Technology Transfer and Absorption in Korea: Methodology and Measurement

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The purpose of this essay is to categorize technological knowledge and to examine its transfer from developed countries to Korea. The empirical investigation is carried out with data available from the firms surveyed: Hanyang Chemical Corporation in petrochemical industry, Kolon Co. Ltd. (KOLON) in synthetic fibers, Daewoo Heavy Industries Ltd. in machine industry, and Pohang Iron and Steel Co. Ltd. (POSCO) in iron and steel industry.

We start by revealing the procedure dictated by the concept of the process and methodology of measurement, and moves through its stages, from the planning stage at the beinning to such various further stages as negotiation with foreign suppliers, design, construction, starting-up, operating the equipment, securing improvements, developing new products and techniques, absorption and diffusion of imported technology. Comparisons are at the heart of the summary, and in particular a comparison with Japan is indicated. The broad implication is that the presently reported statistical evidence provides not only a description of the technology transfer but also a prescription, that is, an inquiry into how the transfer can be conducted skillfully in developing countries. (*JEL* Classification: O33)

I. Introduction

In industrializing, most countries first acquire technology. Before production can begin, even before plants can be constructed and equipment installed, a minimal amount of information about the manufacturing technique must usually be imported. Up to the time of transfer, this information will reside in patents and other published documents, in blueprints, in design and operators' manuals that are

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the private possession of construction and producing firms abroad, and in the accumulated experience of individuals who have perfected the technique. This reservoirs of technological knowledge are many, deep and distant.

Yet, somehow or other, the fluid that resides in these distant sources must be tapped, and piped as swiftly and economically as possible to the potential users in the developing countries. Moreover, as a fluid to be supplied by one group of individuals and acquired by another group of individuals, technical knowledge is very complex, so complex that its nature is difficult to define and its transfer to describe. To categorize technological knowledge and to investigate its transfer from developed countries to Korea are the objectives of this paper.

It might be said that attaining these objectives would be sufficient to justify carrying out the study, for relatively little is known about what constitutes technological knowledge and about how this knowledge is drawn upon; but the choice of Korea provides further justification. By general agreement, Korea has been particularly successful in industrializing; it therefore should be able to provide not only a case study of the transfer of technology—i.e. a description—but also an inquiry into how the transfer can be conducted skillfully—i.e. a prescription.

It is unlikely that Korea's achievements would have been so great had its acquisition of modern technology been slow and inefficient; so the presumption can be made that the transfer of technology to Korea has been relatively smooth. Nevertheless, this general statement is not very revealing; it immediately leads one to ask in which activities, involved in the transfer, Korea may have excelled and in which not. It also leads one to ask fundamental questions concerning the relations between the acquisition of technology on the one hand and the production of goods on the other hand and the meaning of excellence. Economists have reasonably good ideas of what is meant by excellence in production and exchange, centering on efficiency in the static sense and on innovation and responsiveness in the dynamic sense, but they have few ideas of what is meant by excellence in the transfer of technological knowledge. In the observation of what one imagines to have been a successful transfer some ideas may emerge; to evoke these ideas is an aim of this paper.

