KOREAN TECHNOLOGY POLICY AT A CROSSROADS
THE CASE OF COMPUTERS

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Abstract

The government of South Korea began promoting the computer industry in the early 1980s as part of its strategy of shifting the Korean economy into technology-intensive industries. Korea's policy mix included a five-year ban on imports of personal computers, a government-industry R&D consortium to develop a Korean minicomputer, computerization of government agencies, and the building of computer networks to increase computer use and create demand for the domestic computer industry. These policies appeared successful as computer production, exports and use grew rapidly during the 1980s. However, the Korean computer industry has suffered a reversal of fortunes in the 1990s, with overall production and exports declining and the personal computer industry collapsing. This downturn contrasts with Korea's success in becoming a world leader in production of dynamic random access memory (DRAM) chips, one of the key components of the personal computer.

This paper analyzes the reasons that Korea has failed to develop a competitive computer industry while it has succeeded as a producer of consumer electronics and memory chips. It explains these successes and failures as a result of two key factors: (1) Korea's highly concentrated industry structure, dominated by a few vertically-integrated industrial groups, or chaebol, and; (2) government technology policy, which has successfully supported the chaebols' entry into commodity electronics markets, but failed to address Korea's fundamental shortcomings in computer production and use.

The government and industry face the challenge of reorienting their strategies in the face of rapid changes in the international computer market. The government is also struggling to develop new mechanisms for policy formulation and coordination as centralized, bureaucratic rule is replaced by more democratic decision making and competition, and conflict among government agencies.

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Introduction

South Korea (hereafter Korea) has emerged as a major producer of electronics products and now ranks sixth in the world in total electronics production. Korea's electronics companies started manufacturing consumer electronics products such as televisions and VCRs in the 1970s, then expanded their production during the 1980s to include semiconductors, telecommunications equipment and computer hardware. In perhaps its most striking success, Korea is now challenging Japanese supremacy in production of dynamic random access memory (DRAM) chips, with Samsung becoming the world's number one producer of DRAMs.

As part of its strategy to upgrade and diversify the electronics industry, the Korean government targeted the computer industry, employing a combination of import protection, export promotion, support for research and development, and financial subsidies to producers. Thus, competing in computers became a major industrial strategy for both business and government. Korea's computer industry grew rapidly in the 1980s, when PC demand grew rapidly and leading brand name producers maintained high profit margins, creating openings for low-cost makers of IBM clones. However, the global computer market changed in the early 1990s, as leading producers launched price wars and product generations became steadily shorter. Success in the PC industry can no longer be achieved simply by copying existing products and manufacturing them more cheaply. Instead, companies must respond rapidly to market conditions with flexible engineering and production capabilities.

Korea's computer industry has had serious problems in this environment. Its companies have been slow to respond to market conditions and have failed to develop strong capabilities in software, systems integration and circuit design. Korean PC makers saw their profit margins squeezed by price competition from brand name computer companies and by their dependence

on imported technology and components. By 1992, it was estimated that Korea's five largest PC companies were all losing money in the computer industry. Korea's position is even weaker in the fast-growing software and services industries. As users, Korean companies have been slow to adopt computers as a tool to improve productivity and competitiveness.

At the heart of Korea's problems are two issues. One is Korea's industry structure. The Korean economy is dominated by a handful of industry groups, or chaebol, which control virtually every manufacturing sector. These vertically integrated giants have been very successful in industries which involve mass production of commodity products, but they have been much less successful in the computer industry, with its demand for flexibility and innovation.

The second issue is that government policy has been ineffective in promoting computer production and use. Korea's computer policies in the 1980s focused on computer production, with little attention paid to software or computer use. The policy mix included a ban on imports, R&D consortia to develop a Korean minicomputer, and development of government networks to create demand for Korean computers. Since the late 1980s, the government has adopted a new rhetoric emphasizing market liberalization, development of generic technological capabilities and development of a national information infrastructure (NII). However, some policies touted as generic technology initiatives are actually closely tied to specific industrial sectors and even specific companies. Even the NII project has an underlying theme of creating demand for Korea's telecommunication equipment producers.

Development of computer industry policy has been plagued by competition among government agencies, leading to duplication of efforts and lack of policy coordination. The issues of production, use, R&D and communications infrastructure have fallen under the jurisdiction of different ministries and agencies. There is still little cooperation between the ministries involved in computer policy, but the emergence of NII as the central policy focus has moved the newly reorganized Ministry of Information and Communications to the forefront of information policy.

Industry Structure

Korea has one of the most concentrated economic structures in the world. The leading companies such as Hyundai, Samsung, Lucky-Goldstar and Daewoo are big, even by international standards. The chaebol consist of many large and small companies in widely disparate industries linked by cross-ownership and coordinated management structures.

The large chaebol that dominate the electronics industry are also the leaders in computer hardware production. The five leading PC producers are Hyundai, Trigem, Samsung, Daewoo and LG Electronics (formerly Lucky Goldstar). Four of the five are members of Korea's largest chaebol. The fifth, Trigem, is part of a mini-chaebol called the Anam group and has an equity relationship with Japan's Seiko Epson. In addition, there are a large number of small companies that assemble PCs for the domestic market, but they have very limited technological capabilities.

The chaebol have impressive strengths as well as serious weaknesses. Their ability to make large investments has enabled them to achieve economies of scale and bring down manufacturing costs to compete in commodity products where production costs are critical. Evidence of this success is found in Korea's electronics industry, which ranked sixth in the world as of 1993, with total production of US$27.2 billion (Elsevier, 1994). Korea has become a leading producer of dynamic random access memory (DRAM) chips, with Samsung ranking first in the world in production. Korean companies are also major producers of consumer electronics such as televisions, microwaves and VCRs.

However, the chaebol structure has been more of a liability in the computer industry, where product generations are measured in months and Taiwanese competitors can take an engineering concept from drawing to volume production in a few months. The chaebol are geared to mass production, not to producing small quantities of products for niche markets, and their decision making process is often slow and cumbersome. The chaebol are also not known for having strong market intelligence capabilities and can be slow to respond to changing demand.

The chaebol lack technological capabilities in many areas and still rely on Japanese and American suppliers of critical components and manufacturing equipment. Yet rather than concentrate on developing these capabilities, they have continued to diversify further into new industries. The logic of the chaebol has been to compete for domestic market share in virtually every industry sector. The export market becomes an extension of this battle, as well as an outlet for excess capacity created by heavy investment in domestic production.

The presence of a large electronics industry could be an advantage for Korea's computer industry, by providing a supporting infrastructure of components suppliers, services and complementary skills. The computer industry has benefited from the chaebols' strength in television production, which has helped Korea become a leading producer of computer monitors. The industry could likewise benefit from access to domestic DRAM production, given the global shortages of DRAMs that have prevailed in recent years. However, Korea lacks capabilities in circuit board design, and most of Korea's DRAM production is exported and ends up on computer motherboards made in Taiwan or the U.S. Even with a tariff in place on imported motherboards in the late 1980s, Korean companies were unable to compete with the Taiwanese companies who dominate that market.

