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UNCTAD/ICTSD Capacity Building Project on

Intellectual Property Rights and Sustainable Development

Technology Transfer and Intellectual Property Rights:

Lessons from Korea's Experience

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Explanatory Note

This case study by Prof. Linsu Kim on technology transfer, absorptive capacity and intellectual property rights, has been prepared in the context of the Project on TRIPS and Development Capacity Building sponsored by the Department of International Development (DFID UK). The Project is being implemented by the secretariat of the United Nations Conference on Trade and Development (UNCTAD) (Project Number INT/OT/1BH) and the International Centre for Trade and Sustainable Development (ICTSD). The broad aim is to improve the understanding of TRIPS-related issues among developing countries and to assist them in building their capacity for ongoing as well as future negotiations on intellectual property rights (IPRs).

The Project produces a series of documents through a participatory process involving trade negotiators, national policy makers, as well as eminent experts in the field, NGOs, international organizations, and institutions in the North and the South dealing with IPRs and development. The published outputs are not intended to be academic exercises, but instruments that, in their final forms, will be the result of a thorough process of consultation. This will be achieved by rapid development of working drafts and circulation of these to experts and to the intended audiences for their comments. These documents include:

- **A Policy Discussion Paper** intended to be a clear, jargon-free synthesis of the main issues to help policy makers, stakeholders and the public in developing and developed countries to understand the varying perspectives surrounding different IPRs, their known or possible impact on sustainable livelihoods and development, and different policy positions over TRIPS. (A preliminary draft of the Paper was issued on 20 Nov. 2001)

- **The Resource Book on TRIPS and Development** conceived as a guide that will provide background and technical information on the main issues under discussion in TRIPS.

- **Case studies** on various IPRs issues to supplement the Resource Book and the Discussion Paper. This will allow concrete evidence to emerge and shed light on the impact and relevance of IPRs in developing countries. In addition to the present study on technology transfer, others cover such issues on non-voluntary licensing (first study available in September 2002), geographical indications (available as of June 2002), traditional knowledge (forthcoming), and nutrition (forthcoming)

In addition, the Project produces background material on Indicators of the Relative Importance of IPRs in Developing Countries (see draft of November 2001) and a Review of Activities being carried out by other organizations and institutions on TRIPS related questions and a Review of Literature (both available on the website). For details on the activities of the Project and available material, see <http://www.ictsd.org/unctad-ictsd>.

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List of acronyms used

EOI	Export-oriented industrialization
ERC	Engineering Research Centre
FDI	Foreign direct investment
FL	Foreign licensing
GRI	Government supported research institute
IGTDP	Industrial Generic Technology Development Project
ISI	Import-substitution industrialization
KIST	Korea Institute of Science and Technology
MNC	Multinational corporation
NIE	Newly-industrializing economy
ODM	Own design manufacture
OEM	Original equipment manufacture
R&D	Research and development
SCI	Science Citation Index
SRC	Science Research Centre1

1. Introduction

The protection of intellectual property rights (IPRs) has increasingly become an important issue in multilateral trade negotiations. The current debate on IPRs is dominated largely by two extreme positions. Some advocate IPRs as an effective instrument for advancing technology as a facilitator for technology transfer to developing countries. Others take the contrasting position that IPRs as currently conceived solely defend the interests of advanced countries. For instance, some economists claim that the present international IPR regime has decidedly shifted the global rules of the game in favour of advanced countries, and that the promise of long-term benefits for many developing countries, particularly the poorest countries, from the Agreement on Trade-related Aspects of Intellectual Property Rights (hereinafter TRIPS) seems uncertain and costly to achieve (World Bank, 2001). These critics argue that despite the assertion in TRIPS that "the protection and enforcement of IPRs should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare," (WIPO, 1994). the Agreement in reality mainly reflects the interest of advanced countries on this matter. Opponents of the Agreement raise serious questions on the potential role of IPRs in technology transfer and investment flows to developing countries. For instance, a recent report submitted to the Council for TRIPS by Kenyastates that strong IPR protection, on the scale required by TRIPS, does not by itself lead to increased FDI; nor does it encourage technology transfer or local innovation in developing countries (SUNS, 2000).

However, a set of recent studies, including one commissioned specially for the UNCTAD-ICSTD project (Maskus, 2000, Lall and Albaladejo, 2001) provides new insight on the relationship between IPRs and technology transfer to developing countries. They find that the effects of IPRs on technology transfer to and local innovation in developing countries vary according to countries' levels of economic development and to the technological nature of economic activities

This position is reconfirmed by the present country case study. Based on a long period of research on the behaviour of firms in technology transfer and local capacity building in South Korea, this paper shows that:

a) IPR protection would hinder rather than facilitate technology transfer to and indigenous learning activities in the early stage of industrialization when learning takes place through reverse engineering[1] and duplicative imitation of mature foreign products;

b) only after countries have accumulated sufficient indigenous capabilities with extensive science and technology infrastructure to undertake creative imitation in the later stage that IPR protection becomes an important element in technology transfer and industrial activities. The paper underscores the point that Japan, Korea, and Taiwan, not to mention the United States of America and Western European countries during their industrial revolutions, could not have achieved their current levels of technological sophistication if strong IPR regimes had been forced on them during the early stage of their industrialization.

An earlier study (Lall, 2001) reaches a similar conclusion that developing countries can reap long-term benefits from strong IPRs only after they reach a certain threshold level in their industrialization, when it contests Maskus' (2000) argument that higher costs associated with strong IPRs would be more than offset by the long-term benefits of IPRs even in developing countries. In other words, strong IPRs would thwart developing countries from attempting industrialization at the very early stage. And under such an IPR environment, few could emerge as newly industrializing economies (NIEs), like Korea and Taiwan, in the future.

[1] Reverse engineering refers to activities that take apart an object to see how it works in order to duplicate or enhance the object. It is a practice undertaken not only in older industries but also in computer hardware and software. In the automobile industry, for instance, a manufacturer may purchase a competitor's vehicle, disassemble it, and examine the welds, seals, and other components of the vehicle for the purpose of enhancing their vehicles with similar components. Reverse engineering requires a great deal of expertise and effort.

In the age of rapid technological change and consequent hyper global competition, average product life cycles in advanced countries are getting shorter. In the electronics sector, for instance, the life cycle of many products is no longer than two or three years, if not shorter. In few other sectors do life cycles outlast the twenty-years of protection provided by patents. In other words, in most, if not all, sectors in advanced countries, product life cycles are getting far shorter than the life of IPR protection. For this reason, most firms in advanced countries appropriate more returns than R&D investment within the shorter life cycle of the product and before the technology involved reaches the mature stage.

Thus, the economic consequences of strong IPR protection for products at the mature technology stage may be marginal for IPR holders in advanced countries. But they are devastatingly costly for aggressive large and small local firms in developing countries that depend upon imitative learning and find that their growth is stifled. For developing economies, the result of stronger IPR protection is a reduction in knowledge flows from the advanced countries, and a lower rate of innovative activity. In short, IPR enforcement should be contingent upon the level of economic development if the intention is to benefit both technology suppliers in advanced countries and technology recipients in developing countries. In addition, production complexity of the sector involved, and the aggressiveness of the firm in building local absorptive capacity also account for differences in the relations between IPR and technology transfer.

This paper first presents four analytical frameworks – technology trajectory, production complexity, absorptive capacity, and technology transfer. These are then assimilated to form an integrative model, which will be used to analyze the effect of IPRs on technology transfer to, and local innovation in the Republic of South Korea and by implication other developing countries. IPRs in this paper refer largely to patents, as copyrights and trademarks raise different sets of issues.