II. Methodology

The chief means employed in trying to meet the aims of this work

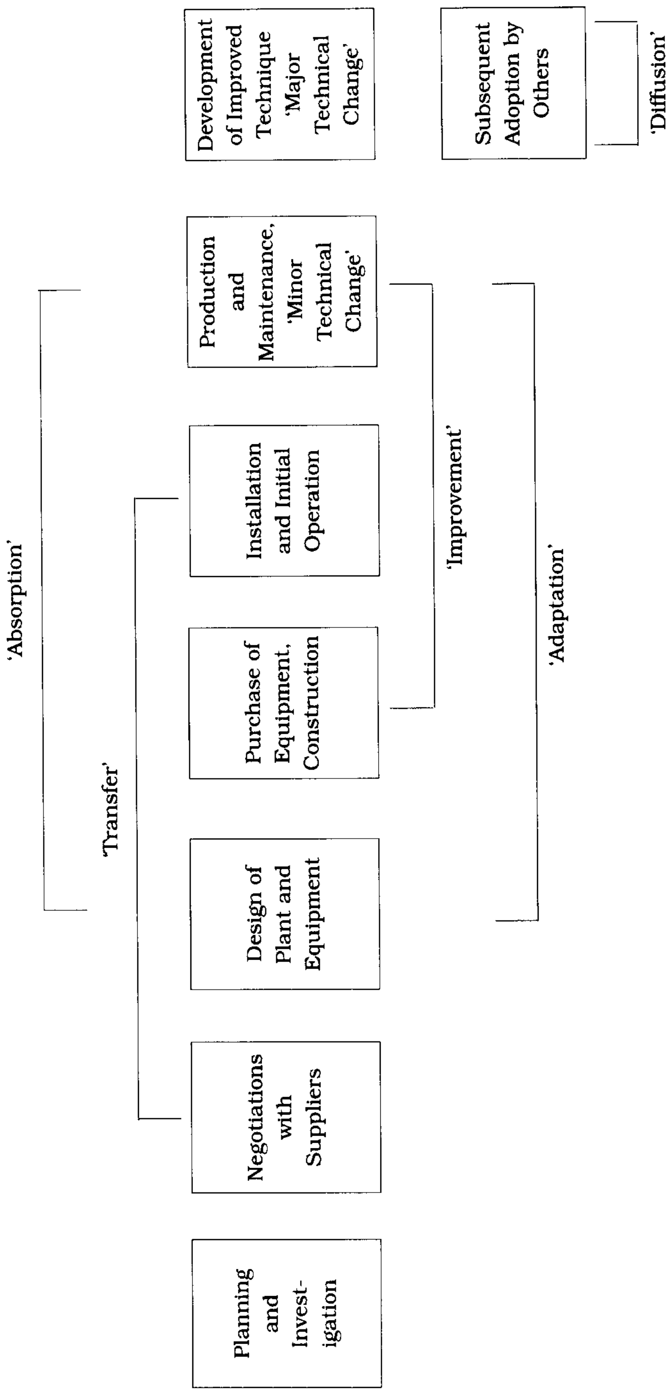

FIGURE 1
FLOW DIAGRAM ILLUSTRATING ACTIVITIES IN PROCESS OF INCORPORATING FOREIGN TECHNOLOGY

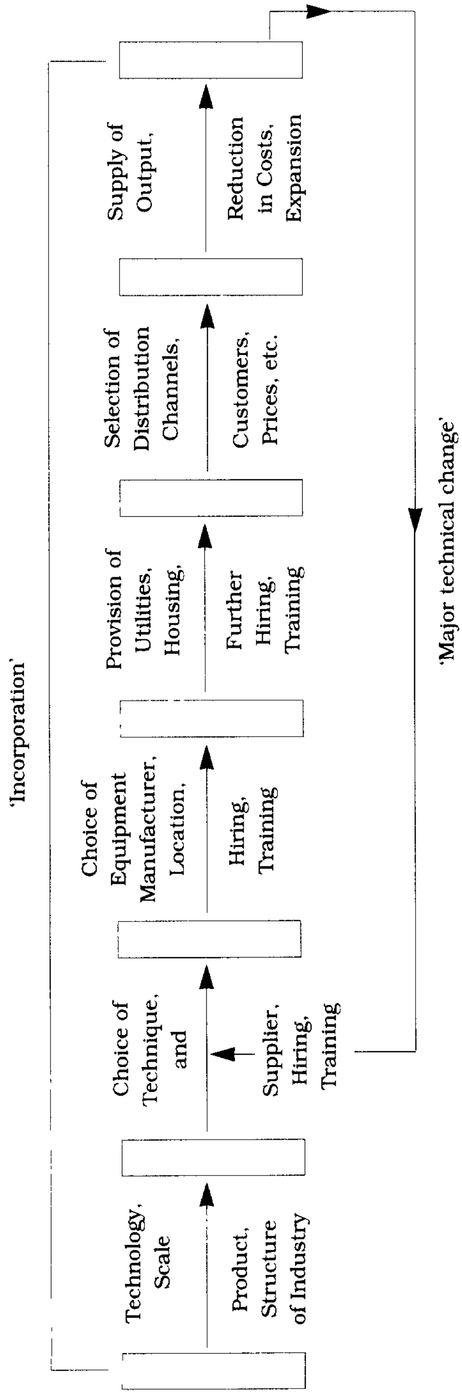

FIGURE 2
FLOW DIAGRAM ILLUSTRATING MAJOR DECISIONS

were detailed case studies involving the recent acquisition of sophisticated technical knowledge by Korean companies. The historical period involved is the recent past, extending from the mid-1960s to mid-1980s; the technologies involved are chemical (polyethylene, VCM, synthetic fibers), metallurgical (iron and steel), and mechanical (diesel engine). The firms surveyed are Hanyang Chemical Corporation in petrochemical industry, Kolon Co. Ltd. (KOLON) in synthetic fibers, Daewoo Heavy Industries Ltd. in machine industry, and Pohang Iron and Steel Co. Ltd. (POSCO) in iron and steel industry.

We refer first to Figures 1 and 2 in which the majority are displayed for the process of incorporating foreign technology. The two figures are complementary; both start with the same event (industrial planning) and both portray the same sequence of events. The difference between the two figures is that Figure 1 focuses on the activities that take place, whereas Figure 2 focuses on the major decisions that follow each activity. Thus the first activity in the sequence, 'planning and investigation', leads to the choices of what technology is to be employed, what products are to be manufactured, what scale of operation is to be selected and to what structure the producing industry is to conform. The reason for splitting activities from decisions or choices is that some of the terms to be defined refer chiefly to the activities that are undertaken within the developing country while other terms refer chiefly to the decisions that are made. To take as an illustration the term that has been used already, adoption, it is meant to cover the sequence of decisions or choices from the first activity to the last, inclusive; it therefore appears in Figure 2.

Returning to Figure 1, it can be seen that no single term covers all the activities from beginning to end. This is not surprising, for the variety of activities is vast, extending over long periods of time and drawing upon many different individuals and organizations. Yet it would seem to be useful to have some way of consolidating all the activities in the sequence. The concept that will act as the unifying force is that of the 'course', in this case the course that, when followed, leads to the adoption and diffusion of the technology. The association is with the race course, over which a race is held, or an obstacle course. The course is so broad as to be all-encompassing; it extends through time, taking several years or even a few decades, to come to completion; it extends across space, from the point of import into the rest of the country; it extends through institutions, public and private, profit and non-profit, economic and political; and it extends from individual to individual, involving some at the very beginning, some later, some at the end, but hardly any single person throughout.

As an indicator, change in the direction of the flow of resources is crude, being neither quantitative nor detailed; other indicators are needed which are more precise and more sensitive. Moreover, it would be surprising if a single measure were available for such a complex set of activities as those which comprise the course of adopting and diffusing a foreign technique: rather, one would expect to find many measures, some of which would apply to no more than a single step on the course, others of which might apply to two or three steps.

So far as the first three steps on the course are concerned—determining needs, examining alternative techniques and suppliers, and making a choice among them—the only quantitative measure that is feasible is the number of alternatives available. Measures of the precise terms on which alternatives are available will be difficult to assemble, since the only supplier whose terms are specified will be the one that is finally chosen.

The fourth step on the course which is our main concern—the absorption of the imported technology in its first application in industry—can be measured reasonably well. Four measures, two general and two limited, offer themselves. The general measures are easy in their construction, although not necessarily simple in their interpretation; they are the speed with which each of the activities involved in absorbing a technology is carried out and the percentage of the individuals carrying out each of the activities who are citizens of the importing country. The difficulty in interpreting these measures arises because an activity may be terminated prematurely or a foreigner replaced too soon, with a subsequent loss in efficiency or increase in cost. The opposite could be observed too, namely an activity extended too long in time or a foreigner held in his post longer than necessary, although these last phenomena would not be expected to occur often. So long as the activities are carried out effectively, and so long as the citizens of the importing country perform their duties adequately, the measures of speed of accomplishment and replacement of expatriates provide revealing measures of the degree of absorption.

The two limited measures of absorption both apply to the production of output only. To be sure, production of output is the rationale for the import of a technology, but it is only part of one step, albeit a long one, in the course of adoption. These two measures of absorption are the actual rate of output relative to the design rate and the cost of production. Since it is dimensionless, the rate of capacity utilization is effective for comparisons across industries within a single country as well as across countries for a single industry.

Cost of production is a measure without these comparable features, and yet, for a single technology, it is probably the most revealing one to be conceived. Moreover, from it can be obtained, as by-products, partial measures of efficiency of use of each factor of production, i.e. productivities. The difficulties in the derivation of a measure of cost are chiefly informational.

Considering measures of diffusion, the most common and elegant—the sequential pattern, through time, of adoptions by firms in the industry—is not appropriate for any of our studies excepting possibly that of the textile industry. The other industries are all monopolized, so the first firm to incorporate the technique is the only one. To find measures of diffusion we must look backward to the suppliers of inputs for the operating firm or forward to the customers. Where suppliers of inputs are concerned, perhaps the most significant for the developing countries are the capital-goods manufactures; the higher (in value terms) the fraction of the plant and equipment that local capital-goods manufactures supply, the further has the technology diffused. But the same sort of measure could be applied to suppliers of other inputs—materials or energy, for example. If the base of the measure of diffusion is the total cost of all the inputs, then a more nearly complete measure of diffusion to suppliers would be the fraction of total cost of inputs supplied by domestic firms.

No such quantitative measure exists for diffusion to customers; where this phenomenon is concerned we will have to resort to description, from general observations on the flow of technical knowledge to users of the product, to universities and technical schools, and to government. This descriptive material will occupy parts of the four case studies on the absorption and diffusion of imported technology, one each in the petrochemical, textile industries, machinery and iron and steel.

The final measure worthy of mention is not quantitative but qualitative—the objectives of the participants. Technologies themselves, being impersonal, have no objectives, but all the individuals who evaluate and choose and employ and improve them have objectives of their own. As their objectives differ, so will their behaviour. Assuming rationality, the former can be inferred from the latter, perhaps with greater accuracy than objectives can be determined directly by questioning. But if the two sorts of information—one from inferences, the other from questions —are consistent, an accurate knowledge of objectives can have considerable explanatory power.

What theory is available to guide an inquiry into the adoption of sophisticated techniques in the economy of a developing country? The answer must be, unfortunately for our purposes, very little. And what theory there is not well designed for our use. Reasons for theoretical inadequacy are not hard to find; the adoption of a foreign technique is a complex and extended activity, and the important variables do not lend themselves readily to precise definition and measurement. The following theory, or theories, may therefore seem fragmentary and inappropriate, but they are the best that are available.

The most nearly comprehensive theory, or non-theory, of the course of adopting a technology is the neo-classical micro-economic theory of the firm, devised by Walras, Marshall, Hicks, Samuelson and their many followers. In its simplest version, the neo-classical theory of the firm assumes that knowledge is acquired instantaneously and without cost. Moreover, knowledge is defined so broadly as to include all the abilities and skills needed to assimilate an imported technology into the local environment. The local environment is represented in the theory solely by a different set of relative factor prices. By these assumptions any difficulties are effectively dispensed with, and the course of absorption offers no challenge at all.

