Reflections on Korea's Acquisition of Technological Capacity

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Abstract

This paper explores technological development in relation to industrial strategy in Korea. What technologies does Korea possess? Where did they come from? How were they obtained? What was the role of trade? The paper begins by establishing a conceptual foundation for discussing the Korean experience. Next, it describes the salient aspects of Korea's development in general terms. Then, because of the importance of exports in Korea's strategy, the paper analyzes the interactions between technological development and export activity.
Summary

Technological development usually is not associated with the industrialization of developing countries because invention, the central aspect of global technological development, plays only a minor part in the industrialization of these countries. But industrialization adds to the variety of products made and processes used in a country -- and thus involves technological development in the sense of gaining mastery over products and processes that are new to a developing economy. Most of the technology introduced in developing countries is transferred in one way or another from overseas. This technology is not assimilated, however by passively receiving it from overseas. Assimilation requires investment in understanding the principles and use of technology. The choices associated with such investment are complicated by the fact that technology is a system of related elements, and these complications have some important implications. Most important is that a country does not have to possess all the capabilities needed to provide each of the various elements of technology. These elements can in principle be obtained -- individually or in a variety of combinations -- from abroad.

Several things stand out in Korea's technological development during the 1960s and 1970s. One is the limited reliance on proprietary transfers of technology by direct foreign investment and licensing agreements. Among formal transfers of technology, turnkey plants and machinery imports have played by far the greater role. Another prominent feature of Korea's technological development is the apparently tremendous importance of a wide variety of informal transfers involving imitation and apprenticeship as well as the use of information obtained in exporting.
Also striking is the selectivity of Korea's technological development and the part played in this selectivity by imports and exports of the elements of technology. Koreans have acquired much technological capability, but they have done it in piecemeal fashion as more sophisticated capabilities have been acquired and put into practice. The capabilities have been acquired through purposive efforts involving a succession of incremental steps, with production capabilities being developed somewhat in advance of investment capabilities. The selectivity of import substitution for the elements of technology has meant continued reliance on imports for at least some elements in almost all industries. But the pattern of imports has continually shifted as local capabilities have replaced foreign ones and as new industries have been developed. In turn, the selectivity of import substitution has been complemented in the pattern of exports by specialization in the elements of technology in line with Korea's comparative advantage. And there is evidence that the pattern of exports, like the pattern of imports, has been shifting rapidly in response to Korea's fast-paced acquisition of technological capability in many areas. What is perhaps most remarkable in this respect is that export activity appears to be an important vehicle for acquiring additional technological capabilities.

Like other advanced semi-industrial economies, Korea is a substantial exporter of many of the elements of technology. But among these countries it stands out as having the largest volume of such exports. Discussed in the paper are five kinds of project-related exports -- overseas construction, plant exports, direct investment, licensing and technical agreements, and consulting services. These exports and those of non-project-related capital goods constitute the exports of elements of technology. Overseas construction
and plant experts for social overhead projects have predominated. The bulk of
this export activity appears to have been performed in accord with detailed
specifications provided by purchasers. Korea's revealed comparative advantage
in exports of the elements of technology is not in newly created technological
knowledge but in project execution, mostly in embodiment activities in the
form of construction and metal-working (including erection and fabrication).
These activities exploit Korea's comparative advantage in its endowment of
human capital and its competence in production. In addition, the Koreans are
acquiring considerable capability -- and numerous new technologies -- through
their participation in overseas project execution with foreign firms from
developed countries. By affording a wider variety of experience in more
diverse circumstances, export activity is compressing the time needed for
accumulating experience, thus contributing to dynamic changes in Korea's
comparative advantage.

Trade in the elements of technology can thus influence a country's
technological development in several ways -- ways that make it possible for
its industrial development to proceed faster than its technological
development. Imports make it possible for foreign capabilities to substitute
for local capabilities, until such time as it is possible or sensible for
local capabilities to replace imports. It is possible, even desirable, to
embark on a line of production without having all the local capabilities
needed to establish and run it efficiently. Imports and exports alike make it
possible for locals to work side by side with foreigners, observing them,
asking them questions, being taught by them -- and thus to develop human
capital through apprenticeship.
More generally, trade of all kinds affects a country's technological development in other ways as well. By increasing the size of the market, it makes it possible for a country to establish new lines of production earlier and at economically efficient scales -- and thus to increase the range of a country's technological experience. By increasing competitive pressure, it forces local producers to engage in technological efforts to reduce prices, improve quality, and expand or adjust the range of products made. And by increasing the access to a broad range of foreign technological information, trade makes it possible for a country to augment its technological capabilities at very low cost.

The foregoing reasons explain why trade -- including trade in the elements of technology -- is a critical dimension of any strategy for technological development. And in Korea, export promotion has been a strategy as much for developing industry as for capitalizing on the industrial competence at each point along the way.
Korean industrialization is unusual not only in its remarkable pace but in other significant respects as well. It thus is a fruitful subject for studying industrial development, as is demonstrated by what has been written on the trade aspect of Korea’s industrial strategy. But there has been little study of — and even less written about — the technological development accompanying Korea’s industrialization. Our purpose in this paper is to document what our reflections on the technological aspect of Korean industrial strategy have taught us.

In our previous attempts to convey what we have learned about Korea’s technological development to colleagues, we have been frustrated by the fact that economists typically do not think of industrialization as technological development. That may be the result of their not having a satisfactory analytical framework for thinking in these terms. We thus find it necessary to establish a conceptual foundation for discussing the Korean experience. Sections 1 and 2 provide this foundation, which — though largely derived from our reflections on Korea — we believe is generally valid. Korea’s technological development is then described in general terms in section 3. Because of the importance of the export-led character of Korea’s industrialization, we explore the interactions between technological development and export activity in the section 4. Findings and speculations are summarized in the final section.

1. Technological Development in Relation to Industrialization

Why is it that economists typically do not associate technological development with the industrialization of less developed countries? Perhaps because invention, the central aspect of global technological development, plays only a minor part in the industrialization of these countries. Most technology introduced in less developed countries is transferred in one way or another
from industrially more advanced countries. But because industrialization adds to the variety of products produced and processes used in a country, it surely does involve technological development in the sense of gaining mastery over products and processes that are new to the local economy. The minor role of invention simply means that much technological development consists of assimilating foreign technology.

Another possible explanation for the neglect of technological development in industrialization is that assimilation often seems to be characterized as being automatic and without cost. If the characterization were correct, assimilation would not merit much attention. But assimilation is not accomplished by passively receiving technology from overseas. It requires investments in understanding the principles and use of technology, investments reflected in increased human and institutional capital. These investments have a big effect on productivity. And they have a big effect on possibilities for adapting technology to suit local circumstances better.

A third possible explanation for the scant attention paid to technological development is that assimilation is not only seen as being absolute, but also as something unitary and discrete. But rather than being absolute, assimilation has an aspect of proficiency. And in addition to having an aspect of proficiency, the choices associated with investments in assimilation have an aspect of complexity. That complexity follows from the character of technology as a compound system of interrelated elements. If this complexity is forgotten, as it often appears to be, the nature of assimilation is trivialized.

The complexity of choices associated with investments in assimilation -- complexity inherent in the separability of technology into its many elements -- has extremely important implications. Most important is that a
country does not have to possess all the capabilities needed to provide each of the various elements of technology. All the elements of technology can in principle be obtained -- individually or in a variety of combinations -- from foreign sources. It is in this respect that Korea provides a particularly interesting and instructive case. Its experience during the 1960s and 1970s shows how a country can successfully assimilate technology in piecemeal fashion.

International trade in the elements of technology means, too, that there need be no necessary relationship between industrial development and technological development -- the former seen in the size and composition of industrial output and the latter seen in the local capability to provide various elements of technology. Certainly there is no necessary relationship over short periods. That is why many paths of local technological development can be taken to reach the same level of industrialization. Those paths can differ in the mode of technology transfers as well as in the extent and nature of investments to assimilate technology -- to acquire the capabilities to provide the various elements. There naturally are differences in costs and benefits for different modes of transfer. But these differences may be of secondary importance, since they can be overcome by tailoring investments in assimilation to offset them.

How, then, is technological development to be assessed in relation to industrial development? Any survey of a country's past technological development can at best yield imprecise results owing to the limited usefulness of readily available information. Many indirect modes of technology transfer -- such as ideas conveyed through the open technical literature -- are not easily traced. Many forms of investment in assimilating technology -- such as the investments associated with the accumulation of
experience -- also go unrecorded. Except in rare circumstances, costs cannot be assessed precisely, even through detailed analyses of case histories of firms and sectors. Benefits are at least as difficult to assess owing to the difficulties created by the likelihood of externalities. Contemporary attempts to uncover the costs and benefits associated with different paths of technological development are further hampered by the paucity of adequate case histories.

In sum, current surveys of technological development in industrializing countries can only address descriptive questions: What elements of technology have been assimilated and in what sequence? Where did they come from? How were they first obtained and then absorbed? Which of them were adapted, in what respects and how? These are the questions we address in this paper.

2. The Nature of Technological Capability

Analysis of technological development requires a conceptual framework that distinguishes the possible choices associated with investments in assimilation. In building such a framework, we have found it most useful to focus not on technology but on technological capabilities distinguished by the functions served. In this section we will provide a functional classification of technological capabilities and discuss how these capabilities relate to trade in the elements of technology.

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1/ This section builds on Dahlman and Westphal (1982, 1983). The former paper uses "mastery" in much the same sense that "capability" is used here. Nelson's (1981) overview of issues in technological development also provides a pertinent perspective from which to understand the framework expounded in this section.
The term, technology, refers to a collection of physical processes that transform inputs into outputs, to the specifications of the inputs and the outputs, and to the social arrangements that structure the activities involved in carrying out these transformations. Technology thus is the practical application of technological knowledge, which is what underlies and is given usable expression in technology. Such knowledge has technical and transactional elements. The technical elements relate to product characteristics and physical processes, the transactional elements to social arrangements. These social arrangements include various kinds of market and contractual relationships among entities as well as organizational modes and procedural methods to regulate an entity's internal operations.

Technological capability is the ability to make effective use of technological knowledge. It is the primary attribute of human and institutional capital. It inheres not in the knowledge that is possessed, but in the uses of that knowledge and in the proficiency of its use in production, investment, and innovation. Owing to the complexity of technology, there are many distinct technological capabilities, classifiable in numerous ways, each corresponding to a different way of distinguishing the aspects of technological knowledge and its application. We sketch here a classification by broad areas of application.

1/ Institutional capital refers to the know-how used to combine human skills and physical capital into systems for delivering want-satisfying products. In terms of Hart and Johnson's (1970) conceptual framework, institutional capital includes system-specific and firm-specific technology plus some elements of general technology.

