Technology Transfer: The Case of the Korean Electronics Industry

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Abstract

Technology is transferred through various channels by many different agents. The Korean electronics industry has been heavily dependent upon licensing from foreign firms. The level of technology in the Korean electronics industry nearly matches that of developed countries in terms of generalized products. However, Korea falls behind in both basic engineering and in the production of parts and materials as well as fundamental technologies for designing and producing new products. The lesson is that a nation must develop its own indigenous technological capabilities in order to gain leverage in much more advantageous technological transfer arrangement.

1. Introduction

Technology is transferred through various channels and by many different agents. Although various forms of technology transfer are considered, licensing is discussed more often than others. Since Korea's outward technology is negligible, only inward technology is discussed. In order to gain some insights, technology transfer in the Korean electronics industry is examined.

Since a country's technology transfer is affected by the overall industrial and technological policy of the country and by R&D efforts of firms. Although Korea has been fairly successful in its economic growth, its technology policy and performance have not always been as successful. Despite its remarkable achievement in building up its technological capability, there remain many areas which have been neglected and many problems to be solved.

Section 2 discusses the forms and channels of technology transfer. In the section 3 , I will remark on the importance of technology transfer in the context of product cycle theory. Section 4 discusses the case of the Korean electronics industry. Section 5 conclude.

2. Forms & Channels of Technology Transfer

As shown in Table 1, we may consider several forms and channels of international technology transfer. Technology can be transferred between two countries(bilaterally) or among many countries, through international institutions (multilaterally). It can take the form of commercial or non-commercial transactions in public or private sectors. Major channels and means of technology transfer include licensing, FDI, trade of capital goods, and strategic alliances. Technology transfer may take the form of intra-firm transfer, inter-firm transfer or inter-government transfer.

Firms in Korea acquire foreign technologies mainly through licensing, and role of FDI is limited. Table 2 is one survey result which confirms this characteristic of the various channels of technology transfer; licensing accounted for 31.8%, the highest, whereas FDI accounted for only 6.5% in 1991. Many other surveys report similar observations that the role of FDI in technology transfer to Korea has been negligible. This phenomenon is a result of the strong orientation of Korean entrepreneurs and government toward independent operation of business, which is in turn deeply rooted in the personality of the Korean people.

3. Is Technology Transfer to the South Detrimental to the Interest of the North?

Technology transfer is an important means by which regional economies can achieve the transition to activities relying more on advanced technologies and skilled labor. Technology innovation in the Northern developed countries and the transfer of technology to LDCs play an important role in shaping the pattern of world trade and its changes. Among the extensive verbal and empirical literature on this topic, Vernon's[13] concept of the "product cycle" stands out as the stylized description of the processes of international flows of technology. In the Vernon's 1966 paper[13],

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"Development and initial manufacturing of new products takes place in the North, because R&D capabilities are well developed there and because proximity to large, high-income markets facilitates the innovation process. Then, technology transfer or imitation by Southern firms takes place, whereupon the bulk of production migrates to the South to capitalize on the relatively cheap labor there. Inter-regional trade in manufactured goods involves exchange of the latest, more established goods, produced predominantly or entirely in the South."

Table 1. Forms of Technology Transfer

Forms			Objectives	Characteristics	Remarks
Private Sector	Intra-Firm		-Protection of technology -Strengthening subsidiary's competitiveness	-Monopolistic ownership of technology by parent company -Risk of weakening monopoly power of parent company	FDI Internal transaction
	Inter-Firm	Market Type	-Royalty earnings -Direct technology transfer	-Technology markets -Licensing	Commercial transaction
		Non-Market Type	-Utilization of externalities	-Low degree of transfer effects -Technology transfer by contracts	Non-commercial transaction
		Alliance	-Utilization of complementary assets	-Cross-licensing, collaborative R&D, co-ownership of technologies -OEM, exchange of complementary assets and function by joint venture, etc	Quasi-commercial transaction
Inter-Government			-Technology Assistance -Collaborative technology development and utilization	-Political objectives -Common use of public welfare-oriented technologies -Human resource development	Non-commercial transaction

Source : Yoo Soo Hong, *Japan's Strategy for Technology Transfer to Asia and Korea's Response*, 1993, p.22.