The fact that Korea's computer industry is mostly embedded within the electronics divisions of the large chaebol also seems to result in a lack of urgency about competing in computers. The executives of the chaebol regard computers as a small piece of the electronics industry, and do not seem to be panicked about their declining fortunes in the personal computer industry. Samsung has responded by buying a 40% share of the U.S. PC maker AST Research, suggesting that it feels it can maintain a presence in PCs through acquisition rather than developing its own capabilities. This may make sense from a corporate perspective, but is not likely to enhance Korea's national competitive position in the computer industry.

Related to the power of the chaebol is the absence of a dynamic small business sector which could compete with the chaebol in the domestic market and provide a source of innovation and diversification for the economy. There have been numerous government programs to boost

Korea's small and medium-sized enterprises (SMEs), but the economic structure continues to grow more concentrated. The growth of SMEs is hampered by the market power of the chaebol who have access to cheaper capital and control of distribution channels. Also, some SMEs claim that they have developed innovative products, only to have the chaebol import and distribute a competing foreign product. The weakness of SMEs is especially troublesome in the computer industry, where small companies have played an important role worldwide, responding quickly to market opportunities and producing innovative products for niche markets.

SMEs in Korea are generally locked into the production network of one chaebol and lack the ability to innovate and improve their competitiveness. This contrasts with Japan, where many SMEs are part of a keiretsu business group, but sell outside that group to both domestic and foreign customers. Equipment and component suppliers in Japan often have strong technological capabilities in their own right. This is not the case with most affiliates of the Korean chaebol. In addition, Japan's electronics industry has seen the growth of several independent companies, such as Sony, Canon, Kyocera and Nintendo, into market and technology leaders. There have been no equivalent successful independents in Korea's electronics industry.

The structure of the software industry is quite different from the hardware industry. There were 769 software companies as of August 1992, of which 674 had less than 100 employees. The software industry mostly adapts imported programs, and produces little original software. The independent software companies lack access to capital and technology. Most Korean banks do not understand the software industry, and are unwilling to lend to small companies without tangible assets. The chaebol themselves develop some custom software for their own use, but are not major producers of commercial software. They remain hardware oriented, competing on the basis of manufacturing prowess rather than innovation or "soft" skills.

Technology Policy

Technology policy in Korea today is regarded as the "new industrial policy." Rather than promote key industries as it has in the past, the government now places emphasis on promotion of strategic technologies. This approach is seen by government as more appropriate for a country nearing the level of an advanced industrial nation, which is not supposed to subsidize or protect specific industries. It is also more palatable to trade partners who themselves often cloak industrial policy in the terminology of technology policy.

In reality, Korea's technology policy seems to be less of a break with past industrial policy than the rhetoric would suggest. The technologies being targeted are often closely linked to a particular industrial sector. For instance, the Korean government is supporting research in DRAM production technologies, mainframe computers, minicomputers and workstations, in each case in cooperation with the four big electronics chaebol (Samsung, Goldstar, Hyundai and Daewoo). Such strategies are clearly tied to promoting specific products and companies in the electronics and computer industries.

The environment in which those efforts are taking place has changed considerably however. The political arena has been expanded by democratization and the big companies have been able to circumvent policies with which they disagree. Within the government itself, power is becoming less centralized, with agencies becoming more autonomous and battling for influence over technology policy. Computer and information policy falls within the domain of a number of government institutions (Figure 1).

[Insert Figure 1 here.]

The Ministry of Trade, Industry and Energy (MOTIE), formerly the Ministry of Trade and Industry (MTI), historically has been the key focal point for industrial and technology policy in Korea. MTI developed and implemented most of the policies for promotion of the electronics and information industries through the 1970s and 1980s. *The Ministry of Information and*

Communications (MIC), formerly the Ministry of Communications, competes with MOTIE over policy turf. With government policy shifting emphasis to developing Korea's national information infrastructure, MIC has taken the lead in information technology policies. *The Ministry of Science and Technology (MOST)* coordinates government R&D. The *National Computerization Agency (NCA)* was established in 1987 to develop the National Basic Information System (NBIS). Its primary focus has been the creation of the National Administrative Information System, a series of government computer networks. NCA is now the lead planning agency for NII policy.

The *National Computerization Board (NCB)* is an advisory board for the NBIS. The NCB is supposed to coordinate policy among ministries, but its authority is not honored by the ministries and it cannot force compliance with its decisions. The chair of the NCB is the Minister of Communications, which some claim makes it impossible for the board to act as an impartial coordinator of the various agencies involved.

Bureaucratic competition and the lack of a coordinating agency in government has led to a number of individual initiatives being developed without agreement on a coherent long-range vision of what role computer and information technologies should play in Korea's future. The following review of Korea's computer policies will show a steady emphasis on hardware production. Even policies aimed at promoting computer use have had a strong implicit goal of creating demand for domestically-produced equipment. This pattern has helped to reinforce the hardware orientation of the chaebol. Also, Korea's policies have failed to spur the development of an independent small business sector able to innovate and respond to opportunities in niche markets too small for the chaebol to serve.

Computer industry promotion

Korea's computer policies grew out of the government's efforts to promote the domestic electronics industry. Electronics promotion began in 1969, when the government enacted the Electronics Industry Promotion Law. The law created a development fund and established policies for technical development, training and the creation of an Electronics Industry Council.

The formulation and implementation of electronics policy was primarily carried out by the MTI throughout the 1970s and 1980s (Kohama and Urata, 1993).

During the 1970s, the government promoted consumer electronics production, but during the 1980s the focus shifted toward computers, peripherals, telecommunications equipment and semiconductors. Over time the policy goals changed from achieving export and production targets to increasing vertical integration and technological upgrading. Both targets are related to Korea's desire to reduce its dependence on Japan for advanced components and technology.

The government supported the electronics industries with tax incentives, low-cost loans, and subsidies. Income and corporate taxes are waived for electronics firms for a certain period after production is started. Also, R&D expenditures can be deducted as expenses from taxable income. Several funds have been established to provide low interest loans to the electronics industry and other high-technology industries. These are illustrated in Table 1.

[Insert Table 1 here.]

The first specific targeting of computers came in the 1982 Five-Year Plan which designated computers and semiconductors as strategic industries for technological upgrading and export production. The Term Notice of 1982 banned imports of personal computers, microcomputers and many peripherals. The ban was lifted in 1987 as part of a broader trade liberalization strategy. However, in 1988, the government raised duties on imported motherboards from 3% to 15-20% to try to protect Korean companies from Taiwanese competition. This decision raised the cost of motherboards for Korean PC makers, making them less competitive, and Korea still failed to compete with Taiwan, which controlled 80% of the world motherboard market by 1993.

As part of its efforts to develop a domestic computer industry, the government encouraged IBM to source components and peripherals for its personal computers in Korea. A special promotion fund was established by the Bank of Korea in 1984 to support technology development in the computer industry. Also, several R&D projects have been implemented to develop computer technologies in cooperation with the private sector. These include:

TICOM

In 1987, MOC and MOST established a project to develop a Korean minicomputer to be used in the National Administrative Information System and also to be sold in the commercial market. Four major Korean computer makers (Samsung, Goldstar, Daewoo, and Hyundai) cooperated with the government's Electronics and Telecommunications Research Institute (ETRI) in the development of TICOM 1 (a 10 MIPS machine) which was first commercialized in 1988. TICOM 1 was based on technology from the U.S. company Tolerant, which later went out of business. The group started working on the more powerful TICOM 2 (80 MIPS) in 1987 as well. By 1992, each of the four companies had produced a commercial version of TICOM 2. With the demise of Tolerant, the development group was forced to replace the Tolerant system with an architecture based on Intel 486 chips and AT&T's Unix operating system. In 1992, development began on TICOM 3, a multiprocessor 500 MIPS system, based on Intel's Pentium processor.

