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Strategies for Technology Development in Developing Countries: Focusing on Korea

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Abstract

South Korea has had a rich history of independent thinking and self-reliance since the Korean Conflict. The war left the country the need for infrastructures in a variety of fields. Instead of relying on aid from foreign nations, however, key figures within South Korea's borders fathered the nation's first government-funded scientific and engineering institute, the Korea Institute of Science & Technology (KIST). Even though KIST encountered numerous obstacles, its commitment to research and development (R&D) would ultimately allow it play a crucial role in the rebuilding of the country. As a result of the institute's success, South Korea was able to move forward economically to become a beacon of hope for developing nations around the world.

Keywords KIST, technology, transferor, transferee, research and development

1. Introduction

It is a well-established fact that science and technology are the keys to the development of a national economy. This fact is independent of where a nation stands in terms of economic development. Although scientific knowledge is freely available and plays a role in economic development, effort is needed to apply this knowledge to specific production activities and ultimately develop technology. It is for this reason that information regarding technology is generally not free. While developing countries often feel rushed to apply science and technology for the sake of economic and social development, we should realize that technology itself does result in immediate benefits.

When the Korean War ended in 1953, Korea had no manufacturing industries and had to build

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its industry infrastructure from the ground up. During the 1960's, the turn-key plant technology transfer offered the most efficient way to build an industry, which resulted in it becoming the foundation of the early stages of the national economy. There were, however, more unsuccessful turn-key plants than successful ones. By learning through a series of failures, Korean corporations realized that effective technology transfers failed when the transferee knew little about the technology being transferred.

An effective technology transfer in terms of a turn-key plant also requires the transferee to be well-prepared in order to take full advantage of relevant technology. Turn-key plants do not include manufacturing guidelines. In the process of engineering and testing, however, the results of a technology ultimately transfer. A transferee can thus effectively control the terms and conditions of the technology transfer.

South Korea has discovered that the most effective type of technology transfer is not a turn-key plant but rather the purchasing of engineering and testing results from a developing country. This endeavor requires a great deal of time and effort from the transferee but is more beneficial to developing countries in the long term. The transferee must study the availability of the technology to be transferred and prepare an execution plan for the transferred technology. This means that the possibility of an effective technology transfer is contingent upon the country's scientific and technological infrastructure, which is typically fairly underdeveloped in developing countries.

Many developing countries believe that the establishment of research institutions in science and technology is one of the best ways to strengthen infrastructure. This notion plays a leading role in the planning of and assistance in transferring the results of engineering or testing as well as in the adapting or improving of the transferred technology, but there is generally a great deal of disappointment in such pursuits.

As competent scientists and engineers are only interested in new technology or **technology** related to their field of expertise, they regard **activities related** to technological transfers as neither challenging nor interesting. Scientists and engineers from developing nations are no exception. The United Nations Economic and Social Council has pointed out in a report that the reasons for the ineffectiveness of research organizations in developing countries are as follows: Research institutes are either not conscious of the technological needs of an industry or are indifferent to them (Report of the Advisory Committee on the Application of Science and Technology to Development, E/4960, March 18, 1971).

Until the end of the 1960's, South Korea had been dealing with this particular problem. Even though the country had many research and development (R&D) institutes in universities and government-supported agencies, they were mostly pursuing academically-oriented projects. If the research produced results, they would be published in academic journals but would have little impact on the development of the national economy.

This phenomenon was very common in Korea until the 1960's. Korea has a long tradition of respecting scholars who choose to live in seclusion and seek only knowledge while distancing themselves from material wealth, and scientists and engineers were included in this group of knowledge-seeking scholars. Ultimately, however, South Korea became the first developing nation to bring these scientists and engineers down from their ivory tower and into the world of practical applications.

2. Korean Experience

2.1. The Socio-Economic Background of Korea in the 1960's

The southern part of Korea was historically an agriculturally-based economy, while the northern part of Korea was the base for manufacturing. From 1950 to 1953, the Korean War destroyed everything on the Korean peninsula and left only political chaos. It was around the early 1960's when the South Korean government finally committed to a systematic approach in rebuilding the country. When the South Korean government launched its first 5 Year Economic Development Plan from 1962 to 1966, South Korea was one of the poorest countries in the world, ranking 119th out of 160 countries, with a GNP/Capita of less than $80 (UN, October 15th, 2018).

