Cooperative R&D in Japan and Korea: A Comparison of Industrial Policy

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This article compares and evaluates Japanese and Korean industrial policies aimed at promoting the research activities of firms, with focus on government-sponsored R&D consortia. Korean R&D promotion policies were introduced 20 to 30 years later than Japan. In contrast to the Japanese case, Korean protective industrial policies prolonged and encouraged the duplication of technological capabilities among the major *chaebols*. Korean R&D consortia did not fully promote R&D cooperation, knowledge sharing, or scale economies equivalent to the Japanese level. The organizational and institutional structure which developed under Korean industrial policy became an obstacle to the effective implementation of cooperative R&D.

Key words: R&D consortia, Japan, Korea, industrial policy, R&D promotion

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1. Introduction

The postwar economic growth of Japan has been spectacular, and this experience has been studied extensively (for a survey, see Ito, 1996). In particular, the role of industrial policy in the Japanese "economic miracle" has been a subject of considerable debate.[1] Among those who identify industrial policy .as critical to Japanese development, cooperative R&D ***is*** perceived as the single most important tool of the postwar Japanese industrial policy (for example, Okimoto, 1989).[2] The most celebrated example of Japanese cooperative R&D is the *1975* VLSI (Very Large Scale Integrated circuit) project, designed to help Japan catch up with the U.S. in semiconductor technology. This project was widely regarded as a success, as evidenced by Japanese semiconductor companies' world leadership after the project. While this success story is the best known, it is widely believed that it is only one of many. In addition, U.S. and European countries introduced their own industrial policies which attempted to follow this practice.

Beginning in the 1960's several other Asian nations succeeded in achieving high rates of economic growth. The Republic of Korea (hereafter Korea) is widely regarded as one of the most successful of the developing Asian countries (Christensen and Cummings, 1981), which, like many other high-performing Asian countries, followed the path of the "Japanese model," including extensive government intervention and its own version of cooperative R&D projects.

It was commonly believed that Japan's VLSI project in 1975 was successful for the following reasons. First, the Japanese government (notably the Ministry of-International Trade

[1] See Eads and Yamamura (1987) for a summary of competing views.
[2] Cooperative R&D is defined here as an agreement among a group of firms to share the costs and results of an R&D project prior to the execution of that project. In this article, we use cooperative R&D, cooperative R&D projects, and R&D consortia interchangeably.

and Industry, or MITI) targeted a limited number of promising sectors. Second, participants, who were at the same time direct competitors in the same industry, were willing to cooperate with each other and share costs to pursue a large-scale project. As a result, in the economic theoretical literature on cooperative R&D, the focus has mostly been on the effect of cost sharing in R&D on subsequent competition In both the managerial and public policy literature, on the other hand, the focus has been on case studies of a small number of consortia, particularly those which have been formed in the semiconductor and computer sectors, with attempts to generalize the "success formula" from these limited examples. For example, see Katz and Ordover (1990), Fransman (1990), Murphy (1991), Ouchi and Bolton (1988), and Dunning and Robson (1988). Comprehensive empirical research on this issue is almost nonexistent, except for Irwin and Klenow (1996), Link, Teece, and Finan (1996), and Branstetter and Sakakibara (1998). It is expected that an analysis based on large data sets will provide policy lessons to other countries seeking to emulate Japan's success through the application of this particular style of industrial policy.

This article compares and evaluates Japanese and Korean industrial policies aimed at promoting the research activities of *firms,* with a focus on government-sponsored R&D consortia. Our particular concern is the implications of this kind of industrial policy on both the organization of firms and national innovation systems. Korea is known as a diligent follower of Japanese industrial policy. During the post World War II period, Korea introduced Japanese-style industrial policy with an approximately 10- to 15-year lag. However, the lag widened to 30 years when it came to the introduction of significant R&D promotion policies in Korea in general, and cooperative R&D promotion policy in particular.

Closer examinations of the structure of Korean R&D consortia reveal that Korean R&D consortia did not fully promote R&D cooperation, knowledge sharing, or scale economies equivalent to the Japanese level, even to the level reached by Japan in the 1960s. The organizational and institutional structures developed under Korean industrial policy became an obstacle to the effective implementation of cooperative R&D. This limitation .of Korea's R&D strategy has important implications for many other developing countries that try to model after Japan and Korea in their technology build-up.

This article is organized as follows. Section 2 presents some macro indicators of Korean performance in R&D vis-à-vis comparable countries to evaluate its R&D promotion policies. Korea made remarkable progress in its R&D efforts, but it was only in the 1 990s when its R&D efforts finally became comparable to some Western developed countries such as Germany and France, though its R&D performance in absolute terms still lagged behind major countries including Japan. Section 3 is an overview of industrial policies in Japan and Korea, with focus on R&D promotion policies. In this section, we emphasize the timing and the context of the introduction of policy tools, and organizational and institutional outcomes. Section 4 focuses on a comparison of government-sponsored R&D consortia in Japan and Korea, comparing 237 Japanese and 184 Korean consortia. Korean consortia are found to be much smaller, with fewer participants and shorter duration than Japanese equivalents in the 1960s. Section *5* discusses the organizational implications of cooperative R&D. Finally, this article concludes in Section 6.

2. Evaluation of Korean R&D performance

Korea has achieved remarkable economic development as one of the Asian "Tigers;" the source of this achievement has been analyzed in many studies (for example, see Jones and

Sakong, 1980; the World Bank, 1993). In this section, we focus on Korea's performance in R&D, and identify its current status vis-à-vis those of other developed and comparable countries.

The R&D performance of a country can be evaluated from two perspectives: R&D input and R&D output.[3] Figure 1 presents the ratio of R&D expenditures to GDP for selected countries, and demonstrates that Japan attained similar levels to Western countries in the 1970s. Korea increased its R&D intensity steadily, but it was not until in the 1990s when Korea finally reached the level of Western countries. The growth rate of R&D intensity by Korea surpasses that of Japan and Taiwan, with the Korean growth rate being especially high in the 1 980s and the 1990s. However; Figure 2, which presents the R&D expenditures in constant U.s. dollars, shows that in absolute terms, Korea's R&D expenditures still fall behind those of major countries. Cross-country comparison of R&D expenditures requires cautious interpretation. Japan's rapid increase in R&D expenditures in dollar terms after 1985, for example, is due to the appreciation of the yen. Even with this limitation in mind, Figure 2 still shows that Japan has caught up with European countries in terms of absolute R&D expenditures. Korea. whose GDP is one eleventh of Japan in 1995, has a long way to go in terms of the development of its R&D capabilities.

Figures 1 through 4 about here

The number of patents is frequently used as a measure of R&D output because of its availability.[4] Figures 3 and 4 show the number of patents granted in the U.S. for foreign

3 Data sources of this analysis are summarized in Appendix.
4 It is a difficult task to compare R&D output across countries, because available measures of R&D output are not perfect. The main problems of using patents as a measure of R&D output are that the quality of patents varies significantly, and the propensity to patent differs by industry.

countries. The propensity to patent in the U.S. differs by country according to its current and potential market presence in the U.S. For many Asian countries, the U.S. is the single most important export market, which helps to justify the use of patenting in the U.S. as a measure of R&D output. This measure, however, favors countries that concentrate on electronics related industries (especially Taiwan and Korea[5]), because in those industries a greater number of patents are typically granted to cover a single product/invention than in the machinery or chemical industries. Figure 3 illustrates that Korea along with Taiwan surpasses other "comparable" countries in U.S. patenting.[6] It is apparent from this figure that Korea "took off' in R&D output in the 1990s. Figure 4, however, shows that Korea is still behind Japan and major Western countries in R&D output.