2. Analytical Frameworks

2.1 Technology Trajectory Framework

This framework analyzes and integrates two technological trajectories -- one in advanced countries and the other in developing countries -- as a way to analyze firms in developing countries in acquiring foreign technology and accumulating their own absorptive capacity along the technology trajectory (Kim, 1997a).

"Technological trajectory" refers to the evolutionary direction of technological advances that are observable across industries and sectors. Utterback and Abernathy (1975) postulate that industries and firms in advanced countries develop along a technology trajectory made up of three stages – fluid, transition, and specific. These terms reflect the flexibility of production system involved. These stages, however, are referred to as emerging technology, intermediate technology, and mature technology stages in this paper to reflect the newness of the product technology involved.

Firms in a new technology will 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 performs a function in a way that satisfies some market niche. Product changes are as frequent as 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 the market and technology (Abernathy and Utterback, 1978; Utterback, 1994). In this stage, pioneers in advanced countries secure first-mover advantage in the market on the basis of radical product innovation.

As market needs become better understood and alternative product technology 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 in the intermediate technology stage. Cost competition leads to radical change in processes, rapidly driving down costs. Production capability and scale assume greater importance to reap scale economies. Firms in advanced countries dominate the global market on the basis of their continued innovation in both products and processes.

As the industry and its market mature and price competition grows more intense, the production process becomes more automated, integrated, system-like, specific, and rigid to turn out highly standardized products. The focus of innovation shifts to incremental process improvements, seeking greater efficiency. When the industry reaches this mature technology stage, firms are less likely to undertake R&D aimed at radical innovations, becoming increasingly vulnerable in their competitive position. Industry dynamism may become regenerated through invasions by radical innovations introduced by new entrants (Anderson and Tushman, 1990; Cooper and Schendel, 1976; Utterback and Kim, 1985). Some industries, however, are quite successful in extending the life of their products in this stage with a series of incremental innovations to add new value (Baba, 1985).

At the later part of this stage, industries are typically relocated to developing countries where production costs are lower. The upper part of Figure 1 depicts the above trajectory. This trajectory model is not universally applicable (Pavitt, 1987; Nelson, 1994) and may change significantly with a shift in the techno-economic paradigm (Freeman and Perez, 1988). But it is still useful in analyzing technology transfer to and capability building in developing countries (Kim, 1997a).

See Figure 1, p. 24

On the basis of research in the Korean electronics industry, Kim (1980) developed a three-phase model -- acquisition, assimilation, and improvement -- to extend Utterback's. During the early stage of industrialization, developing countries acquire mature 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 produce fairly standard, undifferentiated products.

Once the acquisition task is accomplished, production and product design technologies are quickly diffused within the country. Increasing competition from new entrants spurs indigenous technical efforts in the assimilation of foreign technologies to produce slightly differentiated products. The relatively successful assimilation of imported technology and increased emphasis upon export promotion, together with the enhanced capability of local scientific and engineering personnel, lead to the gradual improvement of mature technology. Technological emphasis during this stage is duplicative imitation, producing knockoffs and clones.

Linking the technology trajectories of Utterback and Abernathy (1975) and Kim (1980), Lee, Bae and Choi (1988) postulate that the three-stage technology trajectory in developing countries (Kim, 1980) takes place not only in the mature technology stage but also in the intermediate technology stage. In the face of rising wages and increasing competition from the second tier NIEs, firms in the first tier NIEs, which have successfully acquired, assimilated and sometimes improved mature foreign technologies, aim to repeat the same process with higher-level knowledge in the intermediate technology stage. Technological emphasis at this stage is creative imitation, generating facsimile products but with new performance features. It involves not only such activities as technology transfer and benchmarking but also notable learning through substantial investment in indigenous R&D activities. Many industries in NIEs (e.g., Taiwan and Korea) have arrived at this stage.

If successful, some of these industries may eventually accumulate sufficient indigenous technological capabilities to generate emerging technologies and challenge firms in advanced countries. Innovation is the watchword in these industries. When a substantial number of industries reach this stage, the country may be considered to be a member of the advanced countries. In other words, as shown in the lower part of Figure 1, developing countries reverse the direction of technology trajectory in advanced countries

This oversimplified model provides a fairly accurate explanation of the evolutionary process that took place in the first tier NIEs in East Asia (Hobday, 1995; Kim, 1997a). In the 1960s and 1970s when the local technological base was very primitive, Korea and Taiwan first acquired and assimilated mature technologies to undertake duplicative imitation of existing foreign products with their skilled but cheap labour force. Then the accumulation of technological capability through learning by doing, together with the quality upgrading of the educational system, enabled these countries to undertake creative imitation in the face of rising labour costs and increasing competition from the second tier NIEs. Singapore also underwent a similar process, producing mature foreign products at a lower cost under foreign direct investment. As Singapore's skill base improved, multinational corporations (MNCs) shifted their strategy to that of using Singapore as a production locale for more sophisticated products with significant local R&D, and moving labour intensive plants to the second tier NIEs. Many East Asian economies such as Thailand, Malaysia, Indonesia, Vietnam, and the Philippines are at this mature technology stage, undertaking duplicative imitation of existing foreign products with cheap labour forces. In contrast, other countries such as coastal China and some of the East European economies may not evolve from the duplicative imitation to the creative imitation and to the innovation stages, as they have a longer history of technological accumulation and have already reached the duplicative imitation stage before they opened their economies. Some of the sectors in these economies may have enough capability to enter the intermediate technology stage at the outset. If they evolve from the mature technology stage, the speed of evolution to the intermediate technology stage is expected to be faster than that of others.

The trajectory model is more applicable to sectors than to economies. That is, not all sectors within an economy evolve over the trajectory at the same time. Dynamic sectors, which have accumulated technological capabilities through the mature technology stage, may be able to reach the intermediate technology stage with sufficient local R&D efforts. The speed of the evolution depends largely on the complexity of technologies involved and the absorptive capabilities of major players within the sector. Less dynamic sectors, relying largely on cheap labour, find themselves relocated to other developing countries where labour costs are low.

2.2 Production Complexity and Scale Framework

Woodward (1965), in her seminal work on the relationship between production technology and organizational characteristics, suggests three categories of production complexity – unit and small batch production (hereinafter small batch), large batch and mass production (hereinafter large batch), and continuous process production (hereinafter continuous process). The small batch operations usually produce highly differentiated products such as in heavy machinery and shipbuilding, whereas the continuous process operations produce the least differentiated products such as in chemicals, steel, and pharmaceuticals, with the large batch operations such as in electronics and automobile assembly in the middle. Such relations may be depicted as in Figure 2. Based on a series of in-depth research of Korean firms in all three categories of production complexity, Kim and Lee (1989) conclude that firms with different complexity of production technology exhibit different patterns in technology transfer and local innovation, as the production technology dictates the direction of technological efforts.

Figure 2: Technology complexity framework

		Degree of product differentiation			
		Low	Middle	High	
	Small batch and unit production			Machinery	Shipbuilding
Degree of technology complexity	Large batch and mass production			Electronics Automobiles	
	Continuous process production	Chemical Pharmaceutical Cement, etc			

Amsden and Kim (1985) suggest that the scale of operation also accounts for variation in the behaviour of technological change at the firm level, as the scale encompasses to a large extent financial and technological capability, the bargaining power against foreign technology suppliers, market share, and human resource capability, all of which have a strong bearing on a firm's strategy toward its own R&D efforts and the acquisition of foreign technology. The fact that in general large firms produce sophisticated products whereas small firms produce unsophisticated ones may also account for differences in technological behaviour between the two groups of firms.