The most pressing problem for the South Korean government at that time was the provision of the basic needs of its people. To address these needs, the government began to build industries such as mills and production plants for flour, sugar, textiles, plants, nylon, iron, cement, and oil. These projects were usually carried out under turn-key plant arrangements in which a technology transferor arranged foreign loans for projects guaranteed by the South Korean government. These turn-key plant technology transfer projects were the only available way to build these much needed industries in a short amount of time, and as investors believed that the only way to start a business was through turn-key plant technology transfers, the number of turn-key plant projects rose drastically.

Many of these turn-key plant technology transfers in the 1960's, however, were found to be expensive and difficult to pursue. Many local companies went bankrupt as a result of inadequate, obsolete technology, unfair contracts of technology transfers, and false anticipation of profit. Despite these many business failures, however, many companies not only successfully modified transferred technologies to local conditions but also improved them to compete with international markets, ultimately becoming international conglomerates.

The South Korean government had discovered the consequences of turn-key plant technology transfers. The government also realized that the possibility and impact of the effective transfer of technology to a country would depend on its scientific technology as well as its managerial and financial infrastructures. In 1966, the South Korean government decided to establish the Korea Institute of Science & Technology as the foundation of its national scientific and technological infrastructure.

2.2. The Establishment of the Korea Institute of Science & Technology

The Korea Institute of Science & Technology (KIST) was established in 1966 with funding of $12 million from the US government. This funding from the US was in addition to land, building, and endowment funds from the South Korean government. The first president of KIST, Dr. Hyung Sup Choi, was a scientist with a Ph.D. in metallurgy from the University of Minnesota. Dr. Choi was also an engineer with various fields of expertise.

Dr. Choi firmly believed that South Korea needed a radically new R&D institute to play a leading role in creating a scientific and technological infrastructure for the country. President Park endorsed Dr. Choi's vision and gave him his full support. This vision was encapsulated in the management philosophy and operational policies of KIST. These policies stated that KIST should: (1) apply industrial research, not theoretical research limited to a specific field, (2) conduct contract research, (3) recruit key staff members from abroad, and (4) maintain systems of guaranteed autonomy for R&D activities.

2.2.1 Multidisciplinary Applied Industrial Research

Until the 1960's, all research institutes in South Korea were for scientific research in a specific field. KIST, however, was focused on the development of technology for an industry. As an applied industrial research institute, KIST was responsible for all the industries in South Korea that needed technological support, which led the institute to adopt a multidisciplinary approach from the beginning.

For this multidisciplinary approach, KIST had to identify each field of concentration. KIST launched comprehensive industrial survey projects that mobilized 23 foreign experts and 48 local specialists for 10 months starting November 1966. This survey covered 17 fields in South Korea. Based on the findings, KIST created 5 major fields of concentration and 4 supporting fields.

The major research fields included material science, mechanical engineering, electronics or electrical engineering, chemical engineering or chemistry, and food science. The supporting research fields included technical information services, techno-economic groups, computer services, and chemical or material analysis.

2.2.2 Recruiting Research Members

South Korea in the 1960's had very few engineers and scientists with industrial research experience, as the country itself lacked sufficient production facilities. Therefore, it was natural for KIST to create operational policies to recruit key research staff from abroad.

During the 1960's, many developing countries faced the problem of "brain drain" through which they were losing many of their young, well-educated citizens to better educational and professional organizations abroad. South Korea was no exception. The Korean War destroyed its educational system, as many young teachers were drafted into the war. The end result was that most high school graduates in the southern half of Korea dreamt of receiving higher education abroad and ultimately settling down in a country that had more to offer than their war-torn homeland. Therefore, KIST focused on developing a "Counter Brain Drain" (CBD) program.

Most international experts had serious doubts about the success of the CBD plan initiated by KIST. KIST, however, was determined to show the world that a CBD program could work if developing countries created good jobs at home with well-paid salaries and fringe benefits. For example, while senior researchers in their 30s were paid about only about a third of what they could receive abroad, this salary was double that of a full-time professor in Korea. More importantly, working for the government and contributing to the development of a country gave these young scientists and engineers a sense of pride that supplemented their lower wages. KIST was able to foster this sense of national pride because the program had the personal support of President Park.

