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FACTOR BIAS AND SUBSTITUTION WITH EMPHASIS ON IMPORTED AND DOMESTIC INTERMEDIATE GOODS

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FACTOR BIAS AND SUBSTITUTION WITH EMPHASIS ON IMPORTED AND DOMESTIC INTERMEDIATE GOODS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF
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IN ECONOMICS

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BY

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ABSTRACT

The primary focus of this study is to elucidate the determinants of changes in input ratio, particularly the ratio of domestic intermediate goods to foreign intermediate goods in the Korean machinery industry. It is observed that the ratio of foreign to domestic intermediate goods demanded by each industry is the highest for the machinery industry. In addition, firms' discrimination between imported and domestic intermediate goods is conspicuous in this sector.

In developing countries where industrialization proceeds on its way backward from the 'final touches' stage to the domestic production of intermediate goods, and finally to that of basic industrial materials, the relationship between the two groups of intermediate goods is of considerable importance. The rate of substitution of imported for domestically produced intermediate goods affects the rate of industrialization, economic growth and employment.

The theory of induced innovation provides theoretical foundation for this study. According to this theory, any technical progress augments one or more inputs of production. This enables firms or industries to produce a certain amount of output with less inputs. A given technical progress is not necessarily related to a simple proportionate reduction of all inputs.

Once the technical change is allowed we can postulate three different ways by which the optimal input ratio are influenced. The

observed ratio changes or share changes might have come about through biased technical change and through ordinary input substitution in response to changes in the relative price of inputs. In addition, the non-homothetic nature of the production function is another source of change in the optimal input ratio.

As an analytical method, I adopt generalized Leontief cost function approach. Our cost function incorporates imported and domestic intermediate goods as separate input groups. It amounts to a division of material input into two subgroups which have been treated as a single input group in the traditional studies of input substitution. Such a division of material input enables us to analyze the sources affecting the substitution of one for the other.

Major findings of this study are as follows.

(1) The most important factors that affect input ratio for the Korean machinery industry are the relative price of inputs and the biased technical change. On the contrary, the scale effect on input ratio is negligible.

(2) The model justifies the disaggregation of intermediate goods into two components, domestic and foreign intermediate goods. The results show that domestic and foreign intermediate goods respond differently to the price change of other inputs, capital and labor. If we employ an alternative model that incorporates domestic and foreign itermediate goods to a single bundle, say material input, then we are forced to assume that each component of material interacts with other input price changes to the same extent, as well as in the same way.

This assumption is rejected by our study.

(3) Our finding of moderate complementarity between capital and labor (E_{LK}=-.32, E_{KL}=-.28) differs from those of most empirical studies for manufacturing data. The complementarity of the two is supported by a high ratio of skilled workers in the machinery industry compared to other industrial sectors. It is reasonable to assume that the more capital services are employed, the more technicians and specialists are needed. We have other empirical evidence that shows capital and skilled workers are complementary.

(4) Domestic intermediate goods and foreign intermediate goods are found to be substitutes as expected. The substitutability between them is strong and significantly so. The relationships of individual items between the two groups are divergent. Some pairs are complements and others are substitutes. We find that the force of substitutability between individual items in foreign intermediate goods and those in domestic intermediate goods are dominant over the complementarity between them. Our study provides the first empirical evidence that they are substitutes.

(5) The price elasticities and elasticities of substitution are significantly different across the subsectors in the machinery industry.

(6)The Korean machinery industry experienced foreign-intermediate-goods-using and domestic-intermediate-goods-saving technical change. It implies that if prices of all inputs vary equiproportionately the ratio of F to D tends to rise.

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CHAPTER I

INTRODUCTION

The purpose of this study is to investigate the determinants of input ratios, especially the ratio of imported to domestic intermediate goods. This study is motivated by a question asking what are the main sources that determine the import substitution of intermediate goods in the production process of a firm or an industry.

Specifically we are interested in the following questions;

(i) Are imported intermediate goods and domestic intermediate goods strictly substitutes?

(ii) Is the input ratio of the two affected by technical progress? If so, is the direction of technical change imported-intermediate-good-using or domestic-intermediate-good-using?

(iii) How strong is the bias effect, relative to the price effect, on the ratio of the two?

There are many theoretical and empirical studies of input substitution. The majority of the empirical studies confine themselves to the relationship between capital, labor, material and energy. In the meantime, there have been continuous attempts to disaggregate each group of inputs to a lower level. Much of the empirical analysis in the labor economics field divides labor input into skilled and unskilled workers, young and old workers, or foreign and native workers. With regard to capital inputs, there are some models that discuss the relationships between subgroups of capital such as structure and equipment. After the energy crisis of the 1970s, many empirical studies have focused on interfuel substitution. However, to the best of our knowledge, there has been no systematic study that disaggregates material input into its subgroups.

In today's world where inter-country movement of production inputs is an important aspect of economic activity and the bulk of the international trade is composed of raw materials and intermediate goods, the relationship between foreign and domestic inputs deserves the attention of economists.

Many industrial sectors in developed and developing countries use both imported and domestic intermediate goods. In developing countries it is a universal phenomenon that firms distinguish imported intermediate goods from domestic intermediate goods. This is the topic of chapter III. This is mainly because both price and quality levels of the imported intermediate goods, as well as their growth rate, are different from those of domestic intermediate goods.

If firms discriminate between domestic intermediate goods and imported intermediate goods, it is possible that the two interact in different ways with other inputs, labor and capital. In this case, if we do not disaggregate them, we must assume that the price effect and the technical bias effect on the demand for them are identical and assume that the ratio between the two remains constant as output increases. This is highly implausible.

In developing countries where industrialization proceeds on its way backward from the 'final touches' stage to the domestic production of intermediate goods, and finally to that of basic industrial materials, the relationship between the two groups of intermediate goods is of considerable importance. The rate of substitution of imported for domestically produced intermediate goods affects the rate of industrialization, economic growth and employment.

As far as international commodity market remains free from trade protectionism, the concentration on the production of exportable final goods with imported intermediate goods can be a desirable economic policy for a country which desires to speed up economic growth and increase employment. However, a change of economic environment requires the reorientation of economic policy. For example, we have seen the worldwide trade protectionism in the 1970s mainly against final goods, accompanied by a sharp rise in the price of imported intermediate goods.

During this period, the export-oriented economies like Korea suffered from an ever-rising trade deficit. If a country has such economic problems as heavy foreign debts and a chronic trade deficit, in large part due to the importation of massive amounts of intermediate goods, the import substitution of intermediate goods can be a desirable way to reduce the deficit as well as the unemployment rate. In this case, the correct information about the sources determining the substitution rate is required. Some of this information, we hope, could be provided by our present study.