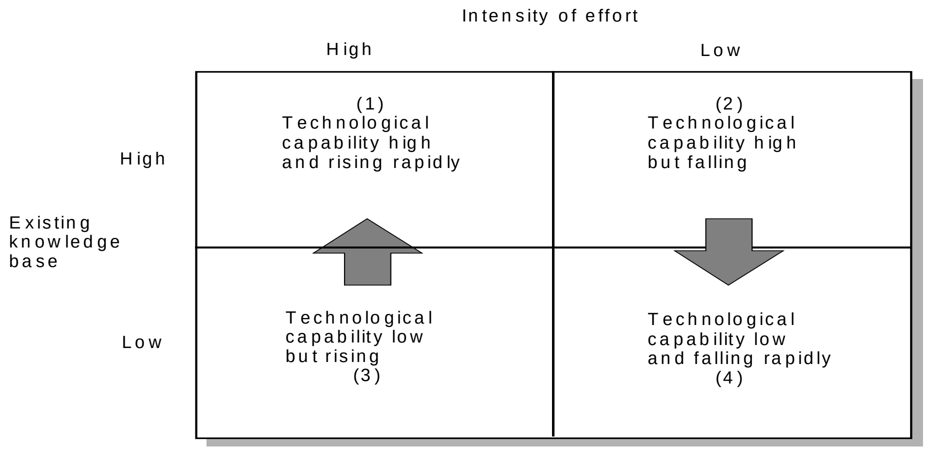
2.3 Absorptive Capacity Framework

Technological capability is acquired through the process of technological learning. And effective technological learning requires absorptive capacity, which has two important elements: the existing knowledge base and the intensity of effort (Cohen and Levinthal, 1990, Kim, 1998).

First, existing knowledge or competence is an essential element in technological learning, as knowledge today enables individuals or organizations to create increased knowledge tomorrow by influencing learning processes and the nature of learning. The existing knowledge base refers to existing individual units of knowledge available within the organization. Accumulated existing knowledge increases the ability to make sense of, assimilate and use new knowledge. The relevant knowledge base includes the basic skills and general knowledge that is necessary to support relatively easy technological tasks in developing countries as well as the most recent scientific and technological knowledge in advanced countries.

Second, the other important element is the intensity of effort or commitment. The intensity of effort refers to the amount of energy relinquished by the organizational members to solve problems. It is insufficient merely to expose firms to the relevant external knowledge without exerting effort to internalize it. Learning how to solve problems is usually built up over many practice trials on related problems. Thus, it requires considerable time and effort directed at solving problems early on before moving on to solving the more complex problems. The effort intensifies interaction among the organizational members that in turn facilitates technological learning at the organizational level.

Figure 3. Absorptive Capacity



These two variables – the existing knowledge base and the intensity of effort -- in the organization constitute, as presented in Figure 3, a 2x2 matrix that indicates the dynamics of technological capability. When both existing 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 knowledge and low intensity of effort (Quadrant 2) may have high capability now but will gradually lose it, as existing knowledge will become obsolete as technology moves along its trajectory. Those organizations will gradually move down to Quadrant 4. In contrast, organizations with low existing knowledge but with high intensity of effort (Quadrant 3) may have low technological capability now, 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 is the existing knowledge for long-term learning and competitiveness of the firm.

On the basis of the above discussions, firms may be crudely grouped into two – aggressive and non-aggressive – in building local absorptive capacity. Most aggressive local firms in developing countries are progressing from Quadrant 3 to 1, expeditiously accumulating their existing knowledge base on the basis of strong intensity of effort. In contrast, there may also be a large number of local firms that are not aggressive technological learners. Empirical evidence shows that non-aggressive large local firms tend to become highly dependent upon foreign technology suppliers. And non-aggressive small local firms are typical petty shops with primitive technology and meagre finance (Kim and Lee, 1987).

2.4 Technology Transfer Framework

Technology transfer from foreign firms in advanced countries can be a very important source of new knowledge for firms in developing countries. The literature on technology transfer, however, focuses largely on formal mechanisms such as foreign direct investment (FDI), which is intra-firm technology transfer, and foreign licensing (FL). These formal mechanisms, however, reflect only the tip of the iceberg. A series of empirical studies at the firm level show that informal technology transfer is far larger than formal technology transfer, particularly during the early stage of development (Kim, 1991; 1997).

Two dimensions may be used in the analysis of transfer of technology: market-mediation and the role of foreign suppliers. In the firstdimension, technology transfer may or may not be strictly mediated through the market. In market-mediated technology transfer, the supplier and the buyer negotiate payment for technology transfer, which may be either embodied in or disembodied from the physical equipment. Foreign technology may also be transferred to local users without the mediation of the market; in this case the technology transfer usually takes place informally without written agreements and payments.

In the second dimension, the foreign supplier may take an active role, exercising significant control over the way in which the 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 the market and the role of foreign suppliers -- offer a useful 2x2 matrix, as shown in Figure 4, to identify and evaluate different mechanisms of international technology transfer (Fransman, 1985; Kim, 1991). In other words, firms in developing countries have many alternative mechanisms for acquiring foreign technology. Foreign direct investment (FDI), foreign licensing (FL), turnkey plants, and technical consultancies are major sources of formal technology transfer in Quadrant 1. Contract research with local universities and government research institutes also becomes an important source of Quadrant 1, as industrialization progresses in developing countries.

See Figure 4, p.25

Trade in capital goods also transfers machine-embodied technology (Quadrant 2), which increases productivity of production processes. It also provides important demonstration effects for reverse engineering of similar capital goods. For these reasons, capital goods are important instruments for technology transfer.

Foreign equipment suppliers transfer crucial technical information free of charge to ensure that equipment sold functions as designed and local engineers in developing countries master how to operate and maintain the equipment properly. In addition, original equipment manufacturing (OEM) buyers often transfer critical knowledge to local producers to ensure that the producers' products meet the buyers' technical specifications (Quadrant 3) (Kim, 1991).

Printed information such as sales catalogues, blueprints, technical specifications, trade journals, and other publications, together with observation of foreign plants, serve as important informal sources of new knowledge for firms in developing countries (Quadrant 4) (Kim and Kim, 1985). In addition, reverse brain-drain or return of native foreign-trained professionals and moonlighting foreign engineers give significant rise to technological learning of the firm in developing countries (Kim, 1993). The most significant way firms in developing countries benefit from mechanisms in quadrant 4 may be the reverse engineering of foreign products.

In other words, if firms in developing countries have absorptive capability, they can effectively acquire foreign technology, especially those in public domain, informally with little or insignificant costs (Quadrants 3 and 4). Although knowledge sources like moonlighting engineers, publications and overseas observations will involve certain costs, these are insignificant compared to the costs associated with formal mechanisms, such as acquiring licenses to produce locally. Even though informal technology transfer cannot be quantified, a series of studies in over ten different sectors in Korea show that informal mechanisms have played a more important role in strengthening Korea’s competitiveness in the international market and in evolving along the technological trajectory (Kim, 1997a).

3. Korea’s Experience

The four frameworks presented above may be assimilated into an integrative model, as shown in Figure 5. This model will be used to examine how firms with different production complexities and degrees of aggressiveness in building local absorptive capacity select the different modes of technology transfer and innovation activities at the different stages of technology trajectory.

See Figure 5, p. 26

Many developing countries have tried to industrialize their economies. Yet the majority of them have made little progress; only a few such as Korea, Taiwan, and Singapore have managed to make significant strides in catching up from the mature technology stage to the intermediate technology stage. The paper uses Korea as a case in point..

Not all the 18 cells in Figure 5 are relevant to issues raised in this paper. In technology trajectory, the first two stages – mature and intermediate -- will be used as a basic structure for discussions. After all, when a country reaches the emerging technology stage, it is no longer considered a developing country.

3.1 Mature Technology Stage (Duplicative Imitation)

Korean firms entered the mature technology stage in the 1960s and 1970s by acquiring, assimilating, and improving generally available mature foreign technology through various mechanisms and evolved into the intermediate technology stage in the 1980s and 1990s through aggressive indigenous efforts to strengthen their technological capabilities. Their paths, however, exhibit some differences largely stemming from production complexities and scale.