2/ The identification of technological capability as something distinct and worthy of attention conforms to Salter's separation of technological knowledge and technology. He uses the terms "technical knowledge" and "techniques of production" (1960, pp. 13ff.).
2. Functional classification of capabilities

Technological capabilities are separable into three broad areas: production, investment, and innovation. The first capability is for operating productive facilities, the second is for expanding capacity and establishing new productive facilities, and the third is for developing technologies. Proficiency in production capability is reflected in technical (or \( \eta \)) efficiency and in the ability to adapt operations to changing market circumstances. Proficiency in investment capability is reflected in project costs and in the ability to tailor project designs to suit the circumstances of the investment. Proficiency in innovation capability is reflected in the ability to develop technologies that are less costly and more effective.

The boundaries separating these broad areas of technological capability recognize differences that originate in the specialization of activities applying technological knowledge. Table 1 provides a list of the principal activities associated with production and investment capability.

Much technological knowledge is tacit -- it resides as much in minds as in manuals. That is why experience is critical for becoming proficient in each of these activities. But the scope for transferring capability gained through experience in one activity to other activities is limited. For example, the understanding required for repairing and maintaining physical capital has very little in common with that required for optimizing the scheduling of production. For another example, basic engineering requires

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1/ Hayami and Ruttan (1971, pp. 175ff.) use an analogous typology in discussing transfers of agricultural technology. They distinguish transfers of material, design, and capability, which as they define them imply the attainment of production, investment, and innovation capability.

2/ For supporting argument and a survey of the relevant empirical evidence on these points, see Dahlman and Westphal (1982).
Table 1

Elements of Production and Investment Capability

<table>
<thead>
<tr>
<th>Production Capability</th>
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<tbody>
<tr>
<td><strong>Production management</strong> - to oversee the operation of established facilities</td>
<td></td>
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<tr>
<td><strong>Production engineering</strong> - to provide the information required to optimize the operation of established facilities, including:</td>
<td></td>
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<tr>
<td>Raw material control - to sort and grade inputs, seek improved inputs</td>
<td></td>
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<tr>
<td>Production scheduling - to coordinate production processes across products and facilities</td>
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<tr>
<td>Quality control - to monitor conformance with product standards and to upgrade them</td>
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<tr>
<td>Trouble-shooting - to overcome problems encountered in the course of operation</td>
<td></td>
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<tr>
<td>Adaptations of processes and products - to respond to changing circumstances and to increase productivity</td>
<td></td>
</tr>
<tr>
<td><strong>Repair and maintenance of physical capital</strong> - according to regular schedule or when needed</td>
<td></td>
</tr>
<tr>
<td><strong>Marketing</strong> - to find and develop uses for possible outputs and to channel outputs to markets</td>
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<tr>
<th>Investment Capability</th>
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<tbody>
<tr>
<td><strong>Manpower training</strong> - to impart skills and abilities of all kinds</td>
<td></td>
</tr>
<tr>
<td>Preinvestment feasibility studies - to identify possible projects and to ascertain prospects for viability under alternative design concepts</td>
<td></td>
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<tr>
<td><strong>Project execution</strong> - to establish or expand facilities, including:</td>
<td></td>
</tr>
<tr>
<td>Project management - to organize and oversee the activities involved in project execution</td>
<td></td>
</tr>
<tr>
<td>Project engineering - to provide the information needed to make technology operational in a particular setting, including:</td>
<td></td>
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<tr>
<td>Detailed studies - to make tentative choices among design alternatives</td>
<td></td>
</tr>
<tr>
<td>Basic engineering - to supply the core technology in terms of process flows, material and energy balances, specifications of principal equipment, plant layout</td>
<td></td>
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<tr>
<td>Detailed engineering - to supply the peripheral technology in terms of complete specifications for all physical capital, architectural and engineering plans, construction and equipment installation specifications</td>
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<tr>
<td><strong>Procurement</strong> - to choose, coordinate, and supervise hardware suppliers and construction contractors</td>
<td></td>
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<tr>
<td><strong>Embodiment in physical capital</strong> - to accomplish site preparation, construction, plant erection, manufacture of machinery and equipment</td>
<td></td>
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<tr>
<td><strong>Startup of operations</strong> - to attain predetermined norms</td>
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</table>

**Source:** Westphal, et al., (1984), Table 1.

**Notes:** The elements listed under production capability refer to the operation of manufacturing plants, but similar activities pertain to the operation of other types of productive facilities as well. In turn, our use of "production engineering" departs from conventional usage in that we use the term far more broadly to include all of the engineering activities related to the operation of existing facilities. In our usage, the term encompasses "product design" and "manufacturing engineering" as these terms are generally used in reference to industrial production. See the entries under these headings in the McGraw-Hill Encyclopedia of Science and Technology (New York: McGraw-Hill Book Company, 1977).
highly specialized knowledge of the relevant core processes, while detailed engineering activities, such as designing architectural and civil works, require other specialized knowledge. And so on.

Moreover, the experience gained in operating, say, a steel mill has little to do with (in the sense that it is not sufficient for) establishing a new steel mill. The differences between the activities involved and the specialized knowledge used are simply too great. In fact, many elements of the experience gained in the operation of one steel mill may not transfer to the operation of another steel mill using a somewhat different technology. But the transferability varies across industries. For example, experience operating textile factories may suffice for the establishment of similar factories since textile machinery is available in standardized designs.

Innovation capability pertains to the activities of conceiving and implementing changes in the technical and transactional elements of technology. Included are all the activities spanning invention to innovation that are involved in technological changes that range from radical (major) new departures to incremental (minor) improvements in existing technology. Basic research has no direct relationship with innovation capability because its objective is to gain knowledge for its own sake. But there is an obvious and important indirect relationship because basic research feeds into applied research and development, either as the source of new knowledge or as the locus of human and institutional capital accumulation. Innovation capability is directly related to applied research and development, the objectives of

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1/ It can be argued that the introduction of existing technology into a new environment requires capabilities that are not unlike some of those involved in innovation, as is commonly defined. But in our framework this form of "local innovation" entails investment capability rather than innovation capability.
which are to obtain knowledge with specific commercial applications and to translate such knowledge into concrete operational form. It needs to be recognized, however, that some development activities, such as the creation of pilot plants, also involve production and investment capabilities.

As the examples of textiles and pilot plants suggest, the boundaries that separate the three broad areas of capability -- production, investment, and innovation -- are fuzzy, particularly in adaptation. In industrializing countries as elsewhere, the successful use of technology in production is known to require continuous adaptation involving the activities associated with production capability (see table 1). Adaptation is important because the optimum utilization of technology is rarely achieved at the outset. Not only is the scope for optimizing within given circumstances almost limitless, but circumstances are constantly changing in input and output markets.

Adaptations are not costless -- they require the allocation of resources to purposive technological efforts. The changes are typically implemented through trial-and-error testing of modifications that is like applied research, even though it often does not involve inputs from specialized agents of R & D (research and development), either within the firm or outside of it. Similarly, adaptation often involves elements of investment capabilities.

1/ See Dahlman and Westphal (1982, pp. 113-17), who conclude from the available evidence that "the cumulative sequence of [minor, incremental] technological changes following the initiation of a [successful] new activity [in an industrializing country] may have a greater impact on the productivity of employed resources than that produced by its initial establishment."

2/ Adaptations have been observed to take place through changes that stretch the capacity of existing plants, break bottlenecks in particular processes, improve the use of by-products, adjust to new input sources, alter the product mix, and introduce a wide variety of incremental improvements in processes and product designs. See Katz (1978, 1980, 1982) and Teitel (1981) who provide summaries of the most extensive program of case history research to date.
capability. This is true because adaptations are frequently embodied in minor changes or additions to physical capital. In some cases these adaptations take place through a process that encompasses all aspects of investment capability, even though the amount invested is small.

More generally, experience-based technological efforts to adapt production technology can provide part of the understanding necessary to carry out some -- but not all -- of the activities involved in investment and innovation. For example, plant engineers may acquire some capability in plant design and spare parts production from experience in breaking bottlenecks, maintaining equipment, and solving production problems. But it is unlikely that they will acquire a capability in basic plant design, capital goods manufacture, or the creation of radically new technologies. The background and experience to carry out many of these activities is different, and the relevant capabilities tend to be developed in specialized entities such as process engineering firms, capital goods producers, and technological research institutes. In turn, the accumulation of local experience in carrying out investments can provide some of the understanding that is relevant to innovation -- for example, knowledge of basic engineering or the ability to embody technology in capital goods. But innovation often involves highly specialized technical knowledge that goes beyond what is needed in relation to investment.

To summarize, the boundaries between areas -- though fuzzy -- show that specific investments are required to assimilate distinct capabilities. These investments often involve experience in adapting existing technology. Moreover, the differentiating characteristics of the various technological capabilities are loosely reflected in the institutions that organize and coordinate economic activity.
But patterns of specialization and exchange shift both within and among entities, many of which are newly evolved, as existing capabilities are strengthened and additional capabilities are added. The changes are generally, but not always, in the direction of increasing specialization. Where warranted by -- among other determinants -- the extent of the market, some activities become the domain of specialized units within individual entities or of specialized entities. The latter include a wide variety of firms that provide various marketing, consulting, and engineering services; firms that engage in the manufacture and construction of physical capital; and institutions that perform educational and training services. Producing firms necessarily possess some production capability, aspects of which may be concentrated in differentiated marketing, engineering, and other departments. Nonetheless, such firms may often rely on outside entities for services related to marketing, quality control, process optimization, plant and equipment maintenance, and the like. Moreover, producing firms almost always rely on outside entities for at least some aspects of investment capability: feasibility studies, architectural and specialized engineering designs, and fabrication of physical capital, for example. In turn, specialized innovation capability is found in R & D departments and in separate R & D establishments.

Shifts in patterns of specialization and exchange are important because they are the way that the transactional elements of technology change, and rarely can the full promise of technical changes be realized without changes in these elements. Such institutional change is accomplished through investments that are embodied in the form of organizational structures, codified knowledge and procedures, and customs that govern

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1/ Rosenberg (1976) forcefully demonstrates this from the perspective of economic history.
behavior within and among entities. Thus there is good reason to distinguish institutional capital from human and physical capital and to say that technological capability resides in both human and institutional capital.

2.2 Relationship of technological capabilities to trade in the elements of technology

The specialization and exchange in modern economies are such that few entities are wholly integrated systems with all the technological capabilities relevant to their establishment and operation. Instead, technological capabilities are deployed across entities through market transactions in the elements of technology. These transactions take many forms involving goods, services, and information. And they take place between countries as well as within them. Historically, transactions between countries have increased tremendously in volume and diversity as part of the phenomenon of growing global economic interdependence.

For analytical purposes it helps to distinguish several broadly defined elements present — either singly or in combination — in international trade in the elements of technology:

- **Technological knowledge**: the information about physical processes and social arrangements that underlies and is given operational expression in technology.

- **Technical services**: the activities of translating technological knowledge into the detailed information required to establish or operate a productive facility in a specific set of circumstances.

- **Embodiment activity**: the activities of forming physical capital in accord with given and complete design specifications.