As an analytical method, we adopt cost function approach. Our cost function incorporates imported and domestic intermediate goods as separate input groups. It amounts to a division of material input into two subgroups which have been treated as a single input group in the traditional studies of input substitution. Such a division of material input enables us to analyze the sources affecting the substitution of one for the other.

In the empirical analysis, we use data from the Korean machinery industry, because the problem of import substituion of intermediate goods in this sector attracts a great deal of attention both from the policy-makers and the businessmen. Since almost all capital goods are produced in the machinery sector, this sector has a very important role in the industrialization process. It is observed that the ratio of foreign to domestic intermediate goods demanded by each industry is the highest for the machinery industry. In addition, firms' discrimination between imported and domestic intermediate goods is conspicuous in this sector.

Intermediate goods in this study are defined as the materials produced in the manufacturing sector and used as inputs in production activity. This line of definition is based on the usage of a commodity rather than its physical characteristics. For example, an electric bulb is treated as as a final good if it used by a final consumer. On the contrary, it is defined as an intermediate good when it is used as a part of an electric machine by a machine producer. With this definition, we exclude 'raw materials' produced in the primary industrial sectors, such as agriculture, mining and fishing. In a country like Korea, where natural resources are scarce, imported raw materials such as crude oil, raw cotton, iron ore and timber can not be substituted with domestic ones - even in the long run. Hence, within the context of substitution of domestic for foreign materials, we cannot treat the raw materials in the same manner as we treat intermediate goods that can be produced in the country. For the Korean machinery industry, the portion of raw material is less than one percent of total material input. Hence the 'intermediate goods' can validly represent the material input.

The economic theories that are relevant to our purpose are those of induced innovation and of derived demand, specifically, of elasticities of input substitution. Since the latter is usually addressed in textbook microeconomic theory, our attention will focus on the former in the literature survey. The evolution of the induced innovation theory originating from Hicks is examined in the second chapter. The important empirical studies in this field are briefly discussed, with special emphasis on the specification of estimating equations, the choice of functional form, and the methodology of distinguishing the effect of technical change from that of pure price substitution.

The development of the Korean machinery industry and the trends in the ratio of foreign to domestic intermediate goods are reviewed in the chapter III. Firms' demand for them and related government policies are highlighted in the following chapter. The theoretical foundation and the estimating model of measuring the effect of prices, bias and output scale are discussed in chapter V. In this chapter, we give a formal treatment to the relationship between the change in input ratio and the three different sources of it. The empirical results are presented in chapter VI, along with a data description. Finally, policy implications are suggested in the conclusion. Footnotes are attached at the end of each chapter.

CHAPTER II

REVIEW OF THE LITERATURE

It is generally known that technical progress is one of the most important sources influencing input ratio in a firm's production. The theory on induced innovation shows that there is no a priori reason for technical progress to necessarily be neutral in the use of inputs. In this chapter, the evolution of the induced innovation theory, and empirical applications of it, are briefly discussed.

2.1 THE EVOLUTION OF THE THEORY ON INDUCED INNOVATION

2.1.1 Macroeconomic approach

Since Hicks (1932) first suggested the induced innovation hypothesis, substantial progress has been made in the interpretation of the process of technical change. Before discussing the theory's development, clarification of the Hicks' hypothesis and the concept of biased technical change is in order.

Hicks argued that there is no inherent labor-saving bias in technical change. Rather, he said, rising wages would encourage entrepreneur to seek out labor-saving innovations to offset rising labor costs.[1] In a two factor model of capital and labor, labor-saving (capital-using) technical change is defined as an increase in the ratio of a marginal product of capital to that of labor with constant capital-labor ratio. It can be directly extended to two alternative definitions of technical change : a labor-saving technical bias is either an increase in the capital-labor ratio or an increase in the capital's share, holding the factor price ratio constant.[2]

It was a generation later when Salter (1960) challenged Hicks' view. He begins with an assumption that entrepreneurs want to reduce costs in total, not particular costs, such as labor or capital costs. There is no reason to concentrate on labor-saving techniques, unless, because of some inherent characteristics of technology, labor-saving knowledge is easier to acquire than capital-saving knowledge. He implicitly considers the production function of knowledge (i.e., technology) at this early stage of theoretical development, though he goes to extremes by arguing that any new labor-saving process is equivalent to substituting capital for labor.[3] In effect, he dismisses the induced innovation theory.

His rejection of the induced innovation hypothesis is subject to Kennedy's (1964) criticism. According to Kennedy, an important historical fact, (i.e., the rough constancy of the distributive share of capital and labor in the U.S.) can not be explained without the aid of technical bias, because there is no a priori reason why the elasticity of substitution should take a particular value, one. In addition, he suggests a different source of induced innovation than suggested by Hicks. Technical change is induced by a change in the cost share, rather than a change in the relative price of factors. His macroeconomic approach describes innovation possibilities by an innovation possibility frontier (IPF), which is a trade-off frontier between the capital augmentation rates and the labor augmentation rates. With an approach of maximizing cost reduction, he concludes that the greater the share of labor costs in the total costs, the more labor-saving the innovation chosen by the entrepreneur will be.

Kennedy's positon is reconfirmed and strengthened by Samuelson's (1965) mathematical elaboration of Kennedy's model. He derives the condition for the constancy of relative shares, even under the capital deepening and less than unitary elasticity of substitution. If, and only if, the induced technical change is relatively labor augmenting, so that the ratio of the effective factor supplies in the 'efficiency units' remains unchanged, then the relative shares of the two factors could remain constant.

Drandakis and Phelps (1966) present another extension of the invention possibility hypothesis. Based on an interpretation of Kennedy's invention possibility hypothesis, they come to the same conclusion as Samuelson. They employ a production function with constant returns to scale which includes the rate of factor augmentation as endogenous variables to show the behavior of factor shares, and of the growth rate of capital, in the context of the induced innovation hypothesis. Their macroeconomic approach, assuming that the growth rates of input quantities, rather than the input prices, are exogenously given, describes the behavior of factor shares as follows.

$$\hat{s}_K = (1-s_K)[(1-\sigma)/\sigma][\hat{r}_L(s_K)-\hat{r}_K(s_K)-(\hat{K}-\hat{L})]$$

where s_K=share of capital
σ=Hicks elasticity of substitution
r_L=augmentation index of labor
r_K=augmentation index of capital
K=quantity of capital input
L=quantity of labor input

and $\wedge$ denotes growth rate of corresponding variable.

The equation shows that even when σ is not equal to unity, the capital share could be remain constant if the capital deepening $(\hat{K}-\hat{L}>0)$ is exactly offset by a difference in the augmentation rate between labor and capital $(\hat{r}_L-\hat{r}_K)$.