In the small batch sectors such as machinery and shipbuilders, large firms relied heavily on foreign sources in the form of foreign licensing and technical consultancies for the initial installation of production processes and for the design of their products. For instance, the machinery industry in the aggregate (ISIC 38) accounted for almost half of all technology licensing in Korea but barely 10 percent of total domestic value added between 1962 and 1981. Large firms accounted for most of these foreign licenses. These local firms purchased foreign licenses (quadrant 1 in Figure 4), because that is the most cost effective way to acquire the initial skills.

In contrast, small firms, which lacked both financial and technical resources, established their initial production facilities with primitive technologies developed by themselves, and then gradually upgraded product quality through the imitative reverse engineering of foreign products and processes. For instance, Wonil Machinery Work, a small machine repair shop, developed the first rolling mill through reverse engineering on the basis of the observation of a firm using an imported rolling mill, machine repair experience, and technical literature. The lax intellectual property rights regime prevailing at the time meant that little attention was paid to the legal aspects of copying imported technology through reverse engineering.

These firms, however, have relied increasingly on their own R&D to master imported technologies and to give rise to product design capabilities in order to reduce their dependence on foreign licensors for subsequent product development, as they accumulated experience in production and product design. In these sectors, expansion of production system can easily be undertaken by adding more capital- goods, once engineers master production processes. In this process, aggressive local firms acquired a large amount of relevant knowledge through informal mechanisms and developed products through reverse engineering processes (quadrant 4 in Figure 4).

Technical knowledge needed by these local firms during this stage was generally mature and gave little competitive advantage to technology suppliers in advanced countries. Such knowledge is also readily available in the form of printed materials or as embodied in products. For these reasons, smart producers could easily reverse-engineer technology in generating duplicative products.

In the large batch sectors such as electronics and automobiles, in which both product and production processes matter, aggressive large firms were initially dependent on foreign firms to establish production processes and to design and manufacture products. But they were not as dependent as firms in small batch sectors. This is because the former produced a smaller number of standardized products than the latter. These firms, however, exerted local efforts, as those with small batch technology, to assimilate imported foreign technology and to generate new products by reverse engineering. For instance, LG Electronics began its radio assembly business by licensing technology from Japan to establish production processes, but has rapidly progressed in accumulating its own technological capabilities through assertive learning and R&D activities.

Small firms in the same industries, in contrast, deployed small batch production to suit quantity requirements. Technical knowledge in the form of printed materials and as embodied in products was readily available for these firms. And smart local firms can easily reverse engineer these foreign products to produce imitative products. For instance, a large number of small electronics firms in Korea have grown through this process in producing final products and components.

These firms soon become important local original equipment manufacturing (OEM) suppliers for MNCs (Dieter and Kim, 2002). In this case, MNC buyers provided product designs and technical assistance free of charge in order to ensure that locally produced goods meet the buyers' technical specifications (quadrant 3 in Figure 2). Then, these firms accumulated sufficient technological capabilities through "learning by doing" to become own design manufacturers (ODM). In the course of such an evolution, aggressive large local firms acquired technological capability through imitative reverse engineering of existing foreign products traded in the market (quadrant 2 of Figure 2). Subcontracting arrangements also played a very important role in allowing Korean firms to get acquainted with international standards and technical specifications as well with the international market.

In the continuous process sectors such as chemicals, pharmaceuticals, steel, and paper, which produce well-known standard products through complex production processes, some began from the outset at a large capacity to reap scale economies. Such large firms imported turnkey plants (quadrant 1 of Figure 4) in order to ensure swift construction and smooth start-up of their initial production processes. For instance, lacking indigenous technological capabilities, all fertilizer and steel plants and some chemical and paper plants were first established in Korea through turnkey plant arrangements. Initial production capability to operate and maintain such process-oriented plants stemmed largely from extensive training by foreign suppliers before, during, and after the setting up of the initial production processes. These firms, however, used deliberate strategies with considerable efforts to acquire capabilities not only for the operation and maintenance of the processes but also for the design and erection of new plants. Consequently, such efforts enabled the local firms to undertake a series of minor improvements, resulting in a significant productivity increase, and to progressively take charge of engineering tasks in the subsequent expansions. For instance, POSCO steel mill relied completely on the Japanese in the first phase in 1971 to achieve an annual capacity of one million tons. But by 1981 capacity had been increased to 8.5 million tons in three expansions that were increasingly under the direction of Korean engineers, rapidly decreasing foreign engineering costs from $6.13 per ton to $0.30 per ton during the same period.

In contrast, some aggressive local firms have dynamically grown from primitive small firms to large modern firms in the continuous process sectors. Most large local pharmaceutical and cosmetic firms (Kim, Kim, and Lee, 1989) and some paper and chemical firms (Amsden and Kim, 1985; Kim, 1997a) have organically evolved from small firms, imitatively developing their own primitive production processes to become significantly large innovative firms over decades. For instance, leading local pharmaceutical firms first started as importer/dealers of packaged finished drugs and later entered the drug manufacturing business by packaging imported bulk drugs. Then, they gradually extended into more intricate operations, first by formulating imported raw materials and later, through backward integration, by producing the chemical components. Through this process, they grew in size and in technological capabilities. As a result, local firms accounted for almost 90 percent of the domestic drug market in Korea as compared to 22 percent in Brazil, 47 percent in Argentina, and 30 percent in India in the early 1980s (UN, 1984). During this period, Korea honoured only process patents but not product patents in the chemical, cosmetics, and pharmaceutical industries, opening an avenue for local producers to work around patented processes to produce relatively well known chemical and pharmaceutical products (Kim, Kim, and Lee, 1989). Were it not for such lax IPRs, it would have been impossible for the local pharmaceutical firms to have achieved so much. Some of the local firms have advanced technologically to a level where they can undertake serious R&D activities and discover new drug compounds (Lee and Kim, 2001).

Many foreign subsidiaries, both wholly owned and joint venture, play an important role in transferring technology to developing countries in the form of FDI and FL (quadrant 1 in Figure 2) in the mature technology stage. One may argue that the lack of IPR protection may deter FDI to developing countries. But empirical evidence shows that IPR protection is not a major factor for MNCs in determining investment in developing countries (Lall and Albaladejo, 2001; Rasiah, 2001). At this stage, MNCs transfer production plants to developing countries in the form of FDI to establish production locales with low wage labour in order to produce mature products for export to other countries and/or to secure local markets. In this case, local subsidiaries will not infringe IPRs. At this stage, few critical technologies are involved in such investment except for that embodied in production processes. Technological spillover effects on other local firms and economy are largely in the form of human mobility.

A more important point is that an effective transfer of technology is likely to take place through the efforts of aggressive local firms than FDI. For instance, in manufacturing, MNCs are motivated to undertake FDI in order to locate their plants, where they could optimize sourcing inputs and produce goods and services for their global strategy. For this purpose, FDI definitely transfers production and management capabilities to ensure efficient production of foreign-designed products. Some MNCs undertake limited R&D activities in these countries to adapt their products to meet local or regional needs. They, however, hardly transfer engineering and innovation capabilities.

A comparative analysis of technological learning process and market performance between Hyundai Motor, an independent domestic firm, and Daewoo Motor, a joint venture with GM -- the largest company with the largest R&D expenditures in the world -- is illustrative. Hyundai licensed technologies from multiple sources and independently took the responsibility to integrate them into a workable mass production system, entailing a major risk. But this forced and motivated Hyundai to assimilate foreign technologies as rapidly as possible throughout the process, because Hyundai, not the foreign suppliers, stood to bear all the costs if it failed. In addition, Hyundai invested heavily in R&D in attempts to accumulate design and innovation capabilities.