As of 1994, 503 TICOM systems had been sold. Of these, 65% were bought by government institutions (Table 2). Another 9.7 percent went to the state-owned telecommunications companies and 4.3% to financial sector firms, which are heavily regulated and must connect to government sponsored networks. All of these institutions may be required, or "encouraged," to purchase TICOMs by the government. Of the 96 purchased by private firms, most went to firms affiliated with the four chaebol who produce the TICOM. This suggests that very few TICOMs were purchased by independent companies on the basis of the quality of the product. So far there is very little evidence of the commercial viability of the TICOM, although some buyers who were originally hesitant to purchase the computer have reported being satisfied with its performance. 1

[Insert Table 2 here.]

The history of TICOM highlights the risks faced when choosing technologies for development. The choice of Tolerant technology made the TICOM 1 obsolete and required switching to a new processor and operating system, while continuing to support the existing

technology in the installed base. Of course this happens to companies as well as countries, but if government directs a number of producers as well as many users toward the wrong technology, the costs can be high. TICOM may yet catch on commercially, but the results so far show that promoting technology transfer and guaranteeing government sales are not enough to ensure success. It is also important to consider the needs of customers, particularly for software applications which provide the real value to users.

Massively parallel processing computers

In 1992, the U.S. computer company Unisys initiated discussions with MOTIE on a joint R&D program to develop mainframe technology. Unisys was willing to transfer mainframe technology to Korea in return for government support for a joint project. The government agreed to the idea, but decided to open the project to bids from other companies (Paik, interview, 1993).

After reviewing the technology, MOTIE decided to focus on massively parallel processing technology (MPP), which it sees as the future of large computers. MOTIE put the Research Institute of Advanced Computer Technology (RIACT) at Seoul National University in charge of coordinating the project and choosing foreign and domestic partners. RIACT chose AT&T GIS (formerly NCR) as the foreign partner, while Samsung and Hyundai were selected as domestic partners on the project.

The Korean partners plan to sell AT&T GIS's System 3600 computers in the Korean market, and later are expected to produce components for the system. AT&T GIS will be expected to transfer technology to the Korean companies so that they can begin to build components and, they hope, eventually complete systems. In return AT&T GIS will gain access to the Korean public sector market, in particular to provide MPP-based servers for a number of government-sponsored networks. 2

The wisdom of targeting mainframe computers is questionable when world demand for mainframes is in decline. The Korean mainframe market has been stagnant since reaching US$200 million in 1991, and is projected to decline in the future (confidential industry sources).

MPP is seen by many as a cost effective solution for coordinating large networks and managing huge databases. MPP is also a relatively new technology in which Korea feels it has the opportunity to compete with U.S. and Japanese hardware companies. Targeting MPP is a high-risk strategy, however, as Korea will find it difficult to match the R&D resources, as well as the market presence of the established players in the industry. The choice of AT&T GIS also looks questionable in the light of AT&T's decision to spin off its computer unit as a separate company. The new company is expected to focus on its traditional retail and banking markets, and MPP technology may not be a high priority in the future.

Multimedia workstation project

The government initiated a US$4 million project in 1992 to develop a multimedia workstation. The project was supported by MOC and MOST and carried out at ETRI, with participation by Goldstar, Daewoo, Samsung and Hyundai. A prototype, called the "Combi Workstation," was completed in 1993. It is based on the Pentium microprocessor and capable of moving picture display and two-way audio communication (*IT Asia*, December, 1993: 30).

The Korean government plans to continue to promote multimedia technology, announcing it will spend 50 billion won (about US$60 million) from 1994 to 1998 on multimedia technologies, with that amount to be matched by the private sector. One part of this plan is a continuation of the multimedia workstation project, coordinated by ETRI, with 12.3 billion won from MOC and MOST. The first stage, from 1994 to 1996, involves design and development of hardware systems, software and components for a multimedia workstation. The second stage, from 1997 to 1998 will involve development of high capacity multimedia hardware and virtual reality software.

Software promotion

Compared to hardware, the software industry in Korea is underdeveloped. However, in recent years, software has received more attention from policymakers. In 1993, the government completed a draft of a Basic Plan of National Strategy for Software Industry Promotion. MOST announced that it would invest heavily in the software industry with the goals of increasing

software production to 2% of GDP and to increase software exports from US$15 million to US$1 billion (*IT Asia*, December, 1993: 5). The Medium-Term Software Technology Project is slated to spend 10 billion won per year for five to ten years on database and network development and training in systems engineering skills. The government is also developing a software park in the city of Yong-In with commercial space, housing, schools and hospitals. The budget is 50 billion won, including 35 billion won from the Development Fund for Small and Medium-Sized Business.

In 1995, MIC announced that it would invest about US$1.84 billion by the year 2010 in order to foster the nation's software industry, with about US$125 million invested in the industry annually. The MIC will focus on collecting creative ideas on multimedia, games and PC applications. The plan also includes strengthening protection of intellectual property rights and establishing software research centers and public databases (N.H. Kim, 1995).

Promoting computer use

While the focus of computer policy has been on developing a domestic computer industry, the government has also promoted use through computerization of government agencies and the creation of data communications networks. Government computerization has been used to provide a market for domestic producers of computers, peripherals, telecommunications equipment and other electronics items. Favorable treatment for domestic companies in government procurement has become a source of trade friction, and Korea has been under pressure from the U.S. to open its public sector markets to foreign products. The government now must balance its desire to support domestic industry with the need to respond to its trading partners and avoid trade retaliation.

Network development

The most important element of Korea's government computerization plan has been the Plan for National Computerization, established in 1988 with the goal of building a National Basic Information System (NBIS). The NBIS was created to improve the efficiency and

productivity of government and the private sector and to provide benefits to the public through the development of computer networks. 3

The first stage of the NBIS, completed in 1991, focused on development of the National Administrative Information System (NAIS) and the Financial Information System. The government invested about 150 billion won (about US$200 million) on the NAIS, while the banks were estimated to have spent 500 billion won (about US$650 million) on the financial system. During the first stage, 160 mainframe computers were installed in government offices.

Korea has since entered a second stage of national computerization aimed at linking government networks together and creating broader networks which include private and public sector institutions. This stage has been slowed by budget constraints, however. In the first stage, US$200 million in funding was provided via presidential order, making it easy for agencies to fund computerization projects. The second stage has been forced to submit to the normal national budget system, requiring prior approval of all spending, which has slowed the implementation of this stage. The reduction in government support for computerization spending is due in part to the lack of easily quantifiable returns from earlier investment (Jeong, 1993).

The development of the NBIS has been explicitly aimed at promoting computer use in Korea. An implicit goal is the creation of demand for Korean computer products, particularly the TICOM minicomputer. The Korean computer industry lacks a large domestic market, and the creation of computer networks is one way of enlarging the domestic market.