2.1.2 Microeconomic approach

There is a remarkable contrast between the macroeconomic and the microeconomic approach to the induced innovation theory. While the former concentrates on investigating sources of steady-state growth path where the relative shares of factors are remain constant, the latter attempts to establish the microeconomic foundations of the theory by analyzing determinants of induced innovation.

Fellner (1961) analyzes the [illegible] of changes in the relative factor prices on technical change. In his diagrammatic exposition, he divided a change in the factor ratio induced by relative price changes into two components. When relative prices change, entrepreneurs respond in two ways. They change not only the combination of factors along the initial isoquant, so that the relative quantity of higher priced factor is reduced, but also they attempt to move from one isoquant to another isoquant representing different production techniques.

Ahmad (1966), by introducing the concept of an innovation possibility curve (IPC), extended Fellner's idea a step further. He defines the IPC with the following: At a given time there exists a set of potential production processes to be developed by a firm. This set of processes may be determined by the state of the basic sciences. Each process in the set is characterized by an isoquant with relatively small elasticity of substitution. The innovation possibility curve is the envelope of all the alternative isoquants (representing a given output on various production functions) which the businessman expects to develop with the use of the available amount of innovating skill and time. He uses the concept and the nature of the IPC to revise Fellner's simple proposition that a rise in the factor price leads to the innovation economizing on that factor. He formulates a more general model that yields Fellner's conclusion only as one of the many possible results. According to Ahmad, a rise in the price of a factor need not induce the innovation economizing on that factor if the innovation possibility curve is sufficiently biased toward that factor. In particular, the constraint of scientific knowledge in innovating activities is emphasized in his model.

The macroeconomic approach has been widely criticized on theoretical grounds, in particular, by Nordhaus (1973). He points out important defects in the innovation possibility frontier (IPF) suggested by Kennedy and Samuelson. The crucial assumption on which IPF is based is the stationary nature of the trade-off between the capital-saving and the labor-saving techniques. This assumption presupposes that the trade-off between the two are independent of the current quantity of capital and labor. However, it is more plausible to assume that a decrease in labor might be harder if labor had been reduced very rapidly in the past. Thus, the reduction rate of labor ($\hat{r}_L$) is a function not only of the reduction rate of capital ($\hat{r}_K$) but of the current level of capital (K) and labor (L) required per unit of output such that,[4]

$$\hat{r}_L=F(\hat{r}_K, K, L)$$

Another defect of the macroeconomic approach to the induced innovation theory emphasized by Nordhaus is the ignorance of the production process of knowledge. When firms are moving from one isoquant to another they have to consider the two kinds of production. One is the production of output, the other is the production of knowledge. The production of knowledge, and the change in the production techniques, have uncertainty as well as cost. However, traditional induced innovation theory has not explicitly considered the cost and the uncertainty involved in the technical change. This criticism of the traditional model encourages the subsequent efforts to illuminate the determinants of innovation.

Microeconomics of the induced innovation theory was substantially enriched by Binswanger's (1974 and 1978) works on mathematical modelling of induced innovation. He introduced the research process, or the production of technical knowledge, directly into the production function, just like a factor of production such that,

$$Y=F(K,L,m,n)$$

where Y=output, K=capital, L=labor, m=relatively capital-saving research process, n=relatively labor-saving research process.

Given factor prices and research costs, a firm must determine both the optimal research levels and the optimal input levels. And it must maximize the profit with respect to four variables, K, L, m, n. By using a cost function as a dual to the production function, and maximizing the net benefit from innovation, Binswanger derives the relationship between the optimal level of research activity and the relevant variables. According to his conclusion, it is neither factor prices alone as in the Ahmad version of induced innovation, nor factor shares alone as in the Kennedy and Samuelson version, that influence an optimal research mix and, hence, the rates and the biases of technical change. An optimal research mix depends on the research costs, the economies of scale in knowledge production function, the cost share of inputs, and the relative price of inputs.

Through a different approach called the evolutionary model, Nelson and Winter (1973 and 1975) analyze the firm's behavior with respect to technical change. Their initial intention was not to develop an induced innovation model but to develop a theory of the firm, industrial sector, and the evolution of economic capabilities with an approach different from the neoclassical context. Nevertheless, their model contains an induced innovation mechanism in it. Their basic assumptions regarding the firm's behavior are as follows: Firms do not operate according to the profit maximization rule, but search for new techniques of production if profits fall below target levels. Through this searching process, the firms draw samples from a distrbution of input-output coefficients. When firms check the profitability of the alternative techniques their search processes uncover, a higher wage rate will cause certain techniques to fail the profitability test that would have passed at a lower wage rate. This encourages and enables others to pass the test that would have failed at a lower wage rate. The latter is capital intensive relative to the former. Thus, a higher wage rate encourages firms to move towards a capital intensive direction.

In addition, since firms with high capital-labor ratios are not as adversely affected by high wage rates as those with low capital-labor ratios, the capital intensive firms tend to expand relative to the labor intensive ones. For both of these reasons, a higher wage rate tends to increase capital intensity. It is noted that the Nelson-Winter model derives essentially neoclassical conclusions regarding the effect of factor prices on factor ratios, without any recourse to the concepts of either maximization or industry equilibrium.

In sum, the induced innovation theory initially intended to explain the historical constancy of the distributive shares of capital and labor in a macroeconomic approach. It is a highly aggregative theory which does not spell out a microeconomic foundation with respect to the behavior of an innovating firm. Substantial efforts in a microeconomic approach have put their emphasis on the unsolved problems of the macroeconomic approach. As a result, controversies over share-induced or priced-induced innovation have disappeared and the cost of innovation is generally acknowledged as another important determinant of innovation. However, the induced innovation theory still has many subjects that should be developed. So far, all the models presented are in comparative static terms. Pushing them into dynamic terms, and incorporating expectation into the theory, remains almost untouched. Even the confusion over the concepts of factor augmentation and quality improvement do not disappear completely.

2.2 MEASUREMENT OF TECHNICAL BIAS AND HYPOTHESIS TEST

The induced innovation theory has been applied mainly to measure factor biases and to test the hypothesis that an intensive use of a factor is induced by a change in relative factor prices or relative factor share. Various forms of production and cost functions which incorporate technical change in the different ways has been adopted by many economists in this field.

In general, two-factor models adopt the CES function of factor augmenting form, while many-factor models use flexible functional forms such as translog, generalized Leontief, generalized Cobb-Douglas, and generalized Box-Cox. Two-factor models usually define technical bias in terms of the change in the relative marginal productivities of factors, holding factor proportions constant. The majority of many-factor models adopt the translog cost function in which technical bias is defined in terms of the share change holding the factor prices constant. This version of definition has advantages in mathematical treatment. The generalized Leontief function simply adopts change in input- output coefficients with the constant relative factor prices and the output as a definition of the technical bias.