That is how Hyundai developed its first indigenous model “Pony” with 90 percent local content in 1975, and it quickly improved its quality in subsequent years through serious R&D activities, making Korea the second nation in Asia with its own automobile industry. As a result, Hyundai’s local market share in passenger cars increased from 19.2 percent in 1970 to 73.9 percent by 1979. Hyundai exported 62,592 cars to Europe, the Middle East, and Asia, accounting for 67 percent of Korea’s total auto exports from 1976-1980, and 97 percent of total passenger car exports from Korea in the period 1983-1986. Pony accounted for 98 percent of Hyundai’s exports during these periods (Kim, 1998).

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 designing its own products. But technology transfer in the form of joint venture is apt to lead to a passive attitude on the part of the recipient in the learning process, as the supplier guarantees the performance of the transferred technology. The investment in product and process improvement undertaken by Daewoo between 1976-1981 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, Daewoo was operating at 19.5 percent of capacity compared with 67.3 percent for Hyundai in 1982. The differential in labour productivity was just as stark; only 2.61 cars per head at Daewoo compared with 8.55 cars per head at Hyundai. Consequently, Daewoo held a market share in the passenger car market of only 17 percent compared to 73 percent by Hyundai, reflecting the greater consumer preference for Hyundai's vehicles.

But just one year after taking over managerial control from GM in 1983, Daewoo had begun to show marked improvements in product/process development and market performance. Daewoo management established a full-fledged R&D department, adopted the Japanese "kanban" system, streamlined production, instituted a quality control programme, and strengthened its marketing drive. Nevertheless, conflicts between the two partners continued to plague the joint venture, giving the smaller Kia a chance to outpace Daewoo. The 1992 divorce from GM finally freed Daewoo to set its own global strategic direction and navigate at its own ambitious pace, recapturing the second position after Hyundai.

Public institutions also played an important role in transferring foreign technology through reverse engineering. Universities played a minor role in helping industry in Korea . During the mature technology stage, they remained primarily as undergraduate teaching-oriented institutions, undertaking little research. In the absence of research in universities, the government took the initiative in establishing a government supported research institute (GRI) – the Korea Institute of Science and Technology (KIST) – by recruiting overseas-trained Korean scientists and engineers.

As the World Bank (2001) implies, reverse engineering of foreign products led to a significant reduction in the price of technology. For instance, KIST enabled industries to strengthen their bargaining power in acquiring foreign technology. When black and white television sets reached a rapidly declining stage in the export market, the colour television set became the next target product for Korean firms to sustain ever-increasing exports. No foreign colour television producer was willing to license technology to Korean producers and help them invade the U.S. market again, as they did with black and white televisions. Three major television producers, therefore, jointly entered a research contract with KIST in order to gain sufficient knowledge and experience in colour television technology. Experience gained from black and white receivers and learning from the joint research made it possible for local firms to strengthen their bargaining power and brought the royalty rate significantly down in licensing core patents held by RCA in 1974, enabling them to enter colour television set production and build up exports.

KIST also played a significant role in transferring technology to industry through reverse-engineering of foreign technology under lax IPR protection – an activity which was beyond the capacity of Korean industry at the time. For instance, when a Japanese company refused to transfer to a Korean chemical firm polyester film production technology for fear of losing its product market in Korea, the firm in collaboration with KIST successfully undertook a reverse engineering task to invent around the production technology. No sooner had KIST reinvented around the technology than the Japanese company offered a technology transfer arrangement, which the Korean government rejected in order to protect the Korea-developed technology (Kim 1991).

In conclusion, during the mature technology stage, Korean firms had acquired, assimilated, and adapted a large amount of mature foreign technologies largely through reverse engineering of existing foreign products under lax IPR protection. This can be seen in technology transfer statistics of FDI, FL, and capital goods imports. Of the three categories of technology transfer, capital goods imports far surpassed other means of technology transfer in terms of value. Through the mid 1980s, capital goods imports were worth 34 times the value of FDI, 72 times the value of FL, and almost 300 times the value of technical consultancies. The total value of capital goods imports was 21 times that of all the other 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 NIEs, the proportion of capital goods imports to total technology transfer was highest in Korea compared to such NIEs as Argentina, Brazil, India and Mexico, suggesting that Korea had acquired more technology from advanced countries through the importation of capital goods than through any other means and used these capital goods for reverse engineering (Kim, 1997a).

One might argue that from Korea's experience IPRs do not impede the flow of capital goods and therefore do not constrain the most important means of technology transfer for developing countries at this stage. But IPRs impede significant technological learning by limiting reverse engineering activities for duplicative imitation.

The contribution of reverse engineering cannot be quantified, but in-depth studies reveal that such practices were dominant and widespread in electronics (Kim, 1980), chemicals (Westphal, Kim, and Dahlman, 1985), machinery (Kim and Kim, 1985), computers (Kim, Lee, and Lee, 1987), and pharmaceuticals (Kim, Kim and Lee, 1989). In other words, Korea's experience indicates that the majority of important or crucial information needed to solve technical problems in the mature technology stage can be obtained, free of charge, through non-market-mediated informal mechanisms, if developing countries have local capability to undertake reverse engineering tasks, because they are readily available in various forms. Even if such technology was patented, Korea did not enforce IPRs and luckily foreign patent holders were lenient in controlling such duplicative imitation then, as it was no longer useful in sustaining their own international competitiveness. However, IPRs, if enforced more rigorously in the future, would undoubtedly pre-empt such reverse engineering efforts and consequent technological learning by developing countries at this stage.

During this period, IPRs were not an important issue for local Korean firms, as shown in patent statistics. Table 1 shows that patent registration has not only been low but also grown very slowly. In the period 1965-1978 it grew only 48 percent. Moreover, foreign firms accounted for almost 80 percent of them, attempting to protect their IPRs in the Korean market. But local firms neither had capabilities to generate genuine ideas to register patents nor incentives to pay attention to patents. Through this process, Korean firms have built a strong foundation to challenge new technological tasks at the intermediate technology stage for creative imitation

See Table 1, p. 27

3.2 Intermediate Technology Stage (Creative Imitation)

As the industrialization process unfolded and Korean firms mastered manufacturing competencies in the duplicative imitation of standardized, low-cost products, they needed to upgrade their indigenous capabilities and manufacture more value-added products in the face of increasing local wages and emerging competitive threats in the labour-intensive production from the second-tier developing countries. This forced Korean firms in the 1980s to shift their emphasis from strategies focusing on labour-intensive mature technologies to those focusing on relatively more knowledge-intensive intermediate technologies across all the sectors, as depicted in the lower part of Figure 1.

All firms across the production complexity scale started with emphasis on the acquisition of production capability[2], but each of the three different production complexities followed a different sequence so as to maximize the benefits of their technological efforts. For instance, large firms with small batch production soon strove to acquire innovation capability in order to modify and improve their products previously produced under licensing arrangements, because investment capability is less important for them; expansion may be done by adding more capitals.

In sectors with large batch production, emphasis was shifted almost simultaneously to the acquisition of both investment and innovation capabilities after production capability, because ability to expand the production system, which is more complex than the small batch system, and ability to innovate new products were equally important.

In contrast, those with continuous process production went sequentially from the acquisition of production capability to that of investment and then to innovation capability. Because engineering costs were so expensive, firms strove to internalize engineering capability in order to minimize investment costs. Then on the basis of production and investment capabilities acquired, these firms went a step further to deepen their R&D efforts so as to innovate their products as well as processes (Kim and Lee, 1987). In short, all firms across production complexity equally emphasized indigenous R&D efforts to become competitive innovators for creative imitation tasks in the intermediate technology stage.