Setting technical standards

Technical standards are necessary for any computer network to function. They permit computers to communicate with each other and prevent use of equipment or software which might damage the system. However, standards can also be used to favor certain vendors or put others at a disadvantage. Standard setting has become a contentious issue in international trade. For example, the choice of standards for high-definition television (HDTV) in the U.S. and Europe will give an initial advantage to the companies whose technology is chosen.

The Korean government has expressed its desire to set standards that are compatible with international standards, but is also promoting standards which are compatible with the TICOM system to encourage government agencies to use the Korean minicomputers. Any system used on the NAIS must be approved by the government. The government standard is based on Unix, an open standard, but foreign producers claim it is technically difficult to meet due to certain unique specifications. For instance, the basic input-output system (BIOS) control is located in a read-only memory (ROM) chip, rather than in the software. Meeting the Korean standard requires developing a new chip instead of just writing new software, making compliance more expensive. Also, the Korean language standard is different from at least one foreign company's existing Korean language system, and changing to the new standards would be costly. Finally, approval for connection requires that hardware receive the Korean Standard mark of approval from MOTIE, which does not accept certification from a company's home country as other countries do. 4

Infrastructure development

In addition to promoting computer production and use, the government has invested in Korea's information infrastructure, including skilled human resources, telecommunications networks, and research and development capabilities. Government policies throughout much of Asia focus on upgrading the information infrastructure, and two studies (Dedrick and Kraemer, 1995; Kraemer and Dedrick, 1994a) have found a strong correlation between the quality of information infrastructure and levels computer production and use at the national level. Korea has developed a strong basic infrastructure of skilled workers and basic telecommunications services, and its investments in R&D have increased rapidly. However, it still has weaknesses in areas such as post-graduate technical education and advanced telecommunications services. The government is now focusing its efforts on creating a national information infrastructure capable of supporting a more information-based economy.

Human resource development

One of Korea's greatest assets is its well educated, hardworking labor force which approaches the level of industrialized countries in basic education attainment. In development of scientists and engineers, Korea trails the U.S. and Japan, but leads the other East Asian newly industrialized countries (NICs) with 48.8 scientists and engineers per 10,000 workers (Table 3).

[Insert Table 3 here.]

Korea has about 296,000 software engineers, which is roughly comparable on per-capita terms to Japan and the U.S. However, the skill level of those workers is much lower, as Korea produces relatively few people with degrees in computer science and management information systems. Korea produced only 7,070 Masters and Ph.D.'s in science and engineering in 1990. Most Koreans who go on for graduate degrees do so overseas, where they often remain to work after graduation. The government has offered incentives for those workers to return to Korea, and some have done so. It also has begun to expand university graduate programs, but it will take time to develop high quality institutions and produce enough Ph.D.'s to teach graduate students and do good research.

R&D

Technology development in Korea in the 1960s and 1970s emphasized importing and adapting foreign technology through licensing and technical assistance agreements with foreign firms. As the chaebol gained knowledge and experience with imported technology, they began to move into the development of imitative products without foreign assistance. In the 1980s, Korean companies, supported by the government, began to develop full-fledged R&D capabilities and innovate on their own. The number of corporate R&D laboratories in Korea grew from 65 in 1981 to 455 in 1987 (Y. Kim, 1993).

R&D spending in Korea increased rapidly during the 1980s, growing from 0.6% of GDP in 1980 to 1.9% in 1990 (NSF, 1993). This puts Korea first among the four East Asian NICs both in absolute and relative (as share of GDP) terms (Table 4).

[Insert Table 4 here.]

The government requires commercial banks to designate a certain percentage of their loans to R&D investment. It also has directly invested 120 billion won in joint R&D projects with electronics manufacturers. The policy emphasis is now shifting away from general support of the industry toward targeting key technologies for development. One example is the Highly Advanced Nation (HAN) project, which identifies key technologies and outlines plans for upgrading Korea's capabilities in those technologies to reach the level of a developed country. The technologies include semiconductors, fiber optic cable, high-definition television (HDTV), new medicines, agricultural chemicals and new materials for information, electronics and energy. MOST announced plans in 1993 to invest US$1 billion in the core development of those technologies and to establish a Technological Enterprise Training Center in Taejon (USDOC, 1993).

In 1994, MOTIE announced that the government had designated five technologies for strategic investment: semiconductors, liquid crystal display, medium-sized aircraft, multi-purpose satellites and next-generation machine tools. According to MOTIE, the government will invest 60% of the total, and will ask industry to supply an additional 40% in each area (USDOC, 26 January, 1994). The government announced a US$10.3 billion plan to develop telecommunications equipment and semiconductor technology from 1994 to 2003. The plan emphasizes telephone switching equipment, data transmission equipment, radiowave technology and VLSI chip development (USDOC, 27 January, 1994).

An ongoing project is the development of Taedok Science Town, located adjacent to the city of Taejon. Since 1973 the government has spent US$3 billion on R&D facilities in Taedok, including laboratories for ETRI and other government research institutions (Kahaner, 1993).

Telecommunications

The quality of the telecommunications infrastructure is a critical factor in a country's ability to use computer technologies productively and to be a competitive producer of computer products and services. The major productivity gains from computerization come when

computers are linked together in networks to enable users to share information and work together. This requires an adequate telecommunications network capable of transmitting data at high speed.

Korea's telecommunications network has improved substantially in recent years as a large backlog of demand for telephone connection was eliminated. However, Korea still lags well behind the industrialized countries and some NICs in both basic and advanced communications capabilities (Table 5).

[Insert Table 5 here.]

Domestic and international telephone service is provided by Korea Telecom (KT), a public corporation controlled by the Ministry of Information and Communications (MIC). Data communications and international direct-dial service are provided by Dacom Corporation, and mobile communications by Korea Mobile Telecom Corporation (KMT), both state-owned enterprises. The government is in the process of privatizing all three companies. Dacom will be fully privatized, but the government will retain 33% ownership of KMT and 51% of Korea Telecom. The direction of future telecommunications policy is now becoming intertwined with the issue of national information infrastructure development.

National information infrastructure

In 1994, the Korean government followed the lead of Singapore, the U.S., Japan and others and began to develop plans for a national information infrastructure. Plans for Korea's NII are still evolving, but focus on upgrading the telecommunications network and on development of multimedia hardware and software.

The MIC announced plans in 1994 to establish a broadband digital network linking government, academic, research and business organizations (USDOC, 27 January, 1994). This network is being promoted to upgrade Korea's communications infrastructure and to create demand for Korean electronics products and advanced telecommunications equipment. The government plans to invest US$4.4 billion between 1994 and 2003 on the development of

telephone switching equipment, data transmission equipment and radiowave technology (USDOC, 1 March, 1994). 5

The MIC and NCA are still in the process of finalizing plans for Korea's NII. They are studying NII plans in the U.S., Singapore, Japan and elsewhere to better understand national issues. The government is also participating in international efforts to develop standards for regional and global information infrastructure.

Review and comments on computer policies

Table 6 details major computer industry initiatives of the Korean government over the past decade. The figure shows that computer use has received less attention in the past than computer production in Korea. An exception was the investment of US$200 million in the NAIS, which was aimed at promoting use but also at creating a market for Korean computers.

[Insert Table 6 here.]

