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Linsu Kim

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IMITATION TO INNOVATION

The Dynamics of Korea's Technological Learning

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CONTENTS

Switzerland, the United Kingdom, and the United States—and two semi-industrialized countries—Singapore and Korea—studied by Michael Porter.[32] These well-educated Koreans worked long and hard for Korea's success. The average Korean manufacturing worker, for instance, worked 53.8 hours each week in 1985 compared with 33.1 to 42.9 hours in OECD countries, including Japan, 44 to 48 hours in other Asian NICs, and 46 hours in Mexico.[33] Even in 1994, Koreans worked longest among these countries. How has Korea invested for human resource development? What made Koreans work so long and hard?

Fifth, Korea pursued an export-oriented industrialization strategy from the very beginning, when import substitution was still in its early stage. The Korean government made exports a life-or-death struggle in order to achieve economic growth goals. The government pushed and pulled firms with threats and promises. How has the export-oriented strategy affected Korean firms in technological learning?

Finally, the government and *chaebols* used crises as a major means of technological transformation. The government deliberately imposed a series of crises on firms by demanding that they achieve overly ambitious goals. Top management also constructed a series of crises as a strategic means to expedite technological learning. How have *chaebols* turned these crises into creative opportunities for expeditious learning? Why is crisis construction a useful means of technological transformation?

APPROACH AND ORGANIZATION OF THE BOOK

This book attempts to answer these questions and shed light on the dynamics of technological learning in transformation from imitation to innovation. Understanding the dynamic process of technological learning calls for a multilevel, multidisciplinary approach. It requires one to examine interactions among actors at the macro, meso, and micro levels.[34] It also requires one to analyze the process from several perspectives—technology, economics, management and organization, sociology, and cultural anthropology.

There are numerous books about Korea's economic development. Many authors have treated the subject from a macro perspective, focusing primarily on government and its macroeconomic performance.[35] Several have discussed Korean firms at the micro level, focusing mainly on their cultural, anthropological, managerial, or technological aspect, but few have looked at the interactions between

actors at different levels and from a multidisciplinary perspective.[36] One exception is Alice Amsden's work on Korea's late industrialization, which analyzes the role of the state and its interaction with big businesses primarily from a macro perspective. But Amsden also examines the process of imitative learning of two selected industries at the micro level.[37]

In contrast, the primary focus of this book is the dynamic process of technological learning at the microeconomic level—the firm as the unit of analysis—examining how firms learn and unlearn in response to changes in market and technology. It is the firm that brings about product and process changes in order to survive and grow in the competitive market, and that in turn enhances international competitiveness of the economy. This book also examines the dynamic workings from macro and meso perspectives in attempts to understand the mechanism of technological learning at the firm level holistically.

Part I examines the state role and sociocultural factors under which Korean firms have accumulated technological capability. Chapter 2 discusses industrial and technological policies that to a great extent shape the external environment of firms. Chapter 3 examines the educational system and sociocultural factors that mold the characteristics of well-educated, hardworking Koreans.

Part II analyzes industry cases, depicting the transformation from imitation to innovation. Chapter 4 provides several analytical frameworks to help readers deepen their understanding of industry case studies. Chapter 5 discusses the automobile industry, an interesting case that illustrates most vividly how crisis construction facilitates technological learning. Chapter 6 examines the electronics industry, which has made significant strides from reverse engineering to strategic alliances. Chapter 7 treats the growth of the semiconductor industry, which has leapfrogged into the world's frontier in memory chips. Chapter 8 presents the case of small and medium-size firms, showing two contrasting patterns.

In Part III, Chapter 9 draws conclusions on Korea's technological learning. Chapter 10 outlines the implications of Korea's technological learning for public policymaking and corporate management and addresses implications for other catching-up countries as well as technology suppliers in advanced countries.

located knowledge or products which would meet the market needs, and activities that would infuse these two elements into a new project. Reverse engineering also involved purposive search of relevant information, effective interactions among technical members within a project team and with marketing and production departments within the firm, effective interactions with other organizations such as suppliers, customers, local R&D institutes, and universities, and trial and error in developing a satisfactory result. Skills and activities required in these processes are in fact the same in innovation process in R&D.

The above discussions lead to two questions: How did Korea acquire the technological capability to undertake duplicative imitations—reverse engineering—in the 1960s and 1970s? How has Korea accumulated enough capability to conduct creative imitations and innovations in the 1980s and 1990s? Part II of this book answers these questions.

DRIVING FORCES

In the evolution from duplicative imitation to creative imitation and innovation, the configuration of Korea's production and exports has changed significantly. In the mid-1960s, Korea began exporting textiles, apparel, toys, wigs, plywood, and other labor-intensive mature products. Ten years later, ships, steel, consumer electronics, and construction services challenged established suppliers from industrially advanced countries. By the mid-1980s, computers, semiconductor memory chips, videocassette recorders, electronic switching systems, automobiles, industrial plants, and other technology-intensive products were added to the list of Korea's major export items, with the semiconductor chip topping the list in terms of export value. In the mid-1990s, Korea is working on such next-generation products as multimedia technology, high-density television, personal communication systems, and a new type of nuclear breeder. By 1994 Korea ranked second in the world in shipbuilding and consumer electronics, third in semiconductor memory chips, fifth in textiles, chemical fibers, petrochemicals, and electronics, and sixth in automobiles and iron and steel.[30]

What are the driving forces underlying the dynamic process from imitation to innovation in Korea? There appear to be several conspicuous major characteristics, some idiosyncratic to the country: the Korean War, which transformed Korean society; strong government, which directed industrial development; large conglomerates—*chaebols*, the Korean version of the Japanese family enterprise *zaibatsu*—which served as engines; hardworking Koreans who empowered these engines; an export-oriented strategy, which imposed competitive pressure on Korean firms; and crisis construction as a major means of expeditious technological learning.

First, the 1950–1953 Korean War set the Korean economy twenty years back but made a major impact on Korean society, drastically transforming a rigid class society into a flexible, classless society. What was the impact of the war on the formation of Korean mental attitude and organizational life? How did the war impact technological learning in subsequent decades?

Second, one of the most conspicuous characteristics of the industrialization of Korea is the strong government and its orchestrating role. The government held the wheel and supplied the fuel, while private firms, particularly chaebols, functioned as the engines. This prompts several questions: What made it possible for the government to become so strong in Korea? What made Korean technocrats so smart as to make their intervention relatively effective amid widespread and generally inefficient state intervention in most of the Third World? How has Korean government learned relatively effectively from Japanese experience? What policy mechanisms has the government used in facilitating technological learning in industry?

Third, behind the remarkable industrial growth are big businesses, which have emerged as powerful engines in the past decades. Korea's four chaebols—Samsung, Daewoo, Ssangyong, and Sunkyong—were on *Fortune* magazine's list of the world's 100 largest industrial corporations in 1992. Hyundai and LG, formerly Lucky-Goldstar, two of the three largest *chaebols* in Korea, coyly resisted revealing their group revenues, but if they did, they would probably rank just above or below Samsung. That is, Korea's six largest chaebols all rank among the top 100 global industrial enterprises.[31] How has the government helped chaebols form and prosper? What role have the *chaebols* played in acquiring technological capability for labor-intensive industries in the 1960s and 1970s and for technology-intensive industries and the globalization of Korean businesses in the 1980s and 1990s?

Fourth, these *chaebols* employ well-trained, hardworking Koreans who have empowered the Korean engines. Deprived of natural resources, Korea finds its greatest resource in its human resources. Commitment to education by Korea was the strongest among the eight industrialized nations—Denmark, Germany, Italy, Japan, Sweden, as much understanding of the technological elements and the nature of their combination as possible and fill in remaining gaps by independent efforts.[26] Or the imitator must rely substantially on technical assistance in various forms from the forerunner. For this reason, it requires considerable internal capability to identify the nature and source of relevant technology, to negotiate its transfer or reverse-engineer, and to assimilate so as to be able to apply it to the specific market needs and material availabilities facing the firm. Duplicative imitation conveys no sustainable competitive advantage to the imitator technologically, but it supports competitive edge in price if the imitator's wage cost is significantly lower than the imitatee's.

For this reason, when it is legal, duplicative imitation is an astute strategy in the early industrialization of low-wage, catching-up countries, as such technology is generally mature and readily available and duplicative imitation of mature technology is relatively easy to undertake.

Second, design copies, creative adaptations, technological leapfrogging, and adaptation to another industry are creative imitations. Design copies mimic the style of the market leader but carry their own brand name and unique engineering specifications. Japanese luxury cars, for instance, emulate German models but possess their own engineering features. Creative adaptations are innovative in the sense that creative improvements are inspired by existing products. Technological leapfrogging depicts a late entrant's advantage in getting access to newer technology in the wake of more accurate understanding of a growing market, enabling the imitator to leapfrog the innovator. Adaptation to another industry illustrates the application of innovations in one industry for use in another.

Creative imitations aim at generating facsimile products but with new performance features. They involve not only such activities as benchmarking and strategic alliances but also notable learning through substantial investment in R&D activities in order to create imitative products, the performance of which may be significantly better or production cost considerably lower than the original. Michele Bolton argues that Japanese strategy represents these features and calls it reflective imitation.[27]

Korea's 1960s and 1970s strategy was largely associated with duplicative imitations, producing on a large scale knockoffs or clones of mature foreign products, imitative goods with their own or original equipment manufacturers' brand names at significantly lower prices.

Korea's 1980s and 1990s industrialization increasingly involves creative imitations.

TO INNOVATION

Imitation alone is insufficient for Korea to realize its dream of becoming a highly industrialized country. Both creative Japanese-style imitation and American-style innovation are required not only to catch up in existing industries but also to challenge advanced countries in new industries.

Innovation is defined as a pioneering activity, rooted primarily in a firm's internal competencies, to develop and introduce a new product to the market. Distinction between innovation and creative imitation is, however, blurred. Joseph Schumpeter distinguished the two by saying that innovation involves commercialization of invention, which is the purely physical set of creation and discovery, while imitation refers to the diffusion of innovation.[28] Most innovations do not, however, involve breakthrough inventions but are deeply rooted in existing ideas. As Nelson and Winter note, imitators working with an extremely sparse set of clues might claim the title of innovator, since most of the problem is really solved independently.[29]

As the first firm to establish itself in its market, an innovator benefits from first-mover advantages that are unavailable to imitators. They include, among other things, image and reputation, brand loyalty, an opportunity to pick the best market, technological leadership, an opportunity to set product standards, access to distribution, experience effects, and an opportunity to establish an entry barrier of patents and switching costs.

Several industries in Korea, such as semiconductors, electronics, and biotechnology, are stretching their R&D activities to transform themselves into innovators as well as effectively creative imitators. Korea's 1990s innovation drive in selective industries is marked by intensified in-house R&D activities and participation in global alliances and reflects Korea's aspiration to become a member of the industrially advanced community.

Many skills and activities required in reverse engineering have easily been transformed into activities called R&D, as Korea approached the technological frontier. Reverse engineering involved activities that sensed the potential needs in a market, activities that by the Japanese. After the Japanese withdrew in 1945, these institutions were taken over by Koreans, but the volume of banking activity declined drastically. According to a study that described the 1950 financial system, there were no money or capital markets in the accepted sense of the term and no adequate facilities for mobilizing savings. The use of checks was highly underdeveloped and the bulk of the country's monetary transactions was carried out in cash. A large fraction of the aggregate turnover of goods and services did not even involve the use of money, but took the form of payments in kind and barter transactions.[20]

Modern education, first introduced to Korea by American missionaries, was expanded by the Japanese colonial government. The Japanese, however, limited Koreans mainly to the primary grades simply to convert Korean youth into loyal subjects and to train them for subordinate roles in agriculture and industry. Some Koreans were able to go beyond these limits, but they were few. At the end of Japanese rule, only 2 percent of the Korean population older than fourteen had completed secondary school, and the illiteracy rate stood at 78 percent.

The emergence of the United States as the guardian of the free world against communist aggression after World War II led to the Asian version of the Marshall Plan, providing economic and military aid to Korea at the front line of that global struggle. The United States pumped almost $6 billion to Korea through the 1960s. U.S. economic aid financed more than 80 percent of Korea's capital formation and import surplus until the mid-1960s. U.S. military aid built Korea's military machines, providing disciplined training to every male in Korea, leading to the formation of many bureaucrats and managers for both the public and the private sectors.[21] The U.S. military presence also provided opportunities for some Korean firms to learn Western technologies by engaging, for instance, in small construction projects.

In short, the vacuum and chaos caused by the fall of Japanese colonial rule, arbitrary division of the nation into North Korea and South Korea, and the ensuing civil war, all of which occurred between 1945 and 1953, flattened Korea as "a nation with little left of its past and facing a bleak future."[22] In spite of U.S. aid, which brought Korea back to its prewar economic level, Korea still suffered from almost all the problems facing most resource-poor, low-income countries today. Korea, beginning with a far lower technical base than and as the poorest of the newly industrializing countries (NICs),[23] has achieved phenomenal industrial development in a generation.

FROM IMITATION . . .

Such rapid industrialization in Korea stemmed largely from imitation, which does not necessarily imply illegal counterfeits or clones of foreign goods; it can also be legal, involving neither patent infringement nor pirating proprietary know-how. A study shows that 60 percent of patented innovations were imitated legally within four years of their introduction.[24] Imitation ranges from illegal duplicates of popular products to truly innovative products that are merely inspired by a pioneering brand. Steven Schnaars categorizes several distinct imitations: counterfeits or product pirates, knockoffs or clones, design copies, creative adaptations, technological leapfrogging, and adaptation to another industry.[25]

First, counterfeits and knockoffs are duplicative imitations, but one is illegal and the other legal. Counterfeits are copies that resemble the same premium brand name as the original but of low quality, illegally robbing the innovator of due profits, for example, a Rolex watch sold at a fraction of its regular price. In contrast, most knockoffs or clones are legal products in their own right, closely copying the pioneering products in the absence or expiration of patents, copyrights, and trademarks but marketed with their own brand names at far lower prices. IBM PC clones are good examples. Clones often surpass the original in quality.

Duplicative imitation does not require specialized investment in R&D and information channels. Only a low level of learning is necessary since the firms cannot and are not required to generate new knowledge. Nevertheless, duplicative imitation can rarely occur in a vacuum. Unlike replication within the same firm, in duplicating another firm's products or processes, target routine is not substantially available as a template. Therefore, it is not possible to resolve all the problems arising in the imitation by closer scrutiny of the prototype's production system. At one extreme, the production in question may be a novel combination of highly standardized technological elements. In this case, reverse engineering may result in the identification of those elements and the nature of their combination, leading to an economically successful imitation. At the other extreme, the target routine may involve so much idiosyncratic and firm-specific knowledge that imitation is highly problematic, requiring substantial help by means of formal technology transfer from the originator.

In the wide range of intermediate cases, the imitator has to obtain

2 Government as a Learning Facilitator

"Here comes the Korean," once heralded *Newsweek* in its cover story on Korea's economic miracle and Korea's stampede into the international market. Many economists attribute Korea's success to the Korean government's developmental role,[1] concluding that the economic miracle stemmed from a policy miracle.[2] The government envisioned a miracle and provided a policy environment, but it was industry that made it reality.

The role of the government in industrialization is so complex and multifaceted that it cannot be adequately covered in a single chapter. Therefore, this chapter limits its discussions only to those facets directly or indirectly related to technological learning in Korea at the microeconomic level. Other writers have covered the government's developmental role in Korea more extensively, though mostly at the macroeconomic level.[3]

What can the government do to facilitate technological learning at individual firms under a dynamically changing global technology environment? Over the years, the Korean government has adopted an array of policy instruments designed to facilitate technological learning in industry and in turn strengthen the international competitiveness of the economy. This history can be better understood by analyzing it from three perspectives: market mechanism, technology flow, and time.

Market mechanism perspective includes both the demand side of technology development that creates market needs for technological change and the supply side of technology development that strengthens technological capability. The former is often referred to as industrial policy in a narrow sense of the term, while the latter can be thought of as science and technology (S&T) policy.

In other words, this perspective organizes policies related to technological development into three major components: policies designed to strengthen the demand side, creating market needs for technology, policies designed to strengthen the supply side, increasing S&T capabilities, and policies designed to provide effective linkages between the demand and supply sides, attempting to ensure that innovation activities are both technically and commercially successful.[4]

Unless there is a competitive market in which firms believe that innovation in products and processes is necessary to sustaining and raising market competitiveness, there is little investment in innovation activities, as innovation is usually uncertain and risky. Also, strong links to the market are needed to make sure public R&D efforts are effective and efficient. In this sense, science and technology policies should be an integral part of the overall industrial policies that shape market structure and industrial development.

However, even though the market calls for the introduction of new products and processes, countries without indigenous technological capabilities cannot be expected to grow industrially. Some economies have indigenous technological capabilities but still don't grow. To be commercially exploited, technological capabilities must be coupled with the right business capabilities.

Finally, despite the presence of both demand for innovation and supply of capabilities, few innovations can be realized unless there is good management of the R&D system, effectively linking demand with supply. The absence of this linkage explains why in some industrialized countries there is little innovation despite a strong demand for it and an adequate supply of technical capabilities. Some linkage instruments such as institutions to bridge the demand and supply sides of technology and tax and financial incentives for R&D efforts in developing countries are not effective in stimulating technological activities in the absence of demand and supply of technology.

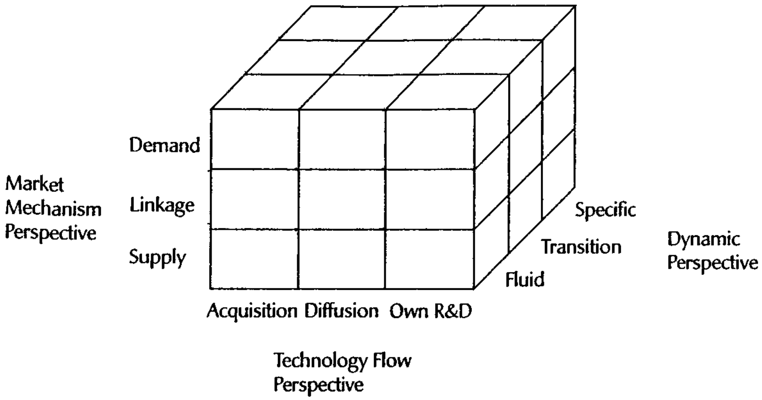
Government policies related to technology development may also be assessed by the technology flow perspective. This perspective is mainly concerned with three key sequences in the flow of technology from abroad to catching-up countries: transfer of foreign technology, diffusion of imported technology, and indigenous R&D to assimilate and improve imported technology and to generate its own technology. The first sequence involves technology transfer from abroad through such formal mechanisms as foreign direct investment, the purchase of turnkey plants and machinery, foreign licenses, and technical services. Such transfer can facilitate the acquisition of technological capability in catching-up countries.

The effective diffusion of imported technology within an industry and across industries is a second sequence in upgrading technological capability of an economy. If a technology is transferred to a firm and its use is limited only to its original importer, it may give the firm monopoly power over other firms for a period of time; however, the broader economic effect of the technology may be considerably limited. To maximize its benefits, imported technology has to be diffused throughout its economy.

The third sequence involves local efforts to assimilate, adapt, and improve imported technology and eventually to develop one's own technology. These efforts are crucial to augmenting technology transfer and expediting the acquisition of technological capability. Technology may be transferred to a firm from abroad or through local diffusion, but the ability to use it effectively cannot. This ability can only be acquired through indigenous technological effort. Local endeavors can include self-directed attempts to copy or reverse-engineer foreign products and processes, those aimed at improving and adapting previously acquired technology, and one's own research and development. Such efforts become increasingly important as industrialization progresses. These activities are necessary to strengthen international competitiveness in the face of increasing pressure from other catching-up countries.

The two perspectives outlined here, market mechanisms and technology flow, may be combined as illustrated in Figure 2-1. The dynamic perspective dimension is added as the third dimension to indicate time, which is very important. The relative impact of the individual sequences of technology flow and the impact of different types of market mechanisms—demand, supply, and linkage—change as an industry advances through different stages of development over time

Figure 2-1 An Integrative Framework



(see Chapter 4 for detailed discussions). This integrative framework is used below to analyze and evaluate Korea's industrial and S&T policies.

GENERAL BACKGROUND

One of the most conspicuous characteristics of the industrialization of Korea is the strong government and its orchestrating role. The government steered the wheel and supplied fuel. It set ambitious goals and directed the private sector with sticks and carrots, and private firms, particularly *chaebols*, functioned as engines. What then made it possible for the government to become so strong in Korea? What made Korean technocrats smart enough to make their intervention relatively effective amid widespread and generally inefficient government intervention in most of the Third World? How has Korean government learned relatively effectively from Japanese experience?

First, when Park Chung Hee seized power in 1961, he was single-minded in his goal to industrialize Korea and transform its subsistent agricultural economy into an industrialized one in spite of the odds against it. Toward this end, he created a highly centralized, strong government to plan and implement ambitious economic development programs. The government was vested with power to license important business projects to private firms and set the direction of industrialization. Commercial banks were nationalized to allocate resources for industrial projects according to national priority. To push industrialization at the fastest possible speed, Park borrowed heavily from abroad rather than waiting patiently for domestic savings to be formed. This mechanism of channelling low-cost foreign finance to private firms further strengthened his centralized power. Then, with a small group of competent economists to advise him, he made all important decisions himself.[5] As a former army general, he was literally a field commanding general of Korea's industrialization drive.

Another important government means to consolidate its power over the private sector was in the handling of illicit wealth accumulation charges. The Park regime arrested thirteen leaders of large business conglomerates charging that they had engaged in illicit and illegal behavior in accumulating wealth during the corrupt Rhee years, 1948–1960, demonstrating that the government was in a powerful position to prosecute them. The government soon released most of the accused businessmen who promised to comply with the government in undertaking some of the major industrial projects, laying a ground rule of government dominance over the private sector during the Park regime through the 1970s.

Second, the centralized decision making by the president was relatively effective and efficient, compared with other developing countries, owing to competent technocrats who formulated and implemented development programs. Cultural values plus a selection process enabled the Korean government to staff its ministries in charge of industrialization programs with the most talented and best-educated young people. Confucian tradition, which imbued respect for scholars over farmers, craftsmen, and merchants and the civil service over all others, attracted well-educated young people to public service despite its low wages.[6] Except for political appointments at the cabinet level, examinations are used in selecting and in many cases promoting civil servants. Together with merit-based personnel evaluation, the system produced "meritocratic elites."[7] Successfully passing the highly competitive examination for the middle-level civil service is one of the most prestigious achievements for a young man in Korea. Such prestige enabled the government to recruit the cream of the leading universities.

Third, Korea had the broadest base from which to learn the Japanese experience effectively. Both Korea and Taiwan had been occupied by the Japanese, but Taiwanese leaders came from the mainland after 1949. In contrast, Korean political leaders and technocrats in the 1960s and 1970s not only mastered the Japanese language but also acquired a significant understanding of Japan's culture and social system during the 1910–1945 Japanese occupation of Korea. President Park, for example, was one of a few who had been trained at the Japanese Military Academy. Many of his advisers and technocrats had also been educated in Japan or in Korea by Japanese during the occupation, studying the Japanese experience in detail. Even in 1990, 250,000 South Korean high school students were learning the Japanese language, accounting for about 70 percent of all non-Japanese high school students around the world studying Japanese.[8] A survey showed that the number of persons studying Japanese outside Japan had more than tripled in ten years to 1.62 million in 1993, and Koreans account for more than half of them.[9]

Although Alice Amsden concludes that on average American-trained Korean economists tend to accept the Anglo-Saxon model as the best solution to Korea,[10] no nation could profit more from an understanding of Japanese industrial success than Korea, given the geographical and cultural proximity and historical relations.[11]

Given the background, what policy mechanisms has the government used in facilitating technological learning in industry? How has the government role evolved in response to the rapidly changing economic environment?