- **Training services**: the activities of imparting the skills and abilities that are employed in economic activity.

- **Management services**: the activities of organizing and managing the operation of productive facilities, the implementation of investment projects, and the development of product and process innovations.

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1/ Reasons for separately distinguishing embodiment activity are given in section 4.2.
Marketing services: the activities of matching the capacity of productive facilities to existing and latent market demands.

The first of these elements is technological knowledge in whatever form it is available without processing or translation to tailor it to (a different set of) specific circumstances. Knowledge in this form is often obtained without payment -- that is, without a market transaction explicitly meant to secure it. Most of the other elements are sometimes also obtained without payment, but much less frequently. What distinguishes these elements is that they consist of activities that reflect the application of technological knowledge in establishing and using productive facilities. Most transactions involving the elements of technology combine technological knowledge together with one or more such activities. These activities are the same ones discussed in relation to the various technological capabilities; the elements listed above simply cluster them in a different way. The importance of distinguishing the activities from the technological knowledge that underlies them rests in the need for a clear framework to analyze comparative advantage in relation to trade in the elements of technology.

Trade in the elements of technology takes many transactional modes that can serve numerous objectives. Licensing, subcontracting, technical agreements, management contracts, marketing arrangements, turnkey-project contracts, direct foreign investment, and trade in capital goods are only some of the forms. Part of this trade simply provides complementary services without any real flow of technology. Marketing services provided under international subcontracting are a case in point, though they are often

1/ In this respect such trade might preferably be called trade "involving" -- rather than "in" -- the elements of technology, but we prefer the single label that better describes most of the trade we are concerned with.
combined with technical services that yield an inflow of technology. Several forms of this trade involve packages of more than one element in addition to technological knowledge. Direct foreign investment and turnkey-project contracts are obvious examples. In turn, while all forms can play an important role in developing local capabilities, this role is not assured for any of them. Even training activities, which have the ostensible objective of imparting technological capabilities, do not always achieve their objectives. Moreover, to the extent that imported elements are not readily available from local sources, imports are more obviously meant -- at least in their initial effect -- to substitute for or complement local capabilities.

Trade in the elements of technology makes it possible to develop most industries through any one of many possible combinations of local and foreign capabilities. At one extreme is the autarkic creation (or recreation) of technology by locally providing all of the requisite elements of technology through accumulating the relevant technological capabilities. This extreme is likely to prove both very costly and very time-consuming even if use is made of freely available foreign technological knowledge. It nevertheless guarantees the acquisition of at least rudimentary proficiency in the relevant technological capabilities. At the other extreme, an industry can be established and operated on the basis of foreign capabilities with no local accumulation of capability. This sometimes happens, for example, with direct foreign investment in an enclave where indigenous involvement is limited to an unskilled labor force. This extreme may prove an effective way of generating employment and earning foreign exchange in the short to medium term, but it does not contribute to technological development. Between these extremes are many possibilities, some of which are illustrated in the following sections on Korea's experience.
Although trade in the elements of technology can play an important role in developing local capabilities, the relationship is not a simple one. Trade in these elements transfers the elements, not the capabilities to provide them, certainly not as a direct (or immediate) result of their being imported. To illustrate: Turnkey projects are a frequent vehicle for establishing new industries in less developed countries. These projects package all the elements required to establish a production facility and train people in its operation. Rarely do these projects transfer any of the investment capabilities. Instead, they are intended to transfer production capability.

The relationship is further complicated by the fact that capabilities that are ostensibly intended to be acquired are sometimes not acquired. This is true because technological development can occur only as the result of purposive effort to assimilate technology. There is abundant and compelling evidence on this point from numerous instances of unsuccessful attempts to assimilate technology. In turn, capabilities that are typically not expected to be acquired, given the nature of the transaction, can be acquired as the result of purposive effort. Examples are given in the following sections on Korea's experience.

It is impossible to discuss technological development meaningfully without reference to the objectives sought. Trade in the elements of technology is an important consideration in assessing these objectives. Much technological development is import substitution to replace foreign capability with local capability in activities related to local production and investment. The benefits of this technological development can -- and often do -- extend beyond simple import substitution to include the ability to adapt technology. Moreover, such development can increase exports, including
exports of the elements of technology, as it has in all semi-industrial economies. And there are possible externalities for technological development in other areas to be considered as well. But the accumulation of human and institutional capital in specific technological capabilities also has costs. These costs include the investment of time and resources needed to accumulate specific capabilities. In addition, as initial experience is being gained, there may be higher costs and greater risks in using local capabilities.

Technological development is not to be seen as having the objective of progressively import substituting for all of the elements of technology. Costs and benefits can not be evaluated without taking account of other opportunities for technological development that are necessarily foregone (or postponed) by dedicating scarce high-level manpower to one area. Particularly in the face of continual global technological development, efficiency in local technological development implies continued imports of many elements of technology, though the pattern of imports shifts as local capabilities are developed.

To conclude: trade in the elements of technology is a critical dimension of any strategy for technological development. That strategy in turn is an important correlate of industrial strategy. Industrial strategies are often discussed simply in terms of the sectoral composition of industry and the market orientation of industrial activity vis-a-vis foreign trade. One of our purposes in this paper is to demonstrate that technological strategy can be discussed in the same terms as industrial strategy. It can be fruitfully discussed in terms of the sequence of choosing the capabilities to be acquired. As should be apparent from the foregoing discussion, sequencing is not simply a matter of the particular industries in which technological capabilities are acquired. It involves broadening -- in part by adding
capabilities to accomplish new technological activities in established industries. It involves deepening -- by achieving greater proficiency and increased differentiation of existing capabilities. And it involves increasing discrimination in the selection of elements of technology that can be efficiently supplied through local development. In turn, technological capabilities can be employed not only in simple import substitution but also in adaptation and in exporting and can be the base from which additional capabilities are acquired. The following sections discuss Korea's industrial and related technological development from this perspective.

3. Korea's Industrial and Technological Development

Korea's rapid sustained industrialization dates from the mid-1960s. Most of our discussion is correspondingly focused on the second half of the 1960s and the 1970s. But the heritage from before 1965 needs be kept in mind when contemplating how the Koreans were able to make such effective use of modern technology after 1965. Thus we begin with a brief historical sketch. We then turn to the past two decades and examine Korea's technological development. We conclude the section with a discussion of the Korea's acquisition of technological capability.

3.1 Historical perspective

Modern industrialization in Korea began in the colonial period, when the Japanese government managed the peninsula's economy as an integral part of its empire. Manufacturing growth during the colonial period was rapid and extensive, but it depended heavily on the Japanese. Nonetheless, Koreans apparently acquired, mostly on the job, substantial knowledge about how to operate modern industries. There is not universal agreement, however, on just how much human capital was built up during the colonial period. Suh (1978, p. 153) emphasizes the "imposed" enclave nature of industrialization during the
colonial period and concludes that the colonial bequest of human capital was negligible. But Mason, Jones, and Sakong [in Mason, et al. (1980)] emphasize the "demonstration effect" of exposure to modern technology and forms of organization" (p. 449) and conclude that the colonial bequest was considerable. We are not sure just how much Korea's subsequent industrialization owes to the colonial period. All we know for certain is that Korea's colonial experience was unlike that of most other less developed countries in that it involved considerable industrialization.

The Korean economy suffered tremendous disruption at the end of the Second World War when its ties to Japan were severed and the peninsula was divided into two political entities. In what now is South Korea, manufacturing production in 1945 was substantially less than a fifth of its level in 1940. But in the light of circumstances at the time, what is really remarkable is that the Koreans were able, with relatively little foreign managerial or technical assistance, to operate nearly half the manufacturing plants that existed in 1944: there was no existing sector in which they were unable to produce at least something. By 1948, with assistance from the United States -- access to raw materials, replacement parts, and technical help -- the Koreans were operating facilities to produce a wide variety of manufactured goods, including shoes, textiles, rubber tires, basic steel shapes, and such engineering products as pumps, bicycles, tin cans, and ball bearings.

Owing to the Korean War, adjustments to dislocation continued to dominate economic activity until the mid-1950s. A respectable but not outstanding rate of industrial expansion was achieved during the latter half

1/ For details, see McCune (1950, chapters 3 and 8).
of the 1950s, with import substitution for light manufactured and nondurable consumer goods playing the major role. A more important development during this period was the tremendous expansion of education, to which American aid contributed. By 1960 Korea had achieved universal primary education, nearly universal adult literacy, and rapidly growing enrollment rates at all levels above the primary level. American aid also financed overseas education and training for thousands of Koreans. In addition, Americans helped the Korean military learn modern concepts and techniques of management and organization, as well as how to operate and maintain all types of machinery and equipment. For almost all the male labor force, military service — which was universal — seems to have been an important source of skill formation and general experience in an organization having many characteristics of modern industry.

The Koreans also gained some industrial competence from their relationship with the United States. Important channels for the direct transfer of industrial technology included the inflow of technical advisers and a modest volume of project assistance. The U.S. military was another channel. Its local procurement program afforded producers in a number of sectors with occasions for assisted learning-by-doing to meet exacting product specifications. Among those benefiting from military purchases were construction contractors, plywood producers, and tire makers — all would later become major exporters.

Large-scale American economic assistance continued through the 1960s. Beginning in the late 1950s, however, there was a gradual shift from grant aid to concessional lending. In addition, the Korean government began

1/ For details about American aid, see Krueger (1979) and Mason, et al. (1980, chapter 6).
to promote inflows of foreign resources of all kinds from increasingly diversified sources. In the early 1960s, as opportunities for easy import substitution rapidly diminished, industrial growth began to falter. A number of attempts were made at policy reform and economic liberalization in the first half of the 1960s, as policy makers came to accept that rapid economic development depended on export-oriented industrialization and a greater effort to mobilize domestic and foreign resources. These attempts culminated in 1964 and 1965, when a number of reforms were successfully implemented. 1/

3.2 Industrial development after 1965 2/

After 1965 the growth of manufactured exports and the rise in domestic demand fueled a rate of industrialization that was much faster-than before. The average annual rate of growth of manufacturing production during 1965-81 was twice the 11 percent rate during 1955-65. Underlying the acceleration of growth in manufacturing, the share of exports in gross manufacturing output increased to roughly one-third in 1981 from less than one-tenth in 1965 -- it was nil in 1955. During 1965-81 the ratio of exports to GNP more than quadrupled, and the share of GNP originating in the manufacturing sector more than doubled. Manufacturing exports became increasingly diversified, so that by 1981 Korea was a major exporter of steel, footwear, machinery and transport equipment, and various manufactures of metal and nonmetallic minerals -- in addition to textiles, clothing, and plywood, which had led the initial growth of exports.

1/ For information about these reforms, see Westphal (1978) and Mason, et al. (1980).