Policies to promote hardware production are marked by a lack of cooperation and duplication of effort (as in the case of separate MPP projects) between MOTIE and MIC. There is also a lack of coordination of production policies with efforts to promote computer use, even though many computer use policies have the implicit goal of creating a domestic market for Korean computers. On a more positive note, there does appear to be a policy convergence on promotion of systems based on Intel processors and the Unix operating system. The adoption of consistent open standards across hardware platforms makes sense, given Korea's limited R&D resources and the need to develop products with appeal to international markets.

Korea's emphasis on hardware production has actually had negative effects on the development of software and services industries. Development of software and information services depends on close interaction with advanced users and benefits from a broad diffusion of hardware throughout the economy (Schware, 1992; Kraemer and Dedrick, 1994b). Applying an import ban to support the PC industry in the 1980s slowed the adoption of computers in Korea, limiting the domestic market for software and services. So far Korea has failed to develop a

cadre of knowledgeable, experienced users who can advance the application of computers in the economy and provide valuable feedback to the software and services industries.

The most important project related to computer use now is the NII, which should encourage investment in computers by improving the infrastructure for high-speed networking of computers. However, rather than taking the lead in developing networks, the government has been cutting funding for its own NAIS. Investment in telecommunications infrastructure is important, but a high-speed communications network will be of limited value without information content and services that will stimulate use of that infrastructure.

Korea's Computer Industry

Korea's computer industry experienced a dizzying boom and bust during the 1980s and early 1990s. Production and exports soared in the 1980s, as Korean companies moved into mass manufacturing of IBM PC clones. However, sales dropped dramatically after 1989, partly because of increased price competition in the U.S. market and also because Korean PCs had gained a reputation for poor quality and customers preferred to pay a few dollars extra for more reliable products. By 1992, even domestic sales of Korean PCs began to fall off, and imports began to gain a share of the market. While PC output dropped, production of peripherals continued to grow, as Korea maintained a strong position in monitors (Tables 7 and 8).

[Insert Tables 7 and 8 here.]

The fortunes of the Korean PC industry are illustrated graphically in Figure 2, which shows PC production and exports, as well as domestic sales of Korean PCs and all PCs.

[Insert Figure 2 here.]

The computers produced in Korea are virtually all personal computers. Domestic production of large and midrange computers was just US$39 million in 1991 and US$44 million in 1992 (EIAK, 1993). The TICOM minicomputer accounted for most of this total. The more successful peripherals industry consists mostly of monitors and printers (Table 9). Korea has not been able to challenge Taiwan and Singapore in components and peripherals such as disk drives, motherboards, keyboards, sound cards and scanners.

[Insert Table 9 here.]

While Korea's hardware industry has experienced ups and downs, the software and information services industries have never taken off at all. Hardware accounts for about 85% of the computer industry, with software and services accounting for the remaining 15% (Table 10).

[Insert Table 10 here.]

Software industry revenues totaled just US$240 million in 1992, and even that figure overstates the value of the industry, since it includes resale of imported software. In 1991, the industry total of US$320 million included just US$132 million of domestically developed products, including US$25.8 million in packaged software (Table 11). Exports of software were just US$15 million (Y. Kim, 1993). The computer service industry, valued at US$500 million in 1992, consists mostly of custom programming and maintenance, with few companies involved in consulting, education or network services.

[Insert Table 11 here.]

The underdevelopment of the software industry can be attributed to several factors. One is the emphasis placed on hardware production by both the government and the chaebol. A second is the lack of the financial resources and technological capacity on the part of Korea's smaller software houses. The third is the lack of intellectual property rights protection. Illegally copied software accounts for over 78% of the packaged software market in Korea (Business Software Alliance, 1994). Domestic producers must compete with pirated programs from abroad and contend with having their own product pirated. After a two year dispute with the United States, Korea changed its laws protecting software in October 1993. Previously, the largest fine for illegal copying of software was about US$375, an amount that hardly discouraged piracy. The new law raised the top fine to US$37,500.

A final obstacle for Korea's software industry is language. There is a huge market for software in English, and large potential in widely used languages such as Chinese, French and Spanish. Korean language software, by contrast, can only be sold in the relatively small Korean market. Developing a product for export requires conversion to other languages. This is not a

big problem for large software houses, but is expensive for small companies. In addition there are the usual problems of establishing distribution channels, gathering market intelligence and providing support to users. These problems have combined to keep Korea's software exports small, and will be difficult to overcome in the future.

Computer use

Korea lags far behind the developed countries in installed computing capacity (Table 12) and in computer investment. Despite rapid growth in spending on computers from 1983 to 1992, Korea was still well behind Japan and Singapore in computer investment as a percent of GDP in 1992 (Figure 3). It does rank slightly ahead of Hong Kong and Taiwan on those measures. Investment is weighted toward hardware, which accounts for about 70% of spending (Figure 4), but the figures for software are undoubtedly kept down by the prevalence of pirated software.

[Insert Table 12 and Figure 3 here.]

It is noteworthy that spending on computer hardware stagnated from 1983 to 1987, when imports of personal computers were banned, and then began to grow rapidly in 1988, when the ban was lifted (Figure 4). This suggests that protectionism applied to nurture the domestic PC industry had a detrimental effect on the diffusion of computer technology in Korea. Recent studies have shown a significant correlation between productivity growth and investment in computers at both the corporate and national levels (Brynjolffson and Hitt, 1993; Kraemer and Dedrick, 1994a). This points to the high economic costs of policies such as import restrictions which discourage investment in computer use.

[Insert Figure 4 here.]

The largest computer user in Korea is the public sector, which spent US$867 million on computers in 1992, followed closely by the manufacturing (US$829 million), finance (US$751 million) and distribution sectors (US$859 million). The home market remains small, at just US$176 million. The public sector experienced a surge in computer investment in 1990 (Figure 4) associated with the implementation of the NAIS. Building the NAIS required investment in mainframe computers to act as network servers, and in smaller computers (e.g., TICOM) and

PCs for users to connect to the networks. The financial sector saw a similar jump in computer investment, probably also related to the expansion of financial networks under the NBIS.

Korea has sophisticated computer users in some sectors, such as manufacturers using computer-aided design (CAD). The public sector is not considered an advanced user, with government agencies computerized in a piecemeal manner and the second stage of NAIS being held up for lack of funds. Computer use by the financial sector is increasing in scale and scope as banks are increasingly linked to the government's financial network.

Most Korean companies lack familiarity with computer use and are hesitant to adopt office automation. There are some who argue that the lack of Korean-language software inhibits computer use, while others say this is not a major problem (interviews with government and industry officials). The emphasis of government and corporate policy on production rather than use is evident in the still low level of computer use in much of the economy. Although the government has made a priority of developing an information society, much work remains to reach that goal.

Conclusions

Korea's experience illustrates fundamental differences between the computer industry and the other industries in which Korea has been most successful. Competing in computers is not primarily a matter of cheap labor, low-cost capital, or mass production capabilities. Instead, it involves responsiveness to market opportunities, close interaction with customers, timely access to technology and market information, and innovation in either technology or marketing. Attaining a dominant position generally involves control of a proprietary standard such as an operating system (Microsoft) or a microprocessor (Intel). There are few opportunities for such control, and so far they remain mostly in the hands of U.S. and Japanese companies. Other countries must look for a role in the global production chain, such as Taiwan and Singapore have done very successfully. The problems of the Korean computer industry in adapting to the international PC industry structure are related to Korea's industry structure and its government computer industry policies.