Recent work in the theory of the firm relaxes the assumption of costless and timeless acquisition of knowledge, in recognition of the fact that resources are consumed in the process. The work, summarized and advanced in the survey by Kamien and Schwartz (1982), still assumes that the enterprise creating and adopting the new technology is a monolithic body responding perfectly to its single-minded owner/manager, and so neglects such factors encountered in developing countries as physical bottlenecks, government controls and regulations, conflicting objectives, uncoordinated behaviour, risk and ignorance. Since these are the very factors that we are focusing on here, in other words since these are our variables not our parameters, we find the neo-classical microeconomic theory of the firm vacuous.

Putting neo-classical theory aside, the investigator seeking guidance is left with a rogue theory, usually called 'learning-by-doing'. The phenomenon was recognized by production engineers, observing that the labour cost per unit in the assembly of a single type of aircraft fell as the number of units increased. Work by economists began with that of

Hirsch (1956) and Enos (1958); the term 'learning-by-dong' was invented, and utilized in the context of a macroeconomic model, by Arrow (1962). Subsequent work is summarized in Rosenberg (1976).

Applied to the production of a single commodity, endlessly repeated, the theory of 'learning-by-doing' states that the direct cost of manufacturing a unit of the good will decline as the experience gained increases. Experience is measured by the accumulated sum of all units previously manufactured; mathematically the relationship appears as

$$c_i = \alpha \sum_{x=0}^{i} x^{-\mu}, \qquad (1)$$

where c_i = average direct cost of producing the i^{th} unit of good x;
α = a scale parameter;
μ = a parameter, whose value lies in the range $0 < \mu < 1$.

There is one thing to notice about this theory; it is mechanistic, saying nothing about how learning takes place. Learning proceeds automatically and costlessly with production. Although the assumption of costless learning is convenient for the development of the theory and for its econometric testing, it is by no means realistic, as economists such as Katz (1978) have argued and as our own case studies demonstrate.

In the case studies we discover that learning takes many different forms, which should be separated one from another. To do so will require that equation (1) above be placed in an explicit time scale and that the output-dependent relationship be decomposed into as many terms as there are recognizable forms of learning.

In equation (1) the index i advances through time. Knowing the time path of output $x(t)$, i and c_i can also be written as functions of time $i(t)$ and $c_i(t)$. Let us define β as the average rate of decrease of direct cost attributable to all forms of learning. This new variable β is related to cumulative output $x(t)$ via $c_i(t)$:

$$\beta = 1 - \left\{1 - \frac{c_i(t)}{\alpha}\right\}^{-t} = 1 - \left\{1 - \left(\sum_{x=0}^{i(t)} x(t)\right)^{-\mu}\right\}^{-t}. \qquad (2)$$

Imagine that there are n forms of learning: the contribution of all will be β. Given separability, the individual β_j—average rates of cost reduction—can be combined additively,

$$\beta = \beta_1 + \beta_2 + \ldots \beta_j + \ldots \beta_n. \qquad (3)$$

We will now identify forms of learning and try to relate them systematically to equation (2). The first, β_1, will be assigned to the cost reduction attributable to the exploitation of static economies of scale in successively larger plants. That a firm in a developing country should initially install a small plant, so as to reduce the risks in adopting a new technology, is sensible: once the technology has been absorbed in the small plant, the accumulated experience can be applied to successively larger plants. If the firm collects and reveals its costs plant by plant, no difficulty arises, since the scale of neither has been altered. It is only if the firm aggregates its cost data across plants, presenting a single, average cost figure for each time period, that allowance for different scale plants must be made. Typically, firms reveal aggregate data only, augmented with the dates when new plants were constructed and these plants' design capacities.

Consider the design capacity of plants, producing a commodity sufficiently homogeneous as to be reported on a multi-plant basis, as $\hat{q}_k$, $k = 1, 2, \ldots, m$ where $\hat{q}_k$ is the rate of output of the kth plant, so many physical units (say, metric tons) per year. Provided that the plant is operated exactly at design capacity throughout its life of t years, $\hat{q}_k$ is equal to cumulative output x in equation (1), divided by t:

$$\hat{q}_k = \frac{x^k}{t}, \tag{3}$$

where k is placed as a superscript, so as to distinguish the kth plant from, in equation (1), the ith unit of output whose average cost is c_i.

Besides $\hat{q}_k$, the annual rate of output at design capacity, we shall need to define four other variables:

$\hat{C}_k$ = total expected cost of production in the kth plant at the design rate;

$\hat{c}_k$ = average expected cost of production in the kth plant at the design rate, often called 'standard cost',

$$\hat{c}_k = \frac{\hat{C}_k}{\hat{q}_k};$$

$\hat{c}$ = average expected cost per unit, a weighted average over all m plants,

$$\hat{c} = \frac{1}{\sum_{k=1}^{m} \hat{q}_k} \left(\sum_{k=1}^{m} q_k \hat{c}_k \right) \tag{4}$$

δ = the parameter representing static economies of scale,

$$0 < \delta \leq 1.$$

Static economies of scale in the operation of different sized plants, say plants 1 and 2, are usually represented by the expression:

$$\frac{\hat{C}_2}{\hat{C}_1} = \left(\frac{\hat{q}_2}{\hat{q}_1} \right)^{\delta}, \tag{5}$$

the smaller is the value of δ, the larger are the economies of scale. Specific values of δ, drawn mainly from engineering studies, are in the range of 0.6 to 0.9 for the production processes (Yotopoulos and Nugent, 1976, Table 1).

It remains to relate the expression for the relative (total) costs of operating different sized plants, equation (5), to β_1, the average rate of reduction in cost from exploiting economies of scale in successively larger plants. Let the index k, in $\hat{q}_k$ and $\hat{C}_k$, run chronologically from the first plant constructed ($k = 1$) to subsequent ones; and let the same subscript apply to the time when the plant begins operation; e.g. the first plant with design capacity $\hat{q}_1$ begins operation at t_1. Assuming that any 'learning' that takes place in the operation of plant 1 between the date it is brought into operation, t_1, and the date the second plant is brought into operation, t_2, is also assimilated into design and operation of the second plant, the relation between the total operating costs of the first and second plants, both producing at design capacity, will be reflected exactly in equation (5). The difference between average costs of the two plants, at t_2, will be $\hat{c}_1(t_2) - \hat{c}(t_2)$ all of which is attributed to the addition of the second, larger-scale plant. Spread over the interval between the initial operation of the first and second plants $(t_2 - t_1)$ the contribution from economies of scale, β_1 averages

$$\beta_1(t_2) = \frac{1}{(t_2 - t_1)} \left(\frac{\hat{c}_1(t_2) - \hat{c}(t_1)}{\hat{c}_1(t_1)} \right), \tag{6}$$

where β_1 is measured at t_2. The total rate of cost reduction β, at t_2 will be

$$\beta(t_2) = \frac{1}{(t_2 - t_1)} \left(\frac{\hat{c}_1(t_1) - \hat{c}(t_2)}{\hat{c}_1(t_1)} \right), \tag{7}$$

and the difference between $\beta(t_2)$ and $\beta_1(t_2)$ will be the contribution of the other forms of learning.