Figures 1 through 4 illustrate that Korea achieved dramatic improvements in its R&D capability over the last three decades. However, it is only in the 1990s when Korean-R&D efforts finally became comparable to developed countries, including Germany and France. At the same time, Korea's R&D performance in absolute terms still lagged behind major countries including Japan.

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[5] The share of electrical equipment in total R&D expenditure between 1991 and 1995 was 49.3% for Taiwan, 49.2% for Korea, *34.5%* for Japan, and 12.2% for the U.S.

[6] A major thrust for the surge of the U.S. patenting by Taiwan from the mid 1 980s is the return of the thousands of U.S. educated and -trained Taiwanese engineers to Taiwan and their starting of electronics related firms while maintaining the two-way knowledge/technology flow between Silicon Valley and Taiwan. The Taiwanese government supported these entrepreneurial returnees by promoting venture capital funds and industrial parks (Saxenian, 1999).

From a broader perspective, Korean R&D performance can be inferred from its total factor productivity growth, that is, an increase in output per unit of input over time. Total factor productivity growth can be achieved by an efficient use of resources (e.g. advances in management) as well as technical progress, so the existence of total factor productivity growth is a necessary but not a sufficient condition for superior technological performance. There. are extensive debates on the technical progress of Asian NICs (Christensen and Cummings, 1981; Tsao, 1985; Dollar and Sokoloff, 1990; Young, 1992, 1995; Kim and Lau, 1994, 1996; Krugman, 1994). The most pessimistic view is presented by Kim and Lau (1994), who argue that the hypothesis that there has been no technical progress during the postwar period cannot be rejected for Korea, Hong Kong, Singapore and Taiwan. Capital accumulation accounts for between 68% and *85%* of the economic growth of those countries. In contrast, technical progress accounts for 39% of Japanese and 49% of U.S. economic growth. Contrary to a more conventional view, Dollar and Sokoloff (1990) argue that during the period 1963 to 1979, Korean total factor productivity growth was much higher in medium and light industries than in heavy industries. They also argue that capital over-investment occurred in heavy industries due to extensive capital subsidies provided to these industries, suggesting a limitation of the "targeting" policy. Young (1995) shows that Korea's total factor productivity growth was 1.7 % per annum, no higher than that of developed countries. Though there are ongoing debates about the contribution of the technical progress on the economic growth in Korea and other Asian countries, these observations are consistent with our findings of Korean R&D performance: the Korean economy has achieved extraordinary growth, but the source of this growth is an increase in inputs, especially physical capital, while Korea's technological level still lags behind industrialized Western countries and Japan.

In the following sections of this article, we focus on the development and differences between the R&D promotion policies of Japan and Korea to explain some of the reasons for Korea's lags in R&D performance and technological levels.

3. R&D Promotion Policy in Japan and Korea[7]

There are two sets of industrial policies that affect R&D activities: one is a set of policies that intends to achieve broad goals but have a far-reaching impact on R&D and technological progress, and the other is a set of policies that is targeted to promote R&D. In this article, we examine both sets of industrial policies.

A notable postwar industrial policy that had a broad objective and a *significant* effect on R&D promotion in Japan was the Foreign Capital and Foreign Exchange Control Law. Based on these laws, the Japanese government allocated its scarce foreign currency selectively to those firms capable of adapting and improving import technology in order to encourage the importation of advanced technology and to promote a domestic technology base. By limiting the number of potential licensees, these laws effectively worked to increase the bargaining power of technology buyers and to limit royalty payments (Goto and Wakasugi, 1984).

Japanese policies restricted imports and direct investment until 1964 when Japan obtained the status of an article eight country in IMF and liberalized import and capital inflows (some restrictions on capital flows continued until 1973). These policies, profoundly influenced how Japan built its domestic technology base. Without having the option to export their product or to establish their production base in Japan, the only way foreign firms were able to profit from

7 This section draws upon Komiya et.al. (1984), Tsusbo Sangyo Seisakushi Hensan Iinkai ed. (1989), and Odagiri and Goto (1993).

their technology in Japan was to sell the technology (Odagiri and Goto, 1993). The restriction of imports and direct investment, therefore, facilitated technology transfer from Western countries to Japan in the early post-war era. The restriction also worked to protect domestic firms from foreign competition, which potentially helped domestic firms to earn higher rents and allowed them to invest in R&D.

There is evidence, however, that intense competition among domestic firms existed in the industries which later became world-class industries (for example, see Porter, 1990). Empirical evidence shows that there is a significant positive correlation between the amount of royalty payment for imported technology by industries or firms and their R&D expenditures (Blumenthal, 1976; Odagiri, 1983). This positive correlation indicates that firms which imported technology also invested in their own R&D efforts, driven by either protection or competition, to adopt and improve upon imported technology and build up their own technology capabilities. Figure 1 confirms that Japanese R&D expenditures already reached the level of developed countries in the early 1970s.

Direct policy tools to promote R&D activities can be classified into three categories. They are: (1) direct support of private R&D efforts in the form of subsidies, preferential tax measures, and the supply of low-interest loans; (2) contribution to research conducted in universities and national research institutions; and (3) promotion of cooperative research through technology research associations and other forms.

Direct support of private R&D efforts was introduced in Japan through a variety of programs during the early post-war period, mostly in the 1950s. However, the size of the incentives provided through tax breaks, subsidies, and low-interest loans were modest. In total, they amounted to little more than a hundred billion yen in 1983, or 2.6% of the year's total industrial R&D expenditures, which declined from 8% in 1960 (Odagiri and Goto, 1993).

Budgetary contributions to research conducted in universities and national research institutions by the Japanese government were also modest. In 1970, for example, the government share of the national R&D expenditures was *25%* in Japan, compared to *57%* in the U.s., *45%* in Germany, 64% in France, and *50%* in the U.K. (STA, 1990). The government share to national R&D expenditures declined in all these countries over the next two decades, but the share of the Japanese government remained the lowest in the 1990s (OECD, l996).[8] We will discuss the promotion of cooperative research in the next section.

In sum, the R&D efforts in Japan were mostly driven by the private sector. Industrial policy in a broad sense played an important role to give companies an incentive to conduct R&D. Thought protection was given to industries, early protection did not spoil active R&D investment by companies.

Korea's industrial policy started in the early 1960s, and took the form of a series of Five-Year Economic Development Plans (FYEDPs). The First FYEDP, starting in 1962, aimed at promoting import-substituting industries. In order to promote the targeted industries, the government provided many policy tools, including import restrictions, tax incentives, custom

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[8] One might argue that the R&D budget by non-Japanese governments includes defense-related spending, and so the comparison between the total government R&D budgets of non-Japanese countries and that of Japan is not a fair comparison. Indeed, the US defense related R&D budget accounts for 57% of the total R&D budget between 1960 and 1992, compared with *5%* in Japan. However, many US R&D consortia including Sematech and the flat-panel display development project are funded from the defense budget, and so the distinction between the civilian ~and defense budgets is not important for the argument of government funding of R&D (Sakakibara, 1997b).

rebates, and selected promotion of inward foreign direct investment (Taniura, 1989). The government soon shifted the target to export-oriented industries to repay foreign loans (Cho, 1997). In the Second FYEDP starting in 1967, industries such as steel, shipbuilding, electronics, and petrochemicals were promoted. The promotional policies for these industries were accompanied by policies that directly shaped industrial structure, including entry restrictions for targeted industries, allocation of export rights to specific markets, and allocation of product lines among incumbents in a specific industry (Kodama, 1995).