KIST began by contacting Korean scientists and engineers with industrial research experience working at over 500 organizations abroad. Over 800 of the people contacted sent positive replies. KIST then selected 150 candidates for the first round and narrowed down the search to 75 candidates. In 1968, 18 people were ultimately chosen to form the first wave of repatriated scientists and engineers working for KIST.

That spring, KIST sponsored a seminar on "the prospects of KIST" at the Battelle Memorial Institute in Columbus, Ohio in the U.S., and about 30 KIST candidates were invited.

Dr. Choi explained the role of KIST to these candidates at a luncheon meeting:

> "If your lifetime ambition is to win a Nobel Prize, please don't come work at KIST. South Korea is a very poor country with a GNP/Capita of less than $100. You will have a better chance to achieve your goal here, in America. For the time being, KIST is not a place to conduct the kind of R&D you prefer but is rather a place to conduct R&D that South Korea needs and its industries want. This priority is meant to catch the nation up technologically as soon as possible. The level of technology needed and wanted in Korea with a GNP/Capita of $100 is not very prestigious for now. So, you may be disappointed. But your sacrifice today will ensure that KIST

will conduct very advanced R&D projects in the near future. This sacrifice will lead to Korea competing with developed nations around the world."

These remarks were moving for the potentially repatriating personnel, and many of them decided to join KIST by the end of the luncheon.

2.2.3 Contract Research

One of the operational policies KIST originally established was contract research. KIST emphasized its role in conducting applied industrial research. Even though the concept and purpose of contract research were appealing in theory, most experts around the world were pessimistic about the success of contract research in practice. Contract research meant that research projects had to be sponsored, but as South Korea was one of the poorest countries in the world, industrial sponsors were impossible to find.

However, Dr. Choi was dedicated to this operational policy and wanted to ensure that no project would be carried out without a project sponsor. KIST also had a management system to supplement a related operational policy intended to delegate the head of a laboratory, who would hold an unusually wide range of authority over the laboratory. The head of the laboratory had full authority to hire or fire his/her staff, purchase laboratory equipment, and conduct projects approved by a committee. The head of the laboratory had the responsibilities of finding projects, satisfying the sponsor, and adhering to the rules imposed by KIST.

Under the contract research system of delegating authority and responsibility, poorly performing laboratories would be closed. The head of the laboratory was responsible for finding sponsors for contract research to avoid seeing the closing of the laboratory and the consequent loss of his job. The local market for contract research on new technology, however, offered very little opportunity. The local industries, as potential research sponsors, were not interested in new technologies, but rather technology transfers through turn-key plants.

Under the contract research system, each laboratory leader was required to meet the following criteria: learn the local industries related to his specialty, also known as market studies; establish relationships by visiting potential contract research customers; adjust himself to local conditions. The laboratory leader had to persuade his potential customers to change their preference of turn-key plants to the results of engineering and testing. For this technology transfer, he could assist the transferee to ensure an effective technology transfer and, as a result, induce the project for contract research in the process.

At that time, assisting with technology transfers of engineering and testing results was not considered R&D but merely consulting work and was therefore not the preferred work of the competent scientists and engineers at research institutes. Laboratory heads soon found out, however, that there was satisfaction from being assisted by a sponsor in technological transfers, and that this assistance could lead to the project absorbing and improving the transferred technology. It could also lead to an engineering extension service, also known as the continuation of another contract research project.

Almost all the laboratories in the early days of KIST followed the contract research system, focusing on consulting for technology transfer related projects. In the 1970's South Korea changed its industrial policies from light industries to heavy industries. There were no more turn-key plan technology transfers but rather technology transfers of engineering and testing results. By that point, KIST had built an excellent reputation by making significant contributions to the development of South Korea.

2.2.4 KIST Promotional Law

The KIST Promotional Law established research autonomy and financial stability for KIST. Under this law, the government would provide KIST with annual financial support. The government would not count this support as an operational expense but rather as funding for research projects. Under this law, the government would set up an annual lump-sum research fund. The laboratories of KIST could apply for this research fund through project proposals that had to be approved by the government, which would be the sponsor. This arrangement meant that the government was able to evaluate the results of KIST projects as a sponsor but could not influence their operation or the operation of the institute. KIST was therefore free from government auditing even though it submitted an annual audited financial report.