The formal modeling of the product cycle was pioneered by Krugman[10] and his work has been extended by Dollar[1], as well as Jensen and Thursby[7]. Recently, Grossman-Helpman[2,4] built a general model of international trade and economic growth encompassing scale economies, different stages of production of R&D, intermediates, final goods, and multi-periods. The benefits of rapid technology transfer are supported by Grossman and Helpman[3].

In studies of technology-driven growth, Grossman and Helpman[3] found that "the size of the resource base and the productivity of resources in the learning activities are important determinants of steady-state growth rate. Steady-state growth is faster, the larger is the resource base of the South, and the more productive are its resources in learning the production processes for number of Northern producers compete for resources in the manufacturing sector. The latter effect dominates so faster imitation by the South ultimately strengthens the incentive to innovate in the North."

In comparing the product-cycle equilibrium to one with autarchy in each region, international trade always leads to faster growth in the North in the long run. The migration of some production to the South frees resources for use in the product development sector in the North. In the steady-state equilibrium with trade, the Northern firms have greater incentive to undertake R&D than in autarchy, because each earns a higher profit rate, albeit during a shorter period of time. The South, too, grows faster with trade than without.

Turning to the "boomerang effect", a term coined by Japanese Professor Miyohei Shinohara[12] in 1976. The phenomenon originally referred to the "imports in reverse" into Japan that follow the overseas expansion of Japanese enterprises and the subsequent need to make adjustments in the domestic industry. It has been applied more broadly to the case of technology that intensifies the competition in domestic and third-country markets. Japanese businessmen often talked about the negative

Table 2. Main Channels for Foreign Technology Acquisition

unit: %

	Licen-sing	Sending Engineers Abroad	Techno -logy Train-ing	Information Associated Capital Imports	Foreign Direct Investm ent	Informa-tion from Suppliers	Recruit of Overseas Scientists	Others
Electronics	88	66	57	32	15	11	7	0
Electricity	90	71	54	24	20	15	2	10
Machinery	86	66	61	27	18	11	2	5
Chemicals	90	49	53	35	29	10	1	3
Textiles	91	50	63	31	11	12	3	0
Metals	80	61	57	54	20	15	0	0
Ceramics	94	69	50	42	22	8	3	0
Shipbuilding	90	74	74	16	5	11	0	14
Pharmaceuticals	22	50	46	68	5	9	9	0
Foods	80	50	67	40	7	10	3	0
Average	88	62	58	34	18	11	3	3
Composition	31.8	22.4	20.9	12.3	6.5	4.0	1.1	1.1

Note : Up to three choices were allowed. Composition is the percentage of each average to the total of average
Source : Korea Development Bank, Effect Analysis of Technology Imports, 1991.Adapted.

effects of technology transfers from Japan to Korea. One of their favorite examples is the success of Pohang Iron and Steel Company (POSCO).

In the early 1970s, South Korea planned to build a large integrated steelmill whose construction was first offered to a consortium of Western steelmakers. That arrangement went unsettled due to an unwillingness to provided sufficient credit. Then Japanese steel firms stepped and began supplying plant and equipment on good credit terms. Now the deal has come back to haunt them: POSCO is one of the most efficient steel firms in the world and finally in a position to meet most of Korea's domestic demands, while Japanese steel exports are being cut back correspondingly. Japanese firms also face growing competition in third markets, especially in the United States and Southeast Asia. Japan has begun to import Korean steel. POSCO now produce high-quality steel and sells it on the world markets, as can be seen in Table 3 at very competition prices.