INDUSTRIAL POLICY: DEMAND SIDE OF TECHNOLOGY

Korea's "developmental state" was at the wheel of its industrialization drive, at least through the 1970s.[12] In its efforts to create conditions for industrial growth and to ensure the transition from one stage to the next, the government used a complex web of direct and indirect policy instruments to define growth targets and discipline businesses to reach them. These instruments have largely been employed toward the following objectives: (1) the deliberate promotion of big business as an engine of technological learning, achieved through a systematic and comprehensive array of subsidies and incentives, (2) ambitious export-oriented industrialization, achieved by pushing the private sector into crises to reach imposed targets while providing incentives to make the crises creative rather than destructive, (3) the promotion of technologically advanced heavy and chemical industries, accomplished through even more critical crises, and (4) the repression of labor to

maintain industrial peace, providing a conducive environment for learning.

Big Business

To overcome the disadvantage of a small domestic market and to exploit the stable nature of mature technologies on which initial industrialization strategy was to be built, the Korean government intentionally created large firms, *chaebols*. These organizations were deemed necessary to marshal the scale economies inherent in mature technologies, which would be used to attack government-designated strategic industries, producing export growth to fuel an advancing economy. A *chaebol* is a business group consisting of varied corporate enterprises engaged in diversified business areas and typically owned and managed by one or two interrelated family groups.[13]

The government helped the capital formation as well as the subsequent diversification of the *chaebols*. It sold Japanese colonial properties and state-owned enterprises to selected local entrepreneurs on favorable terms during the inflationary period, handing the local entrepreneurs windfalls. Owning all commercial banks in the early years, the government then provided these firms with scarce foreign currency and preferential financing at the official rates, both of which were only half the real market rate. The government also gave them large import-substitution projects and guaranteed the foreign loans. Foreign debt burdens resulting from currency devaluation were compensated with increased low-interest loans, further reducing the risks for these businesses.[14]

Their resulting huge growth enabled the *chaebols* to dominate Korea's industrial scene and stand out as world-class multinational corporations. Samsung, Daewoo, Ssangyong, and Sunkyong, as mentioned earlier, were among *Fortune* magazine's 100 largest industrial corporations in 1993. Including the two *chaebols*, Hyundai and LG, that did not reveal their group revenues all six rank in the top 100 global industrial enterprises.[15] Korea, sixth in the rank of firms included in the global 100, was preceded only by the United States, Japan, Germany, the United Kingdom, and France. This is especially noteworthy when Korea is compared with other Third World countries; only one state-owned petroleum corporation in each of Brazil, Venezuela, and Mexico made the list. Only Korea among these nations places private, nonpetroleum industrial corporations on it.[16] Six other *chaebols*, also among the global 500, have been powerhouses for Korea's industrialization.

The Korean government managed the *chaebols* relatively effectively compared with similar conditions in other catching-up countries. The government effectively disciplined the *chaebols* by penalizing poor performers and rewarding only good ones, a marked difference from big-business promotion efforts in other developing countries. Good performers were rewarded with further licenses to expand. The government rewarded entrants to risky enterprises with industrial licenses in more lucrative sectors, thus leading them to further diversification. In contrast, the government refused to bail out relatively large-scale, badly managed, bankrupt firms in otherwise healthy industries, appointing better managed *chaebols* to take them over.[17]

> President Park believed that even private projects in the First Economic Development Plan should be completed as scheduled so as not to make them turn into a burden to the government, because the government fully guaranteed the foreign loans. Personally, President Park checked and reviewed the development of all important projects, both public and private.[18]

In addition, *chaebols* that relied entirely on political collusion rather than on performance could not survive long, as they lost political support when power shifted from one hand to another. In contrast, better managed *chaebols* have endured and survived in a series of political power shifts.[19] As a result, only three of the ten largest *chaebols* in 1965—Samsung, LG, and Ssangyong—made the list in 1975. Similarly, seven of the ten largest in 1975 made the list in 1985. In fact, few of the original *chaebols* have survived. Most of them have evolved dynamically from small businesses in the midst of political turmoil, largely through rapid learning under effective strategic and organizational management.[20]

The *chaebols'* rapid growth and diversification have enormously affected industrial structure and market concentration in Korea. By 1977, 93 percent of all commodities and 62 percent of all shipments were produced under monopoly, duopoly, or oligopoly conditions in which the top three producers accounted for more than 60 percent of market share. The ten largest *chaebols* accounted for 48.1 percent of GNP in 1980, making Korean industry even more highly concentrated than that of Taiwan or Japan. Total factor productivity as well as output, however, grew faster in Korea's highly concentrated economy than in that of almost any other country.[21]

Chaebols played a crucial role in the rapid acquisition of technological capability in Korea. They were in the most advantageous position to attract the cream of the best universities. They had organizational and technical resources to identify, negotiate, and finance foreign technology transfer and assimilate and improve imported technologies. They also played a major role in drastically expanding and deepening R&D activities in Korea in the 1980s and 1990s. As a result, by the end of the 1970s, Korea had the largest textile plant, the largest plywood plant, the largest shipyard, the largest cement plant, and the largest heavy machinery plant in the world.

Export Promotion

The import-substitution policy played an important role in creating demand for foreign technology transfer.[22] Since there was no local capability to establish and operate production systems, local entrepreneurs had to rely completely on foreign sources for production processes, product specifications, production know-how, technical personnel, and components and parts. Studies in the electronics, machinery, steel, computer, and pharmaceutical industries demonstrate that import substitution under protection was one of the most powerful instruments that facilitated technology transfer from abroad, leading to the emergence of new industries and the introduction of more sophisticated products in existing industries.[23]

The export drive was a more important policy. The Korean government made exports a life-or-death struggle in order to achieve economic growth goals. The Korean government designated so-called strategic industries for import substitution and export promotion. Plywood, textiles, consumer electronics, and automobiles in the 1960s and steel, shipbuilding, construction services, and machinery in the 1970s are examples.

The strategic industries, which were created in violation of their static comparative advantage, had to suffer from high costs in addition to infant-industry growing pains. To help the industries overcome these problems, the government sheltered the domestic market from foreign competition. The average effective rate of protection was atypically high for the strategic industries. In some, protection was quickly lifted as firms accomplished a rapid rite of passage from infant to exporter. But in others, where technology was complex and marketing more elaborate, protection lasted relatively long, providing a lengthier period of incubation.[24] The United States benignly overlooked Korea's protected market well into the 1970s.

The government pushed firms with ambitious goals. It instituted the export-targeting system in the 1960s as a regular instrument to assess industrial success. Annual targets were assigned to major commodity groups, which were allocated to related industrial associations. They were also assigned by destinations, which were allocated to Korean embassies in respective countries. The Ministry of Trade and Industry maintained a situation room to monitor export performance. The data were then reported to the Monthly Trade Promotion Conference attended by the president of the nation, cabinet members, heads of major financial institutions, business association leaders, and representatives of major export firms. The conference served to solve many problems encountered by exporting firms through guidance and the president's final decisions.[25]

"Sticks" in the form of administrative guidance (a euphemism for Korean government orders) forced firms to reach its goals. If a firm did not respond as expected to particular goals, programs, or incentives, its tax returns were subject to careful examination or its application for bank credit was studiously ignored, or its outstanding bank loans were not renewed. Government agencies often showed no hesitation in resorting to command backed by compulsion. It usually did not take long for a Korean firm to learn that it would be better to get along by going along.[26] In other words, the role of the government was much stronger in Korea than in Japan and Taiwan, especially during the 1960s and 1970s. And it worked.

The government also cajoled firms with incentives, borrowing heavily from abroad and channeling the funds into export-oriented investments at below-market interest rates. Firms were granted unrestricted and tariff-free access to imported intermediate inputs and automatic access to bank loans for working capital for all export activities, even when the domestic money supply was being tightened. These firms also had unrestricted access to foreign capital goods and were encouraged to integrate vertically in order to sustain international competitiveness. These incentives operated automatically and constituted the crux of the Korean system of export promotion. Furthermore, the rationing of longer-term bank loans was used as a carrot to draw firms to new paths of exporting, encouraging diversification, and to export more than ever. These incentives, offered to all exporting firms, were particularly effective when combined with the greater organizational, financial, and political leverage of the *chaebols*, which grew even larger.[27] Exporters also benefited from a variety of tariff exemptions, accelerated depreciation, exemptions from value-added taxes, and duty-free imports of raw materials and spare parts. Tax holidays and reduced rates on public utilities further boosted corporate profitability. Assignment of lucrative import licenses was linked to export performance.[28]

With the government's sticks and carrots, Korea's total exports increased from a mere $175 million, or 5.8 percent of GNP, in 1965 to $1,132 million, or 12 percent of GNP, by 1971. With an average annual growth rate of 36.5 percent, Korea rose from number 101 in the rank of exporters in 1962 to fourteenth by 1986.[29]

How has the import-substitution and export-promotion policy affected technological learning in industry? While it created new business opportunities, it also created crises for firms to invest heavily in technological learning to acquire foreign technologies and assimilate and improve them in order to survive in the highly competitive international market.

As a result, firms in export-oriented industries (EOI) learned significantly more rapidly and in turn grew faster than firms in import-substituting industries (ISI). Likewise, countries with export-oriented industrialization grew faster than those with import-substituting industrialization. The average annual economic growth rate for EOI countries was 9.5 and 7.7 percent, respectively, for 1963–1973 and 1973–1985 compared with 4.1 and 2.5 percent for ISI countries. The real per capita income growth rate was 6.9 and 5.9 percent for the same periods for the former as compared with 1.6 and −0.1 for the latter, as the ISI group had a higher population growth rate.

Heavy and Chemical Industry Promotion

By the late 1960s, Korean government policymakers recognized the necessity of gradually restructuring the economy from labor-intensive light industries to more technology-intensive heavy industries. They understood the importance of developing the technological capability to do so, as Korea's competitive advantage in light industries was shifting to second tier catching-up countries, such as Thailand, Malaysia, China, and Indonesia.

A major change in international political conditions, however, prompted the Korean government to invest for the heavy and chemical industry program ahead of schedule. Frustrated by its protracted war in Vietnam, the U.S. government announced the Nixon doctrine in 1969, signaling its decision not to commit its ground forces in Asian future conflicts, and the Nixon administration withdrew one of two

U.S. Army divisions from Korea in 1971. President Park became obsessed with acquiring a self-reliant national defense capability by developing heavy and chemical industries (HCIs) at a far greater intensity and in a far shorter time than previously envisioned. $12.7 billion was poured into HCIs, accounting for more than 75 percent of total manufacturing investment in 1973–1979.[30] Steel, shipbuilding, heavy machinery, petrochemical, industrial electronics, and nonferrous metal industries were created by the HCI promotion. As a result, it took only fifteen years for the ratio of value added in light industries over HCI to fall from 4 to 1 in Korea, whereas the same shift took twenty-five years in Japan and fifty years in the United States.[31]

This hasty creation of HCIs on a gigantic scale without adequate preparation in technological capability, more for military purposes than for economic rationality, resulted in a rapid rise in foreign debt from $2.2 billion in 1970 to $27.1 billion in 1980.[32] It also bred misallocation of resources, rapid inflation, wage increases far in excess of productivity gains, and further concentration of economic powers in several *chaebols* involved in HCIs.

The most significant effect of the hasty HCI promotion, however, was a major crisis in technological learning. Lacking capability, the *chaebols* had to rely almost entirely on foreign sources for technology. Tasks required to assimilate imported technology were so far beyond the capability available at these firms that the HCI program imposed a major crisis in setting up and starting up plants, let alone mastering them. Firms were forced to assimilate technology very rapidly and upgrade capacity utilization by expediting learning in order to survive. Later chapters present more detailed discussions of how firms in these industries expedited their technological learning to turn the crisis into an opportunity.

Industrial Peace

"Economy is a tender flower. It does not flourish in the soil of war or social unrest," said Paul Samuelson.[33] Likewise, the multinational firm as a buyer, supplier, and investor considers industrial peace, among other things, one of the most important factors in developing and expanding businesses with firms in catching-up countries.

In attempting to create a conducive environment, in which government's development goals could be achieved without interruptions, the Korean government, as the central orchestrator for economic development and exports, also emerged as the responsible agency to control labor movements and maintain industrial peace. The government's leading role in repressing labor was a consistent policy through the late 1980s. Although the formal ban on unions had been lifted in the early 1960s, the legal framework in which unions could function was so restrictive that it virtually eliminated the possibility of organizing any genuine independent unions.[34] Furthermore, the government used the Korean Central Intelligence Agency (CIA) to spy on and repress labor as part of a broader economic strategy through the 1970s.[35] As a result, workers became exceedingly docile. For example, between 1979 and 1984, average lost workdays per 100 workers per year was only half a day in Korea compared with two in Japan and fifty in the United States.[36] A drastic shift toward political democratization in the late 1980s, however, triggered the explosion of labor unrest, which is discussed in Chapter 3.

Many intellectuals, in Korea and abroad, criticized the dreadful negative side of many of the government's practices to suppress labor movements, but it at least provided Korean firms with uninterrupted opportunities to learn cumulatively and discontinuously, making undoubtedly significant contributions to rapid industrialization. Such a repressive policy retarded the growth of trade unions and workers taking part in industrial democracy. Scandinavian and German experiences show that industrial democracy supports and encourages innovation.

In short, the government had been at the core of Korea's industrialization in the 1960s and 1970s. Some say that the government played the role of chairman in Korea, Inc., while *chaebols* functioned as its production units.[37] The government role included not only policy formulation but also the techniques of policy implementation, using an array of direct and indirect incentives and sanctions to harness the private sector in achieving rapid technological learning and, in turn, high growth.

Shift of Economic Environment and Public Policy

The economic environment for Korea, however, changed significantly in the 1980s, for several reasons. First, the world economy generally slowed down in the 1980s, particularly affecting outward-looking economies like Korea. Second, in the wake of rising trade imbalance, North America and Europe moved toward protectionist policies, making it increasingly difficult for Korea to sustain export growth in industries that led its export-oriented strategy in the past. Third, Korea lost its competitiveness in low-wage-based labor-intensive industries, as its real wage rose at an average annual growth rate of 5.8 percent in the

1960s and 7.5 percent in the 1970s. Concomitantly, other developing countries with much lower wage rates were rapidly catching up with Korea in these industries. Fourth, advanced countries, particularly Japan, were increasingly reluctant to transfer technology to Korea as it attempted to enter industries that they dominated. Fifth, Korea was forced to change its copyright and patent laws, preempting the imitative reverse-engineering of foreign products.

In the face of an increasingly unfavorable environment in the 1980s and 1990s, the Korean government set out on a major policy shift. It attempted to reduce government intervention and introduce market mechanisms and to undertake structural change toward the development of more technology-based industries. The policy shift included, among other things, antitrust legislation, trade liberalization, financial liberalization, promotion of small and medium-size enterprises, foreign investment liberalization, and shifting emphasis on innovation-related activities.

Antitrust and Fair Trade

The *chaebols'* increasing economic power gave rise to monopolistic abuses such as creating scarcities, price gouging, and predatory behavior in the domestic market. In response, the government shifted its policy on *chaebols* from promotion in the 1960s and 1970s to the regulation of their growth in the 1980s by adopting a policy of economic democratization. The Fair Trade Act of 1980, along the lines of American antitrust legislation, included, among other things, the prohibition of unfair cartel practices and mutual investment among the *chaebols'* affiliated companies, a ceiling on investment by and credit to large *chaebols*, and restrictions on their vertical and horizontal integration. The government also directed the thirty largest *chaebols* to restructure their sprawling businesses around three or fewer core sectors.

However, the *chaebols* continued to grow, with economic concentration increasing further until the mid-1980s and declining slightly thereafter; the number of affiliated companies of the ten largest chaebols increased from 77 in 1974 to 667 including 365 abroad in 1994,[38] and the combined sales of the five largest *chaebols* as a percentage of GNP increased from 12.8 percent in 1975 to 52.4 percent in 1984 and decreased slightly to 46.5 in 1993.[39] The number of *chaebols* designated by the government as dominating their respective markets increased from 105 in 1981 to 216 in 1985, but only ten were accused of having

abused their economic power. Of 1,172 applications for vertical and horizontal integration, only two were rejected by the government.

Why? Although the antitrust policy made a small dent in the mid-1980s, the economic power of *chaebols* and their collusion with political power were so strong that the government could not implement some announced policy programs, showing a significant gap between what it intended to do and what it actually could do. In addition, the government bailed out insolvent enterprises to mitigate their impact on downstream sectors, not to tarnish the credibility of *chaebols* in the international market. As a result, some of them, anticipating a government rescue, expanded well beyond their evident financial capability and some postponed adjustments to market changes. In many cases, the government was under pressure to accept economic reality rather than fulfill economic justice.

Then, facing accelerating globalization in the 1990s, the government once again shifted its policy on *chaebols* from regulation to liberalization by revising the Antitrust and Fair Trade Act. Restrictions on the credit controls of the thirty largest *chaebols* were lifted, provided that their firms reduced internal ownership to less than 20 percent, raised capital-to-assets ratio above 20 percent, and offered more than 69 percent of its shares to the public. Such a liberalization policy was designed to enable *chaebols* to compete freely in the expanding global market. Although those firms' ownership and management structures have changed significantly in the past decade,[40] the new policy is expected to make significant progress in the separation of management and ownership in *chaebols*. LG Business Group, for instance, announced a plan to reduce its internal ownership (interfirm and family ownership combined) from 39 percent in 1995 to 19.5 percent by 1999 and family ownership from 5 percent to 3 percent during the same period.

In short, after promoting the formation and growth of *chaebols* during the first two decades and attempting unsuccessfully to regulate them in the 1980s, the government decided to limit protection and intervention and rely more on market mechanisms. *Chaebols* have been and will be the dominant factor in Korea's industrialization and globalization.

Trade Liberalization

In drastic contrast to the government's export-targeting system, the situation room, and heavy export subsidy programs in the 1960s, Korea's export trade was significantly liberalized during the 1970s.

Most of the ad hoc incentive measures used in the 1960s were abolished, and Korea's export trade was almost completely liberalized by 1982. The ratio of net export subsidies to the exchange rate dropped, for instance, from 36.6 in 1963 to 6.7 in 1970 to 0.4 in 1982.[41] In other words, although export-oriented industrialization continued in the 1980s and 1990s, Korean firms have been able to compete in the international market without government subsidies in these decades.

Import policies were also liberalized in the 1980s. The government promulgated the Tariff Reform Act in 1984, which was aimed to phase in general reductions in tariff levels. As a result, the import liberalization ratio—defined as the ratio of the number of unrestricted items to the total—rose from 51 percent in 1973 to 95.2 percent by 1988 and to 98.6 percent in 1994. The government also brought down the average tariff rate from 26.7 percent in 1984 to 7.9 percent by 1994. Nontariff barriers such as delay in custom clearance and tax examination of foreign car purchasers were also largely eliminated in recent years. As a result, imports increased, for instance, by 20.1 percent in 1989 compared with a 2.8 percent increase in exports, forcing Korean firms to compete, with little government assistance, against multinational firms not only in the export market but also in the domestic market.[42]

Financial Liberalization

In contrast to its monopoly of the financial sector in the 1960s and 1970s, the government has also taken major steps to liberalize the financial market. For example, the government reduced the regulation of nonbank financial intermediaries, many of which had long been controlled by *chaebols*, resulting in a significant rise in their share of total deposit liabilities in the 1980s. The denationalization of commercial banks led to a shift of significant share from government hands to the *chaebols*. The conversion of local short-term financing firms to either securities firms or commercial banks in 1990 marked another important step forward in restructuring the financial sector, thus allowing increased participation of private firms.

Although the government exercised its influence on financial institutions through its power to authorize the opening of new branch offices, it lost its teeth in allocating financial resources. Nevertheless, the protection of the local market from foreign financial institutions resulted in gross inefficiencies; Korean banks are loaded with nonperforming loans—8.8 percent of total credits in 1992.[43] The timetable has been set to completely liberalize the financial sector by 1997 in preparing to join the OECD, which requires Korea to make obligatory adjustments including complete financial liberalization.[44]

SME Promotion

A major government mistake in the 1960s and 1970s was neglecting to encourage balanced growth between large firms and small firms. It was the late 1970s when the government belatedly realized the importance of small and medium-size enterprises (SMEs) in healthy economic growth. The government began promoting SMEs, particularly technology-based small firms, to remedy the imbalance between the large- and small-business sectors. The government established sanctuaries for SMEs, designating 205 business territories where neither large corporations nor their affiliates can intrude. The Compulsory Lending Ratio program stipulates that the nationwide commercial banks should extend more than 35 percent of total loans and that regional banks offer more than 80 percent of their total loans to SMEs.

The government also took the initiative in establishing the venture capital industry as a means to advancing the emergence of technology-based small firms in which the private sector had no interest. Specifically, the government enacted a special law to establish the first venture capital firm, which was jointly funded by the government and a group of private firms. The government took a further step by enacting the Small and Medium Enterprise Formation Act in 1986, leading to the emergence of more than thirty venture capital firms, all jointly vested by the government and the private sector.

Preoccupied with *chaebols*, the government failed to learn from Japanese experience in developing an institutional framework for technology diffusion to SMEs. Only in 1979 did the government begin establishing several important institutions, such as Small and Medium Industries Promotion Corporations, Korea Trade Promotion Corporation, and SME-related R&D centers, as a way to support SMEs in developing technological capability and promoting their exports. The government also earmarked a significant portion of its investment fund, W (won) 2.5 trillion ($3.1 billion) in 1994, to promote SME modernization. Despite various support schemes, the number of SMEs that went bankrupt increased steadily over the years—6,156 in 1991 to 10,488 in 1994—due mainly to increasing imports from low-waged China and other Asian countries. The severe competitive rules set by the World Trade Organization will make it even more difficult for SMEs to survive.

Intellectual Property Rights

In Korea, as in other catching-up countries, imitative reverse engineering of existing foreign products was a backbone of industrialization through the mid-1980s. Even advanced countries today rely heavily on copying foreign products and refuse to honor copyrights until they develop enough capability to stand on their own. The United States, for instance, refused to join the Bern Convention on copyrights for more than 100 years, saying that as a developing country it needed to retain easy access to advanced foreign works, an argument still used by many developing countries.[45] Japan and Switzerland refused to recognize product patents until 1976 and 1978, respectively, when they developed enough capability to innovate their own new materials. For instance, they invented ninety-three and eighty-seven new materials, respectively, in the year they introduced product patent systems.[46] Now the United States is the world's international property rights (IPR) policeman, forcing ill-prepared catching-up countries to respect IPR.

Under U.S. pressure, Korea introduced new legislation in 1986 to maintain IPR, preempting the reverse engineering of foreign products. This hit all industries hard, particularly pharmaceuticals and chemicals. The new statute also introduced an arbitration system for compulsory licensing and increased penalties for infringement.

Enforcement of the law was not easy in Korea, where, as in other Asian countries, people don't believe in owning an idea or thought and consequently in paying for it. Frequent police raids in major cities and lawsuits have, however, resulted in a rapid disappearance of pirated products in the local market. The number of cases brought to court by police and lawyers almost quintupled in four years, from 2,254 in 1989 to 10,423 in 1993.[47] Although Seoul's Itaewon Street still draws foreign tourists for counterfeit goods produced by small underground shops, a tide swept through major industries, eliminating duplicative reverse-engineering practices to a large extent. Such forced adoption of IPR resulted in significant upward pressure on costs of Korean products because of increased royalties. On the other hand, it forced Korean firms to intensify their technological efforts to innovate on their own.

Shifting Emphasis

The focus of industrial policy has shifted from the promotion of strategic sectors to promotion of innovation-related activities. In the 1960s and 1970s, special incentives—tax concessions, custom rebates, access

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to foreign exchange, and other forms of protection or enhancement—were granted to strategic industries to make them competitive at a world level. In contrast, the government abolished all industry-specific promotion acts introduced in the 1960s and 1970s and instead legislated a new Industrial Promotion Act in 1986 that ties all incentives to special industrial activities such as R&D and human resource development. In the late 1980s, however, the government again designated several high-technology industries, including information technology and aircraft, for support, but its role in these industries is much more limited than that in labor-intensive industries in the previous two decades.