2.3. Case Studies of KIST Performance

In the 1970's, experts around the world assumed that developing countries using the contract research system would ultimately fail. KIST's system of contract research helped it focus on the problems of local industries, which was one of its founding missions. KIST had proved to the world that a contract research system in a developing country could work well under certain conditions. In 2016, to commemorate the institute's 50th birthday, KIST published a book entitled "50 Years of KIST History 1967~2016." The following statistics are based on data from this publication.

Table 1 Contract Volume by Year

Contract Volume by Selected Year (Unit: \ million)						
	1968	**1969**	**1970**	**1978**	**1990**	**2015**
Industry (A)	67	138	280	5,693	3,236	13,165
Government (B)	1	46	175	1,314	18,687	253,082
Total (C)	68	184	455	7,007	21,923	266,247
Number of Regular Employees						
Employees (D)	328	491	571	1,042	795	790

Based on the table above, the following tables are prepared to show a clear indication of the changes in KIST's research directions over the past 5 decades

Table 2 Percentage of Contract Volume between Government and Industries

% of Contract Volume between Government & Industries (Unit: %)						
	1968	**1969**	**1970**	**1978**	**1990**	**2015**
Industry (A)/(C)	98.5	75.0	61.5	81.2	14.8	4.9
Government(B)/(C)	1.5	25.0	38.5	18.8	85.2	95.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 Productivity per Employee

Productivity: Research Volume (per Employee)						
	1968	**1969**	**1970**	**1978**	**1990**	**2015**
Total Contract Volume	68	184	455	7,007	21,923	266,247
Regular Employees (D)	328	491	571	1,042	795	790
Productivity (C)/(D)		374,745	796,848	6,724,568	27,576,101	337,021,519

50 years of activity from KIST could be grouped into four periods based on the tables above. The first period is focused on assisting technology transfers and engineering extension services, the second period on adapting and improving transferred technologies, the third period on taking on more active R&D roles, and the fourth period on challenging future technologies.

2.3.1 1st Period: Assisting Technology Transfers(Engineering Extension Service 1968~1970)

As stated previously, several local industries and government agencies were interested only in the immediate production of goods through turn-key plant technology transfers. Many of these transfers were reckless and produced serious side effects that became critical social and economic problems for the country.

KIST cautioned local markets about reckless turn-key plant technology transfers. Company executives were told that they should look for the most effective type of turn-key plant technology transfers, and KIST was able to do just that. KIST started providing consultation services in order to improve turn-key plants with engineering and testing results. Local markets began to recognize the value of these services, as the plants ultimately became more efficient and economical. Corporations in Korea thus began to rely on KIST for the expertise that they offered.

When the first 18 repatriated senior researchers joined KIST in 1968, the research volume was worth 68 million Korean won. By 1970, 3 years later, the research volume went up to 455 million won, demonstrating that contract research was feasible in developing countries if the proper system was in place. Productivity per employee also went up from 207,317 won in 1968 to 796,848 won in 1970, indicating that the average size of each contract was relatively small but that the numbers were increasing. This is because nearly all contract research projects were also consulting- or service-oriented. The following examples illustrate some of the accomplishments of KIST.

Polyester Yarn Manufacturing

In 1966, Samduk Trading Co., a polyester yarn manufacturer, had turn-key plant technology transfers of 1 ton/day from Sintex Co. of Italy. While the plant first operated as well as the transferor had guaranteed, its productivity gradually started to decline. By the end of its second year, productivity had decreased 40%. Samduk informed the transferor, Sintex Co., of the problem and asked for a solution. Sintex Co. informed Samduk that Sintex Co. could send experts to South Korea to examine and solve the problem for $200,000. This price was too high for Samduk, which led it to seek help from KIST in 1968. At that time, however, KIST had no experience with polyester yarn manufacturing, but it did have several engineers who had worked at chemical facilities abroad. KIST was not able to turn down a request from an industry without even trying, so they sent a task force to Samduk with chemical engineers, mechanical engineers, and factory maintenance experts. The task force's mission was as follows: (1) study and learn as much as possible about Sintex's manufacturing system, (2) find out Sintex's position within the polyester yarn industry and assess Sintex's level of expertise, (3) recommend a way to approach the problem. KIST estimated that this project would last 4 weeks.