In the Third FYEDP starting in 1972, the government instituted the General Trading Company (GTC) in order to further promote exports. Only the major groups of companies were de facto allowed to start the GTCs (Cho, 1987). These companies began to massively diversify into unrelated fields through acquisition in order to secure exportable products, transforming themselves to *chaebol* (IEBM, 1999). The government also favored *chaebol* over independent companies when they gave licenses for entering targeted industries. In so doing, the government expected that *chaebol* would realize the economies of scale and scope and develop exportable products from the targeted industries (Kim, 1993).

In order to expedite the development of export industries, the Korean government promoted assembly industries of final goods. This policy prompted importation of foreign capital goods. In the assembly industries of machinery and electronics, firms often depended on reverse engineering as a major source of learning. Large firms across industries have resorted heavily to foreign sources, notably in the form of acquisition of plants on a “turnkey” basis, in order to ensure quick construction and smooth start-up. Indigenous research was, therefore, not aggressively pursued through the early 1 970s (Kim, 1993).

The first Korean R&D promotion policy can be found in the Technology Development Promotion Law of l972.[9] The role of the government in R&D promotion was limited to the establishment of national research to support industrial technological learning, and funding university R&D. The Korean government, however, did not play a significant role in R&D promotion until the 1980s. Among the 18 industrial policies initiated by the Ministry of Science and Technology (MOST) between 1967 and 1993, only 3 were recorded before 1980 (Cho, 1994).

The 1981 amendment of the Technology Development Promotion Law facilitated various tools to promote private R&D. Compared to the previous industrial policy of the 1970s, the new policy was geared toward both direct and indirect promotion of technology-intensive industries in their R&D stages.[10] The indirect R&D promotion programs also allowed the Korean government to help establish industrial technology research consortia, and enabled the government to promote specific R&D projects through these consortia.

The role of the Korean government in R&D promotion has been limited, compared to R&D promotion through policies that have broad objectives, however. For example, in the

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[9] Although the Ministry of Science and Technology was established in 1967, its role was not clearly defined in the early period.

[10] The direct promotion programs for technology-intensive industries included: subsidies for research expenses (designated R&D project expenses); exemptions of tariffs, special consumption taxes and value-added taxes; reduction of taxes up to 10% of R&D allotments: and priority purchase of products from cooperative development In addition, the promotion programs offered firms preferential loans to set up new laboratories and exemptions of their key R&D personnel from the obligation of military service (Kim, 1993). The indirect promotion programs included: provision of low-interest loans through the banking sector; promotion of exchange and cooperation among R&D personnel; and promotion of cooperative utilization of R&D facilities and information.

1990s, government R&D funding accounted for 20% of total Korean R&D expenditures (MOST, 1994), while the rest of the R&D projects were financed by the private sector, mostly affiliates of the *chaebol* groups. These companies enjoyed monopoly rents in the Korean market that were protected by the government from imported products and entry threats. Though the Antitrust Law was enacted in 1980, the enforcement was not effective enough to preclude the *chaebol* affiliates from exchanging personnel within the group, and underwriting R&D expenditures for new businesses attempted by other group firms. Korean R&D is, therefore, driven by *chaebol* affiliated companies, especially after the 1980s.[11] Korean industrial policy explicitly protected and promoted these large corporations.

Table 1 about here

Table 1 summarizes and compares the timing of the introduction and abolition of various R&D-related industrial policies in Japan and Korea. There are several important observations one can make from this table. First, Korea followed Japanese industrial policies, especially so-called "targeting" policies very quickly, with an approximately 10- to 15-year lag. However, Korea did not "graduate" from protective policies until approximately 30 years after the "graduation" of Japan.[12] This means that there has been a prolonged existence of protective policies and the promotion of "targeted" industries in Korea. Also, the implementation of

[11] In 1993, for example, the top six electronics firms from four *chaebols* , Samsung electronics, LG electronics, LG electron, Hyundai electronics, Daewoo 'electronics, and Daewoo communications account' For '7~I4 of the total Korean electronics R&D expenditures and 30% of the total Korean manufacturing R&D expenditures.
[12] An exception is the liberalization of foreign direct investment, for which Korea was only several years behind Japan.

Korean R&D policies was much delayed, with a 20- to 30-year lag from that of Japan. These phenomena may be partially attributed to the fact that Korea's industrial policies in general do not include graduation dates, although it is hard to determine the causality between these two facts.

There are many implications one can draw from the differences between Japanese and Korean R&D promotion policies. In Korea, imports of technology occurred in the form of import in capital goods and reverse engineering, especially the import of the whole "turnkey" system. This implies that firms have to simultaneously digest all stages of the value chain, from basic research, product and process development, to production. In addition, in order to catch up with Japan and other developed countries quickly, Korean firms had to radically shorten this digestion process.[13] In a Korean automobile manufacturer's case, it took only two years for the company to advance from a licensing contract to producing a car. Being under severe time pressure, Korean firms had limited room to develop their own capabilities at each activity of the value chain.

In contrast, in Japan, the introduction of foreign technology was mainly through licensing of essential technologies. The replacement of imported technologies with domestic technologies in development and production occurred in Japan much earlier than in Korea. Also, activities of the later stage of the value chain were sometimes conducted domestically in the first place. The shift from technology licensing to domestic R&D occurred in the l960s when the technology cycle was still relatively long. Japanese firms were, therefore, able to digest and develop activities in the whole value chain one by one.

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[13] Interview with an R&D executive of a major *chaebol*, September 1997.

Prolonged protection and entry restriction to "targeted" industries resulted in the late entry of Korean firms to international R&D competition in the 198 Os, when world economic growth slowed down. This implies that, compared with Japanese firms, the payback period of the R&D investment by Korean firms was longer, resulting in another disadvantage for Korean firms.

Furthermore, prolonged protection and the late and weak enforcement of the antitrust policy that allowed cross-financing among *chaebol-affiliated* companies created fierce rivalry among *chaebol* groups. This rivalry, however, only invited redundant investments in capacity expansion with similar technologies among *chaebol* groups, instead of forcing them to compete in R&D. At least three policy initiatives could be identified to have affected these tendencies. First, entry restrictions in most of the targeted industries induced the *chaebol*-affiliated companies to expand production capacity in order to dwarf rivals or even preempt them from entering the industry. Second, most of the industry promotion programs such as low-interest export financing were linked to firms' sales volume, which induced companies to expand facilities to quickly capitalize on these incentives. Third, the cost of capital to invest in capacity expansion in targeted industries was low due to governmental subsidies, reducing the incentive to compete at the technology frontier through R&D investment.

The business-government relationship in Korea has a number of important differences to that in Japan. Korean government technocrats have almost unchecked power in setting policy guidelines, while Japanese government officers must go through the laborious process of developing consensus among concerned ministries and between the government and business sectors. In addition, the size of the Korean economy is only one eleventh that of Japan in terms of GNP, thus the Korean government does not have the kind of affluence that its Japanese counterpart may dwell on. Adding to the budgetary limitation is the relatively shallow pool of engineers, who do not have as much industrial experiences as their Japanese counterparts.

These factors are combined to result in the third characteristic: top-down processes in decision making by the government. In Japan, there is a system, though sometimes nominal, which channels the voice of the business sector to government policy-makers. The most notable channel is "deliberation councils", in which government officials, academics, and business representatives discuss and coordinate policies. In Korea, such a communication channel exists, but is does not work in a way that facilitates information exchange. Some Korean industry experts have suggested that the Korean government seeks its own objectives without inputs from the private sector.[14] It is, therefore, quite difficult to formulate a detailed and effective R&D promotion policy in Korea.