Now imagine that both plants are operated until a further date $t(t > t_2)$, and that additional 'learning' of forms β_2, β_3,... β_n takes place. The overall annual rate of reduction in average cost over the entire interval from the initial operation of the first plant, t_1, to t is defined as β, and the contribution of economies of scale is indicated by equation (6), with t substituted for t_2 in the left-hand side and for t_2 in the term $(t_2 - t_1)$ in the denominator of the right-hand side. Substituting total costs, $\hat{C}_k$, for average costs, $\hat{c}_k$, in equation (6), and then design capacities $\hat{q}_k$ for total costs, from equation (5), we can obtain the value for β_1, over the entire interval to t:

$$\beta_1(t) = \frac{1}{(t - t_1)} \frac{\hat{C}_1(t_2)}{\hat{C}_1(t_1)} \left[1 - \frac{\hat{q}_1}{(\hat{q}_1 + \hat{q}_2)} \left\{ 1 + \left(\frac{\hat{q}_2}{\hat{q}_1} \right)^{\delta} \right\} \right]. \quad (8)$$

Examining equation (8) we observe that the expression is appropriate for a sequence of two plants; similar but increasingly more complicated expressions will apply for sequences of three, four or m plants. In all expressions there will appear the total cost of the first plant to be brought into operation, at its initial date, $\hat{C}_1(t_1)$, and at the dates of initial operation of subsequent plants, $\hat{C}_1(t_2)$, $\hat{C}_1(t_3)$... $\hat{C}_1(t_m)$. Also appearing in the expression for an arbitrary k plant will be total costs for the $(k - 1)$ plants previously constructed, at each date up to and including t_k. Finally, the design capacities of all plants and their dates of initial operation will be needed. These data—total costs at different dates, design capacities and dates of initial operation—are generally available, so β_1 can be calculated.

Because of the necessary inclusion of values of total cost, any calculated value of β_1 is not independent of the overall measure of cost reduction β. Such interdependence is not encountered in these additional forms of 'learning' we will attempt to measure, namely those attributable to saving on raw and processed materials (β_2), saving of energy (β_3), savings through the localization of supply, particularly the supply of capital equipment (β_4) and quality improvements (β_5). There are, however, two final forms of 'learning' that are not independent of the previous form, learning that results in a reduction in the cost of labour (β_6) and learning that results in an ability to operate equipment in excess of design capacity, thereby reducing the average cost of capital (β_7). In the chemical process industries, the number of operating (as distinct from maintenance, clerical and managerial) personnel is usually fixed at the time of initial operation, according to the specification of the firm's insurers. 'Learning' only reduces labour costs in the other functions of maintenance, purchasing and marketing, and administration: the reduction in operating labour costs comes about through increases in the scale of operation, already considered, at least in part, in β_1, and to be considered below in β_7. In the mechanical process industries this interdependence between the requirements for operating labour and scale does not arise to such a great extent, and can be neglected without admitting too much inaccuracy.

The last form of 'learning', already labeled β_7 and not independent of β_1, is the ability to operate equipment in excess of its initial ceiling or design capacity. Sometimes this phenomenon is called dynamic economies of scale, so as to distinguish it from the static economies inherent in larger sized equipment, but the dividing line between the two is not clear. In making a distinction between cost reductions attributable to building a succession of larger-scale plants (our β_1) and cost reductions attributable to operating any single plant at a scale in excess of that for which it was designed (our β_7), and in measuring these separately, we are following the habit of engineers, while recognizing, as do engineers and economists, that the separation is arbitrary. Occasionally a plant is 'over-designed' in which case β_1, for the sequence including that plant, would be understated and β_7 overstated; occasionally a plant, perhaps one incorporating an innovation, has a bottleneck that takes some time and effort to eliminate, in which case β_1 is overstated and β_7 understated.

This enumeration of form of learning, together with our ways of measuring them, does not exhaust the possible economies that a swift and steady absorption of technology may generate. The treatment of absorption is further complicated by changes in the technique occurring on its transfer from the developed to the importing, underdeveloped country. For many reasons, the most familiar of which is the desire to exploit differences in relative input prices, the technique may be adapted before or during its transfer. There is a literature on adaptation prior to transfer, more, it must be admitted, on the need to generate techniques that are appropriate to the underdeveloped countries than on the experience of doing so. On adaptation during transfer, there is some case material, interesting in its own right. Work prior to 1974 is reviewed in Jenkins (1974); more recent evidence is provided in Stewart (1978) and Moxon (1979); but the results have not led to the formulation of a theory of the adaptation of techniques for developing countries, nor to any ability on our part to measure its significance.

III. The Result of Measurement

We will now report our chief findings from the study of the process of incorporation of imported technologies in Korea. Our procedure is dictated by the concept of the process, and will thus move through its stages, from the determination of the needs for the technology, at the beginning, to indigenous research and development at the end. Comparisons will be at the heart of the summary; comparisons between different technologies taken side by side.

A. The Planning Stage

So far as the first, planning, stage in the process of incorporating a technology is concerned, the planning of the Korean government and of the industrial firms in our sample seems generally to have been quite accurate and effective. Output targets have been precise enough to enable producers to translate them into demands for their own products, and set long enough beforehand to give them to respond. More importantly, the targets, once established, have been adhered to, and generally attained. This last achievement is impressive and beneficial for once one set of targets is attained, the next set is all the more plausible and all the more likely to be adhered to. To have an impact on the structure and volume of output, planning must be credible.

Although planning in Korea has generally been successful in facilitating the incorporation of imported technologies, there have been variations among the industries we studied. In our judgement, the activity was carried out very well with regard to petrochemical and iron and steel, and less well with regard to machinery and textiles. It must be admitted, however, that the task was much easier in the cases of the first two, because the technologies were being employed for the first time, and the scales of operation were very large: the ministry was forecasting for one industry consisting of one firm utilizing one technology. In the cases of the last two, machinery and textiles, the ministry was attempting to forecast for industries consisting of many firms employing many technologies and producing heterogeneous products. The target figures were highly aggregated, giving neither the ministry nor the manufacturing firms clear indices against which to measure performance. It is not certain that more detailed forecasts would have increased the efficiency of planning, because in machinery and textiles one product can often be substituted for another, enabling one target to be missed without constraining subsequent output. 'Targets' have little meaning as numbers to be attained in such cases.

In the case of medium-sized diesel engines, the forecast of demand and installation of manufacturing capacity were generally in excess of eventual sales. Partly this was the result of the over-ambition of a few ministers and directors of development agencies, who intervened in the Economic Planning Board's calculations; partly it was a failure to anticipate the increases in efficiency of smaller-sized diesel engines, which enabled them to be substituted for medium-sized engines in light buses and trucks. The excess capacity existing in diesel engine manufacture throughout the period studies has had deleterious effects on costs, on profitability and on the ability of the manufacturer to keep abreast of technical advance.

B. The Stage of Negotiation with Foreign Suppliers

The second and third stages in the incorporation of imported technologies—surveying alternative techniques and alternative suppliers, and choosing the best combination—may well be considered together, for the two stages overlapped in time. They also provided those studying the process of incorporation with their most surprising results—that the choice of technology is of negligible consequence and that the choice of supplier is of grave consequence.

Early in the enquiry it became apparent that in Korea the choice of technique had been preempted. Long before the manufacturing techniques were imported, the Korean government had decided to industrialize by producing in substantial volumes a wide range of modern, sophisticated goods in large scale plants employing the most advanced technology. Scrutinizing the lists of process design and construction firms which has recently undertaken new projects throughout the world, the Korean government discovered that there were usually several alternative suppliers of advanced manufacturing techniques differing in their design and operating characteristics but almost identical in the inputs they consumed and the outputs they produced. In the language of the economists, all employed the same production function. In terms of inputs and outputs, there was no choice of technique, only of technician.

But this did not mean that the Korean government had no choice, rather that technology was irrelevant to the choice. Choice there was, and although in making the choice the Korean government may not have been concerned with adapting the technique to local conditions, it was concerned with securing the technique on the best possible terms for the country. Reconstructing the past, it appears that, once access to the modern technique was assured, foremost among the government's preferences were ample supplies of one resource and one output. The resource that was most keenly sought was foreign exchange, almost certain to be very scarce in a country embarking on such an ambitious program of industrialization. The output that was most keenly sought was the product which the technology was designed to produce: the Korean government was determined to secure from the equipment purchased with scarce foreign exchange the maximum rate of production. High profits might be obtained by the producing firms, but only as a consequence of their attaining high rates of output, not as a consequence of their restricting output so as to be able to charge a higher price. Output should be constrained only by the physical capabilities of the equipment and its operators, not by any financial or market considerations.