Industry structure

Korea's vertically integrated industry structure has been an asset in entering commodity electronics markets such as DRAMs, which require huge capital investments and strong manufacturing skills. This structure has been a liability in the computer industry, however, as it slows the decision-making process and reduces flexibility in responding to market changes. Computer makers must continuously upgrade their products and produce systems to meet fast-changing market demand. The chaebol are geared to large scale production for mass markets, not to flexible production for niche markets.

A dynamic small business sector could provide the flexibility and innovation needed for computer production, leaving the chaebol to concentrate on semiconductors, flat-panel displays and other high volume components. However, Korea's SMEs are generally locked into the production networks of one chaebol and lack the ability to innovate and improve their competitiveness. It is very difficult for an independent SME to raise capital or find markets for their products, since the chaebol also control the distribution systems in Korea. Rather than

complement the chaebol, the SMEs are largely subsumed into the chaebol structure or remain on the fringes of the economy.

The Korean computer industry is unlikely to prosper unless a significant change takes place in the industry structure. For now, the chaebol are trying to make up for their weaknesses through investment in foreign companies, such as Samsung's investment in AST Research. Such investments might provide access to international distribution networks and some technologies, but they alone will not make Korea a leader in computers. Korea's position in the computer industry will only improve if changes are made in the industry structure and if serious efforts are made to upgrade the technological capabilities of the Korean companies.

Technology policy

In the early 1990s, Korea thought it was close to succeeding as a computer producer and exporter, but found that more exports were only leading to more technology imports from Japan (Lee, interview, 1993). Korea's leaders have acknowledged the problems of the computer industry, but have not come up with any effective solutions. It may be that the computer industry is beyond the ability of the government to affect directly, given its position within the chaebol and the government's declining influence over the chaebol.

Government efforts to force the chaebol to concentrate on a few key industries have failed to receive more than a superficial response. Rather than reforming Korea's industry structure, government policy has actually reinforced the dominance of the chaebol. For example, projects such as TICOM, and the MPP and workstation projects have been carried out in cooperation with the chaebol, with little or no SME involvement. In addition, much of the money provided for SME development has gone to larger SMEs affiliated with the chaebol, rather than independent companies and startups.

Even as the government has tried to get the chaebol to concentrate on a few key industries, it has spread its own R&D efforts over a large number of technologies rather than concentrating on a few where success is most likely. Korea lacks the resources to compete across a wide range of technologies. In fact, Korea's total R&D expenditures for all technologies

are about equal to those of IBM alone. Some focusing of effort is needed if the country is going to develop its own capabilities and reduce its dependence on foreign technology. Yet government policy, seemingly, is to try to compete in every technology that shows up on a list of "critical technologies."

Underlying the problems in developing effective policy have been the political transition to democracy and bureaucratic power struggles in recent years. These conflicts have resulted in uncoordinated policy initiatives coming out of different agencies. Not only has there been little coordination between production and use policies, but there is even a lack of coordination of production policies (e.g., separate policies to promote MPP by MIC and MOTIE) and use policies (e.g., NII and NAIS).

The recent government reorganization has given MIC more clout, while MOTIE and MOST struggle to maintain influence. Still, MIC has limited influence over policies related to hardware technology, human resource development and government R&D. There remains a need for policy coordination among the various agencies.

Issues for the future

What, then, needs to be done for Korea to regain its momentum in computer production and to increase its use of computers? A number of issues need to be addressed:

1. *Promotion of computer use through continued investment in public and private networks and establishing links to international networks such as the Internet*. Continued funding of the NAIS and NBIS would help create demand for computers if users are able to access network services. Computer use also can be encouraged through programs to familiarize managers and workers with business applications.
2. *Stimulation of innovation in the software and services industries by providing support to independent software companies*. In particular, there needs to be some kind of venture capital system that can finance investments by small companies with little collateral, but good ideas. Domestic software and services companies should be given opportunities to participate in the development of networks, such as NAIS, in order to improve their skills

and provide revenue. Also, better protection of intellectual property rights is needed to reduce pirating of software. Finally, the software industry must be given space to grow outside the often stifling structure of the chaebol system. The chaebol themselves should recognize the value of strong independent software companies. Such companies could develop innovative applications that would create increased demand for the chaebols' hardware, particularly as they try to move into multimedia technologies.

3. *Promotion of alliances with multinational corporations to gain access to their technology and market channels*. The chaebol are large enough to negotiate from a position of strength on their own. However, the SMEs could benefit greatly from relationships with foreign multinationals by gaining access to technology and marketing channels. The government could help promote a dynamic SME sector by helping the SMEs find opportunities for strategic alliances.
4. *Improvement of the telecommunications infrastructure* by deregulation and investment in broadband, digital technology. Korea's NII plans are focused on making these investments, but regulatory reform that promotes competition would help improve services and lower prices for telecommunications services.
5. *Training of computer professionals*, which includes expansion of existing computer science and engineering departments and the creation of new technical institutes specializing in computer skills. Also, groups should be established within business schools which specialize in management information systems to teach managers about the application of computers to business problems and to conduct research on computer use in Korean organizations.

Developing specific policies will require extensive interaction among government, business, academics and other professionals in Korea. Developing an overall strategy for computer production and use will require strong leadership from the top levels of government. The government's ability to influence the private sector is waning as the chaebol grow larger and move more activities offshore. But, the government can still develop a coherent strategy that

includes improving its own use of computer technology, development of the NII, upgrading of R&D capabilities and training of human resources.

Endnotes

1. A 1994 survey of directors of computer services at 209 medium-sized Korean firms reveals some of TICOM's shortcomings (*The Electronics Journal*, February, 1994: 82-114). Of those companies, 81% said they were not using TICOM and had no plans to do so. Ten percent said they were not using it, but planned to do so in the future, and just 6.7% said they were using it now. When asked why they were not using TICOM, 30% of the non-users said the operating system was unstable, 26% said that application software was lacking and 14% said TICOM lacked networking capabilities. These weaknesses in software and networking reflect the more general problems of the Korean IT industry which focuses on hardware, and places insufficient emphasis on software and information services.

2. In the meantime, MIC does not want to be left out of MPP technology, and is developing its own project as well. It is planning to spend 58 billion won by 1997 on smaller (US$10,000 to 500,000) parallel processing machines compatible with the TICOM system.

3. The NBIS consists of five major networks:

    a. The National Administrative Information System (NAIS) involves the computerization of government agencies. The NAIS consists of six independent systems, including the residential information system, vehicle information system, house and land information system, employment information system, customs clearance information system and the economic statistics information system (Jeong, 1993).
    b. The Financial Information System is composed of banks, securities companies, insurance companies and other financial institutions. The Financial Information System is expected to improve the services provided by the financial sector and enhance its international competitiveness (Phang and Park, 1993).
    c. The Education and Research Information System provides computers for primary schools, computerizes educational administrations and is developing a network of universities and research institutions. This network has been slow in developing due to tight budgets at the Ministry of Education.
    d. The National Defense System is part of the NBIS but is run separately by the military.
    e. The National Security Information System is also part of the NBIS, but is likewise, run separately by police and intelligence agencies.