Until 1981, the Korean government, therefore, set its own R&D policy, and utilized government-sponsored research institutes as major sources of R&D activities and technology development (Lee, Son and Om, 1996). As we discuss in the next section, the Korean government began to lean toward government-initiated and -sponsored cooperative R&D with the 1981 amendment of the Technology Development Promotion Law.

4. Cooperative R&D in Japan and Korea

In this section, we focus on government-sponsored R&D consortia, one of the major R&D promotion tools. Government-sponsored R&D consortia in this article include all

[14] Interview with a senior R&D executive of a major *chaebol*, September 1997.

significant company-to-company cooperative R&D projects formed with a varying degree of government involvement.

The promotion of cooperative R&D in Japan started in 1959, when MITI and aircraft makers launched the YS-11 turboprop aircraft development project. In 1961, a formal scheme to promote cooperative R&D efforts was established as the Act of the Mining and Manufacturing Industry Technological Research Association. Under the Act, which was modeled after the British Research Associations initiated in 1917 and later adopted by Germany, France and Sweden, firms can pool researchers and funds into nonprofit Mining and Manufacturing Technological Research Associations (TRAs hereinafter). The formation of TRAs was intended to promote R&D consortia as a means of coping with trade liberalization and to enhance the productivity of Japanese industries. At that time, Japan faced the task of abolishing protective policies for domestic industries following these industries' recovery from the devastation of the Second World War.

Under this scheme, participating companies enjoyed several tax benefits on their research expenses. Typical tax benefits included accelerated depreciation for expenses on machinery and equipment, instant depreciation of fixed assets for R&D, and discounts of property taxes on fixed assets used for R&D (the Council of the Mining and Industry Technology Research Association, 1991). The TRA system was introduced as a substitute for direct R&D subsidies to individual companies, which the Japanese government had to phase out as Japan prepared to join the league of developed countries and to abolish protective policies. After the scheme of TRAs was introduced, the amount of R&D subsidies to individual companies has indeed considerably declined, and in order for firms to receive significant amounts of R&D subsidies, they need to form R&D consortia.

TRAs are not the only form of cooperative R&D in Japan. Other organizational forms for cooperative R&D include foundations and corporations. These forms are chosen by participants on the basis of each form's financial ~and organizational benefits (for details of different types of cooperative R&D, see Sakakibara, 199Th). We documented 237 R&D consortia that existed in Japan between *1959* and 1992. It is not only MITI, but also many other ministries that are involved in the formation and operation of these consortia.

The promotion of Korean cooperative R&D started in 1982. The government introduced the Industrial Research Association (IRA) system, which was modeled after the Japanese TRA system. Under each industry-based IRA, many specific consortia were formed. MOST started this initiative, but later other ministries are involved. We documented 190 R&D consortia that existed in Korea between 1982 and 1997.[15] Unlike in Japan, IRA has been the dominant form of cooperative R&D in Korea. The Korean government provided the participants of IRA with various incentives such as exemptions of military obligations for male researchers, accelerated depreciation of R&D investment, etc. Multiple consortia proliferated within each industry-based IRA, as each consortium was formed on a product basis. The Korea Software Development IRA has led other IRAs with 21 consortia.

A notable development occurred in 1986, when MOST introduced large-scale cooperative R&D projects mainly in the electronics and information areas. The Electronics and Telecommunications Research Institute, a government R&D institute, served as a coordinator, and only large members in electronics-related. IRAs participated in these consortia.

Though the basic systems of government-sponsored R&D consortia in Japan and Korea are similar, the implementation has been very different between the two countries. Figure 5

15 There are cases that IRA member firms receive government subsidies even if they conduct R&D alone. We limited our sample to R&D projects that involve cooperation among multiple firms.

illustrates that the total budget for R&D consortia has been much larger in Japan than Korea. The Korean budget has not exceeded 10% of that in Japan in any year before 1991, and it is in 1991 when the Korean budget finally reached 11.6% of that in Japan.

Figures *5* through 7 and Table 2 about here

Comparisons between Figure 6 and 7 show interesting differences in the industry composition of the R&D consortia in both countries. Figure 6 shows that, in Japan, the electronics and machinery industries were the major industries in terms of their share of the total consortia budget during 1959 and 1992. There are, however, R&D consortia in materials, chemicals, and energy industries that account for a large share of the budget, followed by transportation equipment and information industries. Figure 7 reveals that the electronics and machinery industries also take the lion’s share in the Korean R&D consortia. These two industries accounted for 75% of the total consortia budget in Korea from 1993 to 1997 however, while the share of these two industries in the total consortia budget in Japan was much less, 60% of the total from 1970 to 1992. Between 1993 and 1997, the electronics and machinery industries accounted for 55% of Korean R&D expenditures, which indicates that the Korean government concentrated its efforts to promote R&D in those industries to an extent that is greater than their current share in R&D. Examining the underlying R&D structure, Korean R&D efforts are more concentrated in a smaller number of industries than in Japan end the U.S.[16] The efforts by the Korean government to promote R&D consortia, therefore, might even increase the skewness of the R&D structure.

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16 Between 1987 and 1996, for example, the coefficient of variation (which indicates how the distribution is skewed) of Korean R&D expenditures by industry is 2.5 on average, compared with 1.7 in Japan and 1.1 in the U.S.

There are tradeoffs that are made when the concentration of R&D consortia is limited to certain industries. Concentration allows a country to allocate scarce resources to a few selected industries. This is important for a small country with limited R&D resources. On the other hand, concentration works against the purpose of promoting R&D consortia as a means to create the seeds for the next-generation of technology. Especially considering how difficult it is to predict which industry will lead the global economy in the future, a rational choice for governments in formulating R&D promotion policies might argue against concentrating on a limited number of industries.

Table 2 further investigates the organizational differences of R&D consortia between Japan and Korea. Comparisons between column 1 and 2 illustrates that Korean R&D consortia are very small, with an average budget per project of 7% of the size of Japanese projects. This smaller size is also evident when comparing the number of participants per consortia. On average, there are only 3.4 participants in Korea, while there are 14.8 in Japan. In particular, 78 out of the 190 Korean R&D consortia have only 2 participants. Moreover, the participants of Korean R&D consortia include *25* universities and national research institutes (with 56 project-participant pairs), and so the actual cooperation between companies is even more limited.[17]

A firm can participate in multiple R&D consortia in both countries, but on average, the extent of multiple participation is rather limited. The average number of projects per firm is 1.8 in Korea versus 3.0 in Japan. In both countries, there are many participants that participate in only one project, while there are a number of active participants that participate in many projects, especially in Japan. The most active consortia participant in Korea, Hyundai Electronics, has

[17] In the Japanese consortia, when universities and national research labs are a part of a project, they typically take an advisory role.

participated in 16 consortia, while the most active Japanese participant, Hitachi, has participated in 75 consortia. These active participants tend to be R&D-intensive companies.

A typical Korean R&D consortium has a limited time span. The average duration of Korean consortia is 3.8 years, almost half of the duration of their Japanese counterparts, 6.9 years. In terms of government contributions, the Japanese government's share of 66% is larger than the Korean government's share of 40%.[18]

These findings imply that Korean R&D consortia did not realize economies of scale in R&D, and played a limited role in promoting R&D cooperation and knowledge sharing among participants, as compared with their counterparts in Japan. If, for example, the Korean government wished to achieve economies of scale in R&D consortia, it could promote fewer numbers of consortia, making the scale of each consortium larger. The Korean government could also increase the number of participants per project by limiting the number of consortia it promotes if its purpose is to increase the knowledge flow among participants. Nevertheless, whether the Korean government did not, or could not, increase the average size of a consortium requires further investigation.