<u>CES Production Function</u>. In the 1960s, the factor augmenting form of the CES function was popular partly because it could be conveniently used to estimate the elasticity of substitution and the bias in technical progress simultaneously, and partly because the more flexible functional forms were not available. Ferguson and Moroney (1969), using the CES production function of factor augmenting form, estimated elasticity of substitution and technical bias in twenty 2-digit industrial sectors in the U.S. manufacturing. From the first order condition for constrained cost minimization, they derived an empirical model:

$$\begin{aligned}\ln(K/L)_t &= \sigma \ln(p_L/p_K)_t + (1-\sigma)\ln(a_L/a_K) + (1-\sigma)(\hat{r}_L-\hat{r}_K)t \\ &= b_0 + b_1\ln(p_L/p_K)_t + b_2 t + u_t\end{aligned}$$

where K=capital, L=labor, σ= elasticity of substitution, p_L=wage, p_K=rental price of capital, a_K, a_L=capital and labor augmentation parameter at t=0, respectively, $\hat{r}_L$, $\hat{r}_K$=augmentation rate of labor and capital, respectively, t=time, u_t=disturbance term.

They compute the elasticity of substitution and the technical bias by using the estimated coefficients, b_i (i=0,1,2), and technical bias (B) equation,

$$B = [(1-\sigma)/\sigma](\hat{r}_L-\hat{r}_K)$$

The results of the estimation using time-series data (1948-1962) show that different forces are at work to increase the labor's relative share. Labor's share increased appreciably in seventeen industrial sectors. In thirteen of them, the dominant force was capital deepening, accompanied by an elasticity of substitution less than unity. In the remaining four sectors, the increase in the labor's share was due entirely to labor-using technical progress. In the latter cases, the rates of labor-using technical change were more than sufficient to offset the decline in capital-labor ratio.

The CES model with two factors was also adopted by Richards (1977). His estimating equation is almost identical to that of Ferguson and Moroney (1969). To allow for the possibility of a lagged adjustment to the desired factor proportions, he assumes the Nerlove partial adjustment process,

$$[(K/L)_t/(K/L)_{t-1}] = [(K/L)_t^*/(K/L)_{t-1}]^e$$

where e is elasticity of adjustment and * denotes desired value. This assumption yields an estimating equation, including lagged value of K/L ratio such that,

$$\begin{aligned}\ln(K/L)_t &= e\,\sigma\,\ln(p_L/p_K)_t + et(1-\sigma)(\hat{r}_L-\hat{r}_K)\\ &\quad + (1-\sigma)\ln(a_L/a_K) + (1-e)\ln(K/L)_{t-1} + v_t\end{aligned}$$

Using two equations, one with a lagged structure and one without it, he estimated regression coefficients for the sample of twenty 2-digit industrial sectors of Australian manufacturing. His time-series data (1949-1964) yields significant coefficients for only twelve sectors. The coefficient estimates are consistent with the price-induced innovation hypothesis for only two sectors, for the effect of capital-deepening is almost exactly offset by the rate of the capital-using technical progress. In the other ten sectors, where there was a downward trend in labor share, the effect of capital-deepening (in the presence of inelastic substitution) is more than offset by the capital-using technical progress.

Translog Production and Cost Function. The translog cost function encouraged many economists to adopt it in measuring technical bias. This was mainly because of its theoretical and econometric advantages. Binswanger (1974) formulates two estimating models using the translog cost function. One is based on the assumption of constant rate of technical change over time and the other assumes varying rate of technical change.

First model is expressed in factor augmenting form,

$$\ln C = \ln h(Y) + \ln a_0 + \sum_{i=1}^{n} a_i \ln(p_i/A_i) + 1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln(p_i/A_i) \ln(p_j/A_j)$$

where C=cost, Y=output, p_i=price of i-th input, and A_i=augmentation parameter of i-th input. By totally differentiating the share equation and by eliminating b_{in}, he derives the equation,

$$d\,s_i = \sum_{j=1}^{n-1} b_{ij}\, d\,\ln(p_j/p_n) - \sum_{j=1}^{n-1} b_{ij}\, d\,\ln(A_j/A_n)$$

where s_i=share of i-th input. The second term of RHS denotes the component of the share change caused by pure technical change. He computes technical bias using the above equation.

His second model introduces time, t, like an additional input to derive an estimation equation.

$$\partial \ln C/\partial \ln p_i = s_i = a_i + \sum_{j=1}^{n} b_{ij} \ln p_j + g_i \ln t + u_i$$

Here, the estimates of time coefficient, g_i, are used to compute technical biases. Whether the technical bias is i-using, or i-saving depends on the sign of g_i. If g_i is zero, the technical change is neutral. His empirical results show that technical change in the U.S. agriculture during 1948-1964 has been labor-saving, fertilizer- and machinery-using. The fertilizer and labor biases are consistent with the hypothesis that factor prices account for most of the biases. The machinery bias contradicts it, since the relative price of fertilizer has declined during this period.

The second model of Binswanger (1974) was applied by Duncan and Binswanger (1976) to measure input biases of four major energy sources, coal, fuel oil, electricity and gas in Australian manufacturing. In order to reduce explanatory variables in the estimation equations, they simply assumed separability[5] of the energy input in the translog function, which might have caused some bias in the coefficient estimation. Their specification of the model is,

$$s_r/s_n = a_r + \sum_{k=1}^{n} a_{rk} \ln b_k + a_{rt}t$$

which is derived from,

$$\ln p_n = a_0 + \sum_{k=1}^{n} a_r \ln b_r + 1/2 \sum_{r=1}^{n} \sum_{k=1}^{n} a_{rk} \ln b_r \ln b_k + \sum_{r=1}^{n} a_{rt} \ln b_r t$$

where s_r = the share of r-th energy input in total energy input, s_n=cost share of total energy, b_r=price of r-th energy input, t=time, p_n=price of energy.

Biases of the energy input are measured at two levels: the biases of individual energy inputs in the context of whole inputs and the biases in the context of energy inputs. In order to do this, the required coefficients are estimated from both a full cost function model, as well as the energy sub-model. They use time-series data for the sixteen industrial sectors in Australian manufacturing. The results of the estimation show no clear conclusion with regard to the price-induced innovation hypothesis. However, their evidence is strongly against the share induced innovation hypothesis.