Lower priority was attached by the Korean government to four other desirable attributes of an undertaking—control over the prices of inputs and outputs, uniform treatment of foreign participants, full acquisition of technical know-how by Korean engineers and managers, and automatic access to subsequent technical improvements. Desirable, but conceded if necessary, seemed to be access to later innovations, government control over the internal administration of the firms operating in Korea, acquisition of financial and marketing knowledge, localization of capital goods purchasing, and majority ownership by Koreans. Still thought desirable, but assigned the lowest priority in the ranking of the Korean government were competition in the newly-established industry, ready access to export markets for outputs of indeterminate goods, and the temporary although conspicuous presence of expatriates in positions of technician and financial authority.

With this apparent preference order the Korean government entered into negotiation with all possible foreign suppliers. A few foreign firms had previously approached the Korean government; the rest were approached upon the initiative of the Korean government itself. As the negotiations proceeded and the government's terms became stiffer, the foreign suppliers dropped out, one by one. Left at the end of the negotiations was just one foreign firm, willing to accept the stiffest terms of all.

Compared to the initial terms, the final terms were almost always far better for the Koreans: far better in that they seemed to ensure the swifter absorption of the imported technology and far better in that they seemed to confer greater benefits on the Korean economy as a whole. These two consequences are related; swifter absorption of the technology enables output to be produced at a high rate as soon as possible, generates improvements which lower costs and places Koreans in a position to make decisions and earn incomes. The benefits thus accrue on the supply side of the economy—via increases in output and reduced constraints on inputs—and on the demand side—via increases in the incomes of all the Korean participants, be they operators, engineers, managers or shareholders, public or private. Putting it another way, swift absorption of the technology has desirable effects, both on output and on employment, and swiftness comes at the outset from negotiating favourable terms with the foreign suppliers.

The two main accomplishments of the Koreans in their negotiations with foreign suppliers of technology—lower costs of acquisition and speedier transmission of know-how—are demonstrated in our cases. It is probably the case of iron and steel that best illustrates the former accomplishment: upon the resumption of diplomatic relations with Japan in 1965 the Korean government secured the allocation of a substantial portion of the Japanese government's official grant and concessional credits to the construction of Pohang's first iron and steel mill. Moreover, so fierce was competition among foreign suppliers of the reducing, converting, casting, rolling and shaping techniques from other developed countries that the Koreans were able to secure them at minimum cost. Similar cost advantages are cited by Hogan (1985) for the equipment to be installed in POSCO's second iron-and steel-making plant in Quangyang.

The latter accomplishment—the speedier transmission of know-how—is probably best illustrated in the case of petrochemicals. It is not that the transmission was necessarily faster than in, say, artificial fibers; it is that the case of petrochemical is the fullest documented. There we can see most clearly the complex nature of the technology, the nature of what had to be transmitted and the agencies through which the transmission occurred.

C. The Design Stage

Firmness, perseverance and dedication have carried the Koreans successfully through the stages of planning and negotiation, but these qualities have been of little avail in the next stage of the process of incorporating foreign technologies—learning how to design facilities and the constituent equipment. Here the Koreans have made the least progress. Here, also, experience has been the most varied; from the manufacturers of artificial fiber, Kolon, and petrochemical, Hanyang, who are capable of formulating new processing schemes and of altering existing equipment so as to produce novel products; to the manufacturers of iron and steel and diesel engines, who have generally not acquired the skills and experience of design, deliberately in the former case and unintentionally in the latter. It may be that process and equipment design requires collaboration with capital goods producers, in which event the increase in the provision of capital goods domestically, to be considered later in this chapter under the topic of localization, may still come about.

D. The Construction Stage

If some of the economies in capital cost arose through the successful completion of negotiations with foreign suppliers, others, no less marked, arose through the rapid completion of construction, once begun, Again the most vivid illustration, and probably the most dramatic, comes from the case of POSCO. Not only has POSCO brought its construction to completion faster than firms in other countries, but also it has accelerated from event to event: 38 months were taken to construct the initial plant, 30 months to construct the second, 29 months the third (and that of more than double the capacity of the second) and 24 months the fourth. Statistically, the benefits that accrued to POSCO are impossible to estimate, but the direct savings in interest on the capital committed and the indirect savings via the quicker availability of domestically-produced iron and steel would have been substantial.

E. The Stage of Starting-up and Operating the Equipment

A quick rise to full (equals design) capacity output indicates a speedy absorption of the technology, and a successful one as well; a slow rate indicates the opposite. The experience in our four industries is generally one of rapid absorption and successful production, the exceptions being explained mainly by a lack of demand for the products.

For these two stages in the process of incorporating a technology we have data that are comparable across three of the four industries covered by our cases. For artificial fibers we have only qualitative informa-

TABLE 1

SUMMARY TABLE: DESIGN CAPACITIES AND RATES OF OUTPUT RELATIVE TO DESIGN CAPACITIES

Case	Design Capacity	Actual Output, as a percentage of design capacity, since start-up						
		1 month %	2 months %	6 months %	1 year %	2 years %	5 years %	10 years %
Petrochemical								
(Ulsan plant) Polyethylene	50,000 metric tons/year	71	94	98	113	139	131	98*
VCM	60,000 metric tons/year	40	64	69	93	92	103	86*
(Yeocheon plant) Polyethylene	100,000 metric tons/year	69	38	12	75*	63	115	–
VCM	150,000 metric tons/year	11	22	54	63*	76*	87	–
Diesel Engines	24,000 engines/year (one shift/day)	n.a.	n.a.	n.a.	7*	11*	68*	63*
Iron and Steel								
1st stage	1,030,000 metric tons/year	50	72	104	n.a.	n.a.	110 (6 years)	
2nd stage	1,570,000 metric tons/year	n.a.	n.a.	100 (80 days)	n.a.	n.a.	n.a.	108 (2nd–4th stages combined)
3rd stage	2,900,000 metric tons/year	n.a.	100 (70 days)	n.a.	n.a.	n.a.	n.a.	
4th stage	2,900,000 metric tons/year	100 (29 days)	n.a.	n.a.	n.a.	n.a.	n.a.	

Note: * : Insufficient market for output.

tion. Table 1, the first of the tables summarizing the results of our case studies, provides the data on the speed with which facilities were brought into operation, expressed as the instantaneous rates of output, relative to the capacity built into the equipment, achieved at various dates after the initial start-up. The clearest pattern to emerge, and the one giving the strongest indication of an ability to absorb the technology, occurred in the case of iron and steel, where full capacity operation was achieved at each successive stage of expansion after shorter and shorter intervals.

Somewhat surprisingly, the opposite pattern, where the attainment of full capacity operation took longer for the second than the first plant, occurred in the case of petrochemical. To be sure, the second plant, at Yeocheon, had larger capacities than did the first, but the same was true for the facilities producing iron and steel. Of the possible reasons for the slower attainment of full capacity operation in the second petrochemical plant, vis-a-vis the first, the demand factor is probably the most significant; the engineers and managers at Yeocheon, in 1980 and 1981, were not under the same pressure to generate output and satisfy market demands as had been the engineers and managers at Ulsan, in 1973 and 1974.

Insufficient demand to spur production is an important factor, although perhaps not of such overwhelming significance, in the cases of diesel engines and the first excursion into the polymerization of the artificial fiber nylon. In these two cases technical difficulties also arose, and could not be eliminated swiftly because of a lack of experience. In the case of artificial fibers certainly, and in the case of diesel engines probably, the necessary experience has since been acquired, although in the latter case this presumption cannot be supported by statistical evidence, relying as it does solely on the claims of the engineers involved. Nevertheless, the utilization figures in, say, the column headed '1 year' are markedly higher than those encountered in plants incorporating advanced technologies in other developing countries; overall, we conclude that the Koreans have skillfully started up their facilities and swiftly brought them to fruition.