While the KIST task force was studying the process of polyester yarn manufacturing at Samduk, the group discovered that some of the gauges attached to the equipment were not accurate. They also found out that Samduk had not conducted a routine calibration of the gauges since the factory was founded. The workers just assumed that the gauges were working because the needle on the gauge was moving.

It took an entire week for the task force to check every gauge in the factory, including the gauges in the boiler room. These gauges turned out to be the cause of Samduk's problem. The issue now solved, the company's calibration productivity exceeded 130% of its normal level within a month, an improvement that was the result of a $15,000 contract research project conducted by KIST. In 1969, KIST gained two more contract research projects with Samduk, one dealing with the localization of their draw twister heater project and the other dealing with their heating control systems. With their productivity now maximized, Samduk went on to export $5 million in polyester yarn, the highest in South Korean history at that time.

Pohang Iron & Steel Mill or Integrated Iron & Steel Mill

After the successful development of some light industries in the late 1960's, the South Korean government decided to develop its heavy and defense industries. The 2nd 5-year economic development plan from 1967 to 1971 set guidelines for the establishment of integrated iron and steel mills. In 1967, the South Korean government signed a turn-key agreement with KOPPERS Corp. of the United States, one of the best consulting groups in the steel industry at that time. Under the turn-key plant technology transfer agreement, KOPPERS Corp. were responsible for building integrated iron and steel mills in South Korea. KOPPERS organized an international consortium consisting of KIST experts from around the world. KIST also requested that the South Korean government start civilian work on the infrastructure of Pohang in regard to roads, a harbor, and a dam for water supply.

In 1969, KIST devised a plan to establish these iron and steel mills in Pohang. KIST contacted the international financial community for a project loan. But the International Economic Consultative Organization for Korea (IECOK) and the World Bank stated that the KIST plan to establish iron and steel industries within South Korea was not feasible, thus turning down the loan. This response came as a shock to the South Korean government as well as the global steel industry.

Due to the failure of the turn-key plan for the iron and steel mills, the South Korean deputy prime minister and the minister of the Economic Planning Board were forced to resign. The newly appointed deputy prime minister had to find a new idea for the construction of the iron and steel mills. KOPPERS was one of the best consultants in the field but was unable to do the job. The deputy prime minister had no choice but to rely on KIST as a last resort. The timing of this decision, fortunately, was perfect, as KIST had Dr. J.K. Kim in their group of repatriated personnel.

After graduating from Seoul National University with a B.S. in mechanical engineering, Dr. Kim went to West Germany for his M.S. and Ph.D. Upon obtaining his Ph.D. in metal engineering from the School of Engineering at Munich University, he started work at DEMAG, one of the largest steel companies in West Germany at the time. Dr. Kim worked there until he joined KIST in 1968.

Convinced that South Korea had to build its own iron and steel mills, he systematically compiled data regarding the construction and integration of iron and steel mills and devised his own construction plan.

As Dr. Kim possessed all the relevant technical data for the construction of these mills, it took only 2 months for the task force to come up with an investment plan. The plan consisted of $1.03 million MT/year to be integrated into the mills with $123.7 million and 63,300 million won. This plan was approved by the World Bank, and a task force of experts from Japanese steel companies also considered the South Korean plan feasible. The Japanese government even committed to invest $123.7 million into the project. As a result, the POSCO Iron & Steel Mill opened in 1973.

Development of Freon 12 Technology

Freon 12 is a refrigerant for air conditioning. South Korea had been importing Freon 12 from Japan while exporting the raw material fluorspar, or rock, back to Japan. Freon 12 was developed by Du Pont, and the patent had expired. In 1969, KIST invited Dr. D.J. Park, a retired Korean-American chemist who happened to be part of the development team for Freon 12 while working at Du Pont. KIST hired him as an advisor and started to develop Freon 12. KIST built a pilot plant in 1970, the first of its kind in South Korea, and completed development of Freon 12 in 1973. KIST signed a turn-key plant technology transfer agreement with a local company in 1975 and completed construction of a 2,000 MT/year Freon 12 plant in 1977. In this case, the technology transferor was KIST, and the transferee was Ulsan Chemical Corporation. As Freon 12 was found to be harmful to the environment, Ulsan Chemical later worked with KIST to develop a replacement product.