In short, the focus of industrial policy related to creating the demand for technological learning has shifted significantly. The earlier policy period was marked by heavy government intervention. The new period focuses on the introduction of market principles such as enhancing competition through the control of *chaebols'* growth, trade liberalization, financial liberalization, investment liberalization, and support for innovation-related activities. In other words, government's developmental role has substantially weakened over the years, but some claim that the government still remains relatively powerful in Korea compared with other countries.[48]

TECHNOLOGY POLICY: SUPPLY SIDE OF TECHNOLOGY

The government not only stimulates the demand side of technological learning through industrial policy instruments but also gives rise to the supply of technological capability through technology policy instruments.[49] The technology flow perspective—technology transfer, technology diffusion, and indigenous R&D—provides insight into understanding how developing countries catch up with advanced countries.

Technology Transfer

Lacking technological capability at the outset of its economic development, Korea had to rely on foreign technology imports. However, Korea's policies on foreign licenses (FLs) was quite restrictive in the 1960s. In the case of manufacturing, general guidelines issued in 1968 gave priority to technology that promoted exports, developed intermediate products for capital goods industries, or brought a diffusion effect to other sectors. The guidelines also set a ceiling for royalties at 3 percent and duration at five years. This restrictive policy on licensing strengthened local licensees' bargaining power on generally available mature technologies, leading to lower prices for technologies than would otherwise have been the case.[50]

The 1970s, however, saw a significant change in national policy. In an attempt to attract sophisticated technologies in response to the changing international environment, restrictions on foreign licensing were relaxed in 1970 and 1978, allowing, for one, a higher royalty rate. As a result, royalty payments for FLs increased significantly, as shown in Table 2-1, from $0.8 million during the first five-year economic development plan (1962–1966) to $451.4 million in the fourth one (1977–1981). This increase is insignificant compared with FLs in the 1980s. Most foreign licensing in the early years was associated with technical assistance needed to train local engineers to run turnkey plants.

In contrast to the gradual relaxation of government control on foreign licensing, the government policy on foreign direct investment (FDI) saw a complete swing in the 1960s and 1970s. The FDI policy was quite free in the 1960s, permitting any form of bona fide foreign capital, including fully owned subsidiaries. But few foreign investments were made during the 1960s, primarily owing to questions about Korea's political stability and its uncertain economic outlook.

The government reversed its FDI policy in the 1970s, tightening its control. Joint ventures received higher priority than wholly owned subsidiaries. A general guideline was adopted setting three criteria: first, competition with domestic firms was seldom allowed in both domestic and international markets; second, export requirements were forced on FDIs; and third, foreign participation ratios were basically limited to 50 percent. Korea was one of the few countries with restric-

Table 2-1 Foreign Technology Transfer to Korea, 1962–1993 (in millions of dollars)

Source	1962–1966	1967–1971	1972–1976	1977–1981	1982–1986	1987–1991	1992–1993	Total
1. Foreign Direct Investment								
Japan	8.3	89.7	627.1	300.9	876.2	2,122.3	441.1	4,465.5
United States	25.0	95.3	135.0	235.7	581.6	1,477.7	719.9	3,270.1
All others	12.1	33.6	117.3	184.0	309.6	2,035.9	777.8	3,472.9
Total	45.4	218.6	879.4	720.6	1,767.7	5,635.9	1,938.8	11,208.5
2. Foreign Licensing								
Japan	–	5.0	58.7	139.8	323.7	1,383.6	619.1	2,529.9
United States	0.6	7.8	21.3	159.2	602.7	2,121.9	870.9	3,784.4
All others	0.2	3.5	16.6	152.4	258.5	853.9	307.0	1,592.1
Total	0.8	16.3	96.6	451.4	1,184.9	4,359.4	1,797.0	7,906.4
3. Capital-Goods Imports								
Japan	148	1,292	4,423	14,269	20,673	54,641	25,337	120,783
United States	75	472	1,973	6,219	12,434	33,098	18,832	73,103
All others	93	777	2,445	7,490	17,871	33,213	22,983	84,872
Total	316	2,541	8,841	27,978	50,978	120,952	67,152	278,758

SOURCES: Korea Industrial Technology Association for foreign direct investment and foreign licensing data; Korean Society for Advancement of Machinery Industry for capital-goods import data.

tive regulations on FDI when technology was not a critical element and necessary mature technologies could be easily acquired through mechanisms other than FLs or FDI, for example, reverse-engineering. Under this restrictive policy environment, Korea induced the FDIs, as shown in Table 2-1.

Consequently, the size of FDI and its proportion to total external borrowing were significantly lower in Korea than in other newly industrializing countries (NICs). For example, Korea's stock of FDI in 1983 was only 7 percent that of Brazil, 23 percent that of Singapore, and less than half that of Taiwan and Hong Kong. The proportion of FDI to total external borrowing was only 6.1 percent in Korea compared with 91.9 percent in Singapore, 45 percent in Taiwan, and 21.8 percent in Brazil.[51] The comparative figure reflects Korea's explicit policy of promoting its independence from multinationals in management control.

As a result, unlike these other countries, FDI had a minimal effect on the Korean economy. For example, FDI's contribution to the growth of Korean GNP in 1972–1980 amounted only to 1.3 percent, while its contribution to total and manufacturing value-added was only 1.1 percent and 4.8 percent, respectively, in 1971 and 4.5 percent and 14.2 percent, respectively, in 1980.[52]

Instead, Korea promoted technology transfer in the early years through the procurement of turnkey plants and capital goods. The rapid growth of the Korean economy required commensurate growth in investment for production facilities. However, government policy had been biased in favor of the importation of turnkey plants and foreign capital goods as a way to strengthen international competitiveness of industries using capital goods. Such a policy led to massive imports of foreign capital goods at the cost of retarding the development of the local capital goods industry. Protection of the machinery industry was relatively low until the first half of 1971, giving capital goods users almost free access to foreign capital goods. For example, chemical, cement, steel, and paper industries, established in the 1960s and early 1970s, all resorted to the purchase of turnkey plants and foreign capital goods for their initial setup. But Korean firms assimilated imported technologies so rapidly that they managed to undertake subsequent expansions and improvements with little assistance from foreigners.

The massive imports of foreign capital goods became a major source of learning through reverse-engineering by Korean firms.[53] Of the three categories of technology transfer listed in Table 2-1, capital goods imports far surpassed other means of technology transfer in terms of value through 1981. Capital goods imports were worth twenty-one times the value of FDI and seventy times the value of FLs. The total value of capital goods imports was sixteen times that of the other two categories combined. Although the values of different modes of technology transfer are not strictly comparable since they measure different things, they are useful indicators when compared with other countries. Among NICs, the proportion of capital goods imports to total technology transfer was highest in Korea, suggesting that Korea had acquired more technology from advanced countries through the importation of capital goods than through any other means when compared with such NICs as Argentina, Brazil, India, and Mexico.[54]

Various instruments also played an important role in lubricating the inflow of foreign capital goods to Korea. For example, the slight overvaluation of the local currency, tariff exemptions on imported capital goods, and the financing of purchases by suppliers' credits, which carried low rates of interest relative to those on the domestic market, all worked to increase the attractiveness of capital goods imports.

In short, Korea restricted FDI but promoted technology transfer through other means such as capital goods imports in the early years. Capital was acquired in the form of foreign loans. Such a policy, designed to maintain Korea's management independence from foreign multinationals, was effective in forcing Korean firms to take the initiative and a central role in learning, that is, acquiring, assimilating, and improving imported technologies, rather than relying entirely on foreign sources.

After two decades of restrictive policy toward foreign direct investment and foreign licensing, Korea liberalized its technology transfer policies in the 1980s and 1990s. Progressively more sophisticated foreign technologies were needed to sustain its international competitiveness in high value-added industries. The proportion of Korea's 999 industrial subsectors open to FDI rose from 44 percent in the 1970s to 66 percent in 1984 and to 90.6 percent by 1994. In response to complaints from foreign investors about extremely cumbersome bureaucratic redtape, in 1995 the government introduced the automatic approval system, the expansion of tax and other incentives for investment in strategic high technology sectors, and a one-stop service center.[55]

New FDI in manufacturing has, however, declined steadily in recent years from $1,069 million in 1991 to $527 million in 1993. In contrast, foreign investment in service sectors has significantly increased, accounting for 27.4 percent of the total investment in 1992 and 72.8 percent in the first seven months of 1994.[56] In the 1960s and 1970s, foreign companies invested in Korea to reap cheap labor costs. Now foreign companies are not so willing to collaborate with Korean companies in relatively more technology-intensive areas.

Foreign licensing has been completely open for all industries and for all terms and conditions. The approval system—obtaining prior consent from the government—changed to the reporting system—simply informing the government.[57] The government plans to abolish the reporting system in the near future, except for technologies related to the defense industry.[58] As a result, technology transfer through licensing has soared recently. FLs increased from 247 in 1981 to 707 in 1993, reflecting the liberalized public policy as well as the private sector's aggressiveness in acquiring more sophisticated foreign technologies. Slight drops in the early 1980s and 1990s reflect economic recessions in Korea.

Table 2-1 also reveals that Korea relied heavily on both Japan and the United States for technology. These two countries accounted for more than 80 percent of FDI and more than 70 percent of FLs and capital goods imports during the first two decades of Korea's industrialization. Japan in particular had been the major source of technology for Korea in those years. Korea acquired its mature technologies mainly from Japan and exported its products to the United States in the early years. But the U.S. share of technology transfer has increased significantly in the 1990s. The proportion of foreign licensing cases from the United States increased from 28.4 percent in 1991 to 42.8 percent in 1994. In contrast, FLs from Japan decreased from 47.6 percent to 28.9 percent during the same period, indicating Japanese reluctance to transfer sophisticated technologies to Korea and Korea's preference for U.S. technologies in emerging areas.[59]

Technology Diffusion

In upgrading the overall technological capability of the economy, the effective diffusion of imported technology across firms within an industry and across industries within an economy is as, if not more, important as the acquisition of foreign technology. If technology is transferred successfully to a firm and its use is limited only to its original importer, it may give the firm monopoly power over other firms for a time; however, the economic effect of the technology may be considerably limited. Government interventions that create necessary

institutions would give rise to the firm's learning from the domestic community, resulting in the effective acquisition of knowledge available elsewhere in the economy.

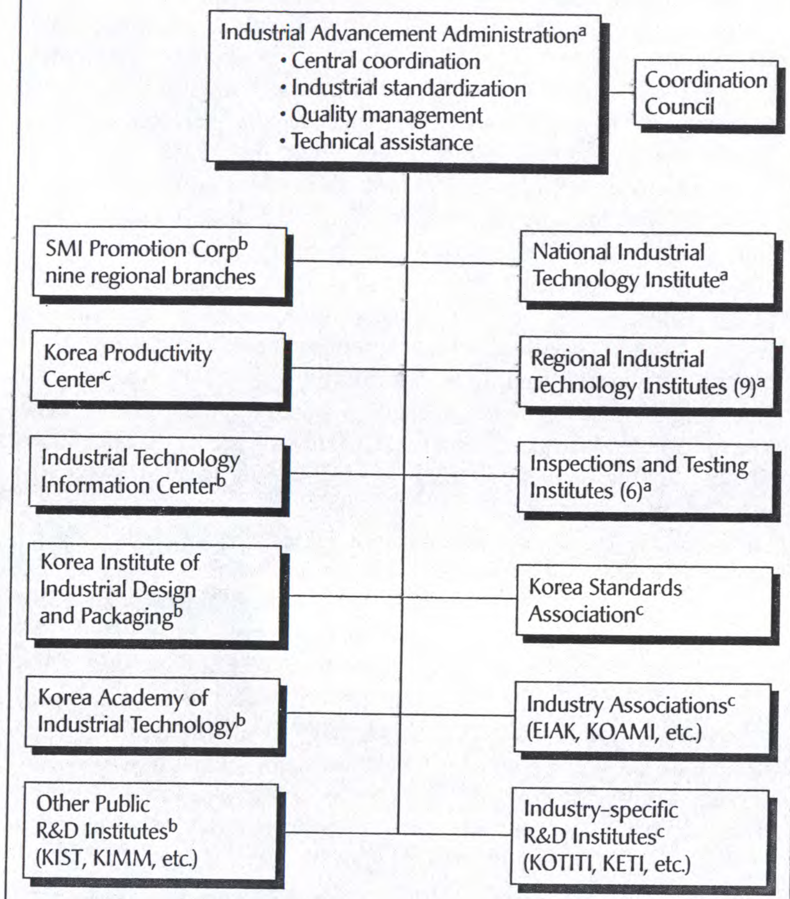
There may be many specialized diffusion agents, such as capital goods producers, consulting engineering firms, and public research institutes, which the government could promote for the diffusion of technology within the economy. But these agents were not effective in Korea in diffusing technology in the 1960s and 1970s.

The government's plan to develop the capital goods sector was initiated in 1968 but not seriously implemented until the mid-1970s. The development of local consulting engineering firms was promoted by the Engineering Service Promotion Law of 1973, which stipulated that, if possible, all engineering projects should be given to local firms as major contractors with foreign partners as minor participants. Such a scheme was aimed mainly at stimulating the emergence of local engineering firms and providing local firms with opportunities to learn from experienced foreigners. But local infant engineering service firms were not capable of playing the role of diffusion agent in the early years of industrialization.

In 1962 the government established a scientific and technological information center as a linking mechanism for disseminating technical information, but its use by industry was quite limited in the early years because mature products were easily imitated through reverse-engineering without the need to consult technical literature. In 1966 the government established a public research institute as a diffusion agent. But Korean researchers, mostly from academic fields or R&D centers in advanced countries, lacked the manufacturing know-how that was in greatest demand during the early years and failed to serve as diffusion agents. The most important diffusion agents the government unintentionally created were the government enterprises established in the 1950s and 1960s. Engineers who accumulated modern production experience in state-owned fertilizer and machinery plants spun off later to head engineering and production departments of private enterprises.

Only in the 1980s did the Korean government introduce an extensive network of government, public, and nonprofit (private) technical support systems to promote technology diffusion within the economy, particularly among SMEs.[60] Some of the support systems dated back to the 1970s but flourished in the 1980s with the growing importance of technology. Figure 2-2 presents a schematic diagram of institutional arrangements related to technology diffusion systems.

Figure 2-2 Support System for Technology Diffusion



NOTES: [a]Indicates government agencies.

[b]Public agencies supported by the government.

[c]Private nonprofit agencies.

The Industrial Advancement Administration, a government agency, coordinates the functions of different technical support agencies for both large and small firms. The National Industrial Technology Institute and eleven regional industrial technology institutes, together with the Small and Medium Industry Promotion Corporation, constitute a national network of technical extension services, while the Korea Academy of Industrial Technology, together with other government R&D institutes (GRIs) and industry-specific R&D institutes under trade associations, comprise a core of an R&D network for technology diffusion. Several private, nonprofit technical support systems also play an important role in technology diffusion among SMEs. The Korea Standard Association with its national network and Korea Productivity Center promote technology diffusion among firms mainly through their educational and training programs on quality control, value engineering, physical distribution, and factory automation. In addition, the government introduced a scientific and technical information dissemination system by developing a data base in ten member institutions and integrating them through an on-line network.

In short, Korea developed, in the 1980s, an elaborate network of technical support systems for technology diffusion, which have evolved dynamically in response to changes in industries.

INDIGENOUS RESEARCH AND DEVELOPMENT

Korean firms acquired and assimilated foreign technology primarily through imitative engineering in the 1960s and 1970s, when relevant technology was readily available in a machine-embodied form and learning by doing was relatively easy. Consequently, none of the policy instruments to stimulate the country's own R&D were effective.

As Korea underwent structural adjustments and entered progressively more technology-intensive industries, the government focused more attention on indigenous R&D activities, primarily through two major mechanisms: direct R&D investment and indirect incentive packages. The government's direct investment is to develop the science and technology (S&T) infrastructure and to promote R&D at universities and GRIs. Its indirect incentive packages, including preferential finance and tax concessions, are aimed at stimulating increased industry R&D. Table 2-2 summarizes the foregoing discussions of industrial and science and technology policies as well as R&D policies discussed below.

Table 2-2 Industrial and Science and Technology Policies

Policies	1960s and 1970s	1980s and 1990s
Industrial Policies	Deliberate promotion of big businesses Export orientation Promotion of heavy and chemical industries Repression of labor to maintain industrial peace	Promotion of SMEs Export orientation Antitrust and fair trade Trade liberalization Financial liberalization Intellectual property rights protection Shifting emphasis on R&D, manpower development
Science and Technology Policies	Restriction on FDI and FLs Promotion of capital-goods import Promotion of GRIs in lieu of university research Promotion of GRIs	Promotion of FDI and FLs Extensive diffusion networks Promotion of university research Promotion of corporate R&D activities Promotion of national R&D projects

Science and Technology Infrastructure Development

Anticipating increasing demands for science and technology, the government established the Korea Institute of Science and Technology (KIST) in 1966 as an integrated technical center to support the industry's technological learning. As Korea's first multidisciplinary research institute, KIST covered a broad spectrum of activities in applied research ranging from project feasibility studies to R&D for new products and processes. KIST spent a large proportion of the nation's total R&D expenditure in its early years.

To keep pace with increasing sophistication and diversity, the government established several GRIs as spin-offs from KIST. Each was designed to develop in-depth capabilities in an area of high industrial priority: shipbuilding, marine resource, electronics, telecommunications, energy, machinery, and chemicals.

The government also created two science centers; Seoul Science

Park started in 1966 with three R&D institutes and three economic research institutes, but it failed to attract private R&D centers to the vicinity. Two of the three R&D institutes have been relocated. In contrast, Taedok Science Town, established in 1978 in an area 200 kilometers south of Seoul, boasts fourteen GRIs and three tertiary educational institutions and has attracted more than eleven corporate R&D laboratories. Eighteen more firms plan to establish their R&D laboratories in the town within a few years, making it the first high-technology valley in the country. But despite almost twenty years of existence, it has neither built a reputation for attracting world-class scientists, as Tsukuba has in Japan, nor become a bustling industrial park with technology-based SMEs that have large shares of world markets for personal computers and peripherals, as Hsinchu has in Taiwan.

The government also created an important milestone in 1975 by establishing a research-oriented graduate school of applied science and engineering, the Korea Advanced Institute of Science, offering both master's and Ph.D. programs, adding another in 1995. These schools draw the most highly qualified entrants by offering extraordinary incentives for students (e.g., full fellowships covering tuition, room, and board and exemption from military obligation).[61] These schools produce almost half of all Ph.D.s in science and engineering in Korea.

University R&D

Research endeavors in universities have been relatively underdeveloped. Their R&D expenditures increased significantly from W 572 million ($1.5 million) in 1971 to W 608 billion ($790 million) in 1994. While those institutions accounted for only 7.7 percent of the nation's R&D spending in 1994, they provided 33 percent of the nation's R&D manpower and 73.7 percent of its Ph.D.-level R&D personnel.

Government statistics indicate that basic research accounted for 14.4 percent, applied research for 23.8 percent, and development for the remaining 61.8 percent of the nation's total R&D expenditures in 1994. The statistics also show that the private sector accounted for 45.1 percent of the nation's basic research and 64.5 percent of applied research, while universities accounted for only 29.1 percent and 6.3 percent, respectively.[62] There is reason to doubt these figures for basic and applied research, particularly the share commanded by the private sector. Only fairly recently have the leading *chaebols* begun rather limited investment in applied research in their largest technology businesses such as semiconductors and information science. Basic research has been even less developed.

The Korean government's attempts to promote university R&D

activities began in the mid-1970s. Frustrated in its efforts to reform the undergraduate teaching-oriented tradition in education, the government conceived a dual system: since almost all universities under the Ministry of Education, public or private, were essentially teaching-oriented, the Ministry of Science and Technology (MOST) founded a research-oriented S&T school in 1975 and another in 1995, establishing a new research tradition in university education.[63]

The government also enacted the Basic Research Promotion Law in 1989, explicitly targeting basic research as one of the nation's top technological priorities. Emulating the U.S. experience, in 1989 the government introduced a scheme to organize science research centers (SRCs) and engineering research centers (ERCs) in the nation's universities. By 1993, fourteen SRCs and sixteen ERCs had been established, receiving government R&D subsidies of almost W 20 billion ($24.2 million) in 1993.

The lack of development in university research has been a major bottleneck in producing well-trained researchers. The government's recent efforts should result in significant reform in university R&D.

GRI R&D

Given the inadequacy of university research, GRIs have served as the backbone of advanced R&D in Korea. The government has made these institutes the major instruments in its Industrial Generic Technology Development Project (IGTDP), National R&D Project (NRP), and Highly Advanced National R&D Project. They have been the recipients of more than 90 percent of the research grants awarded by the government in new technology areas. GRIs undertake most of these projects in conjunction with private firms.

IGTDP concentrates mainly on current problems in existing technology areas with high economic externalities. Each year the Ministry of Trade, Industry, and Energy undertakes a survey to identify urgent R&D projects in industrial firms and offers financial support to GRIs and university laboratories to take on the projects jointly with private firms. Most of them are related to import substitution of Japanese components in the electronics and machinery industries. In 1989, for instance, 174 technologies were identified, 146 of which were designated as projects to be funded. For IGTDPs, the government earmarked W 11.5 billion ($17.2 million) in 1989, W 88.7 billion ($110.8 million) in 1993, about $118,000 per project in 1987 and $388,000 in 1993. These amounts are not substantial enough to solve critical problems.

In contrast, NRP projects focus primarily on future problems in new (to Korea) technology areas with a high risk of failure or with high economic externalities, thus warranting public support. MOST identified several target areas: localization of machinery parts and components, new materials development, semiconductor design, super-mini computer development, energy conservation technology, localization of nuclear energy fuel, new chemical development, biotechnology development, and basic research in universities. The government's total investment in NRPs increased significantly, from W 13.3 billion ($17.7 million) in 1982 to W 98.8 billion ($123.5 million) in 1993.

The most ambitious government vision is the Highly Advanced National R&D Project, also known as the G-7 Project, which is aimed at lifting Korea's technological capability to the level of G-7 countries by 2020.[64] The G-7 project has two parts: product technology development projects and fundamental technology development projects. The former includes new drugs and chemicals, broadband integrated services digital network, next-generation vehicle technology, and high-definition television (HDTV). The latter contains ultra-large-scale integrated circuit, advanced manufacturing systems, new materials for information, electronics, and energy industries, environmental technology, new functional biomaterials, alternative energy technology, and next-generation nuclear reactor. Jointly, the government, universities, and industries will invest $5.7 billion, about half of which will come from the private sector.

The $1.3 billion invested during the first three years involved more than 13,000 researchers and resulted in 2,542 patent applications, almost 2,000 academic articles, and three cases of technology export valued at $6 million. Notable outcomes include quinolon-based antibiotics, liver disease treatment medication, HDTV, and the completion of 256-mega dynamic random-access memory (DRAM) chip development.[65]

In the face of the rapid expansion of private R&D activities and increasing intensity in university R&D, reform of GRIs to redefine their roles has been discussed for some time. But inertia and the labor union of GRI members have made it difficult to implement the reform.

Military R&D

Given the threat of hostilities from North Korea, national security has been one of the major concerns in Korea. As a result, the home market for military technology is unusually sophisticated and demanding.

Seeking to lessen reliance on foreign weapon suppliers and to ensure military independence, the Korean government launched an ambitious program in the late 1970s to build local capability to develop modern weaponry, particularly nuclear warheads and missiles. Startled by Korea's bold move to develop its own defense capability, the U.S. government used carrots and sticks to persuade Korea to abandon the military R&D program.

As a result, the ambitious program was scaled back in the 1980s. Its budget dropped to $114 million in 1988, only 0.2 percent of that of the United States and 4 percent of that of France. The ratio of military R&D budget to total military expenditures was only 1.5 percent in Korea, compared with more than 10 percent in France and the United States. The nature of the R&D is confidential, and the R&D endeavors have been conducted almost strictly within the military: only 1.48 percent of the military R&D budget was allotted to universities in 1988.[66]

The isolated military R&D efforts have had little impact on the development of technological capability in the wider economy. The private sector is involved in manufacturing some traditional weaponry, but the spillover effects of such operations on industrial innovation appear to be negligible, except for improving the degree of precision in the machinery industry.