One might argue that the differences between Japanese and Korean R&D consortia are due to the difference in the development stage of Korean R&D. Column 3 in Table 2 summarized the characteristics of Japanese R&D consortia in the 1960s. A comparison between Column 1 and 3 gives partial support to this argument. The Japanese R&D consortia had smaller budgets and fewer participants in the 1 960s than in the later period. It is still the case, however, that the average size of Japanese consortia in the 1 960s is larger than the average size of Korean

[18]As explained later, a reason of the higher share of the Japanese government is that the Japanese consortia focused on more basic R&D than what Korean consortia targeted.

consortia. On average, Japanese consortia at that time were almost five times larger in terms of the budget and four times larger in terms of the number of participants. The average duration was also much longer.

One might also argue that the knowledge-sharing function is not important for Korea because companies have not accumulated enough R&D capabilities to share. Even if that argument holds, there is evidence that economies of scale at the research project level have a significant impact on research productivity (Henderson and Cockbern, 1996). The Korean government could compensate for smaller-sized Korean R&D expenditures by promoting larger-scale projects.

The nature of R&D consortia also widely differs between the two countries. Table 3 shows examples of cooperative R&D project in Japan and Korea in 1992 and Japanese projects in the 1960s and in the early l970s. Though it is difficult to precisely compare the type and goal of R&D consortia in Japan and Korea, Table 3 shows that Korean R&D consortia in 1992 focused on much more applied, industry-specific technologies with a clear goal that other countries have already proved. In contrast, the focus of Japanese consortia in the same year is more basic R&D with results that can be applied to many industries. Korean consortia in 1992 resemble Japanese consortia in the 1960s rather than in the 1990s.

In order to evaluate the effectiveness of R&D consortia, it is necessary to conduct in-depth econometric analyses. Branstetter and Sakakibara (1998) have shown that Japanese - government-sponsored R&D consortia have a small but positive effect on the innovation efforts of participating firms. They found that if a firm participates in an additional project per year, it would raise its total R&D spending by 2% and its research productivity by between 4% and 8%. Since firm-level R&D data for Korean firms are not readily available, it is difficult to conduct similar analyses on Korean R&D consortia. Given the lack of scale economies and the limited number of participants per project, however, Korean R&D consortia do not have the basic conditions to benefit from R&D cooperation equivalent to the Japanese level.

5. Organizational Implications

The differences in R&D consortia between Japan and Korea identified in the previous section result from organizational and institutional differences between the two countries. The first difference is the business organizations. Business groups formed much later in Korea than in Japan, and the founders of these groups still play active management roles in most cases. The organizational structure of *chaebols* are similar to the prewar *zaibatsu* groups in Japan.[19] with more centralized decision making than *keiretsus* (IEBM, 1999). The control of owner families is stronger in *chaebols* than in *zaibatsu* groups that are more institutionalized. The rivalry among *chaebol* is, therefore, realized at a personal level, making cooperation among firms very difficult. For example, there is anecdotal evidence that the entry of Samsung into the auto industry is more of a personal decision by Samsung Chairman Kun-Hee Lee, who displayed his combative spirit vis-à-vis that of Chairman Joo-Young Chung of Hyundai, than a rational business decision.[20]

The second difference is related to history. Korean R&D consortia did not start until 1982. In contrast, in Japan, with a 40-year history of cooperative R&D, the same set of firms typically participate repeatedly in different cooperative R&D projects. Sakakibara (1997b) argues that in the repeated game situation, a one-time gain from cheating, such as withholding

19 There are important differences between *chaebols* and zaibatsu groups, such as *chaebols* do not have financial institutions in the core.
20 Jaekye Rotary, August 1999.

technical information from other participants while absorbing information from others, can be easily outweighed by the punishment of being excluded from subsequent cooperative R&D projects. Also, even if different types of punishment are not enforceable within cooperative R&D games (since firms might voluntarily decide not 40 participate in additional projects), the threat of punishment in the product market can make cooperation sustainable. This is an implication from Bernheim and Whinston (1990), in which they found that multi-market contacts make cooperation more sustainable even if cooperation in a single market breaks down. Moreover, Baumol (1993) argued that cheating in cooperative R&D can be easily detected in a repeated game situation, and punishment to exclude a cheater from the following projects is very costly for the cheater. In Korea, with its short history of cooperative R&D and the limited extent of cooperation among firms, it would be more difficult to achieve sustained cooperation in R&D consortia.

Not only the history of R&D consortia but also the history of R&D and its development stage affect the nature of the cooperation. With a short history of R&D, Korean firms have not developed cutting-edge R&D capabilities, and they are concerned more with applied technology. R&D cooperation in applied technology makes cooperation difficult, because firms are less willing to cooperate or share knowledge which might result in creating new competitors in the market they are already in or they intend to enter. Korean R&D consortia significantly differ from Japanese counterpart in this regard. Even in the Japanese VLSI project in 1975, which was widely regarded as targeting applied R&D, the targeted technology was indeed three generations ahead of existing technology (Ouchi, 1984), facilitating cooperation among participants. The goal-setting in Korean R&D consortia was not adequate to induce effective cooperation.

The third difference is capabilities of member firms. In Korea, all the *chaebols* have pursued similar research goals, and internal technological development is still limited. The technological knowledge possessed by firms is therefore similar.[21] Sakakibara (1 997a) identified that the sharing of complementary knowledge is the single most important motive for participants of Japanese government-sponsored R&D consortia. Sakakibara (1999) also shows if the R&D contributes not only to firms' rates of innovation but also to their capacities to learn from others, then firms are willing to share knowledge in an R&D consortium when firms possess highly complementary knowledge, and private R&D investment also increases. This finding indicates the importance to have member firms with heterogeneous capabilities in an R&D consortium. In Korea, in contrast, there are limited learning opportunities from other participants through R&D cooperation, which further discourages firms to participate in R&D consortia.

The fourth difference is the business-government relationship. In Korea, an antagonistic business-government relationship has developed[22], which prevented the government from forming effective R&D cooperation policies that can be acceptable to potential participants. In Japan, though it is not always effective, the channel between business and government in the formation of industrial policies has worked to create R&D promotion policies worth implementing.

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21 For example, *chaebol* firms in the same industry target the same low-end to mid markets, and they have very similar product portfolios, suggesting their duplicative technological capabilities (Cho, 1995).

22 The love-hate relationship between Korean business and government has been documented. As discussed earlier the government used *chaebols* as a driving force of the Korean development. However, during the last 50 years, whenever a new president was sworn in, he arrested leading business people (often *chaebol* leaders) in order to get popularity from voters. These prisoners have been quickly released due to insufficient evidence of wrongdoing (Cho, 1992).

6. Conclusion

In this article we compare and evaluate Japanese and Korean industrial policies aimed at promoting the research activities of firms, with focus on government-sponsored R&D consortia. Examinations of Korean R&D expenditures and patent generation reveal that it is only in the 1990s when Korean R&D efforts finally became comparable to developed countries, while at the same time its R&D performance in absolute terms still lagged behind major countries including Japan.