4. It should be noted that the foreign companies interviewed for this paper had different perspectives on the difficulties presented by the Korean government's standards. One found that they presented serious problems and feared the situation would get worse. Another complained about the process, but felt that Korea was about average compared to other countries in terms of the difficulties it presented to foreign vendors.

5. An agreement was signed between the U.S. company Qualcomm and ETRI to develop handsets and groundstations for a mobile telephone network. The new network will use

Qualcomm's code-division multiple-access (CDMA) technology, considered superior to the incompatible time-division multiple-access (TDMA) which is the standard in Europe. The development of CDMA is an attempt to leapfrog ahead of foreign (especially Japanese) competitors in a leading-edge technology. Like the MPP projects, it illustrates Korea's desire to achieve technological leadership and reduce its dependence on Japan, but it also illustrates the risks involved for companies and countries at the cutting edge of technology. If CDMA fails internationally Korea may find that it has wasted time and resources. On the other hand, if CDMA becomes more broadly accepted as an international standard, Korea could reap large benefits from its early investment in the technology. Qualcomm's recent successes in lining up licensees in the U.S. market suggests that the gamble may pay off for Korea.

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Table 1. High-Technology Industry Promotion Funds

Fund	Purpose	Instruments	Expenditures
National Investment Fund	Purchase of domestically produced materials by electronics industry	10 year loans at 10 to 11.5% a year	50 billion won, (US$62.5 million) from 1984 to 1988
Electronic Industry Promotion Fund	Development of prototypes	3 year loans at 6% a year	25.9 billion won (US$32.4 million) from 1982 to 1987
Industrial Technology Improvement Fund	Machinery, components and materials development	10 year loans at 5% a year	65 billion won (US$81.3 million) from 1986 to 1987

Adapted from Kohama and Urata, 1993

Table 2. TICOM Installations

User Organization	Number	Percentage
Central government	71	14.1
Local government	195	38.7
Public sector institutions	65	12.9
Telecommunications firms	49	9.7
Financial sector firms	22	4.3
Private firms	96	19.1
Exports	4	0.7
Total	503	100.0

Source: *The Electronics Journal*, May, 1994

Table 3. Human Resource Indicators for Selected Pacific Rim Nations

	# of Scientists and Engineers 1988	Scientists & engineers per 10,000 workers	Bachelors degrees in sci. & eng. 1990	Masters & Ph.D.'s in sci. & eng. 1990	Number of professional software engineers
U.S.A.	949,200 1,744,616		75.6	169,726	66,508
Japan	505,500 ('91)	74.9	106,508	36,549	850,000
Korea	70,500 ('90)	48.8	51,266	7,070	295,798
Taiwan	46,200 ('91)	27.1	15,483	4,011	121,800
Singapore	5,876	37.2	2,498	200	9,772
China	309,000 993,650		5.6	206,11520,787	

Sources: PECC, 1991; NSF, 1993; ROC, 1993; Jones 1993

Table 4. R&D Expenditures in Asia and Pacific Rim Countries

	R&D as % of GDP	Industry as % of total R&D
U.S.A.	2.67 ('91)	71.5
Japan	2.77 ('91)	76.7
Korea	**1.91 ('90)**	**74.0**
Taiwan	1.70 ('91)	53.6
Singapore	0.90 ('90)	54.2
China	0.70 ('90)	40.0*

* Includes national enterprises
Sources: PECC, 1991; ROC, 1993; NSF, 1993

Table 5. Telecommunications Indicators

	Access lines per 100 population, 1991	Cellular phones per 100 population, 1994
Australia	46.5	5.0
New Zealand	44.0	3.7
U.S.A.	55.3	n.a.
Japan	47.2	1.5
Hong Kong	47.7	4.9
Korea	38.2	1.0
Taiwan	45.5	2.8
Singapore	38.7	4.7

Sources: Davidson, Hubert and St. Croix, 1993; *Far Eastern Economic Review*, 1994: 47-48

Table 6. Korean Government Computer Projects

Project	Funding Agency/Implementing Agency	Expenditures
Production		
TICOM	MOC, MOST/ETRI	TICOM I & II: 33B won TICOM III: 30B won
Mainframe projects		
1. MOTIE	MOTIE/RIACT (SNU)	38B won
2. MOC	MOC/ETRI	58B won
Multimedia workstation	MOC, MOST/ETRI	3B won (US$4 million)
Software Technology Project	MOST	10B won per year, 5-10 years
Use		
NBIS/NAIS	MOC, KT, DACOM/NCA	Stage 1: 150B won (US$ 200B) Stage 2: Determined by annual budget allocation
Infrastructure		
NII	MIC, NCA/KT	37 trillion won (US$50B) over 20 years (planned)

Table 7. Production of PCs and Peripherals, 1982-1992 (US$ million)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
PCs		39	108	183	436	479	1010	1733	1328	1485	834
Peripherals	42	134	283	312	394	946	1288	1423	1831	2000	2796
Total	42	173	391	495	830	1425	2298	3156	3159	3485	3630
Growth (%)		311	126	27	68	72	61	37	0	10	4

Source: EIAK, 1993

Table 8. Exports of PCs and Peripherals, 1982-1992 (US$ million)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
PCs		19	66	148	395	353	807	971	632	719	332
Peripherals	37	73	248	322	448	794	1135	1294	1531	1750	2371
Total	37	92	314	470	843	1147	1942	2265	2163	2469	2703
Growth (%)		148	241	50	79	36	69	17	-5	14	9

Source: EIAK, 1993

Table 9. Computer Peripheral Production and Exports, Leading Products, 1992

	Production (US$ million)	Exports (US$ million)
Monitors	1681	1528
Printers	382	45
Disk Drives	110	29

Source: EIAK, 1993

Table 10. Korea's Computer Production, 1987-1992 (US$ million)

	1987	1988	1989	1990	1991	1992
Hardware	2200	3440	4540	4670	4960	4280
Software*	120	230	250	270	320	240
Information Services	40	90	260	540	700	500
Total	2360	3760	5050	5480	5980	5020

*Includes resale of imported software

Sources: Y. Kim, 1993; EIAK, 1992

Table 11. Korean Software Industry Revenues, US$ million

	1987	1988	1989	1990	1991
a. Dom. sales of developed products	97.6	138.9	119.0	95.6	91.5
b. Exports	0.0	24.4	42.7	21.5	25.8
c. Packaged software	0.0	0.0	0.0	0.0	15.0
d. Sales of imported software	14.3	44.9	75.0	99.1	137.9
e. Commission sales	6.9	13.0	4.3	37.3	35.0
f. Other	3.2	6.7	5.7	12.1	14.7
Total	121.9	227.9	246.8	265.6	319.8
Total sales of domestically developed software (a+b+c)	97.6	163.3	161.7	117.1	132.2

Source: Y. Kim, 1993

Table 12. Computer Use in Asia-Pacific Countries

	INVESTMENT		INSTALLED BASE	
Country	Investment in computers* as % of GDP, 1992	Average Annual Growth 1983-1992	# of computers per 1,000 people	MIPS** per 1,000 people
Japan	1.99	11.85	97	199
Singapore	1.42	17.01	125	241
Hong Kong	0.84	12.85	101	159
Korea	0.87	22.63	37	70
Taiwan	0.77	19.51	74	150
Malaysia	0.64	11.58	n.a.	n.a.
Philippines	0.24	11.23	4	10
Indonesia	0.23	16.82	2	3