Indirect Support for Industry R&D

The government offered various tax incentives and preferential financing for R&D activities in the 1960s and 1970s, but during the 1970s the interest rate for R&D loans was one of the highest, reflecting the low priority of R&D in government policies. At the same time, these mechanisms were largely ignored by industry owing to the absence of a clearly felt need to invest in R&D and the relatively easy means of acquiring and assimilating foreign technologies then available from many sources. Only in the early 1980s did preferential R&D loans become the most important means for financing private R&D activities. Preferential financing amounted to W 671.6 billion ($848 million) in 1987, accounting for 94.3 percent of total corporate R&D financing funded by the government. In contrast, direct R&D investment by the government through NRPs and IGTDPs accounted for only 4 percent of the total and direct investment through venture capital firms accounted for 1.7 percent of the total.

Public financing (W 712.4 billion), mostly in the form of preferential loans, accounted for 64 percent of the nation's total R&D expenditure in manufacturing in 1987. In short, the government plays a major

role in funding corporate R&D in Korea, primarily through allocation of preferential financing. The impact of this financing, however, may be overstated. With rates of preferential loans ranging between 6.5 percent and 15 percent, they conferred little advantage over financing terms available in markets outside Korea.[67]

Tax incentives are another indirect mechanism to make funds available for corporate R&D. In Korea, tax incentives may be classified into five categories, according to objectives to be served. Most important are tax incentives aimed at promoting corporate R&D investment, reduced tariffs on import of R&D equipment and supplies, deduction of annual noncapital R&D expenditures and human resource development costs from taxable income, and exemption from real estate tax on R&D related properties. The incentives also include a tax reduction scheme, Technology Development Reserve Fund, whereby an enterprise can set aside up to 3 percent (4 percent for high-technology industries) of sales in any one year to be used for its R&D work in the following three years. The private sector did not take advantage of this scheme in its early years, in the absence of the need for technological activities, but now considers it an important way to finance its R&D. Other tax incentives are aimed at reducing the cost of acquiring foreign technology, promoting technology-based small firms, reducing the cost of commercializing locally generated technologies, reducing the cost of introducing new products, and promoting the venture-capital industry.

In addition, the government introduced various indirect support programs for specific industrial R&D activities. For instance, the World Class Korean Products program, first instituted in 1986, is a government scheme to make selected Korean products world class. The government selected twenty-seven products involving fifty-nine manufacturers in the existing industries and offered preferential financing and other supports to improve the quality of the products, to develop innovative ideas for future development, and to energize overseas marketing strategies. Sports shoes, fishing rods, pianos, tires, bicycles, compact disc players, ultrasonic scanners, VCRs, and videotapes are examples.[68]

In 1993 the government introduced the New Technology Commercialization Program, in which the government offers preferential financing for activities related to R&D and commercialization of new (to Korea) technologies developed locally and designated by the government. The government certifies them as KT (Korea technology) or NT (new technology).

Realizing the importance of new technology venture firms, the government introduced in 1992 the Spin-off Support program to encourage researchers in GRIs to spin off and establish new technology-based small firms. Financial, managerial, and technical assistance are offered to such prospective technical entrepreneurs.

R&D Investment

Facing the imperative to shift to higher value technology-intensive products, R&D investment has seen a quantum jump in the past decades. Table 2-3 shows that total R&D investment increased from W 10.6 billion ($28.6 million) in 1971 to W 7.89 trillion ($10.25 billion) in 1994. Though the Korean economy recorded one of the world's

fastest growth rates, R&D expenditure rose even faster than GNP. R&D increased its share of GNP (R&D/GNP) from 0.32 percent to 2.61 percent during the same period, surpassing that of the United Kingdom (2.12 percent in 1992). It should, however, be pointed out that there are many reasons to suspect bubbles in the R&D statistics, particularly those of the private sector.

The government has launched various programs to induce the private sector to establish formal R&D laboratories. These include tax incentives and preferential financing for setting up new laboratories and exemption from military service obligations for key R&D personnel. Owing partly to these programs and partly to increasing competi-

Table 2-3 Research and Development Expenditures, 1965–1993 (in billions of won)

	1965	1970	1975	1980	1985	1990	1994
R&D expenditures	2.1	10.5	42.7	282.5	1,237.1	3,349.9	7,894.7
Government	1.9	9.2	30.3	180.0	306.8	651.0	1,257.1
Private Sector	0.2	1.3	12.3	102.5	930.3	2,698.9	6,634.5
Government vs. Private	61:39	97:03	71:29	64:36	25:75	19:81	16:84
R&D/GNP	0.26	0.38	0.42	0.77	1.58	1.95	2.61
Manufacturing Sector							
R&D Expenditures	NA	NA	16.70[a]	75.97	688.59	2,134.70	4,854.1
Percent of Sales	NA	NA	0.36[a]	0.50	1.51	1.96	2.55
Number of Researchers (total)[b]	2,135	5,628	10,275	18,434	41,473	70,503	117,446
Government/Public Institution	1,671	2,458	3,086	4,598	7,542	10,434	15,465
Universities	352	2,011	4,534	8,695	14,935	21,332	42,700
Private Sector	112	1,159	2,655	5,141	18,996	38,737	59,281
R&D Expenditure/Researcher (W 1,000)	967	1,874	4,152	15,325	27,853	47,514	67,220
Researcher/10,000 Population	0.7	1.7	2.9	4.8	10.1	16.4	26.4
Number of Corporate R&D Centers	0	1[c]	12	54	183	966	1,980

SOURCE: Ministry of Science and Technology (Korea), *1994 Report on the Survey of Research and Development in Science and Technology* (Seoul: MOST, December 1994).

NOTES: [a] For 1976.
[b] The figures do not include research assistants, technicians, and other supporting personnel.
[c] For 1971.

tion in the international market, the number of corporate R&D laboratories increased from one in 1970 to 2,272 in 1995, reflecting the seriousness with which Korean firms are pursuing high-technology development. Although small and medium-size firms account for more than 50 percent of corporate R&D centers, *chaebols* dominate R&D activities. R&D spending in the manufacturing sector has grown faster than sales. The machinery and electronics industry spent more than 4 percent of sales on R&D activities beginning in the mid-1980s.

Consequently, there has been significant structural change in R&D investment. The government played a major role in R&D activities in early years, when the private sector faltered in R&D investment despite the government's encouragement. More recently, the private sector has assumed an increasingly larger role in the country's R&D efforts in response partly to increasing international competition and partly to a policy environment supportive of private R&D activities. For example, while the private sector accounted for only 2 percent of the nation's total R&D expenditure in 1963, the figure had risen to 84 percent by 1994, which is the highest among both advanced and newly industrialized countries.

TOTAL GLOBALIZATION POLICY

A report by International Management Development (IMD) in Switzerland ranked Korea low in international competitiveness indicators.[69] Its 1994 study shows that of forty-one advanced and newly industrializing countries included in the survey, Korea ranked thirty-ninth in globalization, thirty-ninth in finance, thirty-first in business management, thirtieth in government, twenty-ninth in infrastructure, twentieth in human resources, eighteenth in science and technology, and seventh in domestic competitiveness. Korea ranked near the bottom in many more indicators, including trade policy support for firms' globalization, domestic market liberalization, foreign investment liberalization, openness toward foreign culture, government's price control, balance in fiscal policy, financial support for firms, ease of overseas financing, and autonomy of financial institutions.[70]

Even among eighteen newly industrializing countries Korea slid from the top in 1991 to fifth in 1994 in domestic competitiveness, from fourth to ninth in infrastructure, from fourth to thirteenth in globalization, from third to ninth in business management, from fourth to tenth in government, from top to third in science and technology,

and from seventh to tenth in finance during the same period. Korea's incredibly low ranking in the IMD study prompted several local institutes to undertake comparable studies just to find similar results.[71]

Shocked by these reports, the government launched another ambitious scheme, *segyehwa*, "total globalization policy," with a goal to raise various activities in Korea to international standards. The *segyehwa* committee is manned by cabinet members and twenty-three representatives from the private sector and cochaired by the prime minister representing the government and a university president representing the private sector. This committee delineated twelve major tasks including the reform of educational system and foreign language training, human resource development for "future" industries, and the acceleration of information to society. *Segyehwa* manifested Korea's belated determination to make major reforms in human resource development and government bureaucracy. Its efficacy, however, remains to be seen.

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SUMMARY

The government played a developmental role in Korea's early industrialization. On the demand side of technological learning, the government created and fostered the growth of large *chaebols* as a vehicle for effective technological learning. The government then sanctioned them to accommodate technologically challenging, government-imposed new industrial projects and overly ambitious export goals and to accomplish them within the planned time frame, inducing a series of challenging crises for the private sector. These crises pushed the private sector into something of a life-or-death struggle and forced them to exert all efforts toward accelerating technological learning. But at the same time, the government provided necessary supports through various incentives to make the crises creative rather than destructive.

On the supply side of technological learning, the government restricted foreign direct investment and foreign licensing, instead promoting technology transfer through such other means as capital-goods imports in the early decades. Such a policy was effective in forcing Korean firms to acquire and assimilate foreign technology primarily through imitative reverse engineering of imported foreign goods in the early decades, when learning by doing was relatively easy. Consequently, none of the policy instruments to stimulate the country's own

R&D were effective. But anticipating increasing demands for S&T, the government established S&T infrastructure and GRIs when the private sector faltered in R&D investment.

Significant changes in Korea's economic environment in recent decades have, however, forced the Korean government to make a major policy shift from protection of the local market, regulation of foreign investment, and direct support of exports and R&D to liberalization of trade, foreign investment and financial market, antitrust legislation to enhance competition, and indirect support for R&D activities. This policy shift was designed to introduce market mechanisms and to undertake a structural change toward relatively more technology-based industries. Despite efforts in the 1980s, several indicators show that Korea's international competitiveness has dwindled mainly as a result of inertia in bureaucracy.

One encouraging sign is rapid growth in indigenous industrial R&D activities, an important indicator of learning in industry. The private sector has assumed a major role in Korea's R&D efforts in response partly to increasing international competition and partly to a policy environment supportive of private R&D activities. The private sector accounted for more than 80 percent of the nation's total R&D expenditures in the 1990s. Korea is, however, far behind advanced countries in R&D activities.

The policy environment described in this chapter, together with education and sociocultural environment, discussed in the following chapter, shaped the way firms have developed technological capability.

3 Hardworking Koreans: Education and Sociocultural Factors

No nation has tried harder and come so far so quickly from agrarian poverty to industrial prosperity as Korea.[1] At center stage of its successful rapid industrialization are dynamic manufacturing firms that responded to the changing market and technology environment. In these firms, committed individuals acquired technological capability rapidly.

Technological capability has two important elements. The first, an existing knowledge base, is essential in technological learning, as knowledge today influences learning processes and the nature of accumulated experience tomorrow. A firm's history determines the rate and direction of the technological efforts it pursues, which connect its past with its present.[2] The second is the intensity of effort or commitment. It is insufficient merely to expose individuals or firms to knowledge. Without the conscious efforts of individuals within a firm to internalize such knowledge, learning cannot take place.

The foregoing prompts two questions: (1) How have Koreans acquired knowledge so quickly (prior knowledge base)? (2) Why have Koreans worked so hard (high intensity of effort)? This chapter examines Korea's education and training system to answer the first question and identifies sociocultural factors in an attempt to answer the second.

4 Analytical Frameworks

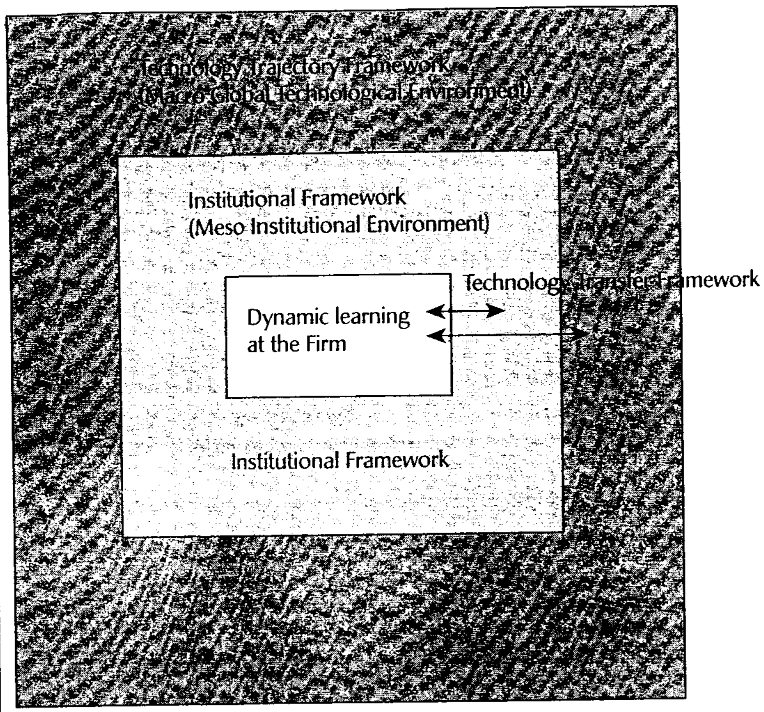
The process of technological learning at firms is so dynamic and complex that it defies a simple analysis. As an attempt to shed light on the dynamic learning process from imitation to innovation in industries, this chapter introduces four analytical frameworks: global technology environment, institutional environment, dynamic learning process at the firm level, and technology transfer. Interrelations among the four frameworks are depicted in Figure 4-1. These frameworks are used as tools to analyze both incremental and discontinuous learning at Korean firms.

GLOBAL TECHNOLOGY ENVIRONMENT FRAMEWORK

This framework analyzes the global *technology environment*, presenting two technological trajectories: one in advanced countries and the other in catching-up countries. Technological trajectory refers to the evolutionary direction of technological advance observable across industries and sectors.

Technological change in catching-up countries stems largely from the acquisition, assimilation, and improvement of foreign technolog-

Figure 4-1 The Analytical Frameworks



ies. Foreign firms transfer these technologies as part of their own global business strategy to extend the life cycle of their products and technologies in the global market. For this reason, it is important for catching-up countries to understand the technology trajectory in advanced countries and global strategy of foreign technology suppliers. The catching-up countries should also understand the technological trajectory of industrializing economies. The interface between these two trajectories creates a dynamic technology environment, in which firms in catching-up countries have to operate. It is this environment that determines, to a significant degree, the strategy of these firms.

Technology Trajectory in Advanced Countries

William Abernathy and James Utterback postulate that industries and firms in advanced countries develop along a technological trajectory

made up of three stages—*fluid, transition,* and *specific.*[1] Although the model is oversimplified to accommodate variations of technological change in different industrial sectors, it provides a useful framework to understand technological change in advanced countries.

According to this model, firms in a new technology exhibit a fluid pattern of innovation. The rate of radical, rather than incremental, product innovation is high. The new product technology is often crude, expensive, and unreliable, but it fills a function in a way that satisfies some market niche. At this stage, technical entrepreneurs form small new firms and new venture divisions within existing firms, competing on the basis of their capability in product innovation. The risk of total failure is highest at this stage. Product changes are frequent, as are changes in the market, so the production system remains fluid and the organization needs a flexible structure to respond quickly and effectively to changes in market and technology. These characteristics are typical of the early history of many existing industries, and new industries continue to show the same dynamics.[2]

As market needs become better understood and alternative product technologies converge or drop out, a transition begins toward a dominant product design and mass-production methods, adding competition in price as well as product performance. Cost competition leads to radical change in processes, driving costs rapidly down. Production capability and scale assume greater importance to reap scale economies. Strong, large firms take advantage of their capabilities in production, marketing, and management as well as R&D. In some cases, the original innovative firm can gradually build such resources. In other cases, larger firms with considerable capital and management resources absorb the small innovative firms.

As an industry and its market mature and price competition grows more intense, the production process becomes more automated, integrated, systematized, specific, and rigid to turn out a highly standardized product. The focus of innovation shifts to incremental process improvements in search of greater efficiency. When the industry reaches this stage, firms are less likely to undertake R&D aimed at radical innovations, becoming increasingly vulnerable in their competitive position. Industry dynamism may be regenerated through invasions by radical innovations introduced by new entrants.[3] Often these are innovations generated elsewhere that migrate into the industry. Some industries, however, are quite successful in extending the life of their products in this specific state with a series of incremental innovations to add new values.[4] At the later stage of this state, industries are typically relocated to catching-up countries where production costs are lower. Most traditional manufacturing sectors in advanced countries that lost their competitiveness to those of catching-up countries are at this stage.

The upper part of Figure 4-2 depicts the above model. The frequency of radical product innovations is high during the fluid stage but diminishes rapidly, while that of radical process innovations is high during the transition stage. In the specific stage, both radical product and radical process innovations are low. The figure also depicts the invasion of new radical ideas reversing the direction of the technological trajectory. However, this model might change significantly with a shift in the technoeconomic paradigm. For example, the spread of microelectronic technology across industries may enable mature industries to regenerate by becoming more flexible and information-intensive and by redesigning mature products to give new life.[5] The Abernathy-Utterback model is still useful in explaining the learning process of Korean firms in the past.

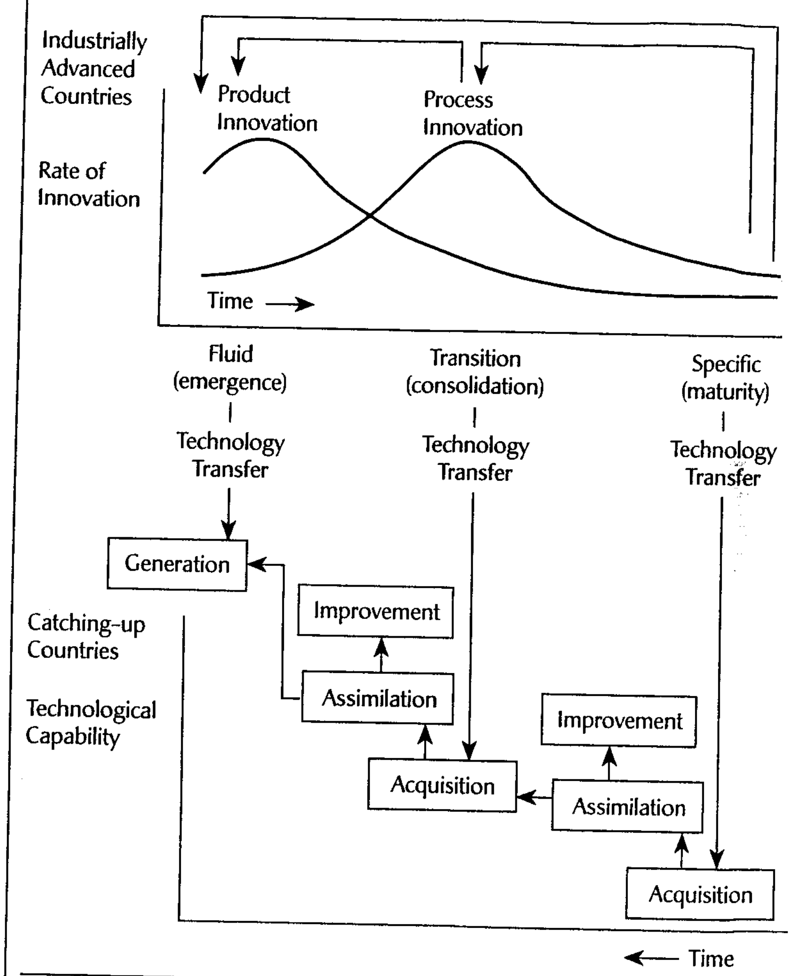
Technological Trajectory in Catching-up Countries

The course of technology development in catching-up countries has been somewhat different from that of advanced countries. On the basis of research in several different industries in Korea, I developed a three-stage model—acquisition, assimilation, and improvement—to extend Abernathy and Utterback.[6]

During the early stage of their industrialization, catching-up countries acquire mature (specific-state) foreign technologies from industrially advanced countries. Lacking local capability to establish production operations, local entrepreneurs develop production processes through the acquisition of packaged foreign technology, which includes assembly processes, product specifications, production know-how, technical personnel, and components and parts.

Production at this stage is merely an assembly operation of foreign inputs to manufacture fairly standard, undifferentiated goods. With low labor costs and little cost pressure in the protected market, the operation is relatively inefficient. The immediate technological task is the implementation of transferred foreign technology to manufacture products whose technology and market have been tested and proved elsewhere. For this purpose, only engineering (E) efforts are required. Foreign technical assistance is most significant in debugging problems in the initial implementation of production operations, but its utility

Figure 4-2 Integration of Two Technological Trajectories



SOURCE: This figure borrows ideas from James M. Utterback, *Mastering the Dynamics of Innovation* (Boston: Harvard Business School Press, 1994) and Jinjoo Lee, Zong-Tae Bae, and Dong-Kyu Choi, "Technology Development Processes: A Model for a Developing Country with a Global Perspective," *R&D Management* 18, no. 3 (1988): 235–250.

diminishes rapidly as local technicians acquire production and product design experience.

Once the implementation task is accomplished, production and product design technologies are quickly diffused within the country. Late entrant firms acquire technological capability by stealing experienced technical personnel from the early acquirers. Increased competition from new entrants spurs indigenous technical efforts in the assimilation of foreign technologies to produce differentiated items. Technical emphasis is placed on engineering and limited development (D&E) rather than research (R). By assimilating imported technology, local firms are able to develop related products through imitative reverse engineering without the direct transfer of foreign technologies.

The relatively successful assimilation of general production technology and increased emphasis on export promotion, together with the increased capability of local scientific and engineering personnel, lead to the gradual improvement of technology. Imported technologies are applied to different product lines through local efforts in research, development, and engineering (R,D&E). In proceeding along this trajectory at acquisition, assimilation, and improvement, firms in catching-up countries reverse the sequence of R,D&E in advanced countries.

Integration of the Two

Linking the technological trajectories of Abernathy and Utterback with mine, Jinjoo Lee and his associates postulate that the three-stage technological trajectory in catching-up countries takes place not only in mature technology in the specific stage but also in growing and emerging technologies in the transition and fluid stages.[7] As shown in Figure 4-2, firms in catching-up countries that have successfully acquired, assimilated, and sometimes improved mature foreign technologies may aim to repeat the process with higher-level technologies in the transition stage in advanced countries. Many industries in the first tier of catching-up countries (e.g., Taiwan and Korea) have arrived at this stage. If successful, they may eventually accumulate indigenous technological capability to generate emerging technologies in the fluid stage and challenge firms in the advanced countries.[8] When a substantial number of industries reach this stage, the country may be considered an advanced country.[9] So far, Japan may be the only catching-up country that reached this stage in the twentieth century. This framework provides an understanding of dynamically changing global technology environment, under which institutions and firms have to operate.

INSTITUTIONAL ENVIRONMENT FRAMEWORK

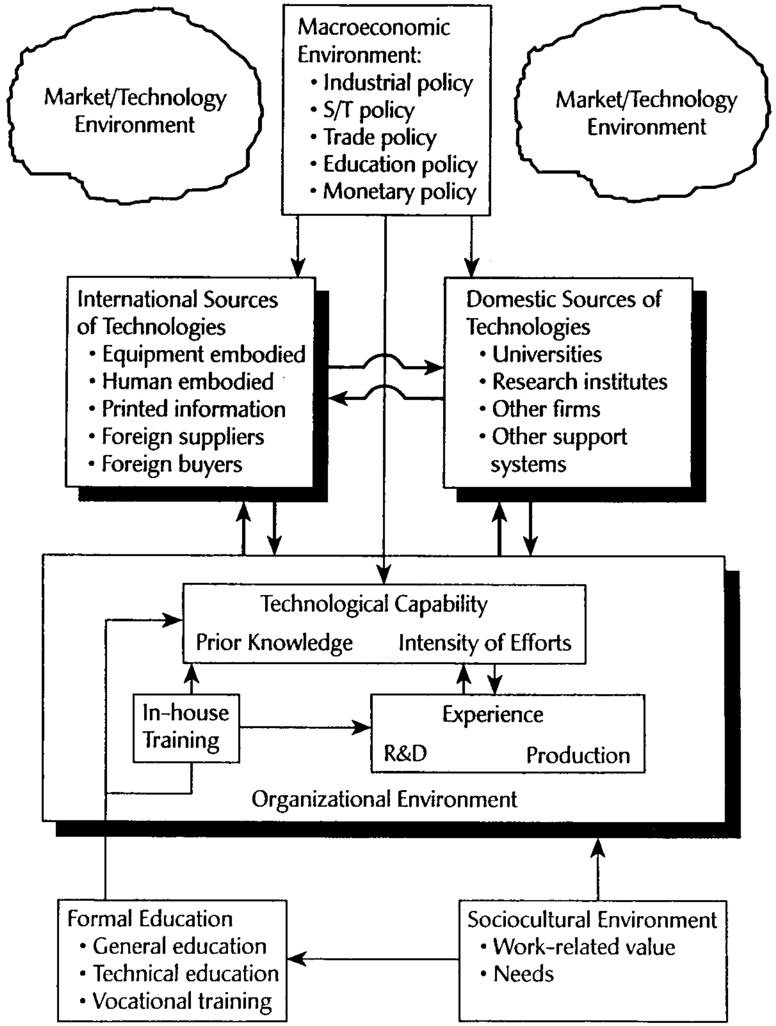
The acquisition of technological capability is a complex learning process at all levels of society. For firms in catching-up countries, there can be many sources of technological learning. These may be grossly categorized into three groups: the international community, the domestic community, and in-house efforts at the firm level. There are also five important factors that significantly influence the learning process: market and technology environment, public policy, formal education, socioculture, and organizational structure. Figure 4-3 depicts the major sources of technological learning, the firm's interactions with these sources, and the factors influencing the interactive process.