Table 3. Comparison of 1988 Steel Prices

	Steel Products ($ per ton)		
Country	Hot Coil	Plate	Cold Rolled Coil
Korea	320	326	451
Taiwan	385	385	473
United States	638	688	765
Japan	435	491	621

Source: Steers et al.(1989)

Japanese companies also opened textile factories in many developing countries which were designed basically for domestic purposes in late 1960's and 1970's. Later, under pressure, they also set up synthetic fiber plants and , to obtain economies of scale, made them considerably large. Now, many of these countries can supply their own goods which have replaced Japanese products. For some time already, they have successfully invaded the international markets, challenging the Japanese in low-price, high quality articles.

To take another example, a similar progression took place with Samsung Electronics Company (SEC), the largest electronics firm in Korea. Much of the firm's original equipment was supplied by Japanese companies; the result has been the rise of the Korean electronics industry have nearly driven their Japanese counterparts out of the market for simple items like radios, cassette recorders and black-and-white televisions and are challenging the market for color televisions and video cassette recorders (VCRs).

The above example vividly illustrate the "boomerang effect". Japan ships plants and equipment abroad, which in time produce goods to replace its own exports. Then, as capacity expands and sophistication rises, these companies begin competing against Japanese products in third-country markets and even, then, are coming back and haunting Japan.

This has been one of the hot issues between Japan and Asian NICs, especially in Korea. When firms want advanced technology transfers, Japanese businessmen and government bureaucrats have often been reluctant to

provide their blueprints worrying about the possible boomerang effects against them. They argue that if a domestic firm licenses their knowhow to a foreign firm, the foreign license will expand its production, eventually exporting to the Japanese market and increasing competition with the original licensor. It is true that the expansion of Korean exports have decreased Japan's market share in the iron and steel, radio and textile industries. We cannot, however, predict adverse effects in other Japanese industries in general. As Table 4 shows, the import penetration of Asian NICs, especially Korea, to Japan has remained steady since the mid-1970s.

Table 4. Japan: Import Penetration by Asian NICs for Total Manufacturing

	Import Penetration Ratio			
	1970	1974	1979	1985
Asian NICs	0.24	0.69	0.82	0.75
Korea	0.08	0.31	0.33	0.30

Source: OECD (1988)

Some Korean economist and businessmen often counter that Korea's trade deficit with Japan actually worsening year by year, while her trade surplus with the U.S. is widening to the point of a U.S. threat of trade war. If we take k(=export-import/export+import) as an indicator of trade imbalance between two countries, as shown by Table 5, Korea's trade deficit with Japan worsened (from k=-0.197 in 1982 to k = -0.267 in 1985), whereas Korea's trade surplus with the U.S. soared sharply (from k=0.042 in 1982 to k=0.306 in 1988). This being the case, it may be that Japan is in effect indirectly exporting to the U.S. by exporting intermediate goods to Korea. From the perspective of an entire industrial structure, production expansion in the Korean downstream market could stimulate exports of Japanese intermediate and capital goods to the technology importer. This upstream expansion partially or overly offsets the profit loss in Japan's final goods industry. So it can be said that Korea might suffer from counter-boomerang effects if her exports to Japan and third country markets were less than her imports of intermediate and capital goods from Japan, that is, net gains in the technology-exporting country could go in either direction a priori.

Table 5. Trade Balance Among U.S., Japan and Korea

A's exports to B/A's imports from B			
A B	1982	1985	1988
U.S. - Japan	24,185/36,546	26,009/66,684	42,267/90,245
Japan-Korea	4,869/3,270	7,156/4,144	15,442/11,827
U.S.-Korea	5,529/6,011	5,956/10713	11,290/21,209

4. The Case of the Korean Electronics Industry

4.1. A Brief History of the Industry

It is of much interest to review the development of the Korean electronics industry in order to better understand the pattern and role of technology transfer due to the following reasons. First, the electronics industry is the leading manufacturing sector in Korea, and it imported more foreign technologies than any other sector. Second, the industry demonstrates well the main features of technology in Korea, both strengths and shortfalls.