Special Steel Mills

The 3rd 5-year economic development plan called for the development of special steel that would provide crucial raw materials for the nation's mechanical and defense industries. The South Korean government had a research contract with KIST for the construction of the first special steel plant in Korea. Unfortunately, KIST did not have the expertise required for this special steel, but the South Korean government had full confidence in KIST and provided them with ample time and research funding. KIST knew exactly what to do to prepare for the eventual technology transfer:

First, in order to determine the demand of special steel, KIST analyzed imported data on special steel for 5 years. This helped to identify special types of steel such as stainless, nickel, chrome, and tungsten. The shapes of the steel were also determined as bar, sheet, plate, and wire. Second, laboratory scale research was conducted to confirm basic technical information, as it was necessary to assess the nature of the know-how on special steel for technology transfers. KIST then prepared an execution plan for a special steel plant in which the nature of its products, its annual amount of production, and its production equipment were determined. Third, KIST inquired 6 special steel mills for the technology transfers. KIST sent researchers to collect more information on each mill. This helped to finally narrow down the list to 2 companies. Fourth, KIST required that each of the company's financial plans be submitted to KIST, including bidding prices and a detailed breakdown of the technology to be transferred. The technology to be transferred was in the form of scheduling for on-the-job training that included the costs involved in the execution of this plan. Engineers in each field would be sent to South Korea for several weeks to train Koreans for their jobs, and their South Korean counterparts would then be sent to the transferor's plant for additional on-the-job training.

For the two months of contract negotiations, KIST was able to adjust the on-the-job training schedules with respect to the number of training instructors, number of training days required, and number of South Korean counterparts to be sent to the transferor's plant. Because of this negotiation, KIST received 30% less than the original offering price for the technology transfer. The main purpose of the contract negotiation, however, was to gain from the transferor as much information as possible on special steel. This information would be useful for the procurement of equipment. KIST's contract with the government ended in 1975, leading to the establishment of Sammi Special Steel Corporation, the first special steel company in South Korea.

2.3.2 2nd Period: Adapting and Improving Transferred Technology 1970 - 1980

Local markets began to realize that technology transfers with KIST consultation were more economical and efficient than turn-key plants. This realization was more important to the transfer itself than the adaptation and improvement of any transferred technology in question.

KIST also realized that satisfying the technology transferee would make the transferee interested in other projects. This would lead to the improvement of transferred technology and engineering extension services from KIST.

KIST was prepared to accept the new challenges of absorbing and improving transferred technology. Marketing was a special challenge preferred by the laboratory, which was, in a sense, an engineering extension. The engineering extension service was intended to solve problems in the daily process of production. The service was also meant to find ways to boost the productivity of plant operations, including their R&D activities. KIST's contract research volume increased drastically during this time as a result of these services.

In 1970, KIST's research contract volume went up from 455 million won to 7,007 million won, an increase of 61.5%, with another increase of 81.2% in 1978. This rise was a clear indication that KIST's contract research was effective for developing nations. Also, the contract volume per employee changed drastically, from 374,745 won in 1969 to 6,724,568 won in 1978. KIST's contract research, which saw a shift from software consulting to hardware research, had improved drastically. The following are some examples that represent KIST's during this decade.

In the mid 1960's, Wang Calculator of the U.S. developed the first desktop electronic calculator to replace the mechanical calculator, leading to a boom of desktop electronic calculator manufactures in Japan. One of OEM's IC chip assemblers based in South Korea asked KIST to develop a desktop electronic calculator, and the product was ultimately successful in local markets. OEM then asked KIST to reduce the size of the calculator, resulting in the pocket size electronic calculator. This company started to export their product to the United States in 1972. The American market showed a favorable response, and sales began to rise rapidly. The following year, *U.S. Consumer Report* named it the best pocket size calculator on the market.

When liquid crystal displays became common in electronic consumer products in the 1970's, KIST successfully developed a prototype LCD Clock and an LCD watch that were only 6 months behind the Japanese models. KIST successfully transferred this technology to local watchmakers in 1976.

During the 1970's, the most popular agricultural insecticide in South Korea was Diaginon, the raw material for which is hydroxyl pyrimidine (HOP). This chemical was patented and had to be imported. KIST successfully developed a new process for synthesizing it in a way that bypassed the existing patent. KIST then transferred the technology through a turn-key plant arrangement to a local chemical company in 1977. This company did very well and was later listed on the South Korean stock exchange.