International Sources

The international community is perhaps the most important source of technological learning for firms in catching-up countries, as changes in the technological trajectory in advanced countries creates favorable windows of opportunity for those striving to catch up.[10] The arrow from the firm toward the international community, as depicted in Figure 4-3, shows how existing technological capability enables a catching-up firm to exploit unfamiliar technologies available in the international community. Technological capability includes not only substantive technical knowledge but also the capacity to identify sources of useful complementary expertise outside the country.[11] Technological capability also enables the firm to recognize the value of new external information, to strengthen its bargaining power in technology transfer negotiations, and to assimilate the transferred knowledge. It also makes the firm more proactive as it is highly sensitive to emerging technological opportunities. The firm aggressively seeks new opportunities to exploit and develop its technological capability. This capability also enables the firm to predict more accurately the nature and commercial potential of technological progress.[12] Thus, firms that develop a broad and active network with the international community strengthen their capacity to identify others' capabilities and to learn from them in order to build own technological capability.

The arrow from the international community to a firm indicates how foreign technology transferred to the firm strengthens its techno-

Figure 4-3 Sources of Technological Learning in Newly Industrializing Countries



logical capability by raising the level of the existing knowledge base, an essential component. This process is often called international technology transfer.

Domestic Sources

Technological capability may also be raised through interactions with the domestic community. The community's existing technological capability enables a firm to identify and explore complementary expertise available within the economy. Local universities, government R&D institutes and other public support agencies, buyers and suppliers, and other firms within the economy could be important sources of scientific and technical information new to the firm. Joint research projects with universities and research institutes could give it a significant rise in technological capability. The observation of advanced equipment in use by other firms or in exhibitions at trade fairs is a major source of imitative reverse engineering.[13] In short, technological capability enhances the competence to exploit external information, while its transfer strengthens firms' knowledge stock, raising technological capability.

In-house Efforts

Figure 4-3 also depicts the interactive mechanism between existing technological capability in a firm and its production experience and R&D activities. Existing technological capability enables the firm to operate and maintain production systems efficiently. Technological capability may be developed as a by-product of operations through learning by doing. This is particularly important for firms in catching-up countries. The more firms become practiced, the more they become capable at activities in which they are already engaged. In addition, production experience enables firms to recognize and exploit new information relevant to particular production methods to improve their own processes.

Technological capability is also generated as a by-product of a firm's R&D, particularly when knowledge is less explicit and codified and more difficult to assimilate in a technologically progressive environment.[14] The more difficult learning is, the more knowledge has to have been accumulated via R&D for effective learning to occur. The more difficult the learning environment, the higher marginal effect of R&D on technological capability.[15] R&D activities enable firms to be aware of the significance of new external signals and exploit available information more effectively. Technological capability also enables firms to identify the sorts of associations and linkages they may never before had considered, leading to creativity in research, development, and engineering activities.[16]

In short, technological capability at the firm level is acquired and accumulated mainly through three mechanisms: interactions with the international community, interactions with the domestic community, and in-house efforts. Further, these three activities intersect and reinforce one another. Effective interactions with both international and domestic communities facilitate in-house efforts, while effective in-house efforts promote interactions with external communities, both through the process of technological learning. The process involving interactions and consequent technological learning are significantly affected by five factors: the market/technology environment, formal education, socioculture, organizational structure, and public policy.

Five Influencing Factors

The first factor, the market and technological environment, affects to a significant extent not only the behavior of a firm, suppliers, customers, and policymakers but also the interactions among them. The process of technological changes and market forces operating thereon compel the firm to intensify its efforts to strengthen internal activities and in turn develop technological capability. It also compels the firm to intensify external activities to strengthen its learning from outside sources. In this vein, an export-oriented industrialization strategy, as discussed in Chapter 2, forces local firms to survive and grow in the more competitive international market than in the highly protected import-substituting local market.

The second factor, the government, can make a significant impact on the process of technological learning through both direct and indirect measures such as industrial, trade, and science/technology policies (see Chapter 2). Such policies affect a firm's interactions with the international community by regulating the inflow of foreign technology. They affect the firm's interactions with the domestic community by influencing the availability and efficacy of local supporting institutions and the quality of educational institutions. And they affect the firm's interaction with the market environment by shaping industrial organizations. That is, these policies set macroeconomic environments in which firms have to operate, thus affecting directly and indirectly the process of technological learning.

The third factor, the structure and quality of the formal education system, affects the accumulation of technological capability at the firm

level. The importance of education in industrialization is well known from the economic history of Western countries. New recruits from the formal educational system provide firms with a continuous inflow of new knowledge and skills, which upgrade their technological capability for future learning.

The fourth factor influencing the process of technological capability acquisition is the sociocultural environment. This includes the beliefs, norms, and values in the society (see Chapter 3) that have significant effects on the formation of work ethics, which in turn influence the mind-set and behavior of people in the firm.

The fifth factor is organization and management. Even within the same socioculture, there are significant differences in the way an organization is structured and managed. These characteristics determine the incentive within the organization that elicits the energy and skills of the people. Many studies show that organizational properties are much more important than the characteristics of its participants in predicting the adoption of changes.[17] A conducive organizational environment fosters not only effective learning by its members but also its translation into organizational capability. In contrast, a rigid organization stifles the creativity of its participants, hindering both individual and organizational learning.

DYNAMIC LEARNING PROCESS AT THE FIRM LEVEL

The foregoing two frameworks provide an environment in which firms have to learn technologically. Understanding the dynamically changing global technology environment and a network of supporting institutions alone can explain neither the different growth rate between catching-up countries nor that between firms within Korea. Many catching-up countries have attempted at one point or another to pursue a similar strategy with few results. Even within the same country and a similar economic and technological environment, some firms are more effective than others in strengthening competitiveness through effective learning.

Understanding the dynamic process of a firm's technological learning is essential, because technological change is localized at the firm level.[18] Firms develop their technological capability through in-house efforts augmented by interactions with domestic and foreign institutions, constrained by regulations, and stimulated by government incentives in the dynamically changing global technology environment.

Thus, the learning effectiveness of individual firms that gives rise to their technological capability is a central issue in technological development. When an economy has many firms that grow dynamically by sustaining competitiveness through effective technological learning, the economy enjoys international competitiveness and healthy growth.[19]

Technological capability includes not only capacity to assimilate existing knowledge (for imitation) but also capacity to create new knowledge (for innovation). Technological learning, whether to imitate or innovate, takes place at two different levels: individual and organizational. The prime actors in the process of organizational learning are the individuals within a firm. Organizational learning is not, however, a simple sum of individual learning; rather, it is the process that creates knowledge, which is distributed across the organization, is communicable among members, has consensual validity, and is integrated into the strategy and management of the organization.[20] Individual learning is, therefore, a necessary condition for organizational learning, but it is not by itself a sufficient condition. Only effective organizations can translate individual learning into organizational learning.

Knowledge and Learning

Technological change, through either imitation or innovation, is a process in which a firm identifies real or potential problems, then actively develops new knowledge to solve them. At this point, it is important to introduce the two dimensions of knowledge: explicit and tacit. Explicit knowledge refers to knowledge that is codified and transmittable in formal, systematic language. Thus, explicit knowledge may be acquired from books, technical specifications, designs, and material embodied in machines. Joseph Badaracco calls it "migratory knowledge."[21] In contrast, tacit knowledge is so deeply rooted in the human mind and body that it is hard to codify and communicate and can be expressed only through action, commitment, and involvement in a specific context. Tacit knowledge can be acquired only through experience such as observation, imitation, and practice.

Ikujiro Nonaka postulates that the organization creates new knowledge through building both explicit and tacit knowledge and, more important, through the dynamic process of four different types of conversion between these two dimensions of knowledge: tacit to tacit, explicit to explicit, tacit to explicit, and explicit to tacit. Conversion from tacit to tacit, called socialization, takes place when tacit knowledge within one individual is shared by another through training, while conversion from explicit to explicit (combination) takes place when an individual combines discrete pieces of explicit knowledge into a new whole. Conversion from tacit to explicit (externalization) can be said to have taken place when an individual is able to articulate the foundations of his or her tacit knowledge, whereas conversion from explicit to tacit (internalization) takes place when new explicit knowledge is shared throughout a firm and other members begin to use it to broaden, extend, and reframe their own tacit knowledge. Such conversions tend to become faster in speed and larger in scale as more actors in and around the firm become involved in knowledge conversions. Using Japanese examples, Nonaka and Hirotaka Takeuchi provide excellent detailed discussions of a spiral model of organizational knowledge creation, showing how an upward spiral starts at the individual level and moves up to the organizational level.[22]

Technological capability at a firm is not a collection of explicit knowledge; rather, it is largely a collection of tacit knowledge. The firm may have some proprietary explicit knowledge such as firm-specific blueprints and standard operating procedures, but those are useful only when tacit knowledge enables its members to utilize them. Richard Nelson and Sidney Winter also note that much of the knowledge that underlies the effective performance of an organization is tacit knowledge embodied in its members.[23]

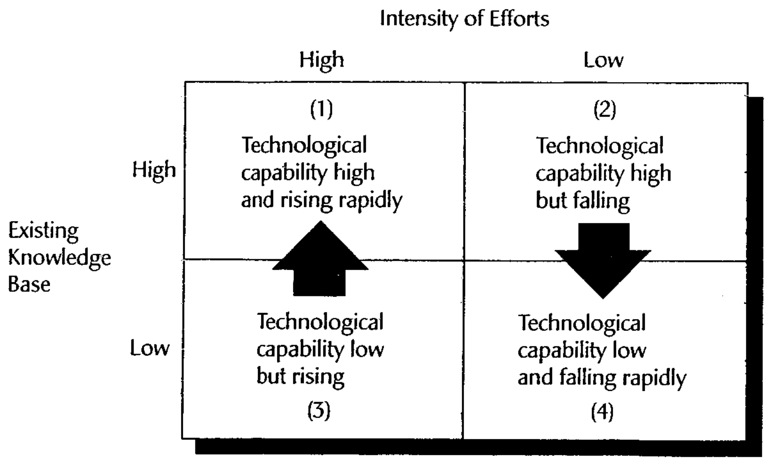
Absorptive Capacity

Effective knowledge conversions to lead to productive technological learning require two important elements: existing knowledge base, of course mostly tacit knowledge, and the intensity of effort. Wesley Cohen and Daniel Levinthal call it absorptive capacity.

First, existing tacit knowledge, as an essential element in technological learning, influences learning processes today and the nature of learning tomorrow. That is, today's tacit knowledge enables individuals and organizations to create tomorrow's increased tacit knowledge through various forms of knowledge conversion. The second important element is the intensity of effort or commitment. It is insufficient merely to expose individuals and firms to explicit knowledge. Without conscious efforts of individuals within a firm to internalize such knowledge, learning cannot take place.

These two variables, existing knowledge and the intensity of effort, in an organization constitute, as presented in Figure 4-4, a two-by-two matrix that indicates the dynamics of technological capability.

Figure 4-4 Dynamics of Technological Learning



When both existing tacit knowledge and the intensity of effort are high (quadrant 1), technological capability is high and rapidly rising. On the contrary, when both elements are low (quadrant 4), technological capability is low and falling. Organizations with high existing tacit knowledge and low intensity of effort (quadrant 2) might have high capability but will lose it gradually, since existing tacit knowledge becomes obsolete as technology moves along its trajectory. Such organizations gradually move down to quadrant 4. In contrast, organizations with low existing tacit knowledge but high intensity of effort (quadrant 3) might have low technological capability but will acquire it rapidly, as both continuous and discontinuous learning can take place through significant investment in learning, moving progressively to quadrant 1. In short, it can be said that the intensity of effort or commitment is a more crucial element than existing tacit knowledge for long-term learning and competitiveness of firms.

Crises and Discontinuous Learning

How then should a firm manage the intensity of effort? When does the firm and its members actively search for new knowledge? When do individuals within the firm vigorously commit their energy to knowledge conversion? When does a spiral pattern of knowledge conversion take place more rapidly and on a larger scale? To state it differently, when does discontinuous learning take place?

Cumulative technological learning can take place under normal circumstances. Discontinuous learning, however, takes place normally when a crisis is perceived in market competition and a strategy is implemented to turn the situation around. In such a case, the firm has to invest heavily, by hiring new personnel, in the acquisition of new tacit and explicit knowledge as well as in knowledge conversion activities to overcome the crisis in the shortest possible time. Just as the word *crisis* in Chinese character (*weiji*) is a combination of two characters (threat and opportunity), some firms manage to turn a crisis into an opportunity to transform their technological capabilities in a discontinuous manner and enhance their competitiveness. A crisis may be creative in this sense; otherwise, it can be destructive.

A crisis may be generated naturally when a firm loses its competitive standing in the market[24] or intentionally when an external principal or top management evokes a sense of crisis by proposing challenging goals.[25] Intentionally evoked crises may be imposed by the external coalition on a focal firm or industry in general. In catching-up countries, particularly where the state plays an orchestral role in industrialization, the government could impose a crisis by setting challenging goals for firms in a strategically designated industry. This is called an imposed crisis.[26]

Or the dominant coalition within a firm could intentionally construct a crisis, which is largely a negative word for mediocre managers. It may mean imminent, unfolding disaster, most possibly resulting in management failure and loss of face. Thus, crisis-oriented learning is discouraged. But for visionary entrepreneurs, crisis construction may be a strategic means of opportunistic learning, bringing about a valuable transformation in the firm. This is called constructed crisis.[27] An effective learning organization may frequently evoke constructed crises and institutionalize the process and structure to make discontinuous learning possible and to turn the crises into opportunities. It may be hypothesized that the owner/entrepreneur may be in a better position to introduce constructed crisis than the employed manager, as the former has stronger, centralized power without competing shareholders. In this vein, the tycoon of family-owned Korean *chaebols*, if he is entrepreneurial, might be in a more advantageous position to generate more constructed crises than managers.

Focal Levels in Firms

In the catching-up process, the shop floor is undoubtedly the focus for cumulative learning, as transferred technology is first implemented there and later incrementally improved to achieve optimal productivity.[28]

The strategic importance of top and middle management should not, however, be overlooked in late industrialization.[29] Their role is vital in discontinuous learning. It is entrepreneurial-minded top management that introduces constructed crises. This forces discontinuous learning that articulates metaphors and symbols to give organizational directions, creates task-force teams to manage organizationwide learning process, provides resources to support learning activities to make crises creative, and clears away any obstacles in the learning process.

It is the middle management that translates the ideas of the top into reality on the shop floor in managing constructed crises. Middle management is at the intersection of the vertical and horizontal flow of crucial information in the firm, managing task-force teams in which close interactions among members and crucial knowledge conversions take place. Nonaka's suggestion of middle-up-down management addresses the same issue.[30]

TECHNOLOGY TRANSFER FRAMEWORK

For firms to learn effectively, technology transfer from foreign companies in advanced countries can be an important source of both explicit and tacit knowledge. To analyze the behavior of firms in the acquisition of foreign technology, another framework is introduced that describes behavior operating in two dimensions. In the first, technology transfer may or may not be mediated through the market. In market-mediated technology transfer, the supplier and the buyer may negotiate payment for the transfer, either embodied in or disembodied from the physical equipment. Foreign technology may also be transferred to local users without the mediation of market; in this case the transfer usually takes place without formal agreements and payments. In the second dimension, the foreign supplier may take an active role, exercising significant control over the way in which technology is transferred to and used by the local recipient. Alternatively, the supplier may take a passive role, having almost nothing to do with the way the user takes advantage of available technical know-how either embodied in or disembodied from the physical items. These two dimensions—the

mediation of market and the role of foreign suppliers—offer a useful two-by-two matrix, shown in Figure 4-5, to identify and evaluate different mechanisms of international technology transfer.[31]

In other words, firms in catching-up countries have many alternative mechanisms in acquiring foreign technology. Foreign direct investment, foreign licenses, and turnkey plants are major sources of formal technology transfer in quadrant 1. The purchase of capital goods transfers machine-embodied information (quadrant 2). Printed information such as sales catalogs, blueprints, technical specifications, trade journals, and other publications, together with observation of foreign

Figure 4-5 Evolution of Technology Transfer in Catching Up

	The Role of Foreign Suppliers: Active	The Role of Foreign Suppliers: Passive
Market Mediated	Formal mechanisms (Foreign direct investment, foreign licensing, turnkey plants, consultancies) (1)	Commodity trade (Standard machinery transfer) (2)
Nonmarket Mediated	Informal mechanisms (Technical assistance of foreign buyers and vendors) (3)	Informal mechanisms (Reverse engineering, observation, trade journals, advanced reverse engineering, etc.) (4)

SOURCE: Linsu Kim, "Korea: The Acquisition of Technology," in Hadi Soesastro and Mari Pangestu, eds., *Technological Challange in the Asia-Pacific Economy* (Sydney: Allen and Unwin, 1990): 145–157.

NOTES: 1. Merge/acquisition and strategic alliances, which are essential mechanisms in transferring technology or technology capability available in advanced countries, are not included in this classification, as they are strategies relevant only in the fluid stage, in which Korean firms have to generate new technology at the frontier.

2. The two dimensions–market mediation and supplier's role–were originally introduced by Martin Fransman, "Conceptualizing Technical Change in the Third World in the 1980s: An Interpretive Survey," *Journal of Development Studies,* July 1985.

plants, serve as important informal sources of new knowledge for firms in catching-up countries (quadrant 4).[32] Foreign suppliers and buyers from original equipment manufacturers often transfer critical knowledge to producers to ensure that products meet the buyers' technical specifications (quadrant 3).[33] In addition, reverse brain drain or return of foreign trained professionals and moonlighting foreign engineers give significant rise to technological learning of firms in catching-up countries.[34]

If firms in catching-up countries have absorptive capability, they can effectively acquire foreign technology without transactions costs (quadrants 3 and 4). When technology is simple and mature and patents have already expired, these firms, particularly small ones, with sufficient capability (high tacit knowledge and high intensity of efforts) do not have to purchase technology through formal mechanisms; rather, they can reverse-engineer foreign products, producing knock-offs and clones.

SUMMARY

This chapter introduced four analytical frameworks that I use as tools to analyze incremental and discontinuous learning at Korean firms. The first framework analyzes the technological environment, in which firms in catching-up countries have to formulate and implement technological strategy along dynamically changing technological trajectories. At the specific state of the trajectory, it may be relatively easy for catching-up firms to acquire mature foreign technologies, which might be generally available for them to imitate freely or to purchase at a bargain price from foreign suppliers. Rapid industrialization in catching-up countries has, however, pushed up wage rates faster than productivity, resulting in the rapid erosion of competitiveness in labor-intensive light industries. As a result, catching-up firms have to compete against more industrialized countries by creatively adding values on mature products or, in reverse, entering the transition state through enhanced technological efforts.

The second framework examines the institutional environment that provides sources of technological learning. The international community offers foreign direct investment, foreign licensing, turnkey plant transfer, the purchase of capital goods, and migration of technical personnel. It may be the major source of technology for catching-up countries, as market-proven technologies are readily available in

advanced countries. In the local community, public research institutes, universities, and other firms may also provide valuable assistance.

The third framework theorizes the dynamic learning process at the firm level. Technological learning or the acquisition of technological capability is the acquisition and assimilation of existing knowledge and, more important, the creation of new knowledge. When successful it proceeds through a spiral process of conversions between explicit and tacit knowledge. To this end, the existing knowledge base and the intensity of efforts are important ingredients in learning. Cumulative learning takes place through learning by doing, but discontinuous learning takes place in crisis. Effective learning firms construct crises intentionally to develop organizational systems and manage their processes to make the crises truly creative.

The final framework categorizes four major modes of technology transfer across national boundaries. The mode of transfer is determined largely by a buyer's absorptive capability. If the buyer has sufficient capability, it can effectively acquire foreign technology without transaction costs and produce knockoffs and clones through reverse engineering.

These frameworks are used as tools to analyze the dynamic process of rapid technological learning at Korean firms and the role played by the supporting institutions and the government in the dynamically changing global technology environment.

5 The Automobile Industry: Crisis Construction and Technological Learning

"Only a handful of car manufacturers would survive the global shake-out of the 1990s and none of South Korea's five automakers was to be among them, having been driven out or relegated to niche markets dependent on alliances with Toyota, Honda, Nissan, Volkswagen, Ford, or General Motors," predicted one economic journal in 1992.[1] Nonetheless, five Korean automakers are determined to become leading automakers on their own in order to contend in the world market.

Korea's automobile industry has grown phenomenally since its birth in 1962, as shown in Table 5-1. Production increased tenfold in the first decade, tenfold again in the second decade, and twentyfold in the third. As a result, Korea has risen rapidly in the ranks of the world's auto producers. It was not even on the charts in 1980—Korean production was about one-tenth that of Brazil, which ranked tenth—yet rose to eleventh in the world in 1986, to ninth in 1991, and sixth by 1993. The Korean government initially envisioned its car industry's growing to fifth in the world by the twenty-first century. Korea's car makers, however, pushed even harder and reached fifth place in 1994 by producing 2.3 million cars, surpassed only by the United States,

Table 5-1 Growth of the Automobile Industry in Korea (in thousands)

	Year							
	1962	1965	1970	1975	1980	1985	1990	1994
Production								
Hyundai	–	–	4.3	7.1	61.8	240.7	676.0	1,134.6
Kia	0.07	0.03	5.7	20.0	34.1	87.2	377.3	619.9
Daewoo	1.7	0.1	16.6	9.3	25.7	45.0	201.2	340.7
Others	–	–	1.7	0.4	2.8	7.5	48.0	216.5
Total	1.77	0.14	28.4	36.8	124.4	380.4	1,302.5	2,311.7
Exports								
Hyundai	–	–	–	–	16.2	120.0	225.4	393.0
Kia	–	–	–	0.01	4.7	1.4	85.8	210.5
Daewoo	–	–	–	–	4.2	5.6	34.2	99.8
Others	–	–	–	–	0.1	0.9	1.7	34.7
Total	–	–	–	0.01	25.2	127.9	347.1	738.0

SOURCE: Based on data provided by the Korea Automotive Industry Cooperation.

Japan, Germany, and France.[2] (See Table 5-2.) In addition, Samsung, the largest *chaebol*, announced plans to join existing Korean firms in producing cars beginning in 1998.

Korea's auto exports also increased rapidly, from 1,341 in 1976 to 737,943 in 1994, making automobiles the nation's seventh largest export item behind electronics, textile products, machinery, steel products, and footwear in 1992.[3] Korea's successful entry to the U.S. market in the 1980s with a subcompact car made by Hyundai repeated West Germany's success in the 1950s with Volkswagen and Japan's success in 1970s with Toyota.[4] How have Korean automakers grown technologically fast enough to emerge as new contenders in the world market? How has the industry interacted with the government in this process?