To tackle challenging new technological tasks, which were beyond their existing capabilities, Korean firms across industrial sectors largely focused their technological efforts on three major areas: foreign technology transfer through formal mechanisms, the recruitment of high calibre human resources from abroad, and local R&D efforts. In addition, the government invested heavily in upgrading university research and diversifying GRIs.

As shown below, all these developments had direct impact on the importance of IPR-related issues in Korea, not only for foreign firms but also for Korean firms. This is evident in the patent statistics in Korea. Patent activities in Korea have significantly jumped in the last two decades compared to the first two, increasing a mere 48 percent in the first 14 years (1965-1978) as mentioned earlier, but almost tripling in the next 11 years (1979-1989) and almost tripling again in the next four years (1989-1993). Furthermore, the share of Koreans in local patent registration also increased from 11.4 percent in 1980 to 69.2 percent by 1999, evidencing the increased R&D activity (see Tables 1 and 2).

Korean firms also became active in registering foreign patents. For instance, Korea jumped from 35th in terms of the number of patents in the U.S. among 36 countries listed in an NTIS report with 5 patents in 1969, to 11th with 538 patents by 1992. This represents an average annual growth rate of 43.32 percent (NTIS, 1993). This growth rate is the highest among countries in the report. A more recent report shows that Korea has jumped to 6th with 3,679 by 1999 only after Japan, Germany, Taiwan, France, and United Kingdom. Samsung Electronics, the most R&D intensive firm in Korea,

[2] Production capability here refers to capability to operate and maintain the production. Investment capability refers to ability to design and erect new ventures and expansions. Innovation capability refers to ability to innovate and improve products and processes.

was ranked 4th with 1,545 U.S. patents, only after IBM, NEC, and Cannon, indicating Korea's seriousness in securing patent rights at home and abroad.

Role of transfer of technology

First, foreign technology transfer continued to serve as a major source of building the existing knowledge base of Korean firms. Simple, mature technologies could be easily obtained free of charge through informal mechanisms, because they are readily available in various forms. As mentioned earlier, even if such technology was patented, foreign patent holders were lenient in controlling such duplicative imitation, as it was no longer useful in sustaining their international competitiveness.

Technologies at the intermediate stage were a lot more complex, requiring significant capabilities to use written documentation. And foreign patent holders were serious about controlling imitation by developing countries, as the technology continued to play a pivotal role in expanding their international business activities and sustaining their competitiveness. Thus, Korean firms had increasingly to resort to formal technology transfer such as FDI and FL. This is evident from statistics. FDI increased from $218 million in 1967-1971 to $1.76 billion in 1982-1986, while royalties associated with FL increased from $16.3 million to $1.18 billion during the same period. Capital goods imports also increased drastically from $2.5 billion to $50.9 billion during the same period.

Use of manpower

Second, to crack more knowledge-intensive technology, Korean firms lured high calibre manpower from abroad. The Korean government took a relatively liberal policy with regard to the brain drain at the mature technology stage. As of 1967, 96.7 percent of Korean scientists and 87.7 percent of engineers educated abroad remained there, mainly in the U.S., compared with the corresponding world comparisons of 35 and 30.2 percent for all countries (Hentges, 1975). They, however, became important sources of an overseas technical network and a high calibre manpower pool for Korea's subsequent development.

When industrialization progressed rapidly in the 1970s, the Korean government made systematic efforts to repatriate Korean scientists and engineers from abroad. The nature of state involvement was very "directive" rather than "promotional" in orientation by offering a highly attractive compensation package (Yoon, 1992). The state-led repatriation programme was quite successful, as few repatriates went back to advanced countries. The programme also became a model for the private sector, which began assertively to recruit high calibre scientists and engineers from the 1980s onwards. Successful stories of Korea's progress in high technology industries have much to do with the mobility of Korean-American scientists and engineers, who played a pivotal role in developing new technologies in Korea (Kim, 1997b; Kim 1998). Saxonian (2002) reports a similar story in Taiwan, China and India.

Private R&D activity

Third, in parallel with enhanced efforts in acquiring knowledge-intensive technologies through formal mechanisms and the mobility of high calibre human resources, Korean firms intensified their own R&D activities to strengthen their bargaining power in technology transfer, expedite learning from acquired technology, and to mitigate foreign dependency in technology. Table 2 shows that R&D investment has seen a quantum jump in the past three decades from 10.6 billion Won (US$28.6 million) in 1971 to 3.349 trillion Won (US$ 4.7 billion) by 1990 and to 13,849 trillion Won (US$ 12.2 billion) by 2000. Though the Korean economy recorded one of the world's fastest growth rates, R&D expenditure rose even faster than GDP. research and Development as a percentage of GDP (R&D/GDP) increased from 0.32 percent to 2.68 during the same period, surpassing that of many West European countries.

See Table 2, p. 27

Consequently, there has been significant structural change in R&D investment. The government played a major role in R&D activities in the early years, when the private sector faltered in R&D despite the government's encouragement. More recently, domestic firms have assumed an increasingly large 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 instance, the private sector accounted for only 2 percent of the nation's total R&D expenditure in 1963. This had risen to over 80 percent by 1994, which is one of the highest among both advanced economies and NIEs.

The R&D growth rate is also the highest in the world. For instance, the average annual growth rate of Korea's R&D investment per gross domestic product (GDP) in 1981-1991 is the highest in Korea (24.2 percent) compared to 22.3 percent in Singapore, 15.8 percent in Taiwan, 11.4 percent in Spain, and 7.4 percent in Japan. The average annual growth rate of business R&D per GDP is also the highest in Korea (31.6 percent) compared to 23.8 percent in Singapore, 16.5 percent in Taiwan, 14.0 percent in Spain, and 8.8 percent in Japan (DIST, 1994).

In addition to intensified in-house R&D, Korean firms began globalizing their R&D activities. LG Electronics, for instance, has developed a network of R&D laboratories in Tokyo, Sunnyvale in California, Chicago, Germany, and Ireland. These outposts 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 instance, 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 telecommunications equipment. Samsung, Daewoo, and Hyundai Electronics have developed equally extensive R&D outposts. Samsung has R&D outposts in San Jose, Maryland, Boston, Tokyo, Osaka, Sendai in Japan, London, Frankfurt, and Moscow. Hyundai has outposts in San Jose, Frankfurt, Singapore, and Taipei.

But MNCs' contribution to R&D activities has been minimal in Korea. As of 2000, only thirty-nine MNCs, or 1.4 percent of the total number of MNCs operating in Korea in manufacturing, have established R&D centres in Korea, accounting for less than 1 percent of the total number of corporate R&D centres in Korea. Most of these MNCs' R&D centres are small and involved largely in adapting their products to local market needs. This is a common practice of MNCs operating in developing countries.

Public R&D efforts

Fourth, in addition, the government invested heavily in expanding and deepening university research in the intermediate technology stage. On one hand, the Korean government and a steel corporation have founded three new research-oriented universities specializing in science and technology. On the other hand, the government enacted the Basic Research Promotion Law in 1989, explicitly targeting universities to upgrade their research capabilities. As a result, university research has also expanded significantly, almost tripling in eight years from 244.3 billion Won ($341.2 million) in 1990 to 1,265.1 billion ($1.06 billion) in 1998. The number of university researchers also more than doubled from 21,332 to 51,162 during the same period. In addition, emulating the U.S. experience, the government also introduced in 1989 a scheme to establish Science Research Centres (SRCs) and Engineering Research Centres (ERCs) in the nation's leading universities. The number of SRCs and ERCs increased from 13 in 1990 to 45 by 1997. These centres receive research grants from the government for nine years.