Most firms in the industry in the 1960s were either manufacturers of simple home electronics such as radio and black-and white TV sets or OEM suppliers for foreign firms. The growth and success of the industry, an obvious late-comer, during the past three decades is remarkable. Between 1985 and 1993, the Korean electronics industry grew at an average rate 23.2 percent per year as shown in Table 6. Consumer electronics is the major subsector of the electronics industry. The industry has displayed remarkable progress in terms of both product quality and diversification. During its early stages in the 1960s and 1970s, the Korean consumer electronics industry focused mainly on assembling foreign parts, usually for radios and black-and white TV sets. During the 1980s, however, the Korean consumer electronics industry has diversified its technological capabilities to such products as color TV sets, microwave ovens, compact disk players, camcorders and digital audio tapes. The industry has shifted from consumer-oriented production to industrial production with technology-intensive processes. Today, Korea is the third largest producer and exporter in the world of world consumer electronics. In 1970, Korea sold merely $55 million worth of electronics to the world market. By 1993, that figure has skyrocketed to $22.2 billion, over 6 percent of the world market. Despite growing trade restriction by the U.S. and other developed countries, personal computers and VCRs made in Korea now occupy an impressive share of their respective markets all around the globe, with exports representing

Table 6. Status of the Electronics Industry in Korea

Unit: Million $, %

	1970	1980	1985	1990	1991	1992	1993	Annual Growth Rate
Production								
GNP(A)	8,800	60,500	83,100	242,300	281,700	294,500	328,700	18.8
Electronics (B)	106	1,179	8,460	29,711	33,104	33,407	36,465	23.2
Consumer El. (C)	-	1,145	3,586	10,261	11,504	10,545	11,198	15.3
B/A	1.2	5.3	10.2	12.3	11.7	11.3	11.1	-
C/A	-	6.4	4.3	4.2	3.9	3.6	3.4	-
C/B	-	46.4	46.4	34.5	33.4	31.6	30.7	
Exports								
Total Exports (D)	835	17,505	30,283	64,016	71,870	76,632	82,236	13.3
Electronics (E)	55	2,055	4,532	17,215	19,334	20,683	22,226	22.0
Consumer El. (F)	-	1,036	1,839	5,529	6,054	5,966	6,253	16.5
E/D	6.6	11.7	15.0	26.5	26.9	27.0	27.0	-
F/D	-	5.9	6.1	8.5	8.4	7.8	7.6	-
F/E	-	50.4	40.6	32.1	31.3	28.8	28.1	

1) Since GNP is value added and electronics is sales, the ratios in the table should be carefully interpreted.
2) Amounts and growth are based on current prices.
Sources : Bank of Korea, Electronic Industries Association of Korea.

more than three-quarters of total production.

4.2. Foreign Investment

It goes without saying that foreign capital and technology have played an important role in the development of Korea's industries. More than most of Korea's other developing industries, the consumer electronics industry has relied quite substantially of foreign investment, typically in the form of OEM agreements. Korea possessed very little indigenous technology in the area of consumer electronics during its early stages. At the same time, however, its workers provided a reliable and cheap source of labor for foreign (usually American and later Japanese) companies. Under its export-led growth strategy, Korean electronics manufacturers had no choice but to heavily depend on OEM agreements to provide both technology and access to overseas markets. With a limited technology base, negligible brand recognition overseas, and no international marketing presence, there were few alternatives for the industry.

Although many of these early agreements initially did not provide much opportunity for the transfer of electronics technology to Korea, a very limited amount of technical know-how was gained and diffused through the Korean electronics industry. The contribution of foreign firms to the production and exports of the Korean electronics industry has declined over time, although they still maintain significant shares in electronics production and exports as shown in Table 7. Firms with foreign capital produced 15.9 percent of total domestics consumer electronics production and exported 25.5 percent of all Korean electronics exported in 1982. However, their shares in 1990 were 6.0 percent and 9.2 percent, respectively. The production share of local firms increased from 74.5 percent to 90.8 percent during the same period.