2/ Much of this section is based on Westphal, et al. (1981, 1984) to which reference may be made for additional details.
There was rapid structural change in manufacturing after 1965. Though the share of textiles, apparel, and leather in manufacturing value added (at 1975 prices) was the same -- 18 percent -- in 1966 and in 1981, the share of food, beverages, and tobacco declined from 37 to 20 percent. Roughly offsetting this decline were increases in the shares of chemical products (including petroleum refining) -- from 15 to 23 percent, basic metals -- from 5 to 10 percent, and machinery and transport equipment -- from 13 to 20 percent. Korea’s chemical industry had its start in the early 1960s when large scale petroleum refining and fertilizer production were introduced. The first petrochemicals complex came on line around 1970. The most notable single event in the development of the basic metals industry was the construction of Korea’s integrated steel mill in the early 1970s. The initial growth of the machinery sector was centered in electrical appliances and electronics. Production of electrical machinery grew far more rapidly than that of nonelectrical machinery throughout the period. In transport equipment Korea’s most remarkable achievement has been in shipbuilding, following the establishment of one of the world’s largest shipyards in the early-1970s.

Until the mid-1970s the government’s strategy largely operated on the accumulation of production capability. Indeed, before the shift in strategy, government policy discriminated against domestic investment capability, most notably by favoring imported capital goods. This policy bias was reversed in the early 1970s, about the same time that the Heavy and Chemical Industry Plan, a long-term plan covering the decade to 1981, was published. Among other things, this plan called for the rapid buildup of capacity to manufacture capital goods, particularly the fabricated structural elements and heavy equipment used in industrial plants producing basic intermediate goods and in power generation and transmission and other social overhead facilities.
As will be discussed in section 4.2, exports of capital goods and related services -- in other words, exports of elements of technology -- burgeoned after the mid-1970s. But the manner in which they grew was not foreseen by the plan. Indeed, the plan was heavily focused on import substitution, reflecting the government's intention not to increase the Korean economy's dependence on export activity. But very soon thereafter the government abandoned its intention. This, together with gradual recognition of the extent of the plan's overambitiousness, led to several revisions of the plan. In the light of Korea's emerging exports of elements of technology, successive revisions became increasingly focused on export activity.

It was also during the mid-1970s that the government began to give serious priority to technological development. And export activity likewise became an integral part of its efforts to promote the acquisition of technological capability more generally. Separate legislative acts to promote the technological development of producing firms and to encourage the development of engineering-services firms included the provision of incentives for exports of the elements of technology. These measures were supplemented by others designed to foster the education and training of qualified personnel in various technical fields and to establish an infrastructure of scientific and technological institutes designed to serve industry.

We turn now to examine briefly Korea's reliance on formal technology transfers, starting with the role of direct foreign investment (DFI). Such investment played only a minor part in Korea's industrialization. There was no DFI between 1945 and 1960, when the first Korean legislation

1/ We know that the Ministry of Science and Technology and the Korean Institute of Science and Technology were created in the mid-1960s and were active before the mid-1970s. But we judge that the real shift in priorities came well after their establishment.
controlling nongrant inflows of foreign capital was promulgated. The first instance of DFI in the postwar period was in 1962. By the end of 1981, the Korean government had approved 693 instances (or cases) of DFI in manufacturing. The cumulative gross inflow amounted to roughly US$1.25 billion. This figure may be compared with cumulative total gross investment in manufacturing over the same period, US$22.7 billion, to see the relative magnitude of DFI. 1/

A big part of DFI has been approved on the condition that it involve exports. Nonetheless, DFI made very little contribution to the expansion of exports during 1962-71 -- that is, during the period when export expansion replaced import substitution as the primary engine of Korea's industrial development. Indeed, Korea's first free-trade zone explicitly designed to attract foreign participation in exports was not established until 1970. 2/ A disproportionate inflow of DFI occurred in 1972-76 (see table 2). Much of this inflow was oriented toward exporting. DFI intended for offshore production became relatively less important after 1976.

The composition of DFI during 1962-81 is compared with that of value added in table 2. For comparability, values for both are cumulative over the twenty years. The principal sectors for DFI included textiles and apparel, chemicals (synthetic fibers and resins plus petroleum refining and other chemicals), and electrical and nonelectrical machinery. Most DFI in textiles and apparel and a large share of it in electronics were related to production

1/ Notwithstanding the relative unimportance of DFI, other foreign capital inflows have been very important as a source of the investment finance needed to achieve rapid industrialization. For example, though the share of capital inflows in total investment has fallen steadily over time, it was 20 percent even as late as 1972-76.

2/ Investments in it and a second zone established later accounted for roughly 10 percent of the cumulative inflow of DFI by the late 1970s.
### Table 2

**Proprietary Transfers of Technology, by Sector and Plan Period**

<table>
<thead>
<tr>
<th>Percentage distribution of cumulative values by sector, 1962-81</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food, beverages, and tobacco</strong></td>
<td>2.6</td>
<td>3.6</td>
<td>2.5</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Textiles, apparel, and leather</strong></td>
<td>9.7</td>
<td>7.2</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Pulp and paper products</strong></td>
<td>0.4</td>
<td>0.1</td>
<td>0.8</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Pharmaceuticals</strong></td>
<td>2.0</td>
<td>1.6</td>
<td>2.9</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Synthetic fibers and resins</strong></td>
<td>14.4</td>
<td>30.9</td>
<td>2.7</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Petroleum refining and other chemicals</strong></td>
<td>1.1</td>
<td>8.2</td>
<td>18.7</td>
<td>36.8</td>
</tr>
<tr>
<td><strong>Cement and ceramic products</strong></td>
<td>3.2</td>
<td>1.6</td>
<td>3.0</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Basic metals</strong></td>
<td>9.1</td>
<td>6.7</td>
<td>9.7</td>
<td>11.4</td>
</tr>
<tr>
<td><strong>Nonelectrical machinery</strong></td>
<td>17.2</td>
<td>8.9</td>
<td>31.6</td>
<td>21.3</td>
</tr>
<tr>
<td><strong>Electrical machinery</strong></td>
<td>24.8</td>
<td>22.4</td>
<td>19.5</td>
<td>12.3</td>
</tr>
<tr>
<td><strong>Transport equipment</strong></td>
<td>1.0</td>
<td>5.0</td>
<td>3.0</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Other manufacturing</strong></td>
<td>14.4</td>
<td>3.9</td>
<td>4.0</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Total manufacturing</strong></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage distribution by plan period</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1962-66</strong></td>
<td>2.0</td>
<td>2.5</td>
<td>1.6</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>1967-71</strong></td>
<td>22.1</td>
<td>6.7</td>
<td>14.2</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>1972-76</strong></td>
<td>56.4</td>
<td>47.3</td>
<td>22.5</td>
<td>18.4</td>
</tr>
<tr>
<td><strong>1977-81</strong></td>
<td>21.5</td>
<td>43.5</td>
<td>61.4</td>
<td>78.8</td>
</tr>
<tr>
<td><strong>Total 1962-81</strong></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

| Aggregate cumulative total | 693 | 1,249 | 1,840 | 565 | 156,351 |

* Value is included in other chemicals.

**Sources:** Ministry of Finance; National Income Accounts.

**Notes:** Values are in millions of U.S. dollars: at current prices for amounts invested and paid; and at constant 1975 prices for value added. Totals may not reconcile due to rounding.
for export and played almost no role in technological development. In the former sector, much of the inflow consisted of the relocation of small plants from Japan to take advantage of low wages. In the latter sector, much was for offshore assembly with very little spinoff to local producers. In contrast, DFI has been a particularly important vehicle for technological development in the establishment of much of the chemicals sector and, more recently, of major elements of the electrical and nonelectrical machinery sectors. DFI has also contributed to technological development in the basic metals sector, but there is no foreign equity in the integrated steel mill.

Formal flows of disembodied technology via other modes also appear to have been rather modest. The cumulative value of technical assistance in manufacturing from bilateral and multilateral sources during 1962-81 was well under US$100 million, as was the cumulative value of technical consultancy by private parties. The latter was heavily concentrated in the chemical and machinery (both electrical and nonelectrical) sectors. Table 2 also shows the composition of licensed technology imports. The total number of approved manufacturing technology imports during 1962-81 was 1,840; royalty payments over the same period totaled US$565 million. The volume of licensed imports was rather modest until the mid-1970s. Thereafter the increased reliance on licensing can be explained by the accelerated development of the technologically more advanced industries in recent years. Licensing has been an important source of technology transfer in much the same industries as DFI -- chemicals, basic metals, and machinery.

International comparisons give a particularly fruitful perspective on Korea's pattern of reliance on different modes of technology transfer. Table 3 compares Korea with four other semi-industrial economies -- Argentina, Brazil, India, and Mexico -- using the best information that we have been able
### Table 3

Indicators of Technology Inflows, Human Capital, and R & D for Five Semi-industrial Economies

<table>
<thead>
<tr>
<th>Item</th>
<th>Year or period</th>
<th>Argentina</th>
<th>Brazil</th>
<th>India</th>
<th>Korea</th>
<th>Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock of direct foreign investment as a percentage of gross domestic product</td>
<td>1967</td>
<td>10.4</td>
<td>4.0</td>
<td>3.0</td>
<td>1.7</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>1977-79</td>
<td>4.7</td>
<td>6.4</td>
<td>2.1</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Payments for disembodied technology as a percentage of gross national product</td>
<td>1970-71</td>
<td>-</td>
<td>0.20</td>
<td>-</td>
<td>0.04</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1977-79</td>
<td>-</td>
<td>0.33</td>
<td>-</td>
<td>0.17</td>
<td>0.23</td>
</tr>
<tr>
<td>Imports of capital goods as a percentage of gross domestic investment</td>
<td>1965</td>
<td>5.3</td>
<td>4.6</td>
<td>10.3</td>
<td>13.0</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>1977-79</td>
<td>8.6</td>
<td>8.4</td>
<td>5.6</td>
<td>27.2</td>
<td>11.8</td>
</tr>
<tr>
<td>Postsecondary students abroad as a percentage of all postsecondary students</td>
<td>1970</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>1975-77</td>
<td>0.3</td>
<td>0.7</td>
<td>0.3</td>
<td>1.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Secondary students as a percentage of secondary age population</td>
<td>1965</td>
<td>-</td>
<td>-</td>
<td>29.0</td>
<td>29.0</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>46.0</td>
<td>17.0</td>
<td>30.0</td>
<td>68.0</td>
<td>37.0</td>
</tr>
<tr>
<td>Postsecondary students as a percentage of eligible postsecondary age population</td>
<td>1965</td>
<td>-</td>
<td>-</td>
<td>4.0</td>
<td>5.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>18.0</td>
<td>10.0</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Engineering students as a percentage of total postsecondary age population</td>
<td>1978</td>
<td>14.0</td>
<td>12.0</td>
<td>-</td>
<td>26.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Scientists and engineers in thousands per million of population</td>
<td>Late 1960s</td>
<td>12.8</td>
<td>5.6</td>
<td>1.9</td>
<td>6.9</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Late 1970s</td>
<td>16.5</td>
<td>5.9</td>
<td>3.0</td>
<td>22.0</td>
<td>6.9</td>
</tr>
<tr>
<td>Scientists and engineers in R &amp; D per million of population</td>
<td>1974</td>
<td>323</td>
<td>75</td>
<td>58</td>
<td>-</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>1976</td>
<td>311</td>
<td>-</td>
<td>46</td>
<td>325</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>313</td>
<td>208</td>
<td>-</td>
<td>398</td>
<td>-</td>
</tr>
<tr>
<td>R &amp; D expenditures as a percentage of gross national product</td>
<td>1973</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>1978</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>0.7</td>
<td>-</td>
</tr>
</tbody>
</table>

- Not available.

