, and finally to science. As the product life cycle gets shorter, industry requires more capability and learning ability from human resources in science and technology, rather than technology alone. This has made human resources in science and technology a substantial and positive contributing factor for economic growth.

Policy direction was set to enlarge the education base of superior human resources by improving the qualitative standard of higher education in science and engineering. A significant investment through

World Bank loans of USD 150 million over 8 years (1980-88) and USD100 million for 5 years (1983-88) was implemented to support university programs in engineering and natural sciences to make them develop graduate-school-oriented faculties. The purpose was to modernize laboratories and increase research support.

To foster excellent research at graduate schools in science and engineering fields, a high-quality human resource nurturing program named BK21 (meaning Brain Korea of 21st Century) was implemented in 1999 to aid candidates in master courses, PhD studies, and advanced-level research. This project was to produce 'next generation leaders with creativity' through financial grants over 7 years; with a total sum of USD 1.2 billion in program funding allocated for the first phase. The second phase of BK21, started in 2006 would further facilitate the introduction and establishment of systems for research-oriented universities. Also included in the objectives of BK21 are the transferring of knowledge from universities to industries and increasing the ratio of technologies transferred from universities to the private sector.

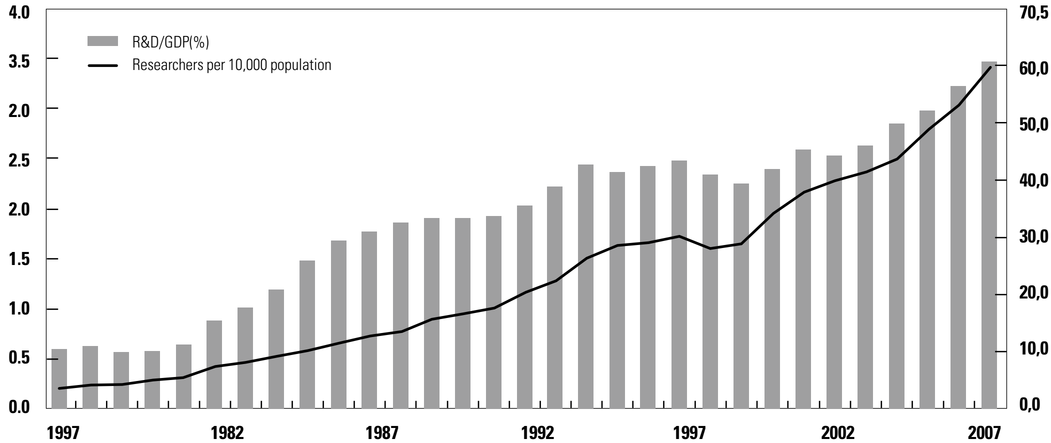
A recent threat to the human resource ability of Korea is the insufficient supply of science and engineering graduates. Since the 1990s, the enrollment rate in science and engineering college majors has gradually declined. More human resources are demanded as the economy develops into a knowledge-based science and engineering phase, the current supply is unable to meet the demand of industry. To avert the trend, the government offers a military duty exemption program for, young males who choose to enter graduate schools in science and engineering, those who work for three years in small and medium-size firms in the manufacturing sector, and those who are employed in R&D institutions. Since then, the military service exemption program has been evaluated as the most successful, especially for small and medium sized firms that are in need of highly educated science and engineering human resources.

6. KEY RESULTS OF HUMAN RESOURCE CAPACITY BUILDING

The successful administration of a science and technology human resources development policy has dramatically increased the capacity of human resources. During the last thirty years, while the R&D expenditure has been constantly increasing at an average rate of 10.7%, the number of researchers has recorded a higher average increase rate of 15.7%. It shows that R&D expenditure as percentage of GDP in Korea has increased from 0.60% of GDP in 1977 to 3.47% in 2007 and that the number of researchers per 10,000 of population has increased from 3.5 in 1977 to 59.7 in 2007.