Turnovsky, Folie and Ulph (1982) estimated a translog cost function with time-series data for Australian manufacturing. Whole inputs are divided into four groups, capital, labor, energy and materials. Their specification of the estimating equation is exactly the same as the Binswanger's (1974) second model. Even though they use the aggregate data at the level of manufacturing as a whole, their model assumes that the input prices are exogenous.

Berndt and Wood (1975) addressed this problem in their empirical study on the derived demand for energy in U.S. manufacturing. At the level of the individual firm, it may be reasonable to assume that the supply of inputs is perfectly elastic, and, therefore, that input prices can be taken as fixed. At the more aggregated industry level, however, input prices are less likely to be exogenous. Thus, the assumption of the fixed input price in the empirical study for manufacturing as a whole introduces the possibility of simultaneity bias.

Cain and Paterson (1981) examine the proposition that U.S. manufacturing experienced biased technical change during the period of 1850-1919. By estimating the translog cost function including four inputs, capital, labor, materials and others, they conclude that no single sector among nineteen 2-digit industrial sectors was free from biased technical change. They also found that labor-saving biases were present in most sectors. Another important finding was that the bias effects were stronger in a greater number of cases than ordinary substitution effects, which contributed only modestly to the change in factor proportions in most sectors. However, their measurement of biases should be interpreted with caution because they did not undertake a series of tests on the functional specification such as homogeneity and concavity of cost function.

Recently J. H. Lee (1983) adopted the translog production function without augmentation parameters. He relaxes restrictions on the producton function by assuming that the production function is homogeneous in factor inputs of degree e, rather than of degree one. He specifies the bias of technical change in quantities within the context of the translog production function by decomposing the rate of share change into two components: one is caused by a change in input quantities, and the other by a technical change such that,

$$B_i = d \ln s_i - [d \ln X_i + \sum_{j=1}^{n} s_j (C_{ij} - e) d \ln X_j] \qquad (i=1,2,\ldots,n)$$

where B_i=bias index, s_i=share of i-th input, X_i=quantity of i-th input, C_{ij}=cross-elasticity of complementarity. He obtains B_i using observed d ln s_i, d ln X_i, and estimated value of C_{ij} and e. His empirical evidence for the pooled data of the cross-section and the time-series in Japanese agriculture agrees only partly with the price-induced bias hypothesis.

<u>Generalized Leontief Cost Function</u>. Another important flexible functional form, the generalized Leontief, was adopted by Lynk (1982) to measure factor bias. For the purpose of estimating simultaneously the substitutability between the inputs, the returns to scale and the biases in technical change, Lynk adopts a variant of Diewert's original generalized Leontief cost function.[6]

$$C = Y \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} (p_i p_j)^{1/2} + Y^2 \sum_{i=1}^{n} g_i p_i + Yt \sum_{i=1}^{n} a_i p_i$$

where C=cost, Y=output, p_i=price of i-th input, t=technology or time.

Estimating equations are derived from the cost function, which is linear in parameters,

$$(\partial C/\partial p_i)(1/Y) = X_i/Y = \sum_{j=1}^{n} b_{ij}(p_j/p_i)^{1/2} + g_i Y + a_i t \quad (i=1,\ldots,n)$$

In this model, technical bias is defined in terms of a change in input-output coefficients holding relative prices constant. Biases are measured using,

$$\partial(X_i/Y)/\partial t = a_i$$

The results of his empirical study, using time-series data (1952-1971) of fifteen 2-digit manufacturing sectors in India, confirm the common impression of increased capital intensity of production and a strong capital-using bias over the period. His empirical evidence, however, must be cautiously interpreted because the relevant coefficients estimated are not significantly different from zero. In addition, the presence of significantly negative off-diagonal elements of C_{ij} matrix ($C_{ij} = \partial^2 C/\partial p_i \partial p_j$) suggests that the cost function may not behave well, in the sense that it is not concave in input prices.

Generalized Box-Cox. Berndt and Khaled (1979) have proposed the generalized Box-Cox functional form which takes on the translog, generalized Leontief, and generalized square-root quadratic functional form as special or limiting cases. Using the highly general form, they formulate a model of producer behavior that simultaneously identifies the substitution elasticity, the economies of scale, and the rate of technical change. They specifies generalized Box-Cox cost function incorporating technology variable as,

$$C=[(2/r)\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}(p_i p_j)^{r/2}]^{1/r}\ \gamma^a\ \mathrm{Exp}[t(g+\sum_{i=1}^{n} g_i \ln p_i)]$$

In this functional form, technical bias is defined as a change in the factor share caused by the technical change. Thus, technical bias is estimated by using the coefficient of t in the factor share equation which is derived from the cost function.

The richness of the specification enables them to estimate a wide variety of models, depending on the nature of returns to scale and the technical change. Pairwise combinations given by three states of technical change (1-no technical change, 2-neutral, and 3-non-neutral technical change) and four types of returns to scale (1-constant returns to scale, 2-homogeneous, 3-nonhomogeneous but homothetic, and 4-nonhomothetic returns to scale) result in twelve different models. Using annual U.S. manufacturing data from 1947-1971, they find that homotheticity, homogeneity and constant returns to scale must all be rejected; and that the neutrality of technical change is also rejected. Moreover, their evidence shows that technical change has been significantly capital- and energy-using, labor- and intermediate-material-saving.

<u>Models without Specificaton of Production or Cost Function</u>. While most estimating equations of technical biases are derived from underlying production or cost functions, some models attempt to test the induced innovation hypothesis without applying a specific production or cost function.

Hayami and Ruttan (1970) attempt to analyze the manner in which differences in factor price movements in Japan and the U.S. have influenced the process of technical change and the choice of inputs in two countries. They simply regress the land-labor ratio and the power-labor ratio on relative factor prices with the use of Japan and U.S. time-series data from 1880-1960. According to their empirical results, more than 80 percent of the variation in the land-labor ratio and in the power-labor ratio is explained by the changes in their price ratio in the case of U.S. agriculture. However, they could not decompose quantitatively the variation in factor ratio into the component of price substitution and that caused by technical change. Hence, their test is not a test of the induced innovation hypothesis in a strict sense. They simply infer that the wide variations of factor proportions can not be explained by the limited elasticity of substitution alone.

Doutriaux and Zind (1976) formulate a model which can be used to measure augmentation rates of factors, i.e., efficiency growth rates. Their model assumes competitive markets and profit maximization. This assumption, and factor augmenting form of the production function in the most general expression, give the relationship of first derivatives such that,

$$dQ - p_L dL - p_K dK = p_L L \, \hat{r}_L + p_K K \, \hat{r}_K$$

where Q=output, L=labor, K=capital, p_K=wage, p_K=rental price of capital, $\hat{r}_L, \hat{r}_K$ = efficiency growth rate of labor and capital respectively. Their evidence for the data of U.S. agriculture, 1940-1970, shows that capital efficiency has increased at a faster rate than labor efficiency.