IMITATION DRIVE IN THE AUTOMOBILE INDUSTRY

In the 1950s, more than a hundred primitive garages manually fabricated and assembled a few automobiles a year based on used military

parts and components and experience maintaining military vehicles. The Korean Army and Air Force vehicle renovation depots overhauled imported Japanese and American military vehicles to stretch their life cycles. These military depots were the breeding grounds for the experienced technicians with necessary tacit knowledge who would later staff the primitive automobile fabricators.[5]

However, Korea's modern automobile industry can be said to have begun in 1962, when a local firm, Saenara, established the first well-structured assembly plant to produce Japanese subcompact cars in Korea at the instigation and promotion of the Korean government. As part of its First Five-Year Economic Development Plan, the Korean government enacted the Automotive Industry Promotion Law of 1962, which provided tariff exemptions for imports of parts and components, tax exemptions for assemblers, and local market protection from foreign cars. This led to the birth of the first modern assembly plant, a semi-knocked-down (SKD) type of operation, in Korea.[6] Technical assistance and SKD parts came from Japanese Nissan and most of the senior engineers from military vehicle renovation depots.[7] This company evolved into Daewoo Motor.[8]

Three locally owned assemblers emerged soon after; Hyundai began in 1967 to assemble Ford cars, Asia Motor in 1969 to assemble Fiats, and Kia Motor, a motorcycle producer, in 1974 to produce a Mazda model. What is noteworthy is that, unlike other developing countries but like Japan, Korea pursued a unique and independent strategy of developing its automobile industry independently of the multinational automakers in the international oligopolistic market, in which twenty producers from seven countries regularly accounted for more than 92 percent of world production.[9]

Hyundai, one of the two largest *chaebols* and by far the largest and most successful automaker, decided from the start that if it was to become a power in the international automobile industry, it would have to be its own master. (In 1979 Japan's Mitsubishi Motors assumed a 12 percent equity share in return for access to technology, but Hyundai has maintained full independence in global strategy.) Kia, the seventh largest *chaebol* with a background in bicycles, motorcycles, motortricycles, and small trucks, also entered the industry as an independent firm. Kia gave equity stakes totaling 20 percent to Ford, Mazda, and Itochu in attempts to acquire crucial technology, but it has maintained its management independence, pursuing its own technology and marketing strategy. As a result, it has surged to become Korea's second largest producer. In contrast, despite its head start as

Table 5-2 Top 10 Automobile Producing Countries in the World (in thousands)

1950		1960		1970		1980	
United States	8,005	United States	7,905	United States	8,283	Japan	11,042
United Kingdom	738	Germany	2,055	Japan	5,289	United States	8,009
Canada	387	United Kingdom	1,810	Germany	3,842	Germany	3,878
Soviet	362	France	1,369	France	2,537	France	3,378
France	357	Italy	644	United Kingdom	2,098	Soviet	2,199
Germany	306	Soviet	523	Italy	1,854	Italy	1,611
Italy	127	Japan	481	Canada	1,159	Canada	1,323
Australia	126	Canada	397	Soviet	916	United Kingdom	1,312
Japan	31	Australia	326	Spain	536	Spain	1,181
Czech	31	Brazil	133	Australia	473	Brazil	1,165
Korea	*n*[a]	*Korea*	*n*	*Korea*	28	*Korea*	123

1990		1991		1994	
Japan	13,486	Japan	13,245	United States	12,316
United States	9,783	United States	8,810	Japan	10,554
Germany	5,163	Germany	5,015	Germany	4,351
France	3,769	France	3,610	France	4,017
Soviet	2,134	Spain	2,081	**Korea**	**2,311**
Italy	2,121	Soviet	2,012	Canada	2,303
Spain	2,053	Italy	1,878	Spain	2,142
Canada	1,926	Canada	1,872	United Kingdom	1,694
United Kingdom	1,567	**Korea**	**1,497**	Brazil	1,580
Korea	**1,321**	United Kingdom	1,454	Italy	1,534

SOURCE: This table is based on *Market Data Book* published by *Automotive News*, 1995.

NOTES: For years 1950 through 1980, Korea was not in the top 10.
[a] n denotes negligible.

Korea's first automobile company, Daewoo, in a joint venture with General Motors (GM), was so constrained by GM's global corporate strategy that it found itself trailing Hyundai and Kia. Finally, after years of discord, Daewoo bought out GM's equity share in 1992 to pursue an independent global strategy.

The Korean government played a significant role in developing the automobile industry, imposing crises while providing supports to make those crises creative rather than destructive. For example, the government established a domestic content schedule in 1966, which it implemented through various incentive policies. The preferential allocation of foreign exchange was tied to the degree of localization achieved, consequently pushing the domestic content ratio from 21 percent in 1966 to more than 60 percent in 1972 and to 92 percent by 1981, transforming the assembly operation from an SKD to a completely knocked-down (CKD) arrangement.[10]

The government designated the automobile industry as a strategic sector to promote and offered, among other things, various preferential financing and tax concessions, which made it easy for producers to expand production facilities. As mentioned in Chapter 2, these two measures were among the most crucial the government employed in directing the private sector. The rapid industrialization should, however, be attributed as much to miraculously dynamic industrial activities at the firm level as to effective policy intervention.

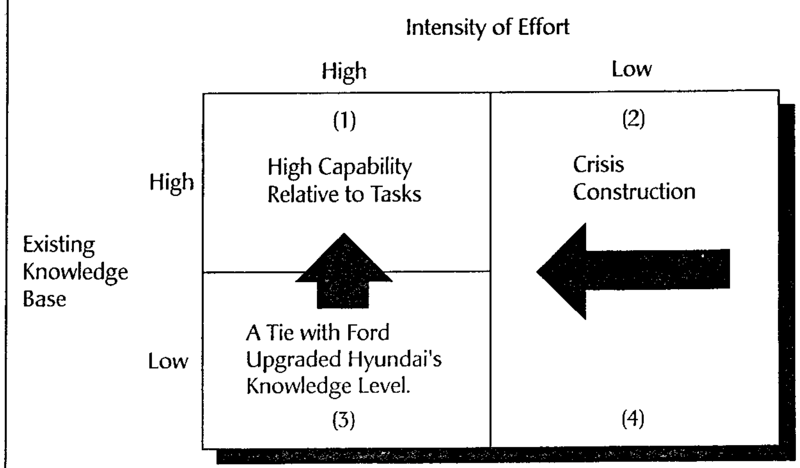
Initial Assembly Operation

Hyundai's entry into the automobile industry illustrates the way Korean automobile producers acquired their initial production capability. Lacking experience in automobile production at the outset, Hyundai formed a task force in 1967.[11] Team members with strong project management and engineering backgrounds came from Hyundai Construction, while others were poached from existing auto producers with auto production experience, providing requisite variety in experience and knowledge. The recruited engineers increased Hyundai's level of tacit knowledge related to automobile production.

In 1968 Hyundai entered an Overseas Assembler Agreement with Ford, whereby Hyundai was to assemble a Ford compact car on an SKD basis.[12] Ford transferred this technology in packaged form to Hyundai with explicit information, including blueprints, technical specifications, and production manuals. The agreement also provided for training Hyundai engineers at Ford sites and dispatching ten Ford personnel to Hyundai. This expedited the translation of Ford's explicit knowledge into tacit knowledge at Hyundai and to transfer Ford's tacit knowledge on procurement planning, procurement coordination, production engineering, process engineering, production management, welding, painting, marketing, and service to Hyundai. Other suppliers also sent engineers to set up equipment and train Hyundai technicians.[13] The most competent engineers trained by Ford were assigned to production and production engineering departments, because mastering production technology was most critical at the outset. In other words, the agreement with Ford enabled Hyundai to further upgrade both tacit and explicit knowledge related to auto assembly, moving up along the Y axis (toward higher prior knowledge level) in Figure 5-1.

At the same time, Hyundai constructed a crisis by setting an ambitious goal to accelerate plant construction in an attempt to minimize production lead time. Hardworking engineers, technicians, and construction workers lived together in makeshift quarters on the plant site, toiling sixteen hours a day, seven days a week. The crisis increased strong interactions among the members, intensifying various knowledge conversions spirally at the individual, group, and organization levels, moving Hyundai left along the X axis (toward higher intensity of efforts) in Figure 5-1, resulting in quadrant 1. Consequently, given

Figure 5-1 Dynamics of Hyundai's Capability Building



high prior knowledge and high intensity of efforts, Hyundai recorded the shortest time, six months, between groundbreaking and the first commercial production among the 118 Ford assembly plants around the world.

Hyundai also created a crisis for its production staff by setting an ambitious goal to acquire production capability in the shortest possible time. While plant construction was under way, teams rehearsed operations by disassembling and reassembling two passenger cars, a bus, and a truck over and over to routinize procedures, internalizing transferred explicit knowledge (production manuals) into tacit knowledge. At the plant's completion, workers had sufficient tacit knowledge to assemble cars with minimum trial and error. At the outset, technical emphasis was largely on mastering production capability to meet Ford's technical specifications. Rapid assimilation of production know-how enabled assembly process to evolve gradually from SKD to CKD operation.

Korean Car Development

In the aftermath of the first oil crisis and structural adjustments toward heavy and chemical industries, the government radically shifted its automobile industry policy from CKD assembly of foreign cars to the development of locally designed cars. Policy implementation to develop "Korean" cars was highly centralized by the government, personally directed by the nation's president at the top with the Ministry of Trade and Industry as a coordinating and implementing agency. In 1973 the government formulated the Automobile Industry Long-term Promotion Plan and ordered three passenger car makers—Hyundai, Kia, and Daewoo—to submit detailed plans to develop Korean cars. The president was briefed regularly on the progress.

The government plan was very specific. For instance, the indigenous model had to be new in the world, with a smaller than 1,500-cubic-centimeter engine and a local-content ratio of at least 95 percent, cost less than $2,000 to produce, and it had to be on the market by 1975. The government also specified a plant production capacity of more than 50,000 units per year when Korea produced merely 12,751 passenger cars annually. The government established seven principles to promote native model development and foster industry growth. These included, among other things, protection of the local market from new entrants and from new foreign knockdown imports, a significant tax reduction for locally designed cars, promotion of vertical integration leading to new business opportunities, preferential financing, tax concessions, and an administrative decree to guarantee a large market share for the Korean model.

This plan led to the appearance of two original new vehicles: Hyundai's Pony and Kia's Brisa. In response to the government's directive and incentives, in 1973 Hyundai submitted its master plan for a new plant with a capacity of 80,000 Korean cars, almost sixteen times the company's production of 5,426 cars that year, thereby constructing another major crisis. This was a major departure from the past strategy of merely assembling foreign cars. The plan required the development of a highly successful Korean subcompact car and a simultaneous drastic increase in both export volume and local market share in order to absorb the proposed production capacity. It was, indeed, a major crisis for Hyundai engineers. This event resulted in Hyundai's second major jump in technological learning.

Although lacking technological capability, Hyundai decided to obtain foreign technologies from many different sources in unpackaged form and integrate them on its own to maintain independence from foreign multinationals. Hyundai, however, had a clear goal of rapidly assimilating imported foreign technology in the shortest possible time. Prior knowledge accumulated from merely assembling largely foreign parts and components was inadequate for the new task. As the first step to overcoming the deficiency, Hyundai organized a project team whose members were to master literature related to various aspects of auto design and manufacture, accumulating tacit knowledge converted from explicit literature knowledge to enhance its prior knowledge level.

Hyundai approached twenty-six firms in five countries for various technologies: ten in Japan and Italy for style design, four in Japan and the United States for equipment in a stamping shop, five in the United Kingdom and Germany for casting and forging plants, two in Japan and the United Kingdom for engines, and five in the United Kingdom and United States for an integrated parts/components plant. These companies provided opportunities for Hyundai engineers to tour not only their sites but also those of the leading automobile manufacturing plants that had used suppliers' technology, enabling the highly motivated Hyundai engineers to relate the tacit knowledge derived from the printed word to physical operations. Through this process they gained significant insights into large-scale, modern automobile manufacturing systems. Hyundai then entered a licensing agreement with Italdesign for body styling and design and with Mitsubishi for gasoline engine, transmission, and rear axle designs and for casting technology. Engineers were sent to these suppliers for training.

How Hyundai assimilated style design technology is informative. It selected a team of five design engineers to study literature related to auto styling, then sent them to Italy to participate closely in the design process with Italdesign engineers. Hyundai set the team the ambitious goal of assimilating all of Italdesign's styling technology to enable them to undertake subsequent designs on their own, which the engineers were desperate to achieve. For a year and half, the highly motivated team shared an apartment near Italdesign, kept a record of what they were learning during the day, and conducted group reviews every evening. Such intensive interaction among the team members resulted in a most rapid spiral process of knowledge conversions and increased Hyundai's tacit and explicit styling knowledge significantly. These engineers later became the core of the design department at Hyundai, and one became the vice president in charge of R&D.

Although many engineers acquired necessary tacit knowledge related to different technologies, Hyundai did not have experienced engineers who could put them together. To minimize trial and error, Hyundai hired a former managing director of British Leyland as its vice president and six other British technical experts for the successful development of its first original model for three years (1974–1977), increasing the firm's prior level of tacit knowledge. These technical experts, as the chief engineers of chassis design, body design, development and testing, die and tooling, body production, and commercial vehicle design departments, played a crucial role in helping Hyundai engineers convert explicit knowledge supplied by licenses into tacit knowledge and to integrate diverse tacit knowledge into a workable system. After the British engineers left, Hyundai employed moonlighting Japanese engineers to troubleshoot problems.

Comparative Analysis

Although foreign direct investment is regarded as an important channel for transferring foreign technology to developing countries, this is not necessarily the case.[14] A comparative analysis of technological learning process and market performance between independent Hyundai and Daewoo, a joint venture with GM—the largest company with the largest R&D expenditures in the world—is instructive. Hyundai's approach constitutes a sharp contrast with the Daewoo-GM partnership, in which technical assistance was always acquired from the parent company. Technology transfer in a package contract or a joint venture is apt to lead to a passive attitude on the part of the recipient in the learning process, as the performance of the transferred technology is guaranteed by the supplier. In contrast, when a local firm unpackages technology transfer and independently takes the responsibility to organize imported technologies and components from multiple sources and to integrate them into a workable mass-production system, it does entail a major risk. But this forces and motivates local participants to assimilate foreign technologies as rapidly as possible throughout the process, because recipients, not the foreign suppliers, must take the total blame if it fails.[15]

That is how Hyundai developed its first model Pony with 90 percent local content in 1975, and it quickly improved its quality in subsequent years, making Korea the second nation in Asia with its own automobile.[16] As a result, Hyundai's local market share in passenger cars increased from 19.2 percent in 1970 to 73.9 percent in 1979. Hyundai exported 62,592 cars to Europe, the Middle East, and Asia, accounting for 67 percent of Korea's total auto exports in 1976–1980 and 97 percent of total passenger car exports from Korea in 1983–1986. Pony comprised 98 percent of Hyundai's exports during these periods.

In contrast, constrained by GM's global objectives, Daewoo had relied solely on GM for technology sourcing, having done relatively little in the way of developing its own technological capability and even less in developing its own product designs. The investment in product and process improvements undertaken by Daewoo between 1976 and 1981 was only 19 percent as great as those undertaken by Hyundai, although its production capacity, on average, was approximately 70 percent as large. As a result, though their products were comparable in engine size and price, Hyundai was operating at 67.3 percent of capacity compared with 19.5 percent for Daewoo in 1982 (see Table 5-3). The differential in labor productivity was just as stark; 8.55 cars per head at Hyundai compared with only 2.61 at Daewoo. Consequently, Daewoo had only a 17 percent passenger car market share compared with 73 percent for Hyundai, reflecting consumer preference.

Not until 1983, a year after taking over managerial control from GM, did Daewoo begin to show marked improvement in product/process development and market performance. Daewoo management established a full-fledged R&D department, adopted the Japanese *kanban* (just-in-time) system, streamlined production, instituted a quality control program, and strengthened its marketing drive. Nevertheless, conflicts between the partners continued to plague the joint venture, giving the smaller Kia a chance to outpace Daewoo. The 1992 divorce

Table 5-3 **Basic Parameters and Performance between Hyundai and Daewoo, 1982**

	Hyundai Motor	Daewoo Motor
A. Capital (million won)	64.4	44.5
B. Number of workers	9,129	5,675
C. Sales (billion won)	116,000	76,000
D. Production (cars)	78,071	14,845
E. Exports (cars)	13,573	114
Capacity utilization (E/D)	67.3	19.5
Labor productivity (E/B)	8.55	2.61
Capital productivity (E/A)	1,212.0	33.6
Export coefficient (F/E)	17.4	0.8
Market share	73.0	13.0

SOURCE: Adapted from Alice H. Amsden and Linsu Kim, "A Comparative Analysis of Local and Transnational Corportations in the Korean Automobile Industry," in Dong-Ki Kim and Linsu Kim, eds., *Management behind Industrialization: Readings in Korean Business* (Seoul: Korea University Press, 1989), 579–596.

from GM finally freed Daewoo to set its own global strategic direction and navigate at its own ambitious pace.

Export-oriented Transformation

The second energy crisis prompted another change in government policy to bring about greater scale economies at the cost of market competition, reducing the number of passenger car producers from four to two. The government's original rationalization program was to have only one Korean passenger car producer by merging the two largest companies—Hyundai and the Daewoo-GM joint venture—and by suspending production by the other two—Kia and Asia. While the latter two ceased passenger car production, the merger between the first two did not occur. GM assumed that it would retain half the share of all Korean automobile production and use Korea as one of many sites for manufacturing "GM world cars" within its global strategy. Hyundai, however, insisted that GM be limited to a minority position in the merged company, that Hyundai be given independent management control, and that Hyundai be allowed to pursue its own global strategy in both domestic and export markets. Since those involved

were unable to resolve their disagreement, the proposed merger was aborted. This failure signaled the waning influence of the state, marking the end of government-directed development and the beginning of industry-initiated growth.

The second oil crisis was also a disaster for the automobile industry. Gasoline prices soared, car sales nose-dived, and losses mounted. At this juncture Hyundai decided to make a major investment to develop the next generation front engine, front wheel drive (FF) car in order to push it in the North American market, attempting once again to turn the crisis into an opportunity.[17] Hyundai's proposed capacity was 300,000 units per year; at the time Hyundai was producing 57,054 passenger cars, using only 32 percent of its capacity (150,000 units), and Korea was producing a mere 85,693 units per year. Clearly, Hyundai was determined to turn the domestic market-oriented automobile business into a highly export-oriented one, a goal that industry analysts within Korea and abroad dismissed as total nonsense. But once again Hyundai constructed a major crisis and turned it into an opportunity, achieving its third huge leap in technological learning.

Hyundai approached several major automakers—Volkswagen, Ford, Renault, and Alfa Romeo—for FF technology as a way to diversify its technology sources. However, all these companies demanded equity and management participation and viewed Hyundai as a local assembly subsidiary for their FF cars. Hyundai eventually approached Mitsubishi again; in 1981 Mitsubishi had agreed to license engine, transaxle, chassis, and emission control technology to Hyundai. In return, Hyundai gave Mitsubishi a 10 percent equity share, but it did not include management participation.[18] Hyundai not only retained all managerial control but reserved the right to imports parts and technology from Mitsubishi's competitors and to compete directly in Mitsubishi's own markets. Hyundai, however, sourced body styling from Italdesign and constant velocity joint technology from British GKN and Japanese NTN.[19]

In addition, Hyundai acquired more foreign technologies from various automobile sources than its Korean competitors. Through 1985 Hyundai signed 54 licenses compared with 22 for Daewoo, 14 for Kia, and 9 for Ssangyong. Hyundai's sources included Japan (22), United Kingdom (14), United States (5), Italy (5), West Germany (3), and others (5), indicating significant diversity. Mitsubishi accounted for only half the licenses from Japan, reflecting Hyundai's independence in acquiring technological expertise.[20]

With the experience of developing and manufacturing Pony since 1976, Hyundai had a sufficient base of prior tacit and explicit knowledge to assimilate FF car design and manufacturing without assistance from the foreign engineers. There were, however, three important learning aspects at this stage. The first was manufacturing a car to meet the most stringent U.S. safety and environmental requirements. The second was adopting computer-aided design/computer-aided manufacturing (CAD/CAM) and assembly line control systems and developing a transfer machine. This led to full computerization from design to manufacturing and to parts/components handling at Hyundai, laying a critically important foundation for the firm to develop cars on its own. The third was the construction of a proving ground, completing the necessary infrastructure for its next strategy.

For the first aspect, Hyundai, in March 1979, organized a project team to develop a long-term plan to computerize design and manufacturing. The team collected literature and catalogs on CAD/CAM and spent the next fourteen months internalizing explicit literature into tacit knowledge. Based on that knowledge, the team purchased an IBM computer system and Toyodenki's plotter and undertook an in-depth study of Mitsubishi's CAD/CAM system in operation. The team was then expanded to include two or three representatives from each department that would be affected by the CAD/CAM system, "socializing" the tacit knowledge of the original members to the new members. During the next nineteen months the expanded team determined the scope of CAD/CAM application and undertook a comprehensive study of available alternative software packages. Hyundai selected the Catia program developed by French Dasso Aerospace in May 1982, then did preparatory work for almost thirty-six months before implementing the system.

Hyundai completed the FF plant in February 1985, tripling its capacity from 150,000 to 450,000 units per year. Its FF Excel passed both emission and safety tests in 1986 and began exporting to the U.S. market in February 1986. In that year Hyundai sold 168,882 Excels in ten months, exceeding its ambitious plan by more than 60 percent and turning its loss into profit. In 1987 Hyundai sold 263,610 more Excels in the United States; Excel became the best-selling import car of the year, overtaking Nissan's Centra, Honda's Civic, Subaru's DL/GL, and Toyota's Corolla. Hyundai's success in developing and exporting a subcompact appears to have prompted GM to source its Pontiac LeMans from Daewoo.

INNOVATION DRIVE IN THE AUTOMOBILE INDUSTRY

Although Hyundai was quite successful in pushing the Excel in the North American market in the mid-1980s, it soon faced a technological dilemma. Mitsubishi, its major source of important FF technology, and other foreign suppliers were unwilling to share their latest technology with Hyundai.[21] But Hyundai lacked the technological proficiency to keep up with its competitors in the North American market in improving car quality. Consequently, like the Japanese car exporters in the 1970s, Hyundai found its Excel listed at the bottom of *Consumer Reports'* automobile ratings, which fatally tarnished its image in the U.S. market. This experience prompted Hyundai to develop an extensive R&D network within Korea and abroad to acquire its own technological capability. "We didn't know the export market before, but now our eyes have been opened," said the president of Hyundai.

Originally Designed Models

"Korea's automakers take on the world again. The West once scoffed at Japan's plans to exports its cars. Now Detroit and other automakers may be underestimating this new global challenge too," warned *Fortune* magazine in 1995.[22] In 1994, for example, the fiercely independent Hyundai unveiled the Accent, the first subcompact it designed—its predecessors were based on Mitsubishi designs—which was benchmarked on the Toyota Tercel for performance and the Chrysler Neon for cost.[23] The new subcompact has energy-absorbing front and rear crumple zones, dual airbags with a state-of-the-art self-diagnostic sensing system, and a four-channel antilock brake system. A big success in both the domestic and export markets, it became the best-selling car in the domestic market and the unexpected rush of orders from abroad resulted in a three-month backlog. How has Hyundai Motor Company been transformed from imitative learning by doing to innovative learning by research?

Hyundai's R&D efforts date back to 1978, when the company established a primitive R&D laboratory to design face-lifts of existing compacts and subcompacts. Efforts to develop its own capability, however, began to take shape in 1984, when it opened its Advanced Engineering and Research Institute to develop its own engines and transmissions. The laboratory also spawned the Passenger Vehicle R&D Center for the design of new passenger cars and the Commercial Vehicle R&D Center for the development of new buses, trucks, and special vehicles. In addition, it set up the Manufacturing Technology Center to design its production system. To augment its in-house R&D, Hyundai established joint laboratories with research-oriented local universities, one with the Korea Advanced Institute of Science and Technology and the other with Pohang University of Science and Technology.

In 1986 Hyundai opened the Hyundai American Technical Center, Inc. in Ann Arbor, Michigan, to monitor technological change related to the automobile industry and to perform emission testing and the Hyundai Styling Studio in Los Angeles to sense the needs of American consumers. Furthermore, Hyundai set up a technical center in Frankfurt to attempt to monitor technological change in Europe and design and engineer new cars for the European market. Hyundai established an R&D center in Japan in 1995 as a step toward entering that country's market in 1997.