Source: Project files summarizing data from diverse international sources, World Bank Research Project Ref. No. 672-48. Details are available on request from the authors.
to obtain. Additional cross-country information cited in Westphal, et al. (1981) supports the indication given by the first two blocks of comparative data that DFI and disembodied technology inflows via commercial channels have by no means been relatively large in Korea. In turn, the third block of data confirms what knowledge of the Korean economy would lead one to suspect, namely that Korea's reliance on imported capital goods has, in contrast, been relatively large. Imports of capital goods were more than twenty percent of the value of investment in Korea throughout the 1970s. The closest country of the other four to Korea in this respect was Mexico, with ratios of 11 to 14 percent during the 1970s.

Korea's dependence on imported capital goods should be seen as a result of specialization within the capital goods sector and of the demands of a rapidly growing and diversifying industrial sector rather than as the result of failure to develop a capital goods sector. While it is true that the growth of nonelectrical machinery production failed to keep pace with the growth of industrial output, capital goods production nonetheless grew during 1962-81. Korea's capital goods sector dates back to the colonial period. Over time, all the important metal-working processes, such as casting and machining, were assimilated by Korean firms and used in copying many types of imported equipment, with the designs subsequently modified on the basis of experience to make them more appropriate to Korean circumstances. But the capability to design and produce capital goods was oriented toward the more labor-intensive segments of those industries that had a relatively long history in Korea. Most export industries used imported equipment extensively, as did most new industries established under government incentives.

Insight about how the Koreans were able effectively to assimilate technology comes from the comparative data on human capital formation in table
3. What stands out about the Korean educational pattern are the high proportion of postsecondary students abroad, the high secondary enrollment rate, and the high percentage of engineering students among postsecondary students. Even more remarkable is the rapid growth of scientists and engineers, such that by the late 1970s Korea apparently had by far the highest percentage of scientists and engineers in the population among the five countries. It likewise appears to have had proportionately more scientists and engineers engaged in R & D and to have spent proportionately more on R & D. The well-known problems of measurement and interpretation of R & D statistics dictate the need for caution not to read too much into these last comparisons. We nonetheless believe that they are indicative of Korea's relative ability to undertake technological efforts related to assimilation and adaptation.

3.3 The acquisition of technological capability

Direct foreign investment and the modes of disembodied technology imports discussed above are formal means of technology transfer, as is the import of capital goods, which is typically accompanied by disembodied technology in the form of manuals and training. There also are other, informal modes of transfer that span a wide range of possibilities. Evidence about their importance is difficult to obtain, but there is information. Some of it comes from a survey of 113 exporting firms by Pursell and Rhee in 1976 (see Westphal, et al., 1981, pp. 38ff). The sample was meant to be representative of all exporting firms in Korea.

The firms were asked about the sources of the basic production, or process, technologies they then used. Domestic sources were considered to be important slightly more often than were foreign sources. For domestic and foreign sources taken jointly, the sources of technology most frequently cited
were buyers of output and suppliers of equipment or materials. Next most important were employees with previous experience working in firms overseas -- many as a result of training under turnkey and similar arrangements -- and in Korean establishments. Indeed the transfer of labor among firms was more important than contacts with suppliers alone or with buyers alone. 1/

Formal mechanisms of licensing and technical assistance, of only modest importance overall, were the most important modes for transferring technologies from abroad. Even so, they were considered to be important only a third of the time that foreign sources were indicated. In turn, foreign buyers contributed informal transfers of technology, frequently as a result of periodic visits to inspect production facilities or of ongoing programs to control and improve quality. Through such things as suggesting changes in individual elements of the production process and improvements in the organization of production in the plant and in management techniques more generally, buyers helped many exporters achieve greater efficiency and lower costs. There can be no doubt that the transfer of know-how from export buyers has been a contributor to minor process innovations of the sort that sequentially lead to gradual improvements, the cumulative effect of which can be great.

For many industries it is important to distinguish between the mastery of production processes and the ability to design products that either conform to the structure of -- or anticipate changes in -- demand. Korean exporters, almost across the board, relied heavily on foreign buyers for product-design technology, far more so than for process technology. Foreign

1/ The importance of labor transfer as a source of technology reflects high labor mobility. Depending on the industry, between 33 and 51 percent of the production workers recruited to individual firms in 1975 had previous experience in the job assigned to them.
buyers contributed to product innovation through the influence they exercised on the characteristics of exported products. Nearly three-quarters of the sampled firms stated that they either modified the characteristics of their product to accommodate buyers' requests or produced in direct accord with buyers' specifications. Nonetheless, the majority of firms produced only some of their exports directly to buyers' specifications. The specifications most often influenced were product design and styling, followed by packaging, basic technical specifications, and minor technical specifications.

It is not surprising that Korean exporters have relied extensively on foreign sources for product innovation. Such reliance is inevitable when technology is transferred to start new lines of production that serve export markets from their inception -- as in much of Korean shipbuilding production, for example. But reliance can also develop if production has first been established to serve the local market, with exports following later, as often occurred in Korean experience. Here mastery of technology is in the first instance often confined to achieving rudimentary standards of product design. These standards may suffice to gain entry into export markets, but continued growth of exports sooner or later requires that product standards be upgraded. Moreover, successful penetration of export markets frequently requires that product-specifications be tailored to the different demands of individual markets. Until some experience has been gained in producing to meet differentiated demands, it undoubtedly is most cost-effective, and may even be necessary, to rely on export buyers for product-design technology. Not to be neglected in this regard is that production for export provides a potent means of acquiring product-design technology through learning-by-doing, which spills over to product development in local markets as well.
The results of the survey of exporters clearly indicate that the acquisition of technological capability by Korean industry in basic production processes had progressed further than in product design, at least in relation to product standards in developed-country export markets. In addition, given the high frequency with which domestic sources of process technology were said to be important, the results attest to considerable Korean mastery of basic production technology. Much of what was considered by the respondents to have come from domestic sources consisted of technology originally developed overseas, subsequently transferred or brought to Korea, and then effectively assimilated and sometimes adapted by Korean industry. Some of this technology, particularly in the traditional export sectors, was part of Korea's inheritance from its colonial past.

The basic production technology for nonsynthetic textile yarn and fabric is an obvious case: among today's leading textile exporters are several that were established before independence, and some senior managers and technicians who gained their initial experience during the colonial period were still active in the 1970s. Plywood -- also an important export, particularly during the 1960s -- offers another example: the first plant to produce plywood was constructed in 1935. Plywood is equally an example of an industry that benefited from technical assistance provided under the U.S. military's program of local procurement during the 1950s. Nonetheless, when queried about the sources of technologies in use today, producers of both textiles and plywood overwhelmingly indicated local sources.

The distinction between domestic and foreign sources thus has little to do with where the technology was originally invented. It has far more to do with the importance of the assimilation and adaptation of technology by local producers, and of the diffusion of technology through formal and
informal contacts and through labor transfers among domestic firms. 1/

Further evidence of the importance of diffusion from domestic sources was found in the sizable number of exporting firms that indicated direct knowledge of diffusion to other firms of technologies they had introduced into Korea.

In industries for which process technology is not product-specific, mastery has frequently led to the copying of foreign products as a means of enlarging technological capacity. The mechanical-engineering industries, among others, afford many examples; such processes as machining and casting, once learned through producing one item, can easily be applied in the production of other items. One case that has been closely studied is textile machinery, particularly semiautomatic looms for weaving fabric (Rhee and Westphal, 1977). In this, as in some other cases, Korean manufacturers have not only been able to produce a capital good that meets world standards, albeit for an older vintage; they have, in addition, adapted the product design to make it more appropriate to Korean circumstances. (The adapted semiautomatic looms fall between ordinary semiautomatic and fully automatic looms in terms of the labor intensity of the weaving technology embodied.)

In other industries in which technology is more product-specific, such as chemicals, mastery of the underlying principles has enabled greater local participation in the technological effort associated with the subsequent establishment of closely allied lines of production. Recognition of the importance of local technological learning also is central to understanding how technologies initially introduced in Korea only very recently -- within

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1/ Kim (1980) provides a model of the underlying process of technological development and illustrates it with reference to Korea's electronics industry.
the past five to ten years -- are now considered, in relation to subsequent undertakings in the same lines of production, to have come from local sources.

Detailed information about Korea's technological capability in particular industries is scanty. Still less information is available about the processes by which its capability has been acquired. In preparing for this paper, Kim undertook an extensive survey of the documentary information available from the records of various government and financial institutions, the objective being to determine whether "technological histories" for specific industries could be compiled from existing project files. He also surveyed existing histories of subsectors and firms. The results were, to say the least, disappointing. It appears that access to historical records that are not publicly available and intensive firm-level interviews are the only feasible way to compile even sketchy technological histories. Though disappointed by this finding, we nonetheless feel that there is considerable value in knowing, with some confidence, that there is no feasible alternative.

Detailed historical evidence helps in understanding the evolution in the direction of Korea's technological development. The rapid growth and increasing diversification of Korea's exports of all kinds give the most compelling evidence of Korea's acquisition of technological capability over time. But this evidence is indirect and is therefore apt to be misleading in certain important respects. Thus it is important to know that Korea's exports have not depended crucially on direct foreign investment or other forms of international subcontracting. The survey of exporters clarifies that Korea's industrialization up to the late 1970s was based largely on

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1/ On international subcontracting, see Westphal, et al. (1981), pp. 52ff.
proficiency in production engineering, more specifically on mastery of production processes as opposed to design adaptation. In turn, the extent and nature of Korea's acquisition of investment capability did not become readily apparent until the late 1970s when Korea began to experience rapid growth in its exports of elements of technology. But detailed case histories make it clear that a process of increasing involvement in project execution had become entrenched in Korean industry much earlier.

Amsden and Kim (1982) have obtained histories of several turnkey plant exporters in their ongoing research on Korea's acquisition of technological capability. Two distinct patterns of technology assimilation are apparent. One of them, the "apprentice" pattern, is well illustrated in the following examples.

- A chemical company that produces soda ash and other products. Its initial soda ash plant was built on a turnkey basis by Japanese firms with Japanese technology. Participation in the plant's construction enabled the firm's engineers to do subsequent expansions without foreign assistance. Experience gained through operating the plant and a subsidiary that produces white cement, together with design capabilities accumulated through expansion projects and the establishment of other related plants, gave the firm turnkey capabilities to export a white cement plant.