The empirical evidence discussed so far suggests different conclusions with regard to the induced innovation hypothesis, the directions and the extent of technical biases. The main source of the varied results is, of course, the differences in the data used. In addition, errors which may arise from functional specification, assumptions about determination of prices and quantities of inputs, and measurement of price and quantity might affect, more or less, the estimated value of relevant coefficients.

A common feature of almost all empirical studies is the assumption that annual rate of technical progress is constant. Since there is no data on the quantity of technical knowledge applied by firms, time is usually adopted as a proxy for the quantity index of technical knowledge. This limitation inevitably leads to the constancy of annual augmentation rates of inputs.

Some empirical evidence rejecting the induced innovation hyothesis can be interpreted in the context of biases in innovation possibilities, which are determined by the level of basic sciences. For example, if the innovation possibilities are extremely biased against a particular input, a decrease in the relative price of that input will hardly induce an increase in the use of that input. As far as empirical evidence is concerned, it is not yet conclusive whether innovations are induced by the prices or the cost shares of inputs. The existence of non-neutral technical change is supported by most empirical studies.

Finally, it is noted that no empirical study pays attention to the relationship between the foreign and domestic inputs that are employed together by a firm or by an industry. Their interests are confined to the relationships between capital, labor, material and energy. After the energy crisis in the early 1970s, many empirical studies have focused on interfuel substitution.

FOOTNOTES(CHAPTER II)

1. Hicks (1932), Chapter 6.

2. Three alternative definitions of technical bias (B) are,

   $$(1)\ B_{(K/L)}^{o} = [\partial(F_K/F_L)/\partial t][1/(F_K/F_L)]$$
   $$(2)\ B_{(r/w)}^{o} = [\partial(K/L)/\partial t][1/(K/L)]$$
   $$(3)\ B_{(r/w)}^{o} = (\partial s_K/\partial t)(1/s_K)$$

   where K, L,= capital and labor respectively, F_K,F_L=marginal product of capital and labor respectively, t=technology index or time, r=rental price of capital, w=wage, s_i=cost share of i-th input. Technical change is capital-using, neutral, or capital-saving respectively, when B is greater than, equal to, or less than zero.

3. Salter (1960), pp. 43-44.

4. Kennedy's invention possibility function is simply expressed as, $\hat{r}_L=f(\hat{r}_K)$. Hence, the past accumulation of capital or labor has no influence on the functional relationship.

5. Separability is often assumed in the specifications of production and cost functions. When inputs X_1 and X_2 are functionally separable in a three input model, we can express the functional form like:

   $$F(X_1,X_2,X_3)=H[G(X_1,X_2),X_3]$$

   Berndt and Christensen (1973a) have established that the weak separability restriction is equivalent to certain equality restrictions on elasticities of substitution. Hence the separability expressed by the above equation implies the restriction, $\sigma_{13}=\sigma_{23}$.
   Since the partition under consideration is limited to two subsets in this example, weak and strong separability are equivalent restrictions.

6. Diewert's original specification of generalized Leontief cost function is,

   $$C= h(Y)\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}(p_i p_j)^{1/2}$$

   The specification of h(Y) indicates the homothetic nature of the underlying production function. If h(Y)=Y, then the underlying production function is homogeneous of degree one.

CHAPTER III

THE ROLE OF INTERMEDIATE GOODS IN THE KOREAN MACHINERY INDUSTRY

3.1. A SHORT HISTORY OF THE MACHINERY INDUSTRY

Before proceeding to the history of the machinery industry the definition of the scope and nature of the machinery industry in Korea is in order. According to the industrial sector classification of the 1978 Korean Input-Output Tables compiled by The Bank Of Korea, the machinery industry is composed of six sectors: fabricated metal products; general machinery; electrical machinery; electronic and communication machinery; transportation equipment; and measuring, medical and optical instruments. They are disaggregated into twenty three subsectors as shown on table 3.1. We notice that the scope of the machinery industry defined in this manner is rather broad, because items in the 'fabricated metal products' can not be regarded as machines in a strict sense. This study adopts a narrower definition of machinery industry so that the 'fabricated metal products' are excluded from it, unless there are no special remarks.

It is generally acknowledged that the machinery industry has the following characteristics: (1) It plays an important role in the process of industrialization because it supplies capital goods to other sectors. In this sense, it has strong backward linkage effects. (2) The development of the machinery industry requires relatively large amounts of capital, sophisticated modern technology and skilled labor.

TABLE 3.1.

INDUSTRIAL SECTORS IN THE MACHINERY INDUSTRY

Sector code	Sector (60-sector table)	Sub-sector code	Subsector (164-sector table)
38	Fabricated metal products	107	Metal furnitures and household metal products
		108	Structural metal products
		109	Tools and general hardwares
		110	Other metal products
39	General machinery	111	Prime movers
		112	Agricultural machinery
		113	Metal-working and wood-working machinery
		114	Special industrial machinery
		115	Other general machinery
		116	General machinery parts
40	Electrical machinery	117	Household electric appliances
		118	Electrical industrial apparatuses
		119	Other electrical equipment and supplies
41	Electronic and communication machinery	120	Household electronic appliances
		121	Communication equipment
		122	Electronic appliances
		123	Electronic components
42	Transportation equipment	124	Ships
		125	Railroad transportation equipment
		126	Motor vehicles
		127	Other transportation equipment
43	Measuring, medical, and optical instruments	128	Measuring, medical, and optical instruments
		129	Watches and clocks

Source : Input-Output Tables 1978, The Bank Of Korea.

(3) Final products in the machinery industry are produced by assembling numerous parts and components. Hence, the quality of machinery products depends to a great extent on the quality of the intermediate goods. (4) Regarding raw material inputs, its ratio to the total material inputs is very low. As of 1980, it was no more than .3 percent.[1]

Primitive Stage of Development-1960s. Korean manufacturing had remained generally undeveloped before The First Five-Year Economic Development Plan (1962-1966). During the 1950s the major items of manufacturing production were those produced in the food and textile industries such as sugar, flour, and several cotton textile products. The ratio of manufacturing output to the GNP was no more than 14 percent in 1961[2]. During the early phase of industrialization, industrial growth was mainly based on the expansion of consumer goods industries. Even though manufacturing production had led the growth of the national economy throughout 1960s, fundamental change in the sectoral structure of manufacturing did not take place. For example, the production of the machinery industry remained below 10 percent of total manufacturing production during this period (see table 3.2) and the products in machinery industry did not include those items which could be produced with advanced production technology.