The majority of Japanese protective industrial policies ended by the early 1970s, and Japanese firms conducted active in-house R&D while they aggressively imported and digested technologies from Western countries in the early post-war era. Japanese R&D promotion policies started in the early post-war period, while Korean R&D promotion policies were introduced 20 to 30 years later. In contrast to the Japanese case, Korean protective industrial policies prolonged and encouraged the duplication of technological capabilities among the major *chaebols*. Prolonged protective policies also resulted in the late entry of Korean firms to international R&D competition, adding another disadvantage for Korean firms.

Korean R&D consortia are concentrated in the electronics and machinery industries, and they did not fully promote R&D cooperation, knowledge sharing, or scale economies equivalent to the Japanese level, even the level reached by Japan in the 1960s. Personal rivalry among *chaebol* leaders, limited learning opportunities, limited resources, the short history of R&D and R&D cooperation, inadequate goal setting, and the antagonistic business-government relationship contributed to the relative ineffectiveness of Korea’s R&D consortia. In other words, the organizational and institutional structure, which developed under Korean industrial policy, became an obstacle to the effective implementation of cooperative R&D.

Overall, this article reveals the limitation of the Korean policies that are largely based on imitation of the Japanese policies. This article, therefore, has important implications to many developing countries, especially other Asian countries which try to emulate the two Asian high-performers. First, policy makers need to decide whether they should concentrate their resources on a few selected industries or spread the resources among a number of seemingly important industries in the future. Second, accumulation of technology through R&D takes time. It requires perseverance on the part of the government as well as the private sector. As Korea would not easily catch up with Japan after only 20 years (it took Japan over 40 years to achieve its current levels of success), so would other late-coming countries not easily catch up with either Japan or Korea. Third, learning takes place when participants have different resource bases. The composition of the membership of the consortium is important for its subsequent performance. More importantly, the economy of a country should be composed of companies with diverse and heterogeneous profiles if it would like to achieve technological progress. Nurturing large and similarly structured companies such as *chaebols* as engines of economic and technological growth might have been an efficient way for a quick catch-up in the 1960s and 1970s, but a downside of this strategy might be more apparent in the 2000s. Fourth, fundamental conditions that facilitate cooperation and communication between the government and private sectors are very important to the success of government-sponsored R&D consortia. Unless there is a mechanism based on which the amicable relation between the two major players of a national economy is established as a routine, one cannot expect to reap the full benefit of such an innovative vehicle for technology development.

There are limitations to this study. First, the outcomes of R&D consortia in Japan and Korea should be compared in order to evaluate the effectiveness of this particular R&D promotion policy. We are currently conducting surveys with Japanese and Korean R&D consortia participants to examine their evaluations of R&D consortia, hoping to discover differences in motives, organizations, and outcomes of R&D consortia at a more detailed level.

Similarly, differences in the performance of R&D promotion policies between Japan and Korea should be evaluated by measuring increased R&D productivity in particular and increased productivity in general, and how much of the progress is attributable to the industrial policy. In order to examine these issues, we need to obtain disaggregated R&D input and output data by industry for both countries, which are not readily available from publicly available sources.

Further research on the issue of cooperative R&D is necessary and encouraged. More broadly, it is important to conduct in-depth studies on R&D promotion policies in other countries, especially Asian countries, which adopted different types of government involvement. We need to understand under what circumstances these R&D promotion policies work, and to identify necessary organizational and institutional conditions that make R&D promotion policies successful.

Appendix. Data Sources

R&D Expenditure
Japan: *Survey Report of the Research in Science and Technology,* General Coordination Office, Japan.
US: *National Patterns of R&D Resources*, National Science Foundation. *Research and Development in Industry. 1989; Funds, 1989, Scientists and Engineers, January 1990,* Surveys of Science Resources Series, National Science Foundation. *Survey of Industrial Research and Development: 1996,* Surveys of Science Resources Series, National Science Foundation.
Korea: *Korea Statistical Yearbook.* Economic Planning Board, Republic of Korea. *Financial Statement Analysis,* Bank of Korea, various years.
Taiwan: *Statistical Yearbook of the Republic of China.* Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China. *Indicators of Science and Technology, Republic of China,* National Science Committee, Administrative Agency, Republic of China.
Germany: *Bundesbericht Forschung, Faktenbericht zum Bundesbericht Forschung,* BMIFT.
France: *Attachment to the Budget Proposal,* France.

GDP, GDP Deflator: *National Accounts,* OECD, Paris, Asian Development Bank Web Page. Exchange Rate: *National Accounts,* OECD, Paris. *Statistical Yearbook of the Republic of China.*

R&D Consortia
Japan: *The 30 Year History of the Mining and Industry Technology Research Associations* by the Council of the Mining and Industry Technology Research Association, 1991, brochures of each project type, issued by MIII and its affiliated organizations, and hearings from each governmental organization.
Korea: hearings from each governmental organization.

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Figure 1. R&D Expenditures / GDP