- An independent chemical engineering company with three chemical manufacturing affiliates and one construction subsidiary. To gain engineering experience and exploit the local market for chemical detergents, the firm imported foreign technology to establish a nonbiodegradable chemical detergent plant. The plant was of German design, with basic technology from an American company; most of its equipment was imported. The firm's engineers took part in all stages of project execution and benefited from intensive training by the American company. The technological capability so obtained later enabled the firm to build a biodegradable detergent plant without foreign technical assistance. Sixty percent of the equipment installed in this plant was made in Korea. Experience in these projects and in numerous other engineering projects provided the capabilities to export an unsaturated polyester resin plant to Saudi Arabia. Except for basic engineering of the core processes, the firm undertook all other stages of project execution.

Many other industries are either known or appear to have followed the apprentice pattern. For example, Kim, in his supplementary survey for this
paper, obtained sketchy information sufficient to confirm that this pattern prevailed in cement and synthetic fibers (specifically, nylon and polyester). 1/

The cement industry is a particularly interesting case because of the continuation of selective foreign participation in basic and detailed engineering, plant startup, and assistance to quality control in recent projects. Continued reliance on foreigners seems to be linked to efforts to remain close to the global frontier in process technology.

Under the apprentice pattern, the first plant in the industry was typically built on a turnkey basis with indigenous involvement "limited" to assimilating as much of the production and investment capability as was practical. The development of investment capabilities began with the participation of Korean engineers -- often more as observers than as anything else -- in the initial project execution and continued through experience gained in production and plant expansion projects. Construction of the second and subsequent plants followed quickly, with Korean engineers and technicians assuming a rapidly expanding role in project design and execution. Indigenous involvement in project implementation expanded through concerted effort to assimilate the know-how involved in project design and execution. The process was effectively one of highly selective and experience-centered import substitution, in which successively more complicated aspects of investment capability were acquired and put into practice. The result was a growing capability in all elements of investment activity.

The rapid accumulation of investment capability through apprenticeship is well illustrated by the expansion path of Korea's integrated

1/ Additional technological histories -- for petrochemicals, paper products, nylon yarn and cord, and the integrated manufacture of basic steel products -- displaying the same pattern appear in Seoul National University (1980) and Enos (1982).
steel mill, which began operation in 1973. The first phase, a turnkey operation by foreigners, created annual capacity of one million tons. By 1981 capacity had been increased to 8.5 million tons in three expansion phases that were increasingly under the direction of Koreans. The progressive substitution of local for foreign investment capability is indicated by the fall in the cost of foreign project engineering per ton of incremental capacity: US$6.13, US$3.81, US$2.42, and US$0.13 in each successive phase. There was also a progressive increase in the share of locally supplied capital goods. Initially 12 percent, it rose to almost 50 percent in the fourth phase. Increased proficiency in investment is further reflected in the shorter times needed to execute successive expansions, even though each phase involved a larger capacity increment: 38 months for the initial, one million ton phase falling to 27 months for the fourth, three million ton phase. The time required from startup to achieve rated capacity also fell in each successive phase. Successful apprenticeship involved large investments in training both in Korea and abroad. Through 1983 the company had sent 1,850 engineers and technicians for training overseas, much of it involving on-the-job experience.

The other pattern of technological development which appears often is the "imitator" pattern. It is illustrated in the histories of two other turnkey plant exporters.

A local manufacturer of steel-pipe, with a subsidiary that manufactures steel-pipe making equipment. After the Korean War the firm developed a primitive steel-pipe manufacturing line using automotive parts and other war surplus equipment, based on observing an imported steel-pipe manufacturing line used by a local bicycle manufacturer. It later developed and improved six separate lines for its own use before importing several more-advanced lines from Japan. Engineering capabilities developed over time and insights from operating the Japanese lines led the firm to develop several modern lines of its own, based on the Japanese lines. The firm's first
A turnkey export (to Kenya) was a renovated line that was about to be scrapped due to economic obsolescence. A second turnkey export (to Bangladesh) was designed and manufactured by the firm. The third was a more sophisticated line than used by the firm. The Saudi Arabian importer specified automated galvanizing lines to save labor.

The only specialized steel-rolling-mill manufacturer in Korea. Originally a machinery repair shop, the firm developed a simple, inexpensive hot-rolling mill for a client. Basic design ideas came from observing an imported mill used by a local firm. Using experience gained from previous projects and technical information obtained from observing more-sophisticated foreign mills operating locally and abroad, the firm developed the capability to manufacture a wide range of rolling mills. It designed and sold 102 mills for domestic use before exporting a turnkey plant to Egypt.

As illustrated by these examples, in the imitator pattern, local firms started with small and rather primitive technologies developed by themselves and gradually upgraded both processes and products through operating experience and using technical information and ideas that came from observing foreign technology. Other capital goods producers known to have followed this pattern include suppliers of machinery for textile weaving and paper manufacturing. The fast pace of Korea's industrial growth has been an important factor in both this and the apprentice pattern. The short intervals between the construction of successive plants to which it led has greatly facilitated experience-based learning.

One of our interests in compiling technological histories was to get some sense of the relative importance of formal and informal technology transfers. Informal transfers have clearly dominated in the imitator pattern and have for a long time been significant in broadening all exporters' capabilities. A study by Kim (1982) indicates that they have also been important in recent innovations by small-scale (less than 100 workers) capital goods producers, many of whom initiated new product lines by imitating foreign equipment — by copying imported models and using information from sales catalogues or from visits to foreign manufacturers. We cannot say in precise
quantitative terms how important informal transfers have been more generally. But everything we know from firm interviews and other sources indicates clearly that they have been very important (Kim and Kim, forthcoming).

4. Exports in Relation to Technological Development

Korea first adopted a strategy of export promotion in the expectation that it would accelerate growth by relaxing the foreign exchange constraint and increase efficiency through resource allocation in line with comparative advantage. These expectations were more than fulfilled. Since the strategy's adoption, exports have led Korea's economic growth. Exports also led the economy's development in a more fundamental sense: in the establishment of new industries and in the acquisition of added technological capability in existing industries.

In this section we first amplify these interactions between export activity and technological capability in general terms. Next we use Korea's exports of the elements of technology to illustrate the interactions in specific terms. We then use the information about these exports to draw some conclusions about Korea's technological capability and its comparative advantage in technological activities.

4.1 Exports and technological capability

Korea's initial export success came largely in industries, such as textiles, established during the Japanese colonial period, before 1945. Exceptions, such as wigs, used technologies easily assimilated, given the technological capabilities then existing in closely related areas. Thus the underpinnings of Korea's export performance during most of the 1960s can be

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1/ Much of this section is taken without further citation from Westphal, et al. (1984), to which reference may be made for additional details.
satisfactorily understood in the conventional paradigm of static comparative advantage. Exports were concentrated in industries in which Korea either already had or could easily acquire the needed technological capability. Moreover, these industries had factor intensities in line with Korea's relative factor endowment. The predominant gains from these exports were the obvious ones, greater capacity use and increased allocative efficiency.

It was in the late 1960s that export activity became important in establishing new industries in which Korea did not already have technological capability. Two wars and their aftermath had opened a hiatus in the establishment of new industries. The hiatus was closed in the early 1960s with the inception of two industries -- chemical fertilizer and oil refining -- both of which were to serve the domestic market with no expectation of substantial exports. Then, in the late 1960s, some new industries were established to serve both the domestic and export markets.

Several of these new industries were characterized by pronounced economies of scale. For these industries, constructing plants at scales sufficient only to meet expected domestic demand would have resulted in production costs well above internationally competitive levels. Thus exports were used to gain the economies of scale needed to realize the potential comparative advantage that Korea had in such industries. Here, a notable example is the integrated manufacture of basic steel products.

Some other new industries had negligible domestic sales at their inception. A few of these, electronic components being an early example, were created by direct foreign investment or relied on other forms of international subcontracting for technology transfer and market access. The rest, such as large-scale shipbuilding, obtained their technology through licensing and turnkey-plant contracts and did not have guaranteed markets at their inception.
Export activity can enlarge technological capability in two ways, by facilitating technology transfer and by stimulating technological effort. Transfers of technology often accompany direct foreign investments to establish plants that are designed to produce for export. They may also be an integral part of transactions involving other means of international subcontracting. But there are few such instances in Korea, since direct foreign investment and international subcontracting have not been very important in most Korean exports. Export activity can also lead to transfers after the acquisition of rudimentary technological capability. Though less obvious, these transfers have been very important in Korea, as was noted previously.

In turn, though there is little direct evidence about the effect which export activity may have in stimulating technological effort, export activity undoubtedly enforces and fosters the acquisition of technological capability. Exporting requires the ability to meet product specifications at a competitive price. And the drive to penetrate overseas markets stimulates efforts leading to the gradual upgrading of product quality. These may even be the most important ways in which export activity adds to technological capability. But this cannot be directly inferred from studies showing that export activity has a strong, positive effect on factor productivity.1/

In sum, under Korea's strategy of export-led industrialization, export activity has been important in exploiting static comparative advantage. It has also been important in dynamically changing comparative advantage through accelerating the broadening and deepening of industrial competence. Export activity made it possible to start new industries much

earlier than they could otherwise have been established without sacrificing economies of scale. In turn, for all industries, and for a long time after their inception, export activity added to technological capability, reflected in a wide variety of minor technological changes. Thus export promotion in Korea has been a strategy as much for developing industry as for capitalizing on the industrial competence at each point along the way. This is well illustrated in the recent growth of Korea's exports of the elements of technology.

4.2 Exports of the elements of technology

Over the past decade Korea has experienced impressive growth in its exports of the elements of technology, which might also be called exports of capital goods and related services. These exports comprise all flows that involve the transmission of technological knowledge and the performance of activities that reflect the application of technological knowledge in establishing and operating productive systems. The constituent elements were indicated and discussed in section 2.2 above. Here we need only add some remarks about the character of embodiment activities which, it may be recalled, are those of forming and maintaining physical capital in accord with given and complete design specifications.

Some capital goods exports consist simply of the manufacture of machinery and equipment (or parts thereof) and the fabrication of structural...
elements in accord with detailed design specifications by the purchaser (or an agent acting on its behalf); that is, they consist simply of embodiment activity. Others of these exports, though made to order, may also include domestic design engineering, the scope of which depends on the completeness of specifications provided by the purchaser. Still others comprise machinery and equipment routinely produced in the country. These latter two categories of exports also consist of embodiment activity. And insofar as they do not simply embody foreign designs obtained under license, they incorporate capability in the design of capital goods; that is, they incorporate an implicit element of technical services.

Overseas construction, in turn, often consists simply of embodiment activity, as when labor services are supplied with a complementary flow of management services.¹ The only analytically important difference between this kind of overseas construction and exports of capital goods made to conform to given, detailed design specifications is in the embodiment activity performed. And even this difference disappears for some kinds of overseas construction. Metal-working, distinct from construction, is the primary embodiment activity in exports of capital goods. But metal-working can also be an important part of overseas construction, as it is -- for example -- in the erection of chemical plants.