F. The Stage of Securing Improvements

The next stage in the process of incorporating a novel technology is that of improving upon its operation. With regard to improvements we have collected a wealth of descriptive material and some measures of resulting increases in efficiency. The many improvements are listed in the studies of each industry; they impressed the investigators by their variety—improvements in the design and construction of equipment, in the operation of the techniques, in maintenance, in the use of raw materials and energy, in the quality of the products manufactured and in the potential of the installed equipment for still higher rates of output.

All these types of improvements can be measured by a single index, that of reduction in total cost of production. This measurement is reported in Table 2 for the manufacture of petrochemicals at Hanyang's first plant at Ulsan, for polymerization of nylon and polyester at Kolon's two plants at Taegu and Gumi, and for iron-and steel-making in POSCO's facilities at Pohang. No measure is available for diesel engines. The first set of measures, that for petrochemical, is the most detailed and the most accurate; it shows that a significant reduction in cost occurred through the stretching of equipment, so that it was able to yield outputs greater than those for which it was originally designed.

Obtaining rates of output in excess of those for which the equipment was designed does not generally show up in figures on cost reduction, yet can be of considerable importance. Occasionally one hears of equipment which, with some modification, is operated at a rate well above that for which it was designed: via improvements its potential to produce output has been substantially increased. Any measure of the direct cost of operation will not capture the improvements; one needs a measure of total cost, after allowance for fixed costs and overheads. Measures of total cost are even more difficult to extract than those of direct cost, and in multi-product and multi-plant firms are more difficult to estimate accurately. Moreover, rates of production in excess of design are often not observed until several years after the start-up of the equipment, when its capabilities have become fully understood. In only one of the cases we investigated had several years passed, and so the significance of this type of improvement could not generally be assessed. In one case, however, that of the petrochemical, polyethylene, production rates in excess of design were achieved in as short a space of time as a year, and maintained at approximately 30 per cent for the following five years. It may, of course, be that the equipment incorporating the polyethylene technology was over-designed initially and had 30 per cent excess capacity built into it, but this seems rather unlikely in such a well-known and frequently employed technique. Credit must be given to the operating firm for extracting more output from its equipment.

TABLE 2

SUMMARY TABLE: AVERAGE ANNUAL RATES OF REDUCTION IN UNIT MANUFACTURING COSTS ACHIEVED THROUGH IMPROVEMENTS

Case	Period Covered	Reduction in Unit Manufacturing Costs (average annual rate, compounded, in per cent)				
		Raw Material Savings %	Energy Savings %	Localization of Supply %	Equipment Stretching %	Total Unit Cost %
Petrochemicals Ulsan Plant	1973-76	0.4	0.4	0.1	1.5	2.4
Synthetic Fibers Taegu Plant						
Nylon Gumi Plant	1974-84	n.a.	n.a.	n.a.	n.a.	5.0
Nylon	1974-84	n.a.	n.a.	n.a.	n.a.	8.3
Polyester	1974-84	n.a.	n.a.	n.a.	n.a.	7.5
Iron and Steel	1973-83	n.a.	n.a.	n.a.	n.a.	4.4 to 4.8

The stretching of equipment was probably also significant in the securing of reductions in average unit cost of manufacture for artificial fibers and iron and steel, although this conclusion can only be subjective, since the cost data cannot be disaggregated. Moreover, the overall estimates of cost reduction for artificial fibers and iron and steel in the last column of Table 2 cannot be taken too precisely, since they were obtained only by deflating current costs for the effect of inflation, and since they did not make any allowance for increases in the variety and quality of the products manufactured. This latter type of improvement may be quite substantial, although absent from these two sets of measures. Certainly it would add support to our contention that, in these three cases, the effect of improvements in the employment of the imported techniques by the Korean firms has been impressive indeed.

G. The Stage of Developing New Products and Techniques

The final stage in the incorporation of imported technology is the research and development that leads to its being superseded by a superior technology. In our investigations we did not encounter any such supercession; nor did we expect to, since all the technologies employed were, at the time of their adoption, highly advanced, representing the highest state of the art in the developed countries.

In each of the industries we studied there have been major innovations between the time when the Korean firms first installed their facilities and now. All these innovations were carried out in the developed countries. In petrochemical and iron and steel, the innovations took the form of new processes, namely the polymerization of polyethylene at low pressures (producing so-called 'linear' low-density polyethylene) and the continuous casting of steel. The two Korean firms, Hanyang and POSCO, kept themselves informed of these developments and installed them on the next occasion that capacity was expanded.

In artificial fibers and diesel engines, the innovations have taken the form of new or improved products, such as fish nets, tyre cords and artificial turf in the case of nylon and engines with better combustion properties and higher horsepower-to-weight ratios in the case of diesel engines. The Korean artificial fiber firm, Kolon, adopted the new products soon after they emerged in the developed countries, but the diesel engine manufacturer, Daewoo, was frozen in the increasingly obsolete design. Awareness of the innovation there was, and appreciation of its effect on engine design and performance, but the ability to imitate the innovation was lacking.

In our studies, however, we did encounter research and development groups in every firm. Although not engaged in fundamental research, out of which an innovation might eventuate, the groups were generally performing useful functions, chiefly through investigating the characteristic and production modes of products that were novel extensions of their existing product lines. Co-polymers at Hanyang; aromatic polyamide and ultra-fine yarn at Kolon; new construction equipment to be powered by diesel engines at Daewoo; these were the sorts of developments that were being advanced by the research groups. To us, the allocation of technical resources to these types of research and development seemed proper.

H. The Absorption of Imported Technology

As measures of the rate of absorption, the speed and intensity of use and reductions in costs through improvements have much to recommend them; yet they are only partial measures, covering only two of the several stages involved in incorporating a foreign technology. Table 3 is devoted to all the stages of incorporation, from planning and negotiation to the conduct of research and development for new products or techniques, and displays a nearly uniform pattern. The data in Table 3 can be read vertically, down each entire column, in order to observe differences across industries in the extent to which Koreans have participated in each of the stages: they can also be read horizontally, across each row, in order to observe differences across stages. These two readings suggest that the Koreans have entered more in the stages of construction, start-up and operation and improvement than in the earlier stages of design, and in the later stage of research and development; and that there are not great differences in participation across industries.

More interesting than comparisons down entire columns or across entire rows are comparisons across rows within a single industry. For the three industries (petrochemical, artificial fibers and iron and steel) with multiple rows, signifying more than one incorporation of a technology, the general pattern is of increasing participation from earlier to later installations. This progress in participation is seen most prominently in the case of iron and steel, in which there has been a general movement from partial to complete reliance on Korean engineers in the majority of the stages. If we think of absorption in a dynamic sense, as an increase, from installation to installation, in participation throughout the process of incorporating a technology, than all three cases

TABLE 3

SUMMARY TABLE: ABSORPTION OF FOREIGN TECHNOLOGY BY KOREAN ENGINEERS, ACCORDING TO THE STAGE OF THE PROCESS OF INCORPORATION

Case	Stage in the Process of Incorporating the Technology						
	Planning and Negotiation	Process Design	Equipment Design	Construction	Start-up and Operation	Improvement	R&D
Petrochemical Ulsan Plant(1945-85)	s	o	o	s	s	x	o
Yeocheon Plant (1975-85)	s	s	s	s	s	x	s
Synthetic Fibers Taegu Plant							
Nylon Line 1 (1969-85)	s	o	o	s	s	s	o
Nylon Line 5 (1970-85)	s	s	s	s	s	s	s
Gumi Plant							
Nylon Line 3 (1983-5)	x	x	x	x	x	x	x
Diesel Engines	s	o	o	s	s	s	o
Iron and Steel							
1st stage (1965-85)	s	o	o	s	s	s	o
2nd stage (1974-85)	s	o	o	s	s	x	o
3rd stage (1976-85)	s	o	s	s	s	x	s
4th stage (1979-85)	x	x	x	x	s	x	s

Note: o: no Koreans Participating
s: Koreans some participation
x: all Korean.

demonstrate an ability on the part of Koreans to absorb foreign technology. This is our major conclusion regarding the absorption of new techniques.