* Hardware, software and services

** Millions of instructions per second, a measure of computing power

Sources: Confidential industry sources; Juliussen and Juliussen, 1994

Figure 1. Korea's Economic and Technology Policy Institutions

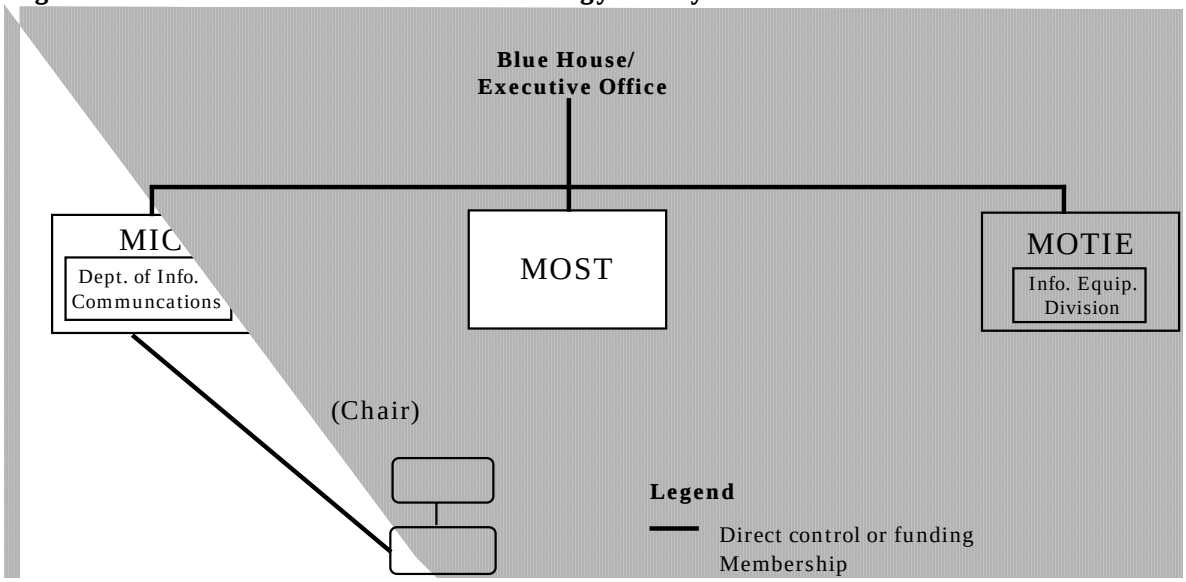

Figure 2. Personal Computer Production, Exports and Sales in Korea

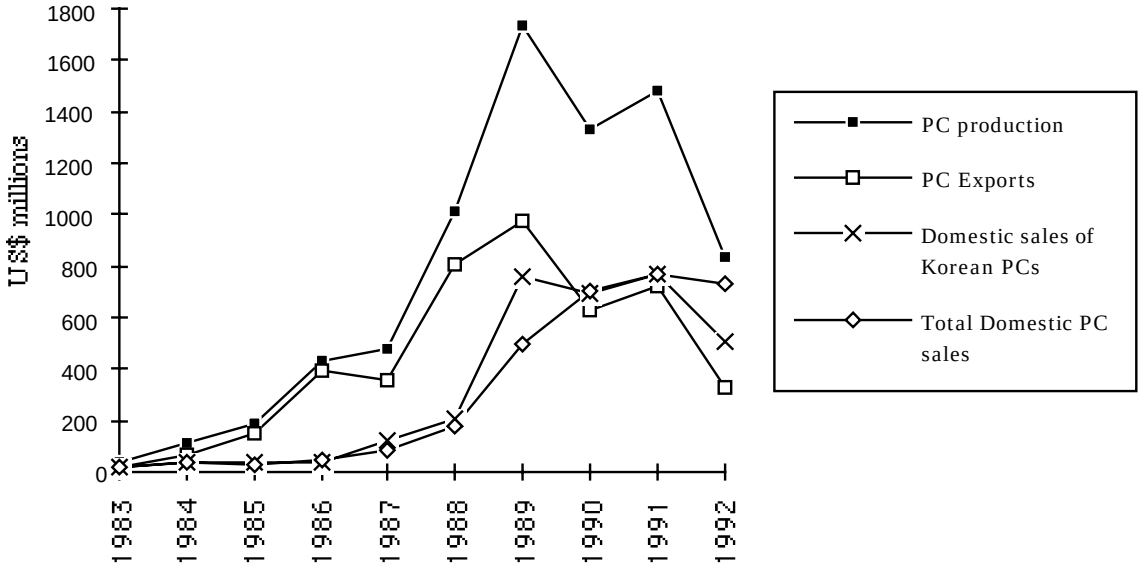

Figure 3. Investment in Hardware, Software and Services, 1983-1992

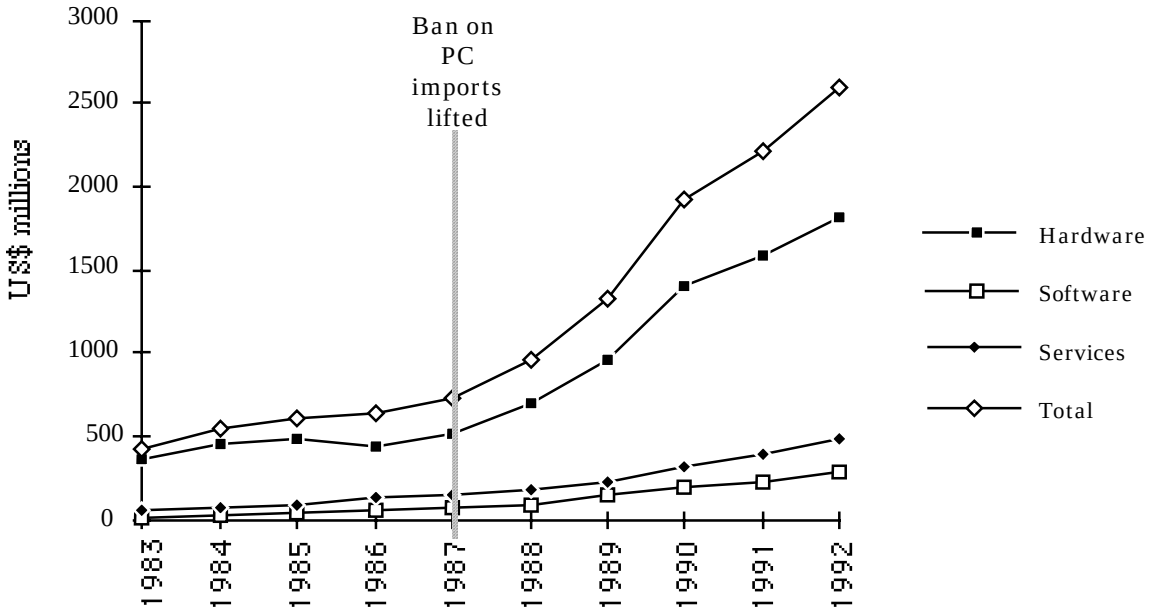

Figure 4. Korean Computer Spending by User Sector, 1983-1992