Like other advanced, semi-industrial economies, Korea is a substantial exporter of many of the elements of technology. But among these countries it stands out as having the largest volume of such exports.² One

¹ Exports of the elements of technology do not include the services of migrant labor when these are not associated with any other elements, nor do they include flows that consist simply of financial capital or intermediate inputs.

² See Dahlman and Sercovich (1983).
reason for this is the Korean government's active encouragement of these exports. Also important is the rise to prominence in the mid-1970s of the Korean chaebol -- large, conglomerate business groups centered around diversified trading companies. These firms have been the leading agents of Korea's exports of the elements of technology.

Table 4 provides summary data on what we will call "project-related" exports, which include all forms of the exports with which we are concerned except some types of capital goods exports. Five kinds of project-related exports are distinguished in the table: overseas construction, plant exports,

**Table 4**

Licensed Project-related Exports, by Kind and Sector
(Cumulative, through the end of 1981)

<table>
<thead>
<tr>
<th></th>
<th>Manufacturing</th>
<th>Social overhead</th>
<th>Services</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overseas construction</td>
<td>2,055</td>
<td>41,777</td>
<td>121</td>
<td>43,953</td>
</tr>
<tr>
<td>Plant exports</td>
<td>472</td>
<td>2,098</td>
<td>-</td>
<td>2,570</td>
</tr>
<tr>
<td>Direct investment</td>
<td>67</td>
<td>36</td>
<td>-</td>
<td>103</td>
</tr>
<tr>
<td>Disembodied technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Licensing and technical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>agreements</td>
<td>139</td>
<td>13</td>
<td>14</td>
<td>166</td>
</tr>
<tr>
<td>Consulting services</td>
<td>155</td>
<td>72</td>
<td>79</td>
<td>306</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,886</strong></td>
<td><strong>43,996</strong></td>
<td><strong>214</strong></td>
<td><strong>47,096</strong></td>
</tr>
</tbody>
</table>

- Zero or not separately distinguished.

**Source:** Westphal, et al. (1984), Table 2.

**Notes:** See the text for definitions of kinds and caveats about double-counting. Totals may not reconcile due to rounding error.
direct (overseas or foreign) investment, licensing and technical agreements, and consulting services. The data are for licensed exports and were tabulated using information from the ministries responsible for licensing them.\(^1\) (Licensing is done as part of the process of administering export incentives and applies to all exports in Korea.)

Overseas construction refers to contracts for construction projects in which the contracting Korean firm provided more than the services of migrant labor. More will be said about the content of these exports below.

Some but not all capital goods exports are included under plant exports. In Korean usage "plant exports" include complete productive systems (such as manufacturing plants and social overhead facilities) and individual elements of such systems (such as textile machinery and distribution transformers). The elements differ from other capital goods exports in that, to be designated as plant exports, they must be purchased for installation in specific productive systems. Moreover, to qualify as a plant export, the transaction has to exceed a minimum value ($100,000 during the period covered) and satisfy minimum local content requirements that differ by the kind of plant export.

The distinctions among the five kinds of project-related exports are not clear-cut. Most important, contracts that packaged several activities may have been licensed under the dominant activity alone, with the licensed value reflecting the value of the entire package. We only know that this was not a uniform practice. In addition, the reporting of each type of export by a different administrative agency may result in some double-counting. Where direct investment is involved, there is double-counting insofar as the Korean

\(^1\) Data for licensed exports pertain mainly to the value of valid contracts made. Given the lag between contract negotiation and project implementation, the data somewhat overstate the values of actual flows of goods and services.
equity contribution was not in cash but in kind, as frequently was the case. In short, the figures in table 4 are to be taken as indicative rather than definitive. But our impression is that the misclassification and double-counting in these figures is not great enough to make them useless for identifying the central tendencies in Korea's project-related exports.

Overseas construction: Korea got into the business of project-related exports through overseas construction, which remains far and away the largest component of these exports. The cumulative value of licensed overseas construction at the end of 1981 was $44 billion, compared with $47 billion for all project-related exports. The composition of contracts for overseas construction exhibits considerable diversity in the size and type of project.

Much of Korea's initial competence in construction activity came from learning-by-doing gained through contracts under U.S. military procurement in Korea. Its overseas construction began in 1966 and was for some time concentrated in Southeast Asia, where it largely served U.S. military procurement in Guam and Viet Nam. The experience gained serving the U.S. military outside Korea added further capability, specifically in construction work overseas. Thus the stage was set for the dramatic and sustained increase in these exports in 1975, when Korean contractors began to take part in the Middle East's building boom. Roughly 90 percent of the cumulative value of all contracts has been for work in the Middle East.

Overseas construction appears to consist largely of embodiment activity, though it also includes related organizational and managerial services. Precise information is lacking on the incorporation of technical services related to project design. But the design engineering was Korean on smaller projects involving buildings -- such as schools, warehouses, office structures, apartment blocks, and the like -- and simple infrastructure. In
turn, the design engineering needed for some large projects, such as those involving large-scale industrial plants, was provided under separate contracts with non-Korean firms.

Plant exports: Korea's plant exports began as an adjunct of its overseas construction activity, and further impetus came from the government's promotion of the capital goods sector in the 1970s. Though moving at a much slower pace than the government first hoped, Korea's capital goods sector expanded its capacity quite rapidly, diversifying into new areas. Exports of capital goods in current prices grew at the rate of 60 percent a year during the 1970s, compared with 35 percent for total commodity exports.

Plant exports first reached substantial proportions in 1977. From then onwards these exports may have accounted for as much as a third of Korea's exports of capital goods, with most of the remainder comprising ships and railway vehicles. The cumulative value of the 276 plant exports licensed by the end of 1981 was nearly $2.6 billion, or equal to about 6 percent of the value of licensed overseas construction. Licenses ranged from a $100,000 contract for power transformers in Indonesia to a $209 million contract for a cement mill in Saudi Arabia.

The provision of a wide variety of manufacturing plants and their elements constituted nearly a fifth of the value of licensed projects, and more than a third of the number. The difference in shares by value and by number reflects the small size of manufacturing projects, considerably less than half the average value for social overhead projects. The most important markets for Korea's manufacturing projects were the Middle East, which accounted for almost 60 percent of the total licensed value, followed by less developed countries in Africa and Asia, with roughly 20 percent in each region.
Social overhead projects made up the lion's share of Korea's plant exports. They were by far more numerous and had an average licensed value of $12.1 million. Very large projects for offshore drilling and coastal facilities were responsible for more than two-thirds of their licensed value. Other projects were related to desalination plants, power generation and transmission facilities, onshore structures, communication facilities, and water treatment plants. Many social overhead projects appear to have been construction-related in that they included on-site construction or erection and installation as important elements. The Middle East initially was Korea's largest market for social overhead projects. More recently, the OECD countries have emerged as the most important market. Other less developed countries, in Asia and to much less extent in Africa, formed the remainder of the market.

Amsden and Kim (1982) have tabulated the elements of 128 plant exports licensed in 1980 and 1981, exports that accounted for nearly half the value of plant exports licensed through 1981. Equipment (including fabricated structural elements) alone was provided in 43 percent of the cases, accounting for 23 percent of the value of the complete sample; equipment and design were provided in 31 percent of the cases, accounting for 35 percent of the sample's value. Fifteen percent of the cases, accounting for 41 percent of the value, were turnkey projects. The remainder of the projects, accounting for about 11 percent of the value, combined several elements including equipment but were not full turnkey projects. Both manufacturing and social overhead projects were included in all of these categories.

The absence of design services from some of the manufacturing projects does not mean that the Korean contractor simply provided embodiment services in these cases. On the contrary, most of these projects appear to
have supplied Korean-designed equipment. The absence of design services simply indicates that the designs were standard Korean designs rather than special designs tailored to the project being served. But circumstances appear to have been different in the social overhead projects: Korean contractors who provided equipment alone probably undertook only the embodiment activities. In turn, design in social overhead projects typically seems to refer to detailed engineering following basic engineering designs provided by the project sponsor. In manufacturing projects, design often appears to have included basic engineering as well.

The driving force behind Korea's plant exports for social overhead projects was its rapidly advancing comparative advantage in embodiment activity, particularly in large-scale construction projects and capital goods production. The underlying technological capability appears to reside primarily in the organization, management, and execution of construction activity and in the production-engineering aspects of metal-working. Additional forces seem to have been at work in the exports of manufacturing projects. Not only did many of these projects appear to include more sophisticated technical services, such as basic design engineering, many also appear to have transferred process technologies that incorporated Korean adaptations. Moreover, several turnkey manufacturing projects called for considerable ability in the organization and management of complex overseas undertakings. In this respect the projects reflected a higher degree of entrepreneurial ability than was probably characteristic of most social overhead projects. Thus the technological capability underlying the manufacturing projects was more extensive in that a much wider range of elements was involved.
Direct investment: A steady flow of outward investment from Korea started in about 1967, with a few cases in the preceding years. By the end of 1981 the cumulative licensed outflow of direct investment was $323 million, of which $103 million was in manufacturing or social overhead sectors. Thirty-four manufacturing ventures were licensed by the end of 1981. The smallest was for $25,000 in a printing firm in Japan; the largest was for $25.7 million, in a cement mill in Malaysia. About three-quarters of this investment was in less developed countries in Asia; most of the rest was in Africa and the Middle East.

There was a considerable overlap between Korea's overseas manufacturing ventures and its manufacturing plant exports. Indeed, in some cases an equity position is either known or appears to have been taken to facilitate the export of a plant. But some investments were motivated more by the desire for access to natural resources, albeit in a processed form, than by anything else. Another factor motivating some joint-venture investments, particularly those in the OECD countries, was the desire to gain access to foreign technology through collaboration with foreign companies.

Disembodied technology exports: In Korean usage, licensing and technical agreements are distinguished from technical consulting services. But the dividing line between the two categories is not clear-cut. The only real distinction we know of is that no contracts involving royalty payments over time (as opposed to one-time lump-sum payments) are licensed under consulting services.

No licensing or technical agreements were recorded before 1978, when two contracts were licensed -- we do not know their value. Of the 39
contracts worth $166 million licensed during 1979-81, 36 were with firms in less developed countries, mainly in the Middle East. Most licensing and technical agreements provided general technical assistance in production engineering and maintenance, many over several years or more. The sectors served were mainly in manufacturing, with a rather wide dispersion among these sectors. And some of the contracts were to plants in whose establishment Korean firms had participated through overseas construction or plant exports.