Table 7. Share of Production and Export of Consumer Electronics by Type of Company in Korea

	1982		1985		1990	
	Production	Export	Production	Export	Production	Export
Local firms	84.1	74.5	88.9	83.2	94.0	90.8
Joint Venture	4.9	6.1	5.4	7.7	4.8	6.0
Foreign Firms	11.0	19.4	5.7	9.1	1.2	3.2

Source: Electronic Industries Association of Korea

The Korean electronics industry has been heavily dependent upon licensing from foreign firms. One constructive case study can be seen in the licensing agreements between Phillips and several Korean companies to manufacture compact disk players. Since Korean electronics corporations possessed most of the technical background to produce such products, and since Phillips, itself, was a major producer of compact disk player deck mechanisms, Phillips licensed the remaining technology to ten Korean corporations for unrestricted production of compact disk players. Likewise, when Hitachi wished to shift its own focus from 1M DRAM microprocessors to 4M DRAM microprocessors, it licensed the technology and provided technical assistance to Goldstar to produce 1M DRAM microprocessors. This allowed such corporations to improve the technological base even further. Such technological transfers have proved to be mutually beneficial for both Korean companies and for Phillips and Hitachi, respectively. The semiconductor industry, a subsector of the industrial electronics industry, is the most successful within the Korean manufacturing sector. It began assembling discrete devices in the 1960s. Having taken over many foreign subsidiaries and joint ventures, local semiconductor producers heavily invested in DRAM facilities to meet growing domestic and foreign demand during the 1980s. Semiconductors are now Korea's largest single export item. Korea accounted for 35 percent of world 4M DRAM production in 1993, and is expected to account for 40 - 50 percent of world 16M DRAM production in 1994.

The Industry's technology level for discrete level and memory devices has nearly reached the same level as advanced countries. Table 8 shows the breath-taking development of Korean DRAM technology over the past 10 years. This vividly demonstrates the possibility for a developing country to catch up with advanced countries in the technology race, if the country satisfies certain conditions.

Table 8. Korean DRAM Technology Gap

	64K DRAM	256K DRAM	1M DRAM	4M DRAM	16M DRAM	64M DRAM
Developed Country	1979	1982	1985	late 1987	early 1990	late 1992
Korea	1983	1984	1986	early 1988	mid 1990	late 1992
GAP	4 years	2 years	1 years	6 months	3 months	same

Source: The Ministry of Trade, Industry and Energy

4.3. Strategic Alliances

Most Korean electronics manufactures established strategic alliances with major manufacturers in developed countries, in particular the U.S. and Japan. Strategic aim to utilize partners' complementary assets, resources, and market in order to enhance comparative advantages. Among the many forms, strategic technological alliances are most prevailing. The semiconductor industry in the most active subsector in the Korean electronics industry for strategic alliances. The technological capability of the sector is demonstrated by the fact that Samsung, Gold Star, and Hyundai set up 16M DRAM production system in 1993, and that Samsung developed 256M Dram chip technology in 1994. Table 9 (Table 10) summarizes major strategic alliances between Korean and U.S. (Japanese) semiconductor producers. All forms of strategic alliances such as technology transfers, OEM, joint ventures, joint R&D, second sourcing, etc. have been established.

As shown in Table 11, strategic alliances in the electronics and communications sector are characterized by the involvement of large firms. This is a common feature in Korea, where big conglomerates are the industrial leaders. Since more than 90 percent of strategic technological alliances are formed between and among large firms in developed countries, the opportunities for Korean firms to exploit this new strategy may be limited. However, the number of strategic technological alliances is expected to continue to increase in the future due to the following reason. First, the ever shortening technology life cycle and the increasing risks and costs of R&D encourage strategic technological alliances. Foreign firms can utilize the technology drive of the Korean government and R&D investments of conglomerates in Korea. Second, firms in developed countries sometimes want to establish strategic alliances with firms in countries such as Korea, Singapore, Taiwan, etc. in order to utilize specific local merits or to use them as complementary alliances. Third, Korea can be utilized as a foothold for expanding business to the rest of Asia, and Korea's market itself is attractive to foreign firms.