Polyester film is used in tape recorders, VTR tapes, X-rays, and the packaging and insulation for electric motors. During the 1970's, production of this film was tightly controlled by 4 international companies: ICI of England, 3M and Du Point of the United States, and Tory of Japan. In 1978, KIST and Sunkyeong Chemical jointly developed the production technology for polyester film, becoming the fifth polyester film production company in the world. Sunkyeong Chemical later became a world leader in the polyester film market.

2.3.3 3rd Period: Seeking a Future National Agenda 1980 - 1990

By the 1970's and 1980's, KIST had successfully proven that domestic R&D could be as good as imported technology. The process of adapting and improving transferred technology was shown to be profitable. Encouraged by the success of KIST, Korean firms had started to move in a positive direction. Many firms began to establish their own R&D centers to handle engineering extension services. The heads of these R&D centers were often recruited from KIST. The government encouraged KIST to handle the ever-increasing demand for engineering extension services through specialized spin-off centers specializing in chemistry, electronics and telecommunications, food, machinery, and so on.

KIST realized that the engineering extension services could be handled by industries or spin-off institutes. KIST also understood that it had to take up more challenging tasks by utilizing its multidisciplinary approach. KIST had decided that it was time to start looking at the problems of the future rather than the current problems of the nation.

KIST conducted a brainstorming session with its laboratory heads. This session was meant to identify social and economic problems that would occur over the next 10 years under a rapidly changing socio-economic environment. There would be rapid changes in the industrial base as a result of shifting from light to heavy industries and from labor-intensive to capital-intensive industries. As export industries began to expand rapidly, there were drastic increases in imports for more expensive raw materials for components required by heavy industries.

The problem of limited natural resources in South Korea was becoming serious. A solution for the effective utilization of limited natural resources had to be found. Developing technologies for import substitutions would become one of the most defining problems for South Korea in the coming decade.

Towards the end of the brainstorming session, KIST asked each laboratory head to come up with project proposals for anticipated problems predicted to occur within their respective fields. This was the first time KIST's laboratory heads were asked what projects they felt they should pursue instead of being told what to do for their country. The responses from the laboratory heads were enthusiastic. Thirty projects were selected from among the 70 proposals submitted to KIST's research review committee. The committee then prepared a 5-year research development plan titled "Challenges to Self-Reliance in Technology."

KIST then persuaded the government to support their 5-year plan. KIST had to change its research direction to handle the upcoming problems of the country. "Challenges to Self-Reliance in Technology" was a 5-year R&D proposal with a budget of 60,973 million. One of these proposals was related to the substitution of import materials and the processing in heavy industries, mechanical industries, defense industries, and automotive industries such as laminated fiber reinforced metal ceramics, silica glass fiber composite metal, graphite reinforced metal, and engineering plastics.

Other outcomes included the utilization of research on computer software to synthesize mechatronics devices, such as a lathe for low-cost automation and a computerized, numerically controlled lathe. The development of fiber optic manufacturing and the application of that technology from multi-code mass production to single-code mass production was also a priority. The development of the industrial application of remote sensing and robots was introduced, as well. Other areas included technology for transportation, such as linear inductive motors and hybrid electric buses for mass transportation, energy-saving diesel motors, the application of solar energy and thin film silicon solar batteries, and preventive solutions for water and air pollution.

The South Korean government approved KIST's proposal for the "Challenges to Self-Reliance in Technology" in 1979 and supported them with 3,500 million won in research funds. In the first year of the 5-year R&D project, KIST saw an increase of 700 million won in contracts under the lump-sum research fund arrangement of 1978. This was the end of KIST's role in solving current technological problems such as assisting technology transfers and providing engineering extension services. This was also the beginning of R&D for future national development projects, which meant the decline of contract research from industries and the increase of contract research from the government.

This decade dramatically changed the role of KIST. In 1978, the total contract research volume was worth 7,007 million won, 81.2% of which was from private industries and 18.8% from the government. In 1990, the total contract research volume surged to over 300% and was now worth 21,923 million won. Unfortunately, the industry's share value went down from 81.2% to 14.8%. In comparison, government shares went up from 14.8% to 85.2% in 1978.