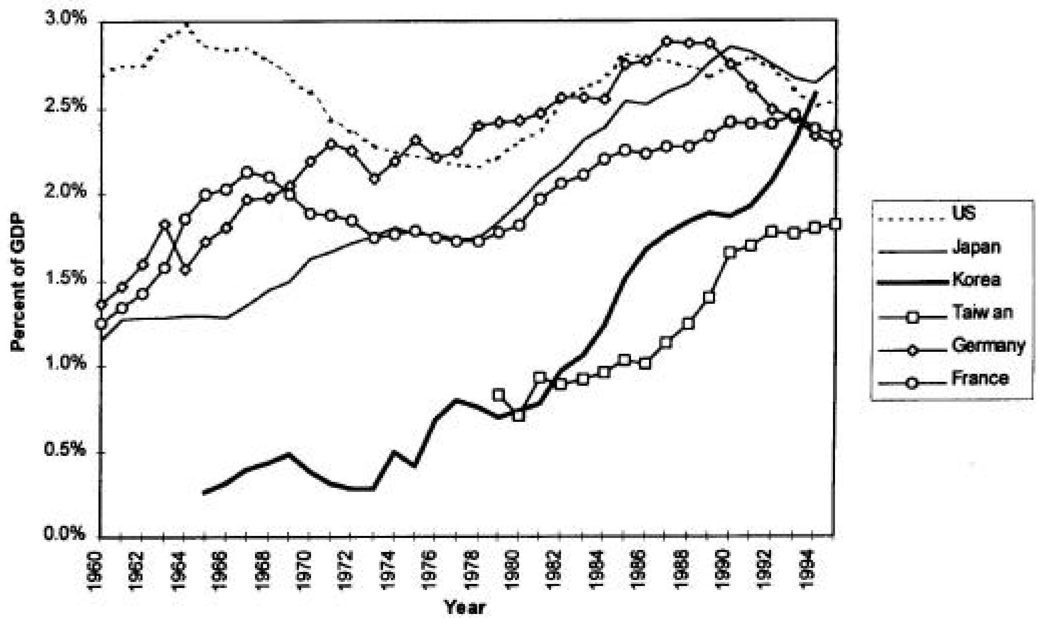

Figure 2. R&D Expenditures in 1980 US $ Million

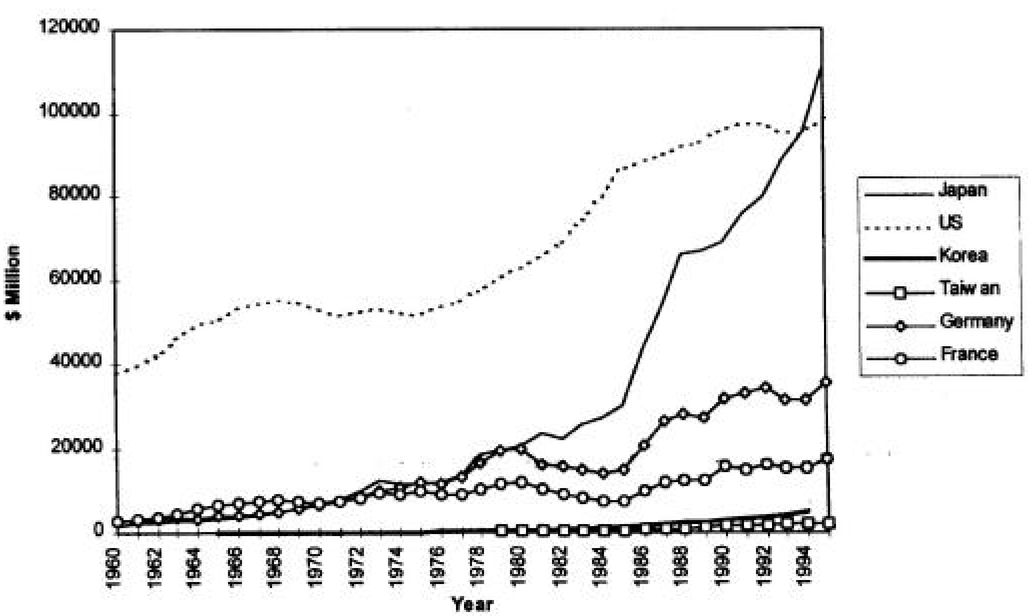

Figure 3. U.S. Patents Granted to Korea and Comparable Countries

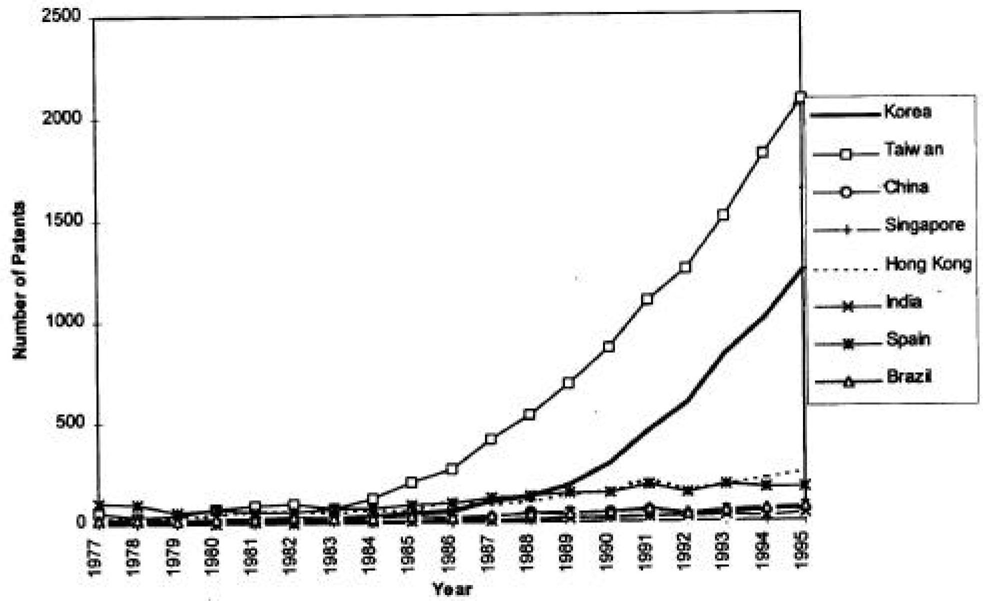

Figure 4. U.S. Patents Granted to Selected Countries

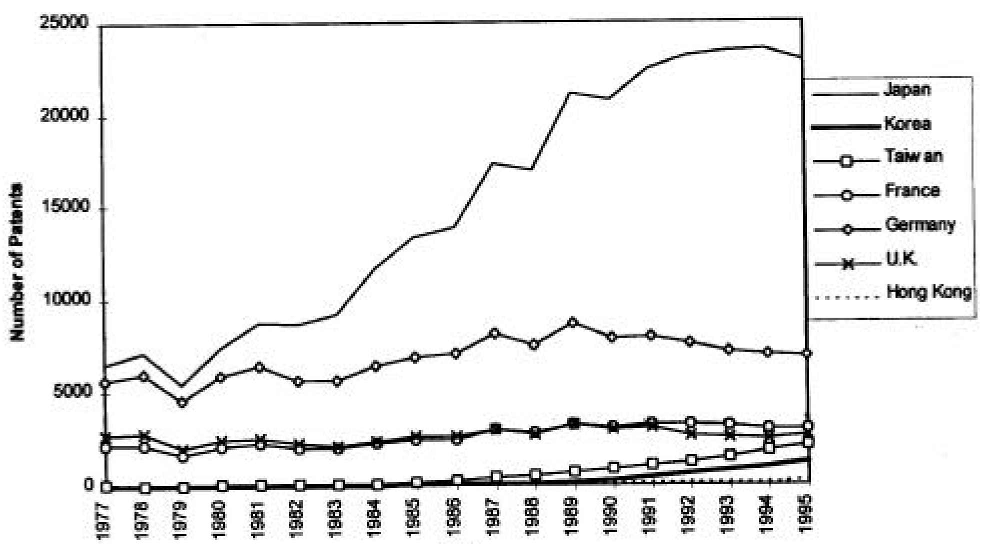

Figure 5. R&D Consortia Total Budget: Japan-Korea Comparison

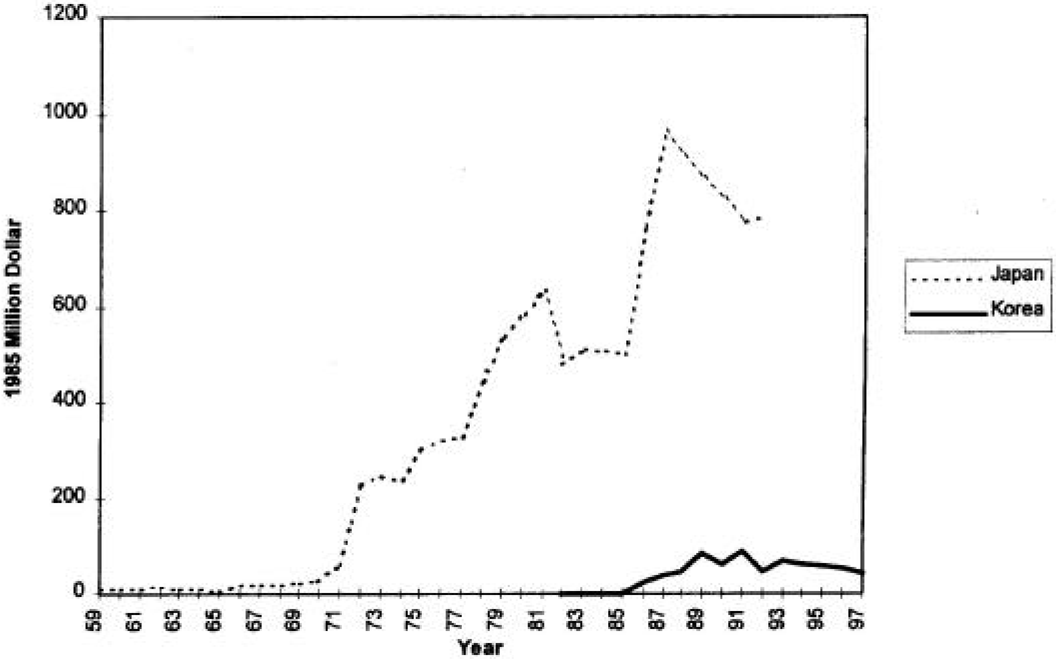

Figure 6. Japanese R&D Consortia Total Budget by Sector

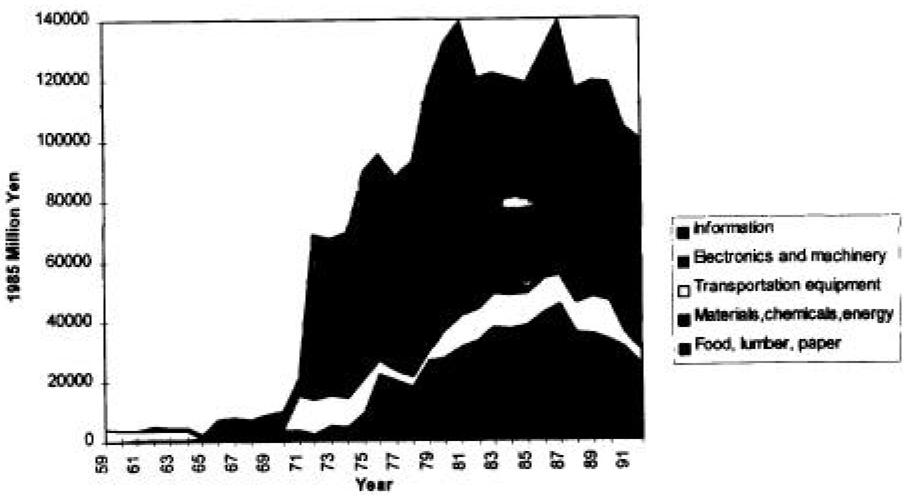

Figure 7. Korean R&D Consortia Total Budget by Sector

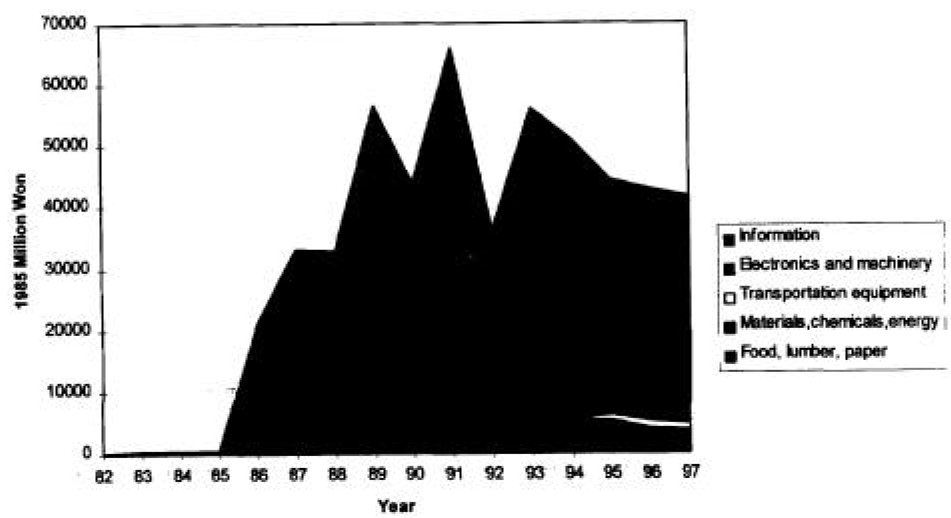

Table 1. Comparison of the Post-World War II Industrial Policies of Japan and Korea

		Japan	Korea	Lag
	<R&D Specific Policy>			
	Overall R&D promotion	Existed pre-war	1972-, expanded 1977, 1981 & 1986	32
	Licensing (approval) of foreign technology imports	1949-68	1969	20
	R&D subsidies	Existed pre-war, restarted 1949, expanded 1968	1967-	27
	Accelerated depreciation of R&D equipment	1952-	1972-	20
	Tax deductions on R&D expenditures	1966-	1981-	15
	Special deductions on foreign tech. Transactions	1956-	1976-	20
	Tax deduction for import technology use	1953-67	1978-	25
	Cooperative R&D	1959-	1982-	23
	Low interest loan for R&D	1951-	1976-	25
	<Import Policy>			
	Foreign exchange allocation for machinery imports	1949-63	1962-	13
G	Abolition of import restriction: color TV	1964	N/A	>35
G	Abolition of import restriction: automobile	1965	1986	21
G	Abolition of import restriction: integrated circuit	1974	N/A	>25
G	Abolition of import restriction: computer	1975	N/A	>24
	<Foreign Direct Investment>			
	Inward FDI restriction (in general)	1950-73	-1972	
G	FDI liberalization: automobile	1971	1978	7
G	FDI liberalization: integrated circuit	1973	1981	8
G	FDI liberalization: computer	1975	1981	6
G	FDI liberalization: information processing	1976	1982	6
	<Industrial Structure>			
	Entry restriction to machinery industry	Did not exist	1967-	
	Entry restriction to electronics industry	Did not exist	1969-	
	Automobile industry promotion	Existed pre-war, 1951-71	1962-	11
	Semiconductor industry promotion	1966-85	1975-	9