4.4. Technological Level of the Korean Electronics Industry

At least until the mid-1980s, low labor costs and

Table 9. Korean-U.S. Semiconductor Technology Alliances

Korean Firms	U.S. Firms	Memory	Non-Memory	Others
Sam Sung	Micron	T,E	T,S	
	Intel	T,M		JV in Portugal
	TI	T,E	T,R	
	HP	M		Assumption of new device business
	IBM	M,T	T	
	AT&T	T		Joint development of 8" equipment
	HMS			
	AMT, Varian			
Gold Star	AT&T	T,E		
	AMD	T		
	Motorola	M		
	Zilog		S	
Hyundai	TI	T,M		
	Intel	M		
	GI	M		
Daewoo	Zilog		T,E	
Anam	TI	M(Assembly)		Merging a Phillipino factory Licensing
	AMD			
	Motorola			

Note: T= Technology Transfer, M=OEM, E= Joint Venture, R= Joint Development
Source: Samsung Electronics

Table 10. Korean-Japanese Semiconductor Technology Alliances

Korean Firms	Japan Firms	Memory	Non-Memory	Others
Samsung	Toshiba	R,T		
	Sharp	T		
	NTT	T		
	Fujitsu	T		
	Oki	T		
	DNS			E(Facility)
Gold Star	Hitachi	T,M		
Hyundai	Sharp	T		
	Ricoh	M		
	Fujitsu	M		
	TI Japan	M		

Note: T=Technology Transfer, M=OEM, E=Joint Venture, R=Joint Development
Source: Samsung Electronics

favorable foreign exchange rates made local consumer electronics very price-competitive on the international markets, even though they were made with foreign key parts and based on foreign technologies.

But, comparative labor cost advantages have eroded recently. Therefore, the development of technology is the most crucial issue for the Korean electronics industry, and the key to future success lies in extensive research and development.

Table 11. Strategic Alliances in Electronics and Telecommunications Industries

	Korean Firm	Counterpart
VAN	SamSung	IBM
	Hyundai	AT&T
	PosData	Compurserve, Sprint, etc
	Ssangyong	Telenet
	Samsung	NEC
	Dacom	Infonet
	GoldStar	EDS
Telecom System	DaeWoo	Northern Telecom
	Kolon Data	AT&T
	GoldStar	NEC
	Samsung	Rolm
	ORELCO	Ericson
	Hyundai	Fujitsu
Computers	Samsung, Gold Star, Hyundai, DaeWoo, Trigem	Sun (Licensing)
	Samsung	HP
	Daewoo	MIDS

Source: Complied from company data

The level of technology in the Korean electronics industry nearly matches that of developed countries in terms of generalized products. However, Korea falls

behind in both basic engineering and in the production of parts and materials. Fundamental technologies for designing and producing new products are also inferior to those in developed countries.

As of 1991, Korean video and audio equipment producers lagged behind their counterparts in advanced countries by a span of 2 - 4 years in the development of new product; however, this gap widens to 5 - 7 years for the development of high-tech products for the next generation. Table 12 shows the technology gap in this area between Korea and Japan.

Table 12. Comparison of Product Development Year between Korea and Japan

Unit: year

	Existing Product					Next Generation Product			
	Color TV	VTR	Cam-corder	Super TV	1M DRAM	HDTV	D-VTR	CD Application	64M DRAM
Korea	1974	1980	1987	1987	1986	1993	1996	1996	1992
Japan	1960	1975	1984	1982	1983	1984	1989	1989	1992
GAP	14	5	3	5	3	9	7	7	0

Source: Ministry of Trade and Industry

Since the 1980s, Korea video and audio manufacturers relied on receiving up 80 percent of their technology from foreign sources, especially from the United States and Japan. As a result, localization of parts and components is still extremely low considering that Korea is on the verge of joining the ranks of the advanced countries in the immediate future. Against these drawbacks, Korean electronics producers are striving to realize technological self-reliance in order to enhance their international competitiveness. Korea has still a long way to go to achieve self-reliance in the area of electronics technology. However, one cannot deny that it has already made remarkable progress in the indigenization of foreign technologies.