I. The Diffusion of Imported Technology

In the four cases we studied there was no diffusion of manufacturing techniques. This was the result of deliberate action on the part of the Korean government: had the Korean government chosen to encourage the construction of small-scale plants there would have been more diffusion, but the government preferred, rightly in our estimation, to exploit the substantial economies inherent in large-scale operation. As a consequence, adoptions of imported technology have been limited, chiefly to one firm. Had we chosen different industries, characterized by many competing firms employing simple technologies on a small scale, we would have been able to draw some conclusions on the diffusion of imported manufacturing techniques; but our choice of industries, characterized by single firms employing sophisticated technologies on a large scale, precluded this.

Knowledge of the capabilities of the products manufactured through the imported technology has diffused to customers. What diffused was chiefly information on the nature and performance of the products they were buying, through such media as conferences of producers and users, trade journals and visits by technical salesmen. So far as we could judge, this diffusion of this limited technological information proceeded adequately.

Of more significance, in our opinion, has been the diffusion of the technology to institutions supplying resources to the adopting firm. The main supplying institution is the industry manufacturing capital goods in Korea. Encouraged by the government's policy of stimulating local production of capital goods, firms adopting foreign technology did communicate their needs and commissioned the purchase of domestic capital goods, usually those of a simple nature but occasionally those of considerable complexity. Complex capital goods were ordered from domestic suppliers when time was short and when the supplier was willing to work closely with the customer, welcoming the customer's engineers in its own factory.

The data for capital goods supplied to the petrochemical firm Hanyang and the iron-and steel-making firm POSCO are summarized in the top and bottom rows of Table 4. Revealing is the success that Hanyang had in obtaining replacements for worn-out capital equipment, the easiest form of domestic capital goods manufactured since user are already familiar with the equipment and since the producers have at hand prototypes (the original pieces of equipment, manufactured abroad) with which to work.

POSCO's success in shifting the source of supply of new capital equipment in successive expansions of its plant is impressive. The increase in the percentage supplied domestically was largest in the fourth stage, which, significantly, was (for the blast furnace and the continuous casting line) a replica of the third.

These same conclusions—a relatively greater success in reproducing or copying existing equipment than in building novel equipment, and an increasing degree of localization with successive installations—have been reached by the authors of a detailed study of the procurement of power plant equipment in Korea (Lee, Jin-Joo and Sharan 1985). From twelve observation, two of small-scale thermal power plants, seven of large-scale thermal plants and three of nuclear plants, the authors found that the domestic portion of total expenditures on engineering design and on capital equipment fell as one moved from smaller plants incorporating simpler technology to larger plants incorporating more complex technology. Moreover, with the passage of time, the portion of total expenditures undertaken domestically on similar sized plants of identical technology tended to rise.

The remaining rows in Table 4 refer not to the localization of capital equipment but to the localization of intermediate products used in final manufacture. The gradual replacement of foreign by domestic components is a familiar characteristic of assembly industries in developing countries, and so the increase in domestic supply of diesel engine components is not surprising. What is complimentary to the Korean component manufacturing industry is the high proportion reached in recent years.

Not appearing in Table 4 but encountered in two separate cases, were once-and-for-all substitutions of domestically-produced for imported raw materials. Ethylene dichloride (EDC), produced at Yeocheon, displaced imported EDC in the synthesis of vinyl chloride monomer (VCM); and caprolactam, produced at Ulsan, displaced imported caprolactam in the polymerization of nylon. The extent to which these two examples of the localization of production were conditional upon the diffusion of VCM and nylon technologies was negligible, however, since the technologies for both EDC and caprolactam manufacture and use had to be imported in their entirety.

TABLE 4
SUMMARY TABLE: DEGREE OF LOCALIZATION OF SUPPLY

Case	Period Covered	Type of Resources Provided Locally	Basis of Comparison	Measure of Localization %
Petrochemical Ulsan Plant	4 years 1974-77	Replacement of original(foreign) Capital equipment	Saving in capital cost	45
Diesel Engines (engine D0846M)	1975-84	Components, parts and materials	Purchases of domestic components, etc. as percentage of total purchases by value	40(1975) 50(1977) 66(1979) 77(1981) 89(1983) 90(1984)
Iron and Steel				
1st stage	1970-73	New capital equipment	Value of locally-manufactured equipment, as a percentage of total value of capital equipment	12.5
2nd stage	1974-76	Same	Same	15.5
3rd stage	1976-78	Same	Same	22.6
4th stage	1979-81	Same	Same	35.0

The last direction of diffusion of imported technologies has been abroad, to countries less developed than Korea. In two of the four case studies, artificial fibers and iron and steel, we encountered examples of the transfer of Korean construction and operating in conjunction with the transfer of the 'core' technology by its original American or Japanese supplier. The historical pattern of transfer abroad—the Korean firm supplying the more easily learned part of the technology and the original foreign supplier, with whom the Korean firm had established bonds when it, the Korean firm, first incorporated the technology, supplying the more difficult part—is the same that Japan had followed in its first exercises in technology transfer abroad some ten years previously (see Ozawa 1971, for a contemporary report).

IV. Comparison with Japan

In brief, we find the processes of incorporating a foreign technology to be similar in both countries, but the agents through whom the incorporation is accomplished to be different. Japan's lead, in terms of years over Korea, varies from a decade or so in the absorption of operating techniques to a longer period in mastering the 'core' technology.

To start with, both countries seem to have intended to adopt the most modern techniques in existence. In the case of the Koreans, this intention can be documented; in the case of the Japanese, it must be inferred from their actions, both in visiting modern plants in the more-developed Western countries and in quickly imitating the techniques that they encountered there.

Given that both countries selected the most modern techniques, the necessity to import most of the technology and to absorb the novel elements therein automatically arose. In Korea the process of absorption was approached systematically, the government assuring itself that the contracts negotiated with the foreign suppliers contained clauses relating to the acquisition of patents, designs and know-how; to the training, both abroad and on the site, of Korean engineers and managers; to the speedy replacement of expatriates; and to access to improvements in the products and processes. The government also made certain that the terms in the contracts were fulfilled.

We do not know, from the evidence available, the extent to which the absorption of foreign technologies was approached systematically in post-war Japan. We would expect there to be more variation in approach, because the initiating agent in the acquisition of the technology was more likely to be a private firm than the Japanese government. We do not know what the government's policy and behaviour towards the absorption of imported technology was.

Looking at the speed with which the speed with which the different stages in the process of absorption were carried out, we find a similar pattern in the two countries. Most swiftly learned were the stages of constructing, starting-up and operating the new techniques, followed by the carrying out of improvements and by the design of separate pieces of equipment. Learning the 'core' technology and applying it to the overall design of a facility took still longer; and longer still, so long that it is only now being undertaken in Korea, did process and product innovation.