The drastic change of contract patterns for KIST during this decade indicated that it had strong support from the government and was entrusted to provide solutions for problems that the country expected to face in the future.

2.3.4 4th Period: The Challenge of Future Technology

In 2015, KIST had 266,247 million won in research volume, and 95% of that was in government contracts alone. With these statistics in mind, the question could be asked: What is KIST doing now? In February 2016, KIST published *Prospects of Science & Technology* to describe some of the work it is currently undertaking. Examples of KIST's current programs include:

Research into the substitution of material processing shifted in 1978 to R&D on new materials such as super engineering plastic that is heat-resistant up to 300oC, biodegradable magnesium implants for medical use, and carbon composite graphene. For computers, the focus of research moved from mechatronics, smart brain interface chips, autostereoscopic 3-dimension displays, and optical fibers to the application of fiber lasers. In the fields of remote sensing and robot research, KIST is now working on environmental sensing and monitoring technology, biosensor-based diagnoses of infectious diseases, smart farm solutions, and socially interactive robots. In the areas of transportation, KIST is now working on hydrogen fuel cell batteries for cars, in addition to nanoparticle titanium dioxide, which is a next generation material for solar batteries. The application of solar energy research moved into solar fuels and artificial photosynthesis. For water pollution, KIST is trying to rethink carbon dioxide that utilizes CCS as well as carbon capture and storage. Decentralized waste water management now uses a membrane bio reactor (MBR).

These topics are neither intended for technology transfers nor for technology import substitutions. Rather, these research projects are paving the way for future technologies and are the focus of engineers and scientists around the world. Recently, Reuters ranked KIST "6th amongst 25 of the world's most innovative research institutes." KIST is now recognized as one of the best R&D institutes in the world, an accomplishment 50 years in the making.

3. Conclusion

The potential for the effective transfer of technology to a country depends on its level of scientific and technological capacity as well as its managerial and financial infrastructure. In 1966, the South Korean government decided to establish KIST as the basis for its scientific and technological infrastructure. KIST has performed this role ever since the 1970's and has made significant contributions to the development of the national economy.

The success story of KIST during the 1970's should be a reference point but is not necessarily an answer for every developing nation that seeks to build S&T infrastructure. KIST proved to the world that a research institute in a developing country could work well and contribute to the development of the national economy under certain conditions. The conditions under which a developing nation can be successful are as follows:

3.1 The Determination of the Government

One of the key elements of KIST's success could be attributed to the operational policy of contract research, delegation of authority, and responsibility. Because this system of contract research forced KIST to concentrate on the problems of local industries, the research teams were motivated from the very beginning. In retrospect, the most important factor that allowed contract research to work for KIST was the role of the South Korean government. Only the government had the authority to establish a research institute as the scientific and technological infrastructure for a developing country, but an experienced scientist or engineer is needed to inform the government of what is needed to develop this infrastructure. The government should also make this research institute the ideal working place in terms of salary, fringe benefits, and level of social prestige. To this end, the government should be willing to bear all budgetary responsibilities with respect to the allocation of limited resources in order to retain personnel and fund affiliated projects.

Without any doubt, KIST was born out of tremendous capital investments from Korean government along with the USAID (United States Agency for International Development) assistance in 1966. As the United States helped Korea to build the research institute that achieved an economic miracle, Korea is currently assisting Vietnam in establishing a research institute, the Vietnam-Korea Institute of Science and Technology in Hanoi (Lee, 2016).

3.2 The Shift from the Analog Era to the Digital Era

It was in the 1970's when KIST was trying to establish the scientific and technological infrastructure of South Korea. It was an analog era then, with no personal computers or internet. Information for technical projects was not as accessible as it is now. KIST's consulting services in the 1970's started with the collection of relevant data and ended with its engineering extension services.

We now live in a digital era. By using personal computers and the internet, the information industry has developed to a point where anyone can easily access required information. Therefore, the nature of the information that the research institute provides must differ from what it provided in the past. The level of information in a country should be evaluated very carefully before setting up marketing plans to execute a research contract. For example, in some developing countries, collecting relevant information may not be as important as the kind of industry consultation KIST offered in the 1970's; engineering extension services may be more appropriate for some developing countries.

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