In the general machinery sector, major products were simple lathes, drilling, planing machines (metal-working machinery subsector), ploughs, threshers, straw-twisting machines (agricultural machinery subsector), and small-size diesel engines (prime movers subsector).

TABLE 3.2

THE OUTPUT SHARE OF THE MACHINERY INDUSTRY IN THE WHOLE MANUFACTURING PRODUCTION

(unit: %)

	1962	1966	1970	1974	1978	1980
Machinery industry as a whole	8.9	9.2	8.8	15.0	21.2	18.8
General machinery	3.9	2.2	1.3	1.8	2.7	2.0
Electric and electronic machinery	1.5	2.4	3.0	8.0	11.4	10.8
Transportation equipment	3.2	4.3	4.2	4.7	6.3	5.2
Measuring, medical, and optical instrument	.3	.3	.3	.5	.8	.8

Source : National Income Of Korea, 1962, 1966, 1970, 1974, 1978, and 1980. The Bank Of Korea.

Most demand for the high quality machines that were used in the modern sectors of construction, textile, chemical, printing, food-processing and machinery industries were filled by imports.

Products of the electrical machinery sector were concentrated in household electric appliances, rather than in electrical machinery for industrial use. The establishment of mass-production capacities of electric bulbs, electric heating and lighting apparatuses, and electric fans were followed by the first domestic production of household refrigerators and freezers. However, heavy electric equipment for industrial use, such as power station facilities, were rarely produced.

Items in this advanced subsector were limited to small- capacity generators and simple transformers. Almost all heavy and large-capacity electric equipment was imported from developed countries. The imports of electrical machinery satisfied 63 percent of domestic demand in 1971.

Industrialization took place earlier in the electronic industry than in other sectors of the machinery industry. With the participation of foreign electronic companies such as Komy Corporation (U.S), Fairchild (U.S), Signetics (U.S), and Motorola (U.S), the household electronic machinery sector saw a remarkable advancement in the 1960s. Radio receivers which had been produced with imported parts since 1959 began to be exported in 1962. Domestic production of record players and black-and-white television sets started in 1965 and 1966, respectively. In 1970, cassette tape-recorders were produced for the first time by a domestic firm. More sophisticated items of household electronic machinery and many products in more important subsectors (i.e., electronic machinery for industrial use and their parts and components) continued to be imported.

The transportation equipment sector was not an exception to the overall structual imbalance of the machinery industry. While shipbuilding remained a minor industry throughout the 1960s, with its output share in total manufacturing comprising less than one percent, the automobile industry saw great progress in its first phase of development. Leading companies set the foundation for mass production of small cars, with the help of foreign companies. The cooperative

TABLE 3.3

THE EXPORT SHARE OF THE MACHINERY INDUSTRY

IN THE TOTAL EXPORTS

(unit: %)

	1968	1970	1974	1978	1980
Total exports (mil $)	455	623	4,460	12,711	17,505
Machinery industry as a whole	7.8	9.2	18.9	26.0	25.8
General machinery	.9	1.0	1.7	1.7	2.2
Electric and electronic machinery	4.2	5.3	10.6	9.8	10.9
Transportation equipment	.3	1.1	2.7	8.8	6.6
Measuring, medical, and optical instrument	.2	.4	1.1	1.5	1.7

Source : Annual Trade Statistics, 1968, 1970, 1974, 1978, and 1980. The Office Of Tariff.

agreement between Shinjin and Toyota (Japan) in 1966 was followed by that of Hyundai-Ford (U.S.) in 1968, Asia-Fiat (Italy) in 1968 and Kia-Toyo (Japan) in 1971. Almost all automobile production by domestic firms during this period was characterized by simple assembling of parts and components provided by foreign partner companies.

Fast Growth and Deepseated Sectoral Imbalance-1970s. The Korean machinery industry took a great step its modernization in the 1970s. This decade saw a remarkable diversification of domestic products and a rapid expansion of output in the machinery industry. Its output share in manufacturing rose from 9 to 19 percent for the period 1970- 1980. This implies that output of the machinery industry expanded twice as fast as the total manufacturing. We notice in table 3.3 that the output growth of the machinery industry had been accelerated by a rapid expansion of foreign demand. Its exports share in the total exports grew from below 10 percent in 1970, to a quarter in 1980.

In the general machinery sector, output growth was led by such items as steam engines, turbines, metal-pressing machines, machines for pulp and paper industry, excavators, etc. At the same time, many new products in modern commodity groups were developed, such as gear-cutting machines, metal-reaming, milling, and rolling machines, leather-processing machines, calculator, copying machines, agricultural tractors and glass-working machines.

In spite of the fast output growth observed in the sector, the overall quality level of the products were relatively low. It was especially so in the metal-working machinery subsector. Most firms in the subsector showed a general tendency to produce less complicated machines of lower quality. Machines equipped with sophisticated modern automation systems for more precise processing of metals, highly specialized machines and large size machines with a high capacity were seldom developed. Thus, the bulk of the advanced machines used in the construction, mining, chemical, printing and machinery industries continued to be imported.

A change in the products composition features the developments in the electric machinery industry during this period. With the development and mass-production of new items of industrial electric equipment and appliances, the output share of this product group rose. However, looking at the level of the production technology in the subsector, we find that there is much room for further improvement. Major items in the subsector are electric generators, motors and transformers, of small- and medium-size.

It was not until 1979 that large-sized transformers with the capacity of 354KV-475,000KVA, for use by power stations, were successfully produced from domestic technology. It was regarded as a great step in the modernization of the electric industry. (In Japan a transformer with the capacity of 750KV was developed in 1978.) Many items in the commodity groups, like power circuit breakers, electric switchgear and protective equipment also were added to the list of domestic electric machinery products. Nevertheless, this subsector still contains many important product groups that remain underdeveloped.

The electronic machinery industry showed the most remarkable performance in the machinery industry during the 1970s. The growth of this sector was led by household electronic appliances, such as televisions, radios, sound recorders and cassette-tape recorders. A structural imbalance of this sector is explained by the backwardness of the industrial electronic machinery subsector. In 1981, the output share of electronic machinery for industrial use was no more than 13 percent of all electronic machinery output. The production activities in this subsector required more sophisticated technology that could be obtained through massive investments on research and development.

Hence, a greater output share of this subsector may indicate a higher technological level of electronic industry. For the electronic industry of Japan, the share was 36 percent in 1980 and 66 percent for the U.S. electronic industry in 1979. This subsector covers telephones, telecommunication systems, broadcasting equipment, radars, X-ray equipment, radioactive measuring equipment, computers, industrial robots and electronic gauges. A small output share of this modern subsector, and its technological backwardness in Korea, indicate that the industrial electronic machinery subsector is in a very early stage of its modernization. The major products recently developed in this subsector are telephone recorders (1980), peripheral equipment of computers (1980), TV cameras (1980), CRT terminals (1981), facsmilie teleprinters (1982), microcomputers (1983), personal computers (1983), wordprocessors (1983), etc. However, the production of these modern items depends heavily on foreign technology and imported parts.