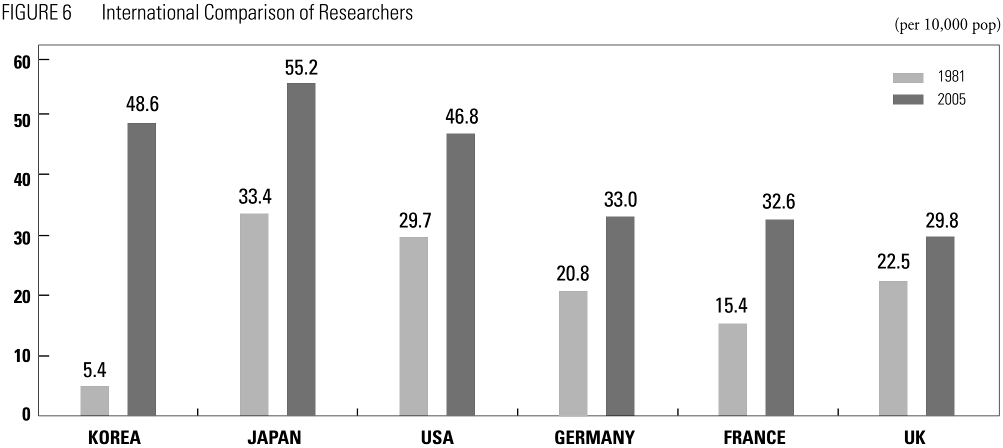
When the numbers are compared with other countries, the spectacular increase is significant. In 1981, number of researchers per 10,000 of population was 33.4 in Japan and 5.4 in Korea, which was 16% of the total of Japan. The numbers in 2005 was 55.2 in Japan and 48.6 in Korea, which was 88% of the total in Japan and showed that the gap has drastically narrowed.

FIGURE 5 Trend of R&D Investment and Researchers



Source: "Research and development (R&D) activities," MEST

FIGURE 6 International Comparison of Researchers



Source: idid

7. BRAIN DRAIN REVISITED

The 'brain drain' was in a controversial issue in society. Poor domestic education and research environments had forced many talented students and scientists to study abroad. Despite successful examples of repatriation to KIST since 1960s, many Korean researchers that completed and earned Doctorate degrees overseas were still reluctant to return to Korea.

Among the reasons were the lack of job opportunities, outdated science facilities, inadequate technology infrastructure, and poor research environments. The education they received abroad made many of them overqualified for the scientific and technological needs of Korea; this made it difficult to absorb their knowledge and ability. A study conducted in 1968 showed that only 6% of Korean students studying abroad returned to Korea after studies; this took place when students were required to obtain overseas study approval from the Ministry of Education. To induce them back to Korea, the government and industry provided big compensation packages to bring back overseas-educated PhD's until 1970s, as in the case of KIST.

The Brain Drain later turned out to be a reservoir of high caliber human resources. By recruiting a group of top Korean researchers from abroad in a short period, KIST made a significant contribution to the technological development of Korea. It also provided a source of well-trained and experienced technical human resources for the newly established institutions KAIST and POSTECH with no impact on existing organizations. Since all of the key members were hired from abroad, there was no drain on existing institutions. Instead, education institutions benefited from the expertise brought by the returnees when a large part of the initial members left for positions in institutions in academia or to industry. In the 1990s, active leading scientists and engineers in the Korean semiconductor and IT industry were largely returnees from U.S. companies. This shows that adequate research facilities and opportunities for career development as a scientist coupled with the prospect of good living conditions would entice researchers back to the Korea.

8. CONCLUDING REMARKS

The importance of human resource development is imperative in the process of national economic and social development since it largely depends on how effectively human resources are cultivated and utilized. Korea has been successful in meeting the industrial needs of fast developing technology and has achieved fast economic growth over the past half a century with the launch of a bold Economic Development Plan in the 1960s. One key element of the success was, conforming to the rapidly developing structure of industry as well as advancing science and technology, the human resources policy for science and technology have been given a high priority, especially in securing the size along with enhancing the creativity. Education and research training for the development human resources has been the number one priority on a strategic level for national development. The key points that led to the successful operation of human resource policy in Korea can be summarized by the following two points.

First, the well planned and timely provisions of proper human resources to the R&D of research institution and to industry has been the driving force in the absorption, assimilation, and adoption of the imported technologies to produce new products, and provide the base from which development take-off was possible. Especially, the simultaneously adoption of a two-fold approach of nurturing technicians for the development of light and import-substitution industries that were in need at the time and in securing highly-qualified scientists to prepare for the next stage of development is the key success point.

Two, to secure an adequate number of scientists, engineers, technologists and technicians, the government did a good job of providing incentives to induce them to R&D laboratories and production plants. Though Korea is a free market economy, the government did intervene to provide enough priming force from which private industry developed and successively generated demand to make the circle virtuous. The incentives were a remuneration package for repatriating overseas brains, social reputation for technicians, and military exemptions that directed young people into science and engineering.

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