When we turn to the subject of the agents responsible for the adoption of foreign technologies we begin to see substantial differences between the two countries. In Korea, at least until 1980, the government has been the primary agent; in Japan it seems to have been, in the era since the Second World War, large private firms. The number of foreign suppliers of technology scrutinized by the agents seems to have been greater in the case of Korea, for two reasons; first, there was a larger universe by the time the Koreans, as latecomers, entered the market for technology. The second reason stems from the thesis that it has been the private firms in Japan which have been the chief agents, firms, which in many industries are nearly as numerous as the foreign suppliers. The first Japanese firm has usually approached the innovator of the technology. The license is usually exclusive, so the first imitator in Japan has had to search for a second foreign supplier, among a possibly small number of suppliers. As the process of adoption continued, each successive Japanese firm was matched with a different foreign supplier. At any point in the process, therefore, the Japanese firm wanting to adopt a foreign technology is likely to face no more than a few alternative suppliers, whereas the Korean firm faces many. We would expect the Koreans to be in a better bargaining position as a consequence, and to extract better terms from the supplier finally chosen; but this hypothesis, like others involving the financial aspects of technological choice, cannot be tested with the data we have.

One financial matter that does not require more data than we have available is that of the binding capital constraint. Korea's industrialization has been constrained by its ability to raise capital abroad, to such an extent that the success of negotiations with potential supplier of foreign technology has often turned on the provision of capital, both loans and equity. The Japanese firms that have adopted foreign techniques have become large and profitable through previous operations, and so have usually been able to finance imports of technology themselves. Thus technology is a singular import for Japan, whereas it is a joint product, combined with capital, when imported into Korea.

Before we end this comparison of Japan's and Korea's incorporation of foreign technology we should admit that we have left out of consideration grander social and political factors such as national aspiration, linguistic and cultural unity, racial homogeneity, educational background and international tensions, in which, from the Western point of viewing at least, the two countries seem to have been remarkably similar. We should also admit that we are, where Japan is concerned, woefully ignorant of the role that government had played during the postwar era in the incorporation of foreign technology.

V. Conclusion

When we began our inquiry, we did not realize how dependent the success of the absorption of the foreign technology was upon precise terms obtained by the Korean government in its negotiations with the foreign suppliers. The Korean government could have behaved in different ways, as do governments of other developing countries: it could have been passive, accepting whatever terms the foreign supplier offered; or it could have negotiated just as firmly but for different terms, terms which might have enriched a small fraction of its citizens while leaving the remainder no better off. We believe that in either of these cases the absorption of the imported technology would have been less successful, and the benefits to the entire economy less substantial. To put this as succinctly as possible, we are persuaded that a major determinant of the ability of a developing country to absorb an imported technology is the preferences of its government, as reflected in the terms that it imposes upon the foreign suppliers. If these terms are output-and employment-oriented, the country's ability to absorb the technology will be enhanced; if these terms are profit-and publicity-oriented, the country' ability will be reduced.

We feel quite confident in drawing this conclusion regarding the strategic importance of the adoption of the foreign technology. Of the verity of the remaining conclusions we are less confident: to the extent that the study has failed to uncover important aspects of the absorption and diffusion of imported technologies the conclusions will be questionable; to the extent that the study has been restricted in its coverage of industries the conclusions will be limited; and to the extent that the study has concentrated on relatively sophisticated technologies employed in large-scale plants the conclusions will be particular and not general. It might have been possible to have drawn more upon other studies, directed towards other industries, and covering primitive and intermediate technologies, but we prefer generally to rely upon our own analysis. What we have relinquished in breadth we hope we have more than compensated for in accuracy. In other words, our conclusions stem from our discoveries and our analysis, for whose correctness we take full responsibility. They do not take account of the studies and conclusions of other research workers.

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Comment

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Although economists have long been aware of the importance of technology in explaining the processes of economic growth, the understanding of the technological change until recently remain quite limited. The recent advancement in economic theory enables economists to be equipped with the methodological tools to shed new light on the puzzles in technological change. The achievement of economic theory, however, seems to be somewhat disappointing. Its contribution is to give a big picture in which details are omitted. There are various reasons. At least, two disappointing reasons are worth to mention. One is that since most of recent theoretical achievements are mainly based on the concept of equilibrium the dynamic aspects of technological change still wait for future explanation. The other is that compared with the seemingly brilliant achievement of economic theory the empirical investigations are not popular partly due to the shortage of adequate data. Professor Park's paper is pleasingly a welcoming piece of gem filling the gap between theory and data.

Professor Park's paper reveals both merits and limitations of the case studies. The merits come from that they are based on vivid facts which can give details of technological change, while the limitations result from that the facts are sometimes very fragile, in other words, the facts lack in some cases generalization and raise difficulty of interpretation. In this respect I have some disagreements with Professor Park.

Firstly, the objective industries of Professor Park's case study have one common aspect: the theoretical innovations in these industries are very rare and, consequently, competitiveness naturally depends on the plant's scale of operation. Let us take petrochemical industry as an example. Nylon was invented in 1935 and Polyethylene in 1938. During the past three decades British Petro-Chemical Co., one of the world-wide leading petrochemical producers, made only one true innovation notwithstanding numerous patents. The market is big-sized and secure, and the products are already standardized. The price is set

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worldwide and the material input is the same. Hence newly established plants must produce to the full capacity, sometimes above the design capacity, in order to outperform existing foreign competitors. Another source of competitiveness is the life span of plant. Roughly they count the life span of petrochemical plant as about 20 years. The working days of obsolete US and Japanese plants are about 300 days per year; the remaining days are devoted to repair the plants. Newly constructed Korean and Chinese plants are running 380 days per year. Some fraction of 80 day running of Korean and Chinese plants are due to the newness of plant. Therefore running to full capacity at the early stage of operation does not necessarily mean the speedy absorption of technology. Some fraction of remaining 80 days are due to the newness of plant. Hence the age of plant should be included in his model.

Secondly, it is highly probable that the performance measure of each firm is overvalued. All those four firms have heavily depended on imported technologies. Technology transfer is not accomplished in one shot; usually it takes several years. For example, from 1970 to 1988 POSCO had made 32 contracts of technology imports, among which 19 contracts were with Japan, 4 with USA and 4 with West Germany. A typical one was made in 1976 with Japan: the contract composed of productivity quality control of the first, second, and third plants, and furnace repairment for lump-sum royalty payment of $4.65 million with 4 year duration. As is shown in this example the importation of disembodied technology includes various kinds of technological supports such as operation technique, training of engineers, evaluation of performance and supplying newer information. Therefore the resulting learning effects cannot be totally attributed to the domestic accomplishments. The foreign contribution should be counted. An additional item of β_t.

Thirdly, to what extent can we refer the absorption of transferred technology? It seems to me that Professor Park infers the concept of absorption in a narrow content. He writes: 'a quick rise to full capacity indicates a speedy and successful absorption of technology.' But I have a reservation here. In his case study it is well documented that the lack of design capability is phenomenal in all four industries. It is widely acknowledged that the core of industrial technology lies in design capability, Not equipped with design capability can we say that we master the transferred technology? My answer is in the negative. The reason to raise this issue is closely related to the developing countries' strategy in technology transfer. Because of the various reasons when negotiating technology transfer the involvement in design stage is not a main agenda. However, from a view of longer term., the learning of design technique is essential in developing indigineous technology. The examples are abundant; korean car industry.

Lastly, the role of government should be evaluated on more general ground. I fully agree with Professor Park on the function of government. Attaining the policy goals the Korean government was apparently very effective. But I imagine that is, instead of pushing heavy-chemical industries which are production-oriented and characterized as bigness and monopoly, promoting, for example, pharmaceutical industry which is science-based and basically favourably oriented toward small/medium scale firms, the growth might be slower but the result quite different from that of today's. In sum, since today's industry structure is, at least partly, the result of government's industrial and technology policies the evaluation of the role of government needs to be based on wider perspective.

Even though I have some different interpretations of the case studies, overall I fully appreciate the contributions of Professor Park's paper, Especially the identification of various learning channels of imported technology so often neglected by economists is a one-step progress in economics profession's understanding of the process of technological change.