5. Conclusion

The economies of the Asia-Pacific are relying more and more on private initiative and competitive markets, as opposed to state intervention, for their economic growth and development. The shift in development strategy is based on the view that economic growth as well as equity can be enhanced by promoting the development of private enterprises. The positive correlation between private sector development and economic growth has received a great deal of attention in recent years. The Asia-Pacific region can be characterized as having adopted a policy approach that embraces two essential elements of promoting private sector development-trade liberalization and deregulation.

Trade liberalization is a very effective way to implement competitive markets and private initiatives. Liberalization aims to promote an outward-looking development strategy, emphasizing the leading role of industry and making trade as means to raise efficiency and productivity through competition, economies of scale, new technology and improved organization skills and management. An example of liberalization is the recent freeing of imports in Korea. To promote internalization of the domestic market, the Korean government raised its import liberalization rate to 97.3 percent and has planned to lower the basic tariff rate from 12.7 percent to 7.9 percent by 1993.

Although Korea has been fairly successful in its technological development, some problems or drawbacks should be pointed out for it future. First, the most serious problem faced by Korea is the structural imbalance between large firms and small firms. It is an irony that Korea can produce world-class semiconductors while it suffers from high rates of defects in the production of rather matured technologies. This is mainly due to the underdevelopment of small and medium-sized firms and the insufficient technological capability of these firms. Without a sound basis for fundamental technologies of small firms, further development of the Korean industry will be hampered.

Second, although Korea has achieved remarkable progress in some high technologies and has mastered mature manufacturing technologies, it lacks self-sufficiency on core technologies for essential parts and sophisticated industrial equipment. Also, Korea lacks the design capability for many sophisticated products. Heavy dependence on foreign technologies for core parts causes two problems: worsening terms of trade of these technologies against Korea due to the expansion of technology protectionism by advanced countries, and crowding out of domestic R&D efforts.

Third, despite a great amount of R&D investments, R&D productivity is low in general, and dissemination and spill-over effects are very limited. Thus, a more efficient national R&D system is an urgent necessity in order to maximize the effects of R&D.

A difficult decision for a developing country to make is

whether to follow a longer but more sound path like the Japanese model, or to follow a faster but much riskier path like the Korean model as we have reviewed so far, in order to successfully catch-up with developed countries in the area of technology.

A slower path implies support for and development of small and medium-sized firms to build a sound foundation of fundamental technologies, which will in turn contribute to the building up of indigenous technological capability in key industrial sectors. This analogous to Aesop's fable of "The Hare and the Tortoise". In the long run, this slower path strategy may turn out to be better. However, in my opinion, an increasing number of late-comers will choose a path similar to that of Korea as technological cycles become shorter and shorter and R&D costs skyrocket.

The experience of Korea renders, first and foremost, the lesson that a nation must develop its own indigenous technological capabilities in order to gain leverage in much more advantageous technological transfer arrangement. Second, the government must play an active role in building science and technological infrastructure. However, technological innovation should be initiated by the private sector, fully utilizing the infrastructure provided by the government.

Finally, a well-educated work force and a relatively stable political climate are needed for the development of such an indigenous technological infrastructure.

As for Korea, its future is quite uncertain. The country has yet to attain cutting-edge status in core technologies in major field. Nevertheless, if the past is any indication of the future, Korea has the potential to catch up with advanced countries at least in some niche areas. Accurately predicting the future is impossible. However, the experience of Korean government and private sectors can offer hopes to the developing countries working very hard to develop key technology-based industries by developing an indigenous technological infrastructure.

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