Exports of consulting services were far more numerous than those of licensing and technical agreements. The cumulative value of the 324 contracts licensed from 1973 through 1984 was $306 million, with more than three-quarters of the contracts (by number and value) having been licensed in 1979-81. Most comprised technical services accomplished by the dispatch of personnel to oversee construction and plant erection, install machinery and equipment, inspect structures and equipment, trouble-shoot, train labor, and the like. The value of licensed contracts was split about evenly between manufacturing and social overhead sectors. Many consulting services, particularly in the social overhead sectors, appear to have been related to Korea's construction exports. Firms specializing in engineering appear to have been responsible for most exports of both licensing and technical agreements and consulting services -- not only exports related to project execution, but also those involving production engineering. These exports thus reflect the growing capability of Korea's recently established engineering firms (see Lee 1981).

4.3 Revealed and dynamic comparative advantage

We have discussed five kinds of project-related exports -- overseas construction, plant exports, direct investment, licensing and technical
agreements, and consulting services. These exports and those of non-project-related capital goods constitute the exports of elements of technology. Overseas construction and plant exports for social overhead projects have predominated. They accounted for more than 95 percent of the cumulative value of licensed project-related exports at the end of 1981 and around half to three-quarters of total exports of capital goods and other elements of technology during 1977-81. The bulk of this export activity appears to have been performed in accord with detailed specifications provided by the purchaser. We thus conclude that Korea's revealed comparative advantage in exports of the elements of technology is in project execution, mostly in embodiment activities in the form of construction and metal-working (including erection and fabrication). 1/

These embodiment activities are moderately intensive in human capital. They require reasonably skilled workers and technicians as well as competent engineers, factors of which Korea has a comparative abundance. But more than this, they require the ability to organize and manage undertakings that are often complex, even in subcontracts. Here Korean firms appear to have an advantage that permits them, for example, to complete projects in far less time than is considered average or normal. Precise information about this is lacking but anecdotes abound. Moreover, much of the marketing of these exports is done by Korean firms, acting without foreign agents. This is one area where Korean know how relating to transactions is second to none.

In most of its exports of the elements of technology Korea is not exporting newly created technological knowledge. Instead, these exports

1/ We are constrained to assess revealed comparative advantage by the composition of Korea's exports. But we doubt that the use of more sophisticated methods would change the conclusion.
largely consist of certain project execution activities. In other words, what underlies Korea's revealed comparative advantage is its mastery of production engineering in construction and metal-working. Korea enjoys a cost advantage in these activities owing both to its mastery and to its comparatively low wages and salaries -- adjusted for skill and productivity differences -- for skilled workers, technicians, and managers.

A small part of Korea's exports nonetheless do appear to transfer idiosyncratic manufacturing technologies created through experience-based adaptive engineering. In turn, technological idiosyncrasies may be an element of Korea's revealed comparative advantage in project execution. That is, the technologies used to carry out these activities might be idiosyncratic. Differences in technology related to organizational modes and procedural methods might, for example, be what underlies the ability of Korean firms to complete projects in record time. This possibility is certainly consistent with our conception of the elements of investment capability.

The technology factor that underlies most of Korea's exports of the elements of technology is much the same as that which underlies most of its (other) manufactured exports. Insofar as the former exports largely reflect mastery of what might be termed the production engineering aspects of project execution, the rapid growth of both kinds of exports reflects the rapid accumulation of proficiency in production. But the emphasis on proficiency in production should not imply that Korea lacks a design capability. Exports of idiosyncratic manufacturing technology indicate that there is some capability in the design of machinery. And Korea does export detailed project-engineering services. But these exports are only a small fraction of the total. What is more significant, Korea does not appear to possess much capability in basic project engineering.
In discussing the general relationship between exports and technological capability in Korea, we emphasized two distinct objectives—exploiting the country's existing comparative advantage, and dynamically changing its comparative advantage. There can be little question, especially in the light of the foregoing discussion, that Korea's exports of elements of technology exploit its existing comparative advantage, in both its endowment of human capital and its mastery of the production engineering aspects of project execution. What, then, of their role in dynamically changing Korea's comparative advantage?

Owing to their highly specialized nature, many activities of project execution are characterized by extreme economies of scale. Korean firms could not be internationally competitive in these activities if they served only the domestic market. Export activity has thus made it possible to establish investment capabilities that could not otherwise have been realized without tremendous sacrifice of scale economies. It has also enabled greater continuity over time in the use of capabilities once established, thereby precluding their atrophy owing to infrequent use. Moreover, the accumulation of experience is a critical input in acquiring most of these capabilities. Export activity not only compresses the time for experience to be accumulated; it also affords a wider variety of experience in more diverse circumstances. It can thus be expected to accelerate cost reductions from learning and to deepen existing capabilities.

These benefits appear to be reflected in changes over time in the composition of Korea's exports of elements of technology toward increasingly

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2/ See the sources cited in the preceding note.
more complex and sophisticated activities. Managers of exporting firms have also confirmed, in interviews with Amsden and Kim (1982), that these benefits are realized. But these managers have indicated another benefit as being even more significant: participation in project execution with foreign firms from third countries has been an important vehicle for acquiring additional capabilities and new technologies. These gains have occurred through a process akin to apprenticeship—a process also observed (as previously noted) in Korean participation in local projects. This broadening of Korean technological capability occurs even in overseas construction. For example, one Korean firm assimilated a complete system of solar energy technology through its participation with a U.S. firm in a project involving this technology in Saudi Arabia.

The broadening and deepening of Korea's industrial competence, particularly its investment capability, appears to be an important motive in the government's promotion of exports of the elements of technology. In the short run, the gains from exploiting existing comparative advantage in these exports are considerable. But in the long run, the gains from further developing Korea's technological capability may well be even more considerable.

5. Conclusion

Several things stand out in Korea's pattern of technological development. One is the limited extent of reliance on proprietary transfers of technology by means of direct foreign investment and licensing agreements. Among formal transfers of technology, turnkey plants and machinery imports have played by far the greater role. Moreover, in only a few sectors, such as electronics, have Korean exports depended crucially on transactions between related affiliates of multinational corporations or on other forms of international
subcontracting. Another prominent feature of Korean technological development is the apparently tremendous importance of a wide variety of informal transfers that have involved imitation and apprenticeship as well as the use of information obtained in exporting. Also to be included under informal transfers is the expertise that has been obtained as a result of the return of Koreans from study or work abroad unassociated with formal training, though the importance of this transfer relative to formal training is not known.

Also striking is the selectivity of Korean technological development and the part played in this selectivity by both imports and exports of the elements of technology. Koreans have acquired a good deal of technological capability, but they have done it in piecemeal fashion as successively more sophisticated capabilities have been acquired and put into practice. The process of acquisition has clearly been one of purposive effort involving a succession of incremental steps, with production capabilities being developed somewhat in advance of investment capabilities. The selectivity of import substitution for the elements of technology has meant continued reliance on imports for at least some elements in almost all industries, but the pattern of imports has continually shifted as local capabilities have replaced foreign ones and as new industries have been developed. In turn, the selectivity of import substitution is complemented in the pattern of exports by specialization among the elements of technology in line with what one would expect to be Korea's comparative advantage. And there is evidence that the pattern of exports, like the pattern of imports, has been shifting rapidly in response to Korea's fast-paced acquisition of technological capability in many areas. What is perhaps most remarkable in this respect is the fact that export activity appears to be an important vehicle for acquiring additional technological capabilities.
Korea’s ability to industrialize without extensive reliance on proprietary transfers of technology is in part explained by the nature of technology and product differentiation in the industries on which its growth has so far crucially depended. Many of these industries — such as plywood or textiles and apparel — use relatively mature technologies; in such cases, mastery of well-established and conventional methods, embodied in equipment readily available from foreign suppliers, is sufficient to permit efficient production. The products of many of these industries are either quite highly standardized (plywood, for example) or differentiated in technologically minor respects and not greatly dependent on brand recognition for purchaser acceptance (textiles and apparel, for example). Thus, in most of the industries that have been intensively developed, few advantages are to be gained from licensing or direct foreign investment as far as technology acquisition and overseas marketing are concerned.

Nonetheless, exceptions exist, most notably in the chemical industry. In this industry Korea has had to rely extensively on direct foreign investment to establish and expand production, no doubt owing to the reluctance of the technology suppliers to transfer technology via other modes. But in other industries where technology is also proprietary, a number of examples attest to the fact that Korean industry has managed to initiate, and in most cases to operate successfully, a variety of high-technology industrial activities by means of licensing and turnkey arrangements. To cite two cases: Korea used arrangements of this kind to acquire the most modern shipbuilding technology in the world, and to incorporate the most recent technological advances in its integrated steel mill.

More generally, Korea’s recent experience in promoting technologically sophisticated industries indicates that their development may
involve greater reliance on licensing as a way of acquiring technology. It is also probable that the shift to new industries may imply greater dependence on direct foreign investment. Indeed, greater dependence on such proprietary transfers of technology is observed starting in the latter half of the 1970s. But for the period in which Korea achieved semi-industrial status—that is, from the mid-1960s to the mid-1970s—there can be no doubt about the overwhelming role of indigenous effort in using capital goods imports and informal transfers of technology to acquire technological capability.

What is unique about Korean experience is not the importance of indigenous effort to assimilate technology. As we indicated at the outset, research on all semi-industrial economies shows that such effort is crucial for the acquisition of technological capability. What is unique about Korean experience is the speed and effectiveness of acquisition and the interplay between technological development and trade in the elements of technology. In section 2 we outlined a framework for understanding and analyzing that interplay. The framework, like everything known about technological development, suggests the importance of paying attention to fine distinctions among technological capabilities when trying to understand the role of experience-based efforts in the cumulative buildup of technological capability. Because of space limitations, our discussion of Korean technological development in sections 3 and 4 glossed over some of these distinctions.

Although we have enough details to conclude that such distinctions are fundamental, we lack a sufficient base of knowledge to generalize from Korea's experience about many key aspects of formulating a strategy for technological development. We would emphasize four areas where more knowledge needs to be sought to understand the sources of Korean success. One is the
positive relationship between education and technological development -- the
details of this relationship remain to be uncovered. Another is the
difference between competition in domestic and in export markets in
stimulating technological effort. We suspect but cannot yet demonstrate that
an export-promoting policy regime provides a far more effective stimulus than
either an inward-looking regime or an outward-looking regime that simply aims
at international competitiveness.

The third area is the role of government policy interventions in
fostering Korea's export-led industrialization and in stimulating
technological development more generally. Enough is known to conclude that
the government's role cannot be characterized or judged in simple terms. We
have not provided much discussion of the government's role because we wanted
to focus on describing the main features of Korea's technological
development. Another reason is that more needs to be known before many
conclusions can be reached. The last area for study is the importance of
"initial conditions" in the early 1960s. Does rapid sustained technological
development in industry require the prior attainment of some minimal level of
industrial competence built up through a process that is either much less
rapidly paced or far more dependent on foreign production capability obtained
through direct foreign investment or the use of expatriate manpower? The
question remains very much open. Combining further study in these areas with
the findings of complementary research on other semi-industrial economies may
move us closer to answering important questions about the formulation of
strategies for technological development.
References