Hyundai's investment in R&D personnel and projects is impressive. First, as shown in Table 5-4, the number of research engineers at Hyundai has increased, from 197 in 1975 to 3,890 in 1994, accounting for nearly 10 percent of total employment. Almost half of them have a postgraduate engineering degree. Second, Hyundai recruited many Korean engineers from American universities, some with experience at General Motors and Chrysler. For instance, all but a few of the thirty-five senior research engineers with Ph.D.'s at its Advanced Engineering and Research Institute were trained in the United States. Third, Hyundai also invested heavily in further training for its engineers. The number of R&D scientists and engineers sent abroad for purposes of short-term training and observation to long-term graduate degree programs increased from 74 in 1982 to 351 in 1986. Fourth, its R&D investment also increased sharply from W 1.1 billion ($2.2 million) in 1975 to W 400 billion ($501.3 million) in 1994. R&D investment grew from 1.8 percent of sales in 1982 to 4.4 percent in 1994, almost 60 percent higher than that of such domestic competitors as Daewoo and Kia.

The development of its alpha engine illustrates how Hyundai struggled to become independent of Mitsubishi, which licensed Hyundai to produce its old engines but refused to share its state-of-the-art models. Lacking experience in designing even a carburetor engine, let alone an electronically controlled one, Hyundai determined to develop a state-of-the-art engine, creating another major crisis in technological learning. Despite skepticism that it would end up developing an engine comparable only to Mitsubishi's engine of thirty years earlier, in 1984

Table 5-4 R&D Investment at Hyundai Motor Company (in 100 million won)

	1975	1978	1982	1984	1986	1988	1990	1992	1994
Hyundai									
Sales	30	216	430	669	1,906	3,411	4,656	6,079	9,052
R&D	1.1	5.4	7.9	22.7	79.5	116.0	190.4	248.8	400.0
R&D as a percent of sales	3.5	2.5	1.8	3.4	4.2	3.4	4.1	4.1	4.4
Number of researchers	197	381	725	1,298	2,247	2,459	3,418	3,192	3,890

SOURCE: Adapted from data provided by Hyundai Motor Company.

Hyundai organized a task force directed by its executive vice president with a vision of developing the most modern engine. But no one on the team had any experience in engine design, and no car with an electronically controlled engine from which Hyundai engineers could learn was available locally.

The task force was divided into several groups: (1) research on hydrodynamics, thermodynamics, fuel engineering, emission control, and lubrication; (2) research on kinetics and dynamics related to engine and car design and CAD; (3) research on vibration and noise; (4) research on new ceramics; (5) research on electronics and control systems; and (6) research on manufacturing control and CAM. More than 300 R&D personnel received training overseas before the engine project was officially launched in 1984. The team members collected all available English and Japanese literature about engines and transmissions and mastered the contents to raise their tacit knowledge. Hyundai then entered into an agreement with British Ricardo Engineering, which provided initial assistance in technical training for engine design. Next, Hyundai hired two Korean experts who had gained engine development experience with Chrysler and General Motors after earning Ph.D.'s at American universities. In 1985 Hyundai hired an experienced engineer from Ricardo for three years.[24]

Despite the training and consulting services of Ricardo and the three experts, Hyundai engineers repeated trials and errors for fourteen months before creating the first prototype. But the engine block broke into pieces at its first test. New prototype engines appeared almost every week, only to break in testing. No one on the team could figure out why the prototypes kept breaking down, casting serious doubts, even among Hyundai management, on its capability to develop a competitive engine. The team had to scrap eleven more broken prototypes before one survived the test. There were 288 engine design changes, 156 in 1986 alone.[25] Ninety-seven test engines were made before Hyundai refined its natural aspiration and turbocharger engines; 53 more engines were produced for durability improvement, 88 more for developing a car, 26 more for developing its transmission, and 60 more for other tests, totaling 324 test engines. In addition, more than 200 transmissions and 150 test vehicles were created before Hyundai perfected them in 1992.

Despite the doubters, Hyundai's alpha engine outperformed comparable Japanese models. Hyundai's natural aspiration engine took 11.1 seconds to reach 100 kilometers per hour compared with 11.3 seconds by the Honda CRX 3V. Hyundai also outperformed Honda in

fuel efficiency. Success in developing the alpha engines (1.3 and 1.5 liters) led to the development of beta engines (1.6, 1.8, and 2 liters), making Hyundai completely independent of foreign licensing in engines for midsize, compact, and subcompact cars. Hyundai's new 1.8 liter, 16-valve double overhead camshaft engine, for example, takes only 9 seconds to reach 100 kilometers per hour, outperforming a similar model of Japan's Toyota.[26]

Hyundai invested $437.5 million and spent fifty-two months perfecting the Accent, its subcompact with the alpha engine. The company freed teams of its engineers to come up with the car they would buy and gave them a Cray supercomputer to help incorporate such safety features as antilock brakes and dual airbags in the snazzy design. "We have created an eye-catching design that will appeal to the young," said a young engineer at Hyundai's engineering center.[27] In 1995 Hyundai unveiled the Avante, a new compact with the beta engine. These two models obviated further royalty payments to foreign automakers.

Hyundai is still behind the high-class Japanese and U.S. manufacturers, but the quality gap has definitely narrowed. Its aim is to meet Japanese quality but at a more competitive price.[28] Nevertheless, Hyundai became an important technology exporter, earning royalties for its exports to Thailand, Egypt, Zimbabwe, the Philippines, Malaysia, and elsewhere. For instance, Hyundai received about $900,000 as a down payment and a running royalty of $90 per car from a Malaysian automaker.

Innovating and improving car quality by enhanced R&D operations, Hyundai won several quality accolades overseas. Canada selected Elantra as the car of the year in 1992. It also won first place at international auto rallies in Australia, Greece, and Malaysia. The National Road and Motorists Association of Australia selected the Elantra as the best car in 1992 and 1993.

As a result of continual R&D efforts, Hyundai sustained the largest domestic market share during the first quarter of 1995, when its Accent was the best-selling subcompact, the Avante the best-selling compact, the Sonata II the best-selling midsize car, and the Grandeur the best-selling full-size car in Korea. Hyundai also bounced back in exports, particularly in new markets, from 225,393 in 1990 to 392,239 in 1994. In Australia, for one, Hyundai is the best-selling import car, representing 13.8 percent of total imports, beating Mazda's 13.6 percent, Honda's 10.4 percent, and Toyota's 9.7 percent. Hyundai also took first place among foreign auto sales in Brazil and Puerto Rico.

Beginning with exports of 1,042 Ponys in 1976, Hyundai exported one million cars by 1988, another million by 1991, and its third million by 1994, accounting for 42 percent of its total production and 68 percent of Korea's total auto exports.[29]

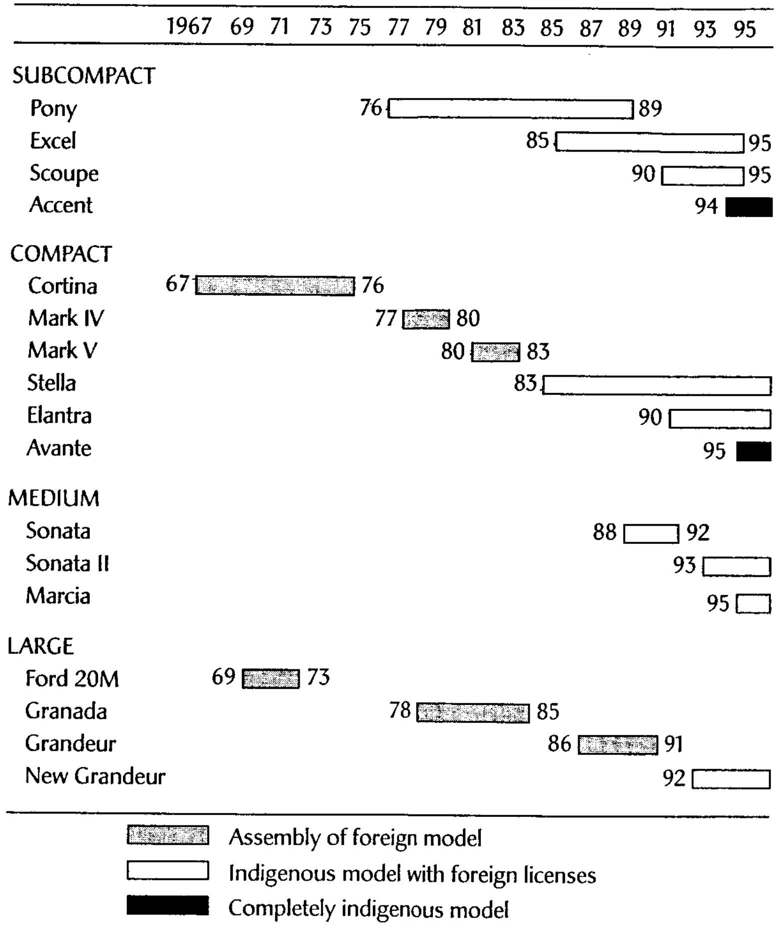
Hyundai increased its output approximately tenfold every decade. It had taken Toyota twenty-nine years and Mazda forty-three years to produce one million cars;[30] it took Hyundai only eighteen.[31] Hyundai Motor was the thirteenth largest automobile producer in the world and the largest in the Third World in 1994, having steadily ascended from sixteenth in 1991. Aspiring to place among the global top ten by the year 2000, Hyundai is expanding its manufacturing capacity, adding another 400,000 cars per year in 1996 to its previous volume of 1.26 million.

Hyundai is spending more than $5 billion on R&D from 1995 to 2000 in a bid for a breakthrough in environmentally friendly cars, lifting its R&D outlay from 4.4 percent of sales in 1994 to 7 percent by 2000. The proportion of R&D funds devoted to environmentally friendly vehicles will rise from 40 percent to more than 60 percent. Hyundai is working on two alternatives—electric-and solar-powered vehicles. It began to concentrate on electric cars in 1991 and more recently entered into a cooperative agreement with the U.S. Ovonic Battery, which produces a nickel-metal hydrogen battery. The research with Ovonic was expected to provide a key to commercial production of electric cars by the end 1996, within twelve months of new U.S. vehicle emission restrictions. In other words, Hyundai is still determined to become a player in the United States, the world's largest car market.[32]

Sequence of Product Development

Figure 5-2 and Table 5-5 summarize the foregoing discussions, illustrating how Hyundai sequenced product development and accumulated technological capability. Figure 5-2 shows that Hyundai first acquired production experience in the assembly of foreign compact and large models for the eight years from 1968 to 1976 before it attempted to develop its own model. Inexperienced Hyundai had to enter into technical assistance agreements with many foreign suppliers. As new vehicle development sequenced from subcompact to compact to medium-size and large cars, the number of years between them decreased steadily. It took seven years (1976–1983) between subcompact and compact, five years (1983–1988) between compact and medium-size, and four years (1988–1992) between medium and large cars. Hyundai's completely native model also sequenced from subcompact

Figure 5-2 New Product Development at Hyundai



SOURCE: Based on Young-suk Hyun, "The Road to Self-reliance: New Product Development at Hyundai Motor Company," paper presented at the International Motor Vehicle Program Annual Sponsors Meeting, Toronto, June 4–7, 1995, Table 4.

Table 5-5 Increasing Localization of Technology for Indigenous Models

	Year Developed	Styling	Body Design	Power Train	Chasis Layout	Total
Subcompact						
Pony	75	1	1	1	1	4
Excel	85	1	3	1	2	7
Scoupe	90	3	3	3	2	11
Accent	94	3	3	3	3	12
Compact						
Stella	83	1	3	1	2	7
Elantra	90	3	3	1	2	9
Avante	95	3	3	3	3	12
Medium-size						
Sonata	88	3	3	1	2	9
Sonata II	93	3	3	1	2	9
Marcia	95	3	3	2	3	11

SOURCE: Based on Gyun Kim, "A Study of the Development of Technological Capability of Korea in the 1980s," Ph.D. diss., Department of Economics, Seoul National University, 1994, and Young-Suk Hyun, "The Road to Self-reliance: New Product Development at Hyundai Motor Company," paper presented at the International Motor Vehicle Program Annual Sponsors Meeting, Toronto, June 4–7, 1995.

NOTES: 1 = Under licensing.
2 = Improved based on licensed technology.
3 = Completely indigenous.

(1994) to compact (1995), requiring a single year. It is logical for an inexperienced company in a catching-up country to begin with a subcompact model, as its competitive edge rests more on price than quality in comparison with larger models.

Table 5-5 provides a more detailed picture of technological learning at Hyundai over the years. Hyundai developed the Pony in 1975 under foreign technical assistance with the localization score (degree of indigenous inputs in car design) of four. It then designed the body for Excel and improved its chassis layout on the basis of imported technology with a localization score of seven, showing a significant stride in technological learning. The score increased to eleven for Scoupe and twelve for Accent. A similar trend is also apparent in compact and medium-size models. It is interesting to note that the starting score was seven for compact and nine for medium-size models, proving that experience accumulated in one model provided a platform for a subsequent model and so on up the line.

SUMMARY

Despite skepticism that Korean automakers would survive the global shakeout of the 1990s, Korean chaebols have enjoyed phenomenal growth in the past three decades to comprise the fifth largest producer in the world. Unlike that of other developing countries, their increase was initiated and driven largely by local firms. Hyundai illustrates how Korean firms expedited technological learning in a short time.

Hyundai has been the most vibrant in technological learning among automobile companies in catching-up countries, having transformed itself from a mere assembler of Ford cars to a designer of its own cars and engines. Assembly technology from Ford in 1967 and various other technologies imported from sundry sources to produce Pony in the mid-1970s were mature and at the specific stage in advanced countries. Assimilating and improving these technologies through learning by doing enabled Hyundai to challenge more advanced technologies related to front engine, front wheel drive cars. Core technologies were again imported from advanced countries. Mastering the FF technologies provided a platform for Hyundai to develop state-of-the-art engines. In other words, Hyundai reversed the sequence of technological trajectory in advanced countries.

Many institutions played an important role in Hyundai's rapid progress. Hyundai Construction, existing auto producers, and military vehicle renovation depots provided crucial tacit knowledge at the outset. British Leyland engineers played a significant role in integrating technologies imported from various sources and expediting technological learning. Foreign suppliers such as Ford, Italdesign, Mitsubushi, and Ricardo Engineering provided important technologies at critical points. Crisis construction and hardworking Korean engineers and production workers enabled Hyundai to acquire, assimilate, and improve imported technologies.

Unlike firms in other developing countries, Hyundai pursued an independent strategy in fostering technological capability. Its process of advancing from one stage to the next through the preparation for, and the acquisition, assimilation, and improvement of foreign technology appears to be spiral. Both the acquisition of prior knowledge and intensity of effort played a major role in expediting technological learning.

First, in catching-up firms, relevant knowledge is available elsewhere in various forms. The acquisition of prior knowledge through literature review and poaching of experienced personnel may be effective ways of identifying and acquiring technology and facilitating learning in the subsequent phases. The mobility of trained personnel has been a major source of new tacit knowledge at Korean firms and of technology diffusion in many Korean industries. Like the Japanese, Korean firms implicitly guarantee lifetime employment. But unlike the Japanese, Korean workers enjoy great freedom to hop from one firm to another as opportunities open in industrial expansion. As a result, the average monthly turnover rate of Korean manufacturing firms is more than 5 percent, even higher than the 4 percent of the United States and more than double that of Japan.[33] Such high mobility resulted in the rapid diffusion of technology within and across the industry in Korea.

Second, crisis construction was a major means of opportunistic learning and a valuable facilitator of technological transformation at Hyundai and other Korean firms. Crises preempted opposition to change and served as an antidote to inertia, enabling the company to marshal consensus on goals. Crises also boosted the intensity of efforts, rendering them creative rather than destructive. The construction and resolution of crises are characteristically grounded in a prophetic, single-minded vision of a proactive manager's creative thinking. That is, crisis construction is an evocative and galvanizing device in the personal repertoires of visionary top managers.[34] An entrepreneurial tycoon of family-owned Korean *chaebols* might enjoy a more advantageous position than employed managers in constructing and resolving crises.

As a result, Hyundai was able to maintain its position in quadrants 1 and 3 in Figure 5-1, rapidly learning to catch up with leading automakers in advanced countries. After four major jumps in technological learning, Hyundai is in a position to generate new knowledge in order to survive not only in the international market but also in the domestic market, which will open to Japanese producers in the near future. Hyundai is doubling its production capacity to ascend to tenth largest automaker in the world by the year 2000, and it planned to increase

its R&D investment from 4.4 percent of sales in 1994 to 7 percent in 1995 and beyond. As long as Hyundai manages to construct and resolve crises (intensifying efforts) and increase its R&D investment (raising knowledge level) in the future, it will remain a contending Korean automobile producer.

6 The Electronics Industry: From Reverse Engineering to Strategic Alliance

Its electronics industry surged so rapidly in one generation that Korea became the fourth largest producer in the world in 1994, after the United States, Japan, and Germany[1] and the second largest producer of consumer electronic products since 1990, after Japan.[2] Unlike that of other developing countries, such growth has been largely driven by Korean *chaebols* and other local firms rather than by multinational subsidiaries or joint ventures.[3]

Although small-scale assembly of vacuum tube AM radios for the domestic market started in 1958, the Korean electronics industry really got its start in the mid-1960s with the production of black and white TV sets and audio equipment through the international transfer of production technology. Since then, Korea's production, excluding parts and components, has grown remarkably, from $47 million in 1970 to $22.5 billion in 1994, as shown in Table 6-1. The consumer electronics industry has been heavily export oriented, foreign shipments accounting for 73 percent of production in 1975, 75 percent in 1981, and 53 percent in 1991.

The industry is highly concentrated. Although small and medium-size firms have mushroomed, four *chaebols*—LG,[4] Samsung, Daewoo,

Table 6-1 Growth of the Electronics Industry (in millions of dollars)

	1968	1970	1975	1980	1985	1990	1994
Production							
Consumer products	12.9	30.4	270.0	1,148	2,669	10.141	12,621
Industrial products	6.7	17.4	93.6	364	1,518	6,345	9,892
Total	19.6	47.8	363.6	1,512	4,187	16,486	22,513
Exports							
Consumer products	0.1	9.0	198.3	1,020	1,752	5,727	7,319
Industrial products	3.6	0.4	35.8	169	783	3,481	5,807
Total	3.7	9.4	234.1	1,189	2,535	9,208	13,126

SOURCE: Korea Development Bank, *Korean Industry in the World, 1994* (Seoul: Korea Development Bank, 1994).

and Hyundai—have dominated production and exports. The oligopolistic market structure led to significant competition among them. LG Electronics (brand name GoldStar) is the pioneer of Korea's electronics industry and a pillar of the LG chaebol. It produces more than 150 items, ranging from home appliances to minicomputers, with nine overseas manufacturing bases, 62 marketing subsidiaries, 5 R&D outposts around the world, and is still expanding its overseas operation rapidly. It sold $6.4 billion and exported $3.6 billion (50 percent) in 1994.

Samsung joined the industry in 1969, eleven years after LG. Investing heavily in technology and human resource development, it became a multibillion-dollar, Korea-based multinational electronics firm with 8 production bases, 43 marketing subsidiaries, 9 R&D outposts, and 2 service firms around the world. Sales totaled $14.6 billion and exports $10 billion (68 percent) in 1994. Among all firms in developing countries, Samsung is considered the most technologically aggressive with the largest pool of engineers. If its semiconductor and telecommunication businesses are excluded, it competes neck and neck with LG.

Daewoo entered the industry in 1983 by acquiring the dwindling Electronics Division of Taehan Electric Wire Company.[5] After the take-

over, Daewoo Electronics, with an aggressive globalization strategy, grew rapidly from $1 billion in 1986 to $3.2 billion in 1994. With 23 production bases, 26 marketing subsidiaries, and 3 research outposts overseas, Daewoo is the most enterprising of the *chaebols* in exploring emerging markets.

Hyundai Electronics, the youngest and smallest of the four electronics industry *chaebols* does not produce consumer electronics. Including its semiconductor and telecommunication businesses, it had sales of $2.59 billion and exported $1.89 billion (72.9 percent) in 1994. Hyundai, the most active in acquiring high-tech companies in advanced countries in an attempt to gain access to cutting-edge technology, has 8 overseas subsidiaries and 5 joint ventures around the world. How has the industry thrived so rapidly in one generation?

IMITATION DRIVE IN THE ELECTRONICS INDUSTRY

The state played a crucial role in the rapid growth of this industry, particularly during the early years. The government's import-substitution policy and tight control of foreign investment and contraband goods in the black market created attractive business opportunities for local entrepreneurs to enter the protected market in the early 1960s. However, growth was slow until late 1969, when the government designated electronics a strategic export industry.

The government promulgated the Electronics Industry Promotion Act in 1969 and released an ambitious Long-term Electronics Industry Promotion Plan;[6] it created the Electronic Industry Promotion Fund, offering preferential financing to foster scale economies in production as well as grants to develop and upgrade public support systems for standardization and R&D. The government also targeted ninety-five products for promotion, offering preferential financing and other incentives to their manufacturers. Yearly production targets were established. Progressive local content requirements were set to promote the parts and components industry. End products for the local market were completely protected from foreign competitors. Foreign investment was allowed largely in the production of parts and components and for re-export, and the government created an industrial estate for electronics to give rise to interfirm efficiency.

The plan included the government's determination to promote the electronics industry as a leading exporter. In 1969, when the industry was still exporting a mere $42 million, the government set the goal at $400 million for 1976, the last year of the plan. Preferential financing, tax concessions, foreign loan guarantees, and the control of entry by new firms formed the crux of the export drive. That is, the government not only set specific export goals and directives, forcing local firms to be competitive in both price and quality in the international market, it also provided incentives. This scheme induced a crisis, compelling local firms to acquire technological capability quickly while providing supports to make the crisis creative rather than destructive. Since marketing was largely in the hands of buyers from foreign original equipment manufacturers, local firms concentrated mainly on the acquisition of product design and production capabilities. In 1976, exports exceeded $1 billion, almost 259 percent of the established target, illustrating the extent of rapid learning in production and product design accomplished by the industry.

The government also took the initiative in organizing a yearly electronics show in an attempt to promote the diffusion of technical ideas in the economy and international marketing for Korean firms. In short, while the government played an important role in all strategic industries, its role in the electronics industry was extraordinary in the early years. Under this public policy environment, electronics firms have grown rapidly as a highly export-oriented industry.

Korea's first consumer electronics producer, LG Electronics, was begun in 1958 by the owner of a small, rudimentary face cream and plastic housewares company, which sensed an attractive business opportunity in the import-substitution policy. Lacking technological capability, the company hired an experienced German engineer to upgrade its tacit knowledge base. At about the same time, the company president embarked on an observation tour of several leading electronics firms in Japan, Europe, and the United States. The vision he formed from it and the German engineer led to LG's first business. In a small-scale garage operation, foreign components and parts were assembled into the first vacuum tube AM radio in the country through imitative reverse-engineering of a Japanese model.[7] The German played a key role in ordering the necessary equipment to set up the production system and training Korean technicians and assembly line workers. The tacit knowledge transferred from the German engineer to his Korean counterparts began to build technological capability at the organizational level. Assimilating the product design and assembly operation was so simple that relatively well-educated Korean engineers acquired enough tacit knowledge to replace the German within a year.[8] LG Electronics soon developed expertise in imitation and began producing such other home appliances as electric fans and refrigerators without foreign assistance.

Television Sets

LG Electronics imported several black and white television receivers to decide whether TVs could also be imitatively reverse engineered. Although LG had accumulated radio design and production experience for several years, it was beyond the firm's capability to reverse engineer TVs mainly because of the significantly large number of parts/components required and TV's greater technological complexity. Thus, in 1965 LG found it necessary to enter into a licensing agreement with Hitachi of Japan to import packaged technology for black and white TV production. The agreement included not only assembly processes but also product specifications, production know-how, parts/components, training, and technical experts, transferring a significant volume of explicit and tacit knowledge to LG Electronics, which sent seven experienced engineers and technicians to Hitachi for intensive training. This group was given the important task of assimilating and mastering TV production technology. Renting an apartment together, the engineers held group sessions every evening, reviewing and sharing the literature they had collected, their observations, and their training, facilitating rapid learning by the team; they played a pivotal role on their return home.