	Shipbuilding industry promotion	Existed pre-war, 1950-75	1967-	27
	Computer industry promotion	1957-85	1969-	12
	Steel industry promotion	1946-60	1970-	24
G	Introduction of the antitrust law	1947, strengthened 1977	1980	33
	<National Research Institutes>			
	Establishments of national research institutes	1882-	1966-	84
	<General Indicator>			
	Joined IMF	1952	1955	3
	Joined World Bank	1952	1955	3
	Joined GATT	1955	1958	3
G	Became IMF Article 8 country	1964	1988	24
G	Joined OECD	1964	1996	32

Source: Cho et.al. (1996), Komiya et.al. (1984), Tsusho Sangyo Seisakushi Hensan Iinkai ed. (1989), Patrick (1983), Kim(1993), Chang (1994), Kodama (1995), Fukagawa (1997), Yoshikai (1985).
"G" in the first column indicates a "graduation" from restrictive policies. The last column is the time lag between Japanese and Korean policies. Pre-war policies are assumed to have started in 1940.

Table 2. Comparison of Government-Sponsored R&D Consortia in Japan and Korea

	Column 1	Column 2	Column 3
Country	Japan	Korea	Japan
Period	1959 – 1992	1982 – 1997	1959 – 1969
Number of consortia	237	190	19
Number of participants	1181 firms	349 firms(1)	206 firms
Average total budget per project (in 1985 million dollar)	$60.7 million	$4.2 million	$19.8 million
Average number of participants per project	14.8	3.4(1)	12.3
Average number of projects per firm	3.0	1.8	1.1
Maximum number of projects per firm	75	16	5
Average duration	6.9 years	3.8 years	9.6 years
Average government contribution	66%	40%	44%

(1) Including universities and national research institutions.

Table 3. Examples of Cooperative R&D Projects in Japan and Korea

Japan 1992	Korea 1992	Japan in the 1960s and in the early 1970s
Atomic-level processing technology	Development of trolley wire	Mainframe computer (FONTAC project)
Real world computing	Development of LED printer head chip	Aluminum surface processing
Optic measurement equipment for organics	Development of stepping motor for FDD	Car emission/safety control system
Interpretation equipment for communications	Small-sized map information system	Safety technology for medical equipment
Image media communication equipment	Development of control motor for car	Direct steel-making by high temperature reducing gas