There is also an encouraging sign regarding the quality of university research. The number of scientific publications by Koreans cited by the *Science Citation Index* (SCI) increased slowly from 27 in 1973 to 171 in 1980, but rapidly to 1,227 in 1988, to 3,910 in 1994, and to 10,918 by 1999, climbing from 37th in the world in 1988 to 24th in 1994, and 16th in 1999. The ranking is, however, still low compared with Korea's rank of 11th in gross national product. One might argue that Korea may be underestimated in terms of SCI due to a language barrier. That is not necessarily true. The reasons for emphasizing SCI in Korea are that the majority of Korean scientists and engineers have been trained abroad. Consequently, writing a technical paper in English is not a problem for them. Also, local language journals are generally regarded as inferior in quality compared to SCI journals.

Fifth, the Korean government also took the initiative in diversifying GRIs from one to over twenty to intensify basic research and serve various industrial needs. GRIs began to play an important role in strengthening the bargaining power of local enterprises in acquiring increasingly sophisticated foreign technologies. For instance, when Corning Glass refused to transfer optical fibre production technology to Korea in 1977, two large copper cable producers in Korea entered a joint R&D project with a GRI. After 7 years of R&D, the locally developed optical cable was tested successfully on a 35-km route in 1983. Although this local effort eventually grounded to a halt due mainly to slow progress in R&D, it nonetheless helped local firms gain bargaining power in acquiring foreign technology on favourable terms. Four firms entered into licensing agreements with MNCs in 1984 (Kim, 1993).

Sixth, in addition, the government introduced two major national R&D projects: the Industrial Generic Technology Development Project (IGTDP) and the National R&D Project (NRP), and used GRIs as the backbone of the national R&D projects. The IGTDP has concentrated mainly on solving current problems in "existing" technology areas with high economic externalities (i.e., "spillover effects"), while 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.

In conclusion, Korea has rapidly evolved from the mature technology stage, undertaking duplicative imitation through reverse engineering, to the intermediate technology stage, undertaking creative imitation through formal technology transfer, the recruitment of higher calibre scientists and engineers, and intensified local R&D activities. In this intermediate technology stage, IPRs became important even for local firms.

4. Policy Implications

This paper presented an integrative model on the basis of four conceptual frameworks – technology trajectory, production complexity and scale, absorptive capacity, and technology transfer – as a tool to examine the relationship between IPRs and development. Using the integrative model, this paper analyzed Korea's experience of rapid industrialization over the past four decades and the relevance of IPRs in this process.

An obvious lesson one could draw from Korea's experience is that if adequate protection and enforcement of IPRs is genuinely intended to enhance development, policy makers should seriously consider differentiation in terms of the level of economic development and industrial sectors. Otherwise, the "one size fits for all" approach is a recipe for disaster for developing countries, particularly for the least developed ones.

Therefore, developing countries should work together to change current trends towards stardadized, and all encompassing multilateral IPR system. They should strive to make IPR policies more favourable to them in the short term. But they should also strengthen their own absorptive capacity for a long term solution. Local absorptive capacity enables developing countries to identify relevant technology available elsewhere, strengthen their bargaining power in its transfer to them in more favourable terms, assimilate it quickly once transferred, produce creatively imitative new products around IPRs, and generate their own IPRs. Korea's experience offers several policy implications for other developing countries in accumulating local absorptive capacity. The absorptive capacity framework, as presented in section 2.3 above, has two elements: the knowledge base and the intensity of effort.

First, human resource development is the most important foundation for the knowledge base. Education was one of the most conspicuous efforts Korea made in industrialization. Several other developing countries have attained an equally rapid growth rate in elementary education as did Korea. But what was unique in Korea was the well-balanced expansion at all levels of education early enough to support its economic development. There is a danger that the expansion of education more rapidly than economic progress, could create a serious unemployment problem of the educated. However, when planned properly, the formation of educated human resources can generate an important knowledge base for the subsequent development of the economy, which would soon absorbe the surplus. Baumol, et. al. (1991) also conclude that the quantity and quality of education in an economy is one of the major influences determining whether the economy is catching-up rapidly to narrow the gap with advanced countries.

Second, lacking technological capability at the outset, Korean firms relied heavily on foreign sources for knowledge. Korea used all modes of technology transfer as discussed under Section 2.4. Well-educated Korean technicians and engineers assimilated imported foreign technology and accumulated their capability through reverse engineering. The majority of important or crucial knowledge needed to solve technical problems in the mature technology stage are readily available and could be obtained at low cost through non-market mediated informal mechanisms (Quadrants 3 and 4 in Figure 3) even today.

Technology transfer strategy should, however, evolve over time, as industrialization progresses. When technology is mature and simple, local firms can reverse-engineer foreign products. When technology is beyond the capacity of local firms and IPRs are involved, firms can rely on foreign licensing. They can, however, pursue efforts to assimilate the imported technology in the shortest possible time. When the technology is at the intermediate stage with proprietary technology still in force, local firms should intensify in-house R&D to strengthen bargaining power in technology transfer negotiations. The Korean experience shows that the three elements (trained human resources, technology transfer, and local R&D efforts) are complementary rather than substitutive. The availability of high calibre human resources enables the country to challenge more sophisticated technologies in in-house R&D and, in turn, strengthen bargaining power in negotiating technology transfer.

Fourth, in the long run brain drain of technical people to advanced countries may bring benefits to the home economies. This allows the migrants to acquire advanced knowledge and experience. Brain drain was a serious problem for Korea through the 1960s. However, these Korean scientists and engineers, who became an invaluable source of new knowledge, returned home and came to play a pivotal role in developing intermediate and emerging technologies.

Fifth, the intensity of effort is another prerequisite to building technological capability in industrialization. Export promotion is the most effective public policy instrument that created competitive stimulus for firms to expedite technological learning. In the Korean experience, the export drive forced Korean firms into a “life or death” struggle to survive in the highly competitive international market. Consequently, firms in the export-oriented industries were forced to learn much more rapidly and grew faster than firms in import-substituting industries. Likewise, countries with export-oriented industrialization (EOI) grew faster than countries with import-substitution industrialization (ISI). For instance, the average annual economic growth rate for EOI countries was 9.5 and 7.7 percent, respectively, for 1963-1973 and 1973-1985 periods, as compared to 4.1 and 2.5 percent for ISI countries. It is for this reason that the EOI-oriented NIEs in East Asia grew faster than ISI-oriented counterparts in Latin America.

In conclusion, for developing countries to be dynamic, they should keep upgrading their knowledge base by investing in human resource development. They should also take advantage of the technologies available elsewhere. At the same time they should invest in in-house R&D efforts to work on imported technologies and to challenge increasingly sophisticated technologies in the process of industrialization. The absence of any of these factors is likely to retard the pace of technological learning.

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Figure 1. Technological Trajectory framework