Even though it invested enough for licensing and overseas training, LG decided to have Japanese engineers supervise the installation and start-up of TV production systems to minimize trial-and-error time. These people played the most vital role in the initial implementation of transferred Japanese technologies by transferring their tacit knowledge to LG engineers and helping them internalize explicit knowledge such as production/quality control manuals and technical specifications. But the utility of the Japanese diminished within a year as the local Hitachi-trained technical personnel acquired enough tacit knowledge through production and design experience.

LG Electronics was able to apply the manufacturing competence accumulated over the years to subsequent assembly of other consumer electronics, such as cassette recorders and simple audio systems, without foreign assistance. The rapid assimilation of imported technologies and their application to other products may be attributed largely to the founder's entrepreneurial strategy of acquiring technological independence and fostering high intensity in learning efforts by relatively well-educated native technical personnel.

Three other TV set producers that started at about the same time acquired and assimilated production ability the same way. Subsequent entrants—ten by 1975—however, lured experienced engineers and technicians from existing firms, resulting in effective diffusion of tacit knowledge from established firms to new ones. LG Electronics, as the first and largest producer, was a major source of such personnel for new entrants. A similar pattern is evident in other electronic products of the same period.[9]

When black and white television sets eventually encountered a rapid decline in the export market, the color TV set became the next target appliance to sustain increasing exports. For black and white TVs, the Korean companies had moved up the production learning curve on the strength of the protected local market prior to competing in export markets. Color TV producers would, however, have to export from the start, because Korean channels did not broadcast in color.

No foreign color TV maker was willing to license technology to Korean makers to help them invade the U.S. market anew. LG Electronics and two other major firms jointly entered into a research contract with the Korea Institute of Science and Technology (KIST), a government R&D institute (GRI), to gain enough knowledge and experience in color TV technology. Experience gained from black and white receivers and learning from the joint research enabled local firms to strengthen their bargaining power in licensing core patents held by RCA in 1974. The R&D team worked around the clock for two years, searching and mastering foreign literature, reverse engineering foreign color TVs. After a series of trials and errors, LG developed a working model of its own color television set. It took another year to set up a mass-production system.

Microwave Ovens

The videocassette recorder and the microwave oven were next targeted for development. Both products went through a similar process. Samsung's approach to developing and commercializing microwave ovens illustrates how Korea acquired the necessary technological proficiency initially through reverse engineering and subsequently dominated the world market.

Intrigued by a new oven heated by microwaves, Samsung approached several Japanese and U.S. producers to license the technology. Turned down by them, Samsung, on the basis of its consumer electronics experience, formed a team in 1976 to design its own microwave oven by reverse engineering a foreign model for export markets, as few Koreans could afford it. Ira Magaziner and Mark Patinkin recount how Samsung reverse-engineered the oven and became one of the world's leading producers.[10]

Samsung had purchased a number of the world's top microwave ovens to choose the best parts of each for its prototype, which provided invaluable explicit knowledge to the firm. The team took the ovens apart, but its tacit knowledge was inadequate to figure out how they worked. Wiring and assembly of the case appeared simple, but many complex parts, including the magnetron tubes that generated the microwaves, were beyond Samsung's tacit knowledge. With only three magnetron producers, two in Japan and one in the United States, Samsung decided to source magnetron tubes from Japan.

It took the team a year of eighty-hour weeks to complete the first prototype, but the plastic in the cavity melted in a test. After more eighty-hour weeks of redesigning and readjusting, the second could not survive a test; this time the stir shaft melted. Finally, in June 1978, after two years, the team developed a model that survived the test; but it was too crude to compete in the world market. Samsung incrementally improved the product and developed a makeshift production line, producing one oven a day, then two, which it placed in local bakeries for feedback from users. The successful development of microwave ovens strengthened the bargaining power of Samsung to negotiate technology licensing with patent holders enabling it to acquire the necessary licenses to clear its way to the export market.

This was a common experience in Korea. When foreign firms were reluctant to transfer technology to emerging Korean competitors, Korean firms reverse engineered the technology. It was only after these firms successfully commercialized the product that foreign firms reluctantly licensed technology to them. It is useful at this point to differentiate the reverse engineering of mature, simple products in the early years from the advanced reverse engineering of sophisticated products to obtain licenses for valid patents. In this case, the purpose of licensing was not to learn technology but to pave the way into the export market.

Samsung decided to try its sales push in 1979, when it obtained Underwriter's Laboratory approval and produced more than 1,000 microwave ovens; in excess of 5 million were then being sold worldwide. In April 1980, the first order, for 240 ovens, came from Panama.

Samsung also sent 1,655 units to the United States and 3,230 to the United Kingdom to test their markets, taking the opportunity to learn the needs of overseas consumers.[11]

Samsung's lucky break came in late 1980, when J. C. Penney inquired whether Samsung could manufacture a low-priced microwave oven to sell for $299 in the U.S. market; the ovens were then selling for $350 to $400. Although the order entailed a completely new design and heavy losses, Samsung accepted it to gain a foothold in the most sophisticated market in the world and to turn a primitive assembly line into an efficient large-scale system. Penney extended technical assistance to the Samsung team to ensure that its ovens would meet Penney's technical specifications.

Turning a primitive assembly line for five or six ovens a day into an efficient production system to meet the first Penney delivery date, only months away, was a major crisis for Samsung. Engineers and technicians labored around the clock; they began at dawn, worked until 10:30 P.M., took a brief nap, then went back to work for the rest of the night. The line took shape and production began, but debugging was inevitably necessary. Because the company couldn't afford to lose production, the personnel manufactured by day and fine-tuned the line at night. Production improved to ten ovens a day, then fifteen. Soon they were making 1,500 a month, enough to meet Penney's first order. Penney liked the ovens and a month later asked for another 5,000 and another 7,000 the following month. Again Samsung worked around the clock to meet the deadlines. Rapid growth in production accelerated learning by doing at Samsung.

Samsung's cost advantage, however, had been eroded by large producers, whose process innovations brought their prices down. To bring its cost down, Samsung had to develop its own magnetron tube, which it still sourced from Japan. Samsung approached two Japanese producers for technical licensing but was turned down. Then, in 1982, Samsung bought and transplanted to Korea the only U.S. factory that produced magnetron tubes, which was going out of business because it could not compete against Japan. Samsung invested heavily in improving productivity by automating its production processes, enabling it to sustain its price competitiveness.

Samsung's rapid assimilation of design and production technology of microwave ovens stemmed largely from the way its engineers and technicians worked. When General Electric (GE) decided to outsource its microwave ovens, the head marketing manager for Appliances asked Samsung managers for a proposal on cost breakdowns, production plans, and a delivery schedule. The next morning, "a group of engineers came in and they gave us their proposal. Their hair was messed up, their eyes bloodshot. Those guys had worked all night." Samsung engineers completed overnight a proposal that would have taken U.S. companies four to six weeks to develop.[12] GE sent its engineers to Korea to outline its technical specifications. Well-trained Korean engineers with enough tacit knowledge and high intensity of effort took advantage of the opportunity to absorb world-class skills from them.

"It was my first glimpse of Samsung since 1977 . . . I went to the R&D lab. It had gone from an old high-school science room to a large, modern operation. Instead of a handful of engineers, there were 500. Everything Samsung had said in 1977 that it would do, it had done," reported Magaziner and Patinkin.[13] Since then, Samsung's R&D projects have led to seventy-four local patents and six overseas patents related to microwave oven technology, enabling Samsung to become one of the most dynamic microwave oven makers in the world. Samsung's production rose more than a hundredfold in two years, from 1,283 in 1979 to 137,931 in 1981, almost tripled the following year, then doubled again in 1983. In 1984, only five years after its first crude, imitative prototype, Samsung's microwave production topped 1.3 million units. By 1994 Samsung was producing 4 million ovens in Korea and 0.8 million more abroad per year, controlling 17 percent of the global market. The world's second largest producer, Samsung trails only Sharp of Japan by a small margin. More than 95 percent of Samsung's production is exported.

Samsung's success in developing the microwave oven prompted LG and Daewoo Electronics to follow. LG first approached Sharp for technology transfer only to be turned down. In 1980, four years after Samsung's entry, LG Electronics organized a task force to develop a microwave oven. The late entrants stole experienced engineers and technicians from Samsung, bringing about effective diffusion of oven technology to the rest of the Korean electronics industry. It took two years for pioneering Samsung to develop its successful prototype, but it took LG only eight months to come up with a successful model, as the Samsung engineers provided a platform. LG Electronics then acquired the necessary licenses to export the product. Samsung magnetron technology even helped LG to license the magnetron tube technology from Hitachi, which had previously refused to license it to Samsung. Now LG produces as many microwave ovens as Samsung. Expansion under way in overseas production increased the three *chae-*

bols' capacity to 5 million units each and Korean firms surpassed Japan to become the largest microwave oven producer in the world in 1996.

INNOVATION DRIVE IN THE ELECTRONICS INDUSTRY

The government played a useful role in creating a demand for technological innovation in recent decades. For instance, the import-substitution policy created a growing market for the computer industry in the early 1980s.[14] The government imposed import restrictions on personal computers (PCs) and peripherals, creating a protected market for small local firms to enter and survive long enough to gain first-stage learning experience in PC manufacturing. The market was later liberalized in 1987 under pressure from the United States.

In addition, the government issued its own procurement orders to create an early domestic market, announcing in 1982 that it intended to purchase 5,000 PCs for public schools in 1983 and increasing the numbers thereafter. The government then created the National Administration Information System (NAIS), investing $170 million by 1988 and $555 million by 1995 and creating demand for more than 80 main computers and about 5,000 workstations. In addition, the government launched computerization of the postal system, the tax system, the national defense system, and the education-research network system, each of which required as much investment in both hardware and software as the NAIS. In procuring merchandise, the government first set technical specifications and targets for the local content ratio, then awarded contracts to the firms that met the requisites. These announcements attracted many newcomers to the industry and induced aggressive investment for in-house R&D to meet the government requirements.

The government also played a significant role in the supply side of technology, establishing several GRIs. The Korea Institute of Electronic Technology (KIET) was set up several years prior to the private sector's entry into computers and semiconductors in an attempt to gain first-stage experience in R&D on new technologies and to produce experienced researchers. KIET, which invested more than $300 million between 1980 and 1984, was sold to a private firm when the private sector had matured sufficiently to undertake the type of design work for which that institution was previously responsible. KIST played a pioneering role by developing prototypes of computers, robotics, and computer-aided design/computer-aided manufacturing. The Electronics and Telecommunications Research Institute played a coordinating role in a consortium with many local firms in developing computers, electronic switching systems, and semiconductor memory chips.

Intensifying R&D Efforts

Given the policy environment and increasingly dynamic market, Korean electronics firms have drastically expanded in-house R&D ventures, establishing several laboratories. LG Electronics, for example, developed an extensive R&D network, shown in Figure 6-1. It also established ten independent R&D centers, six product-specific R&D centers, and five overseas R&D centers. Samsung, Daewoo, and Hyundai Electronics also instituted extensive R&D networks at each strategic business unit in Korea. In addition, Samsung and Daewoo developed an Institute of Advanced Engineering to focus on long-term R&D projects, which set new directions for these companies. LG's Central Laboratory performs a similar function.

Chaebol electronics firms also initiated R&D networks with leading universities by placing their R&D laboratories on campuses in an attempt to augment their in-house R&D projects. With full funding from *chaebols*, Seoul National, Korea, Yonsei, and Hanyang Universities, and Korea Advanced Institute of Science and Technology (KAIST), have constructed large-scale laboratories to be occupied jointly by university and corporate personnel, marking a turning point in university-industry collaboration. LG Electronics, for example, developed a joint R&D laboratory at KAIST, a research-oriented graduate school of applied science, to develop digital measurement, factory automation, a manufacturing information system, and precision fabrication.

The dynamic growth of R&D at Samsung may be seen in Table 6-2. At Samsung Electronics, R&D spending increased drastically from W 5.6 billion ($8.5 million) in 1980 to W 713.3 billion ($905 million) in 1994. Investment has grown much faster than sales, raising its ratio to total sales from 2.1 percent to 6.2 percent during the same period. Consequently, Samsung Electronics has led Korean industries in R&D spending and patent registration. Its patent registrations rose from 17 in 1985 to 1,413 by 1994. Its foreign patent registrations also rose from 2 to 752 in the same period. The number of researchers grew from 690 in 1980 to 8,919 by 1994. The growth rates at other electronics firms are similar. Most leading research scientists and engineers were trained in the United States, Germany, and Japan, some bringing with them extensive experience in leading foreign electronics R&D laboratories.

Globalization of R&D rapidly expanded the boundaries of R&D

Figure 6-1 LG's R&D Organizations

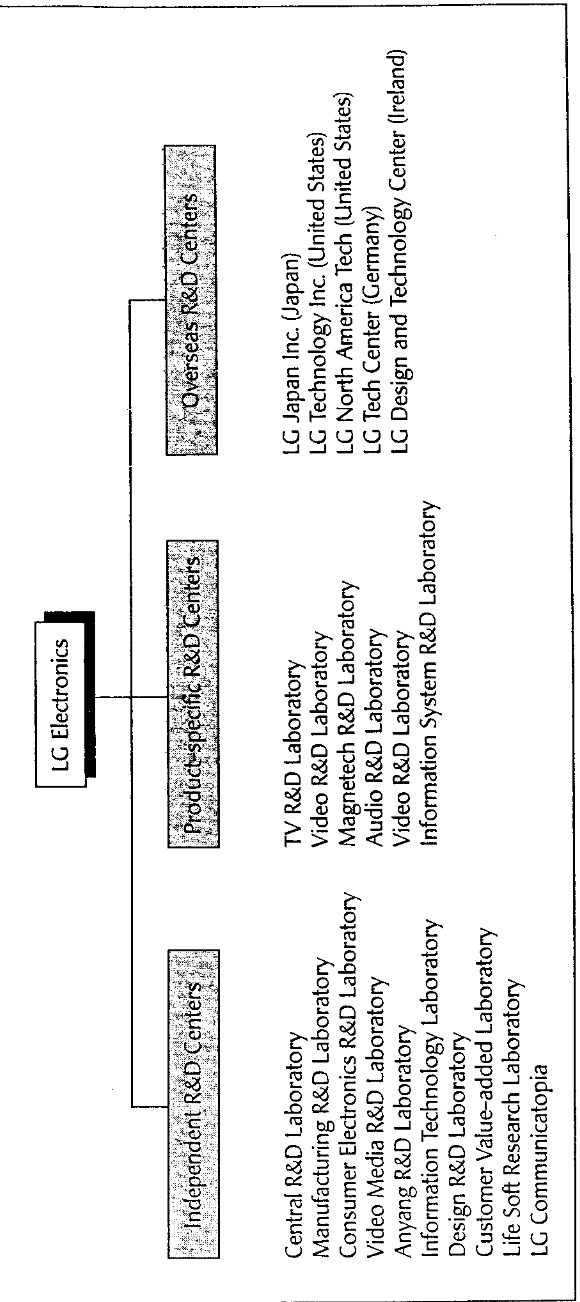


Table 6-2 R&D Activities at Samsung Electronics

	1975	1980	1985	1990	1994
Total sales (W 100 million)	244	2,513	12,985	44,523	115,181
R&D investment (W 100 million)	NA	56	388	1,862	7,133
R&D/total sales (percentage)	NA	2.1	3.0	4.2	6.2
R&D personnel	NA	690	1,821	6,686	8,919
Local patent applications	NA	18	309	1,732	2,802
Local patents granted	0	4	17	640	1,413
Foreign patent applications	0	0	32	1,145	1,478
Foreign patents granted	0	0	2	128	752

SOURCE: Samsung Electronics Company.

endeavors in the Korean firms. LG Electronics, for one, has developed a network of R&D laboratories in Tokyo, Sunnyvale, California, Chicago, Germany, and Ireland. These facilities monitor technological change at the frontier, seek opportunities to develop strategic alliances with local firms, and develop state-of-the-art products through advanced R&D. LG Technology in Sunnyvale, for example, plays a pivotal role in designing the latest personal computers, display terminals, and high-resolution monitors, while the LG North American Laboratory in Chicago concentrates on high-definition TV, digital VCR, and telecommunication equipment. Samsung, Daewoo, and Hyundai Electronics have developed similarly extensive R&D branches. Samsung has R&D operations in San Jose, Maryland, Boston, Tokyo, Osaka, Sendai, Japan, London, Frankfurt, and Moscow; Daewoo has two in France and one in Russia; Hyundai has laboratories in San Jose, Frankfurt, Singapore, and Taipei.

Korean firms also globalize R&D through mergers and acquisitions. Hyundai has been the most aggressive at acquiring equity stakes in foreign firms as a way to gain access to cutting-edge technologies. In California, it acquired, among others, full ownership of Axil Computer, Santa Clara, for computer development; significant stakes in Laserbyte Corp., Sunnyvale, to gain access to magneto-optical disk drive technology; in Metaflow, La Jolla, to develop the SPARC compatible microprocessor; in Image Quest, San Jose, to develop thin film transistor–liquid crystal displays or flat panel displays; and in Maxtor, San Jose, to develop hard disk drive.

In 1995 Samsung Electronics acquired the controlling share (40.25 percent) of AST Research, one of the largest U.S. PC makers, for $378 million, placing Samsung among the five largest PC makers in the world. The acquisition gives Samsung access to more than 190 AST patents and its strategic alliance with IBM, Apple, and Compaq. Samsung also obtained a majority interest in Union Optical (Japan) and Rollei (Germany) to enhance its competitiveness in camera and optical equipment making.

In addition, Korean firms consider Russia an attractive alternative source for new technology, for Russian researchers have some world-class technologies. Samsung unveiled a prototype digital video disk recorder. The high-powered microchip laser technology required to make it was transferred from a leading Russian laboratory, the A. F. Ioffe Physico-Technical Institute in St. Petersburg. Other Samsung subsidiaries have signed contracts to import Russian technologies.[15]

Moonlighting Japanese engineers have been another valuable source of new knowledge. The *chaebols* invite Japanese retirees to visit their R&D and production facilities to solve specific engineering problems. This is a common practice in smaller companies in many industries as well.[16]

Flat Panel Display Development

The development of flat panel display (FPD) illustrates how Korean firms strive to emerge as innovators in the world market. Their move into this industry in the 1990s resembles the development of the semiconductor memory chip industry in the 1980s. When Korean firms made the strategic choice to invest in memory chips, Japanese firms dominated the burgeoning semiconductor market. In ten years, Korean firms, led by Samsung, were able to capitalize on soaring global demand (see Chapter 7). Korea is determined to repeat that success in FPDs, in which Japan again dominates the world market, and Koreans again see an industry ready to take off. They refer to it as the second meal, after semiconductor chips, to feed Korea's electronics industry.[17]

Flat panel display (active matrix)[18] is based on a combination of passive matrix liquid crystal display (LCD) technology and semiconductor technology. Thus, in technology, fabrication, and assembly it mirrors the semiconductor industry. Firms with a strong background in passive matrix LCD and semiconductor technologies are in a good position to build flat panel display technology.

The involvement of Hyundai Electronics in passive matrix LCD dates back to 1988, when it organized an LCD business unit. Lacking

capability, Hyundai first imported the stick form of twisted nematic LCD from Oprex of Japan in 1990 and fabricated it into cell form. At the same time, Hyundai sent its engineers to Oprex for training in production and LCD design and imported a complete production system from Japan. This enabled the firm to gain a significant volume of both tacit and explicit knowledge. Training and in-house R&D led to the development of Hyundai's own twisted nematic LCD within months and super–twisted nematic LCD by 1993. Hyundai could then increase its output more than a hundredfold in three years, from 116,000 units in 1990 to 15.22 million in 1993.[19]

Based on its experience in passive matrix LCDs and semiconductors,[20] Hyundai organized a task force to develop flat panel display. It also approached Japanese and American LCD firms, including Oprex, for technical assistance to expedite learning, but none was willing to share the emerging technology with the Korean firm. Alternatively, in 1992 Hyundai established a joint venture, Image Quest Technology, in San Jose with a group of leading American LCD engineers spun off from Colory Inc. Hyundai invested more than $16 million in developing a 10.4-inch thin film transistor video graphic array (VGA) module prototype and setting up a pilot plant at Image Quest. The joint research brought Hyundai engineers, with their strong background in passive matrix LCDs and semiconductors, up to a par with Japanese competitors.

Two other semiconductor firms, Samsung and LG, are as, if not more, advanced as Hyundai in FPD technology. Samsung developed 14.2-inch FPD with a thickness of less than 3 centimeters in 1994 and 3.1-inch polysilicon FPD in 1995. The polysilicon method, which embeds drive integrated circuits (ICs) on panels to increase the light transmission efficiency up to 80 percent, enables the producers to extend the display size up to 100 inches and diminish defect rates by eliminating the combining process. In 1995 Samsung developed 22-inch FPD screen, one inch larger than the world's previous biggest LCD device produced by Sharp of Japan. This signals Korean companies as innovators in FPD technology. As a result, Korean firms are attractive candidates for strategic alliances with Japanese firms. LG Electronics established a fifty-fifty joint venture R&D with Alps Electric (Japan) to expedite the development of the next generation FPD, like plasma processing and LCD panel processing.

The rush is on among Korean firms to establish production facilities. Samsung Electronics, invested $375 million to complete an FPD plant and began producing 10,000 units a month in February 1995.

The capacity was expanded step by step to 80,000 units a month by the end of 1995. A second plant is under way as part of Samsung's vision to become one of the world's three largest FPD manufacturers. LG Electronics completed its production plant in the second half of 1995 and Hyundai completed its plant in 1996.

SUMMARY

The Korean electronics industry has, within a generation, developed from scratch into the fourth largest producer in the world. In some products, Korean firms have become new contenders in the international market, a transformation driven largely by local *chaebols* rather than multinational companies. When technology was mature and simple, as in the production of AM radios at the specific stage, local firms reverse-engineered foreign products. When technology was beyond the capacity of local firms, pioneering firms relied on foreign licensing and technical personnel, as they did with TV sets. Local firms did, however, pursue efforts to assimilate the imported technology in the shortest possible time. The assimilation of licensed technology enabled these firms to produce newer generations and a broader range of products without foreign assistance. Later Korean entrants acquired necessary capability largely by luring experienced technical and managerial personnel from pioneering firms, bringing about effective diffusion of imported technologies throughout the industry.

When technology was at the transition stage and foreign firms were reluctant to transfer their patented technology to Korea, local firms reverse-engineered it by intensifying in-house R&D, giving them stronger bargaining power in licensing technology from the patent holders. Such advanced reverse-engineering is distinguished from the simple reverse-engineering of mature products in earlier years. In this case, foreign licensing clears a path to the export market rather than to technology, as exemplified by the success in videocassette recorders and microwave ovens.

Facing rising resistance from foreign competitors, the *chaebols* continually intensified their R&D operations, establishing extensive networks of in-house laboratories in order to learn by research. At the same time, they established a number of R&D facilities in the United States, Japan, and Europe to monitor technological change and to tap high caliber Korean and foreign scientists. Korean firms also used mergers and acquisitions to gain access to frontier technologies. In

some technological areas, Korean *chaebols* have grown sophisticated enough to enter strategic alliances with leading foreign competitors.

The government played important roles in the process of technological transformation in the electronics industry. The nation's import-substitution policy provided an attractive business opportunity for local entrepreneurs to enter the protected electronics industry. The ambitious goals of the government's export drive pushed the industry to transform itself technologically and become competitive in price and quality in the international market.

The government role has changed over time from acting as a developmental state to playing an indirect promotional role as Korea entered the technologically dynamic environment. The government was effective in the demand side of technology by creating a market through procurement. In this case, the release of technical specifications stimulated the industry to expedite learning to meet specifications in time for procurement. In addition, the government played an important role in the supply side of technology by strengthening public R&D capability and promoting joint research between industry and R&D institutes and between industry and academia.