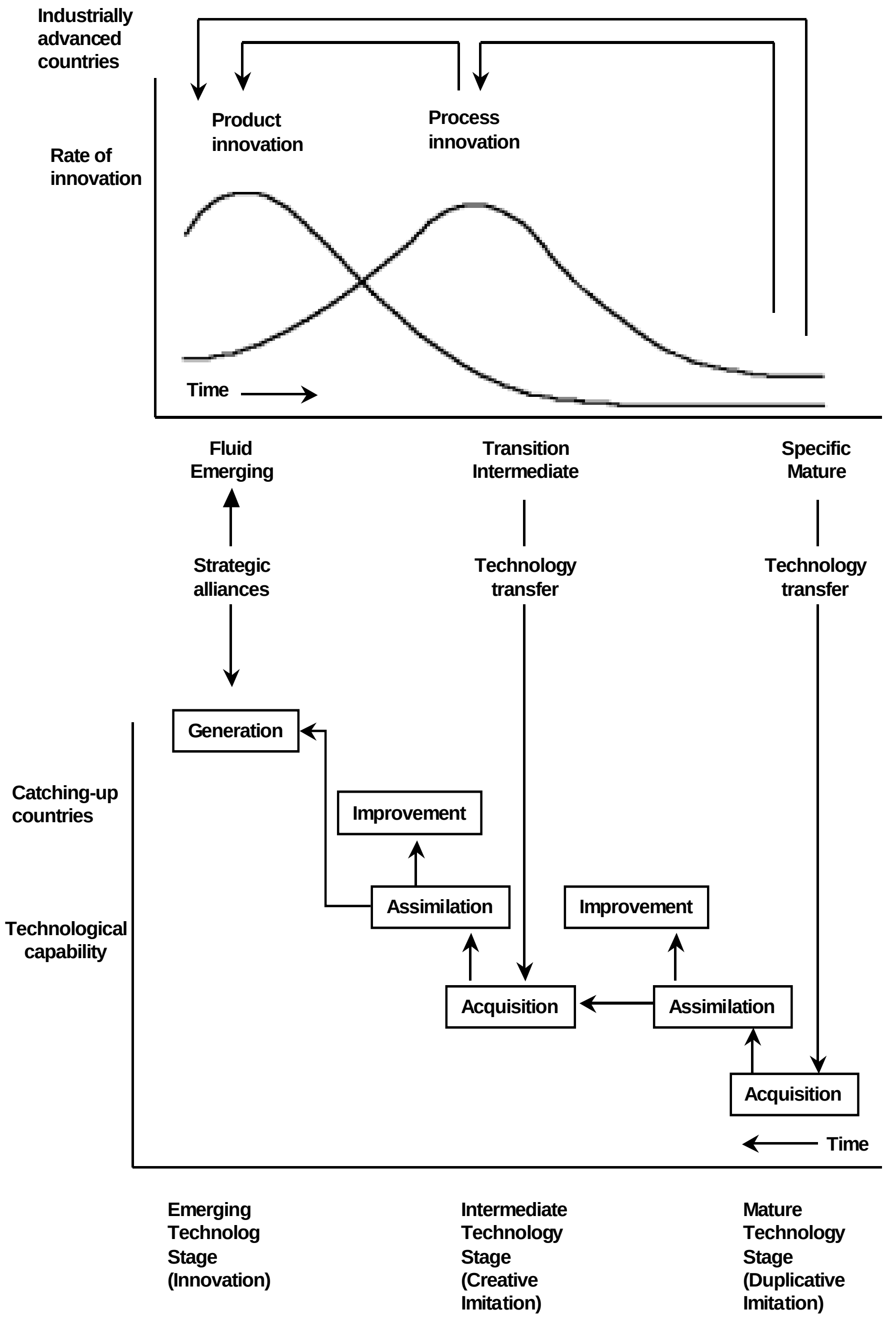

Figure 4. Technology Transfer Framework

	Active	Passive
Market mediated		Standard(serial) machinery (Cell 2)
Non-market mediated	Technical assistance by foreign buyers, technical assistance by foreign vendors (Cell 3)	Imitation, (reverse engineering) observation, trade journals, technological information service (Cell 4)

Figure 5: An Integrative Model

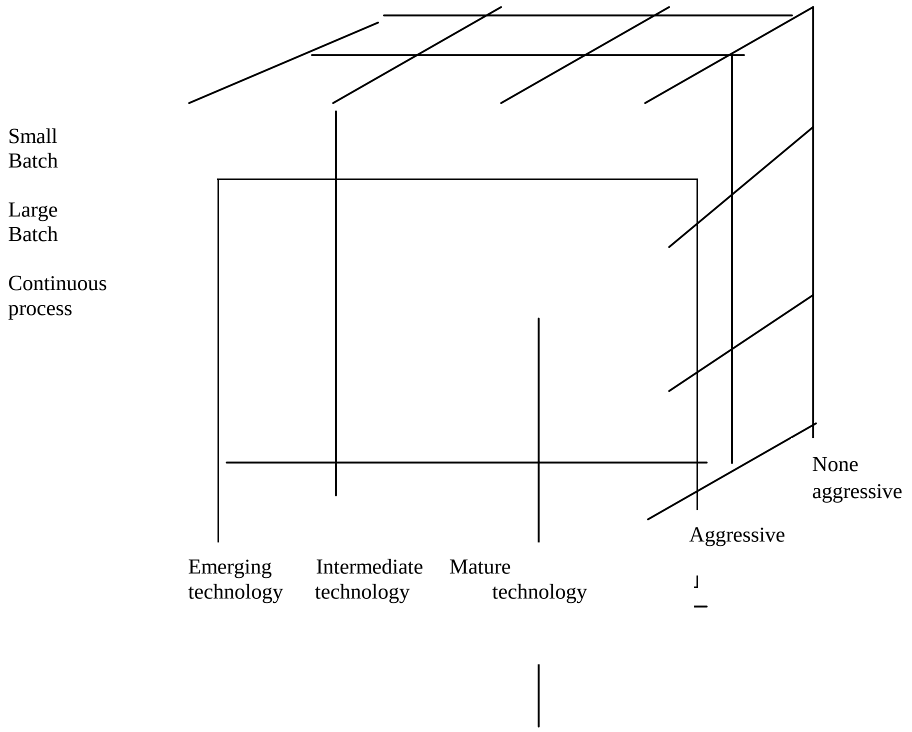

Table 1: Patent Applications and Granted

		1981	1985	1990	1995	2000
Application	National	1,319	2,703	9,082	59,236	72,831
	Foreign	3,984	7,884	16,738	19,263	29,179
	Total	5,303	10,587	25,820	78,499	102,010
Granted	National	232	349	2,554	6,575	22,943
	Foreign	1,576	1,919	5,208	5,937	12,013
	Total	1,808	2,268	7,762	12,512	34,956

Sources: Korea National Statistics Office

Table 2: Research and Development Expenditures

	1965	1970	1975	1980	1985	1990	1995	1998
R&D expenditure	2.1	10.5	42.7	282.5	1,237.1	3,349.9	9,440.6	11,336.6
Government	1.9	9.2	30.3	180.0	306.8	651.0	1,780.9	3,051.8
Private Sector	0.2	1.3	12.3	102.5	930.3	2,698.9	7,659.7	8,276.4
Govt vs. Private	61:39	97:03	71:29	64:36	25:75	19:81	19:81	27:73
University R&D	NA	0.4	2.2	25.9	118.8	244.3	770.9	1,265.1
Govt Res Inst R&D	NA	8.9	28.1	104.5	367.2	731.0	1,766.7	1,979.2
Corporate R&D	0.2	1.3	12.3	81.4	751.0	2,374.5	6,903.0	8,092.3
R&D/GNP	0.26	0.38	0.42	0.77	1.58	1.95	2.51	2.52
Manufacturing Sector								
R&D expenditure	NA	NA	16.7[a]	76.0	688.6	2,134.7	5,809.9	6,439.2
Percent of Sales	NA	NA	0.36[a]	0.50	1.51	1.96	2.72	2.64
Number of Researchers (total)[b]	2,135	5,628	10,275	18,434	41,473	70,503	128,315	129,767
Govt Research Inst.	1,671	2,458	3,086	4,598	7,542	10,434	15,007	12,587
Universities	352	2,011	4,534	8,695	14,935	21,332	44,683	51,162
Private Sector	112	1,159	2,655	5,141	18,996	38,737	68,625	66,018
R&D expenditure per researcher (W 1000)	967	1,874	4,152	15,325	27,853	47,514	73,574	87,361
Researcher per 10,000 Population	0.7	1.7	2.9	4.8	10.1	16.4	28.6	27.9
Number of Corporate R&D Centers	0	1[c]	12	54	183	966	2,270	3,760

NOTES: a: for 1976. b: The figures does not include research assistants, technicians, and other supporting personnel.
c: for 1971.

Source: Ministry of Science and Technology