Another fast growing subsector in the 1970s was the shipbuilding industry. With the construction of shipbuilding dock-yards by Hyundai (1974) and by Daewoo (1981), Korea jumped forward to be one of the greatest shipbuilding countries in the world, second only to Japan. As is the case for other industrial sectors, the fast expansion of this subsector also was not accompanied by corresponding development of domestically-produced intermediate goods demanded by it.

In the automobile industry, the first domestic model of a small car was developed and exported in the 1970s. This subsector has grown to have such a great production capacity that it can produce 190,000 cars, 41,000 buses and 10,000 trucks in a year. The most important problem to be solved in the subsector is the reduction of the great quality gap between domestic and foreign cars, especially the gap in the function of safety, energy-saving and antipollution equipment.

In sum, the Korean machinery industry has expanded output at a high rate since the early 1970s. Its output share of total manufacturing has more than doubled for a decade. However, the expansion of output quantity was not accompanied by the corresponding development of the related sectors that provide parts and components. The backwardness of the intermediate goods sector is a natural result of the concentration of economic resources on the final products sectors. That is the reason why the desirable transition of the sectoral structure, i.e., the transition from a low technology subsector to a high technology subsector, has been retarded. Consequently, more advanced subsectors in the modern machinery industry such as precise metal-working machinery, specialized industrial machinery, electric and electronic machinery for industrial use, measuring, medical and optical instruments remain underdeveloped.

The short history of the Korean machinery industry can be summed up by highlighting the two conflicting aspects: One is the success in the rapid growth of output and the other is the failure in setting up a solid foundation for far-reaching, self-sustained growth. The industrialization of a country can start with the development of the intermediate goods sector, and then it moves toward the final goods sector, or vice versa. The Industrial Revolution in the 19th century followed the former pattern. The latter is a common feature found in developing countries, including Korea. It is beyond the scope of our present study to discuss in depth which of the two developmental patterns is better and why. One of our concerns here is how the industrialization process can be accelerated once the choice of starting sectors has been made. It seems inevitable for developing countries to start with the development of the final goods sector, using imported materials, because at the very beginning stage of industrialization the domestic availability of intermediate goods is limited.

Sooner or later, the initial development of the final goods sector provides stimuli which promote the growth of the intermediate goods industry. The strength of the stimuli partly rests on the input demand by the final goods sector. For example, if the final goods sector has a strong preference toward foreign intermediate goods, the strength would be weaker than otherwise. Then, the maximization of the linkage effect of the final goods sector on the intermediate goods sector, as is discussed by Hirschman (1963), could not be attained.[3] This seems the case for the Korean machinery industry, where import substitution of intermediate goods has been retarded.

3.2 SECTORAL DEMAND FOR FOREIGN AND DOMESTIC INTRMEDIATE GOODS

A quarter of total demand for intermediate goods in Korean manufacturing was satisfied by imports in 1980 (see table 3.4). From 1966 to 1980, gradual import substitution of intermediate goods was

TABLE 3.4.

THE SHARE OF IMPORTED INTERMEDIATE GOODS

DEMANDED BY THE MANUFACTURING SECTORS[a]

(unit: %)

	1966	1970	1975	1980
Average of manufacturing	26.7	36.7	30.1	24.7
Food, beverages and tobacco	5.7	27.8	30.1	23.2
Textiles	16.8	25.0	16.5	15.7
Lumber products	31.3	18.0	11.9	13.8
Paper, printing	18.0	36.3	35.9	27.5
Chemical products	70.0	59.2	37.0	28.7
Nonmetalic mineral products	27.6	10.5	6.3	7.0
Primary metal products	40.7	54.6	36.9	22.0
Fabricated metal products	50.6	32.7	29.5	26.1
Machinery	35.0	46.3	46.6	42.3
Others	49.6	50.3	7.7	18.4

[a] The share for each sector is obtained through dividing the value of foreign intermediate goods by the total value of intermediate goods used in that sector.

Source : Input-Output Tables 1966, 1970, 1975, and 1980. The Bank Of Korea.

observed in seven of ten industrial sectors of manufacturing. In the machinery industry, little substitution took place in terms of the aggregate value of intermediate goods. It is interesting to find that the demand share of foreign intermediate goods relative to total

TABLE 3.5

THE SHARE OF IMPORTED INTERMEDIATE GOODS DEMANDED BY THE MACHINERY INDUSTRY[a]

(unit: %)

	1966	1970	1975	1980
Average of machinery industry	35.0	46.3	46.6	42.3
General machinery	34.6	25.2	31.1	31.2
Electrical machinery	31.1	34.6	23.9	25.8
Electronic machinery	47.5	69.5	60.8	44.4
Transportation equipment	33.7	46.3	43.2	40.1
Measuring,medical,optical instrument	33.7	70.7	66.9	51.5

[a] The shares are calculated in the same manner as those in the table 3.4.

Source : Same as table 3.4.

intermediate goods is highest in the machinery industry. It can be explained by one or more of the following reasons.

(1) Firms in the machinery industry are more sensitive to the quality difference between foreign and domestic intermediate goods than are firms in other sectors.

(2) Quality differences between the two groups of intermediate goods is greater for the machinery industry than for other industry.

(3) Domestic production of intermediate goods used in the machinery industry is more difficult than those used in other sectors.

Looking at table 3.5, the percentage of foreign intermediate goods is different among the subsectors in the machinery industry. It is relatively low in the sectors of general machinery and electrical machinery. It is high in the sectors of electronic equipment, measuring, medical and optical instruments.

The process of import substitution in intermediate goods is characterized by a general increase in the share of foreign intermediate goods at an earlier stage of industrialization. A comparison between the share in 1966 and 1970 indicates that the share of imports rises in all sectors of the machinery industry, except in the general machinery. The sources of this reverse substitution might be:

(1) change of relative price and

(2) failure of the domestic intermediate goods industry to catch up with the rapidly increasing demand for intermediate goods in terms of quantity and quality.

Since the diversification of products introduced many new products and the fast growing machinery industry had a rising demand for required inputs, it was quite possible that demand for intermediate goods far exceeded the domestic availability of them in the earlier stage of industrialization. In contrast to the trends in the 1960s, the share of imports has been falling continuously in all machinery sectors, except in the general machinery sector throughout the 1970s.

The import share in total demand for intermediate goods is partly conditioned by the availability of the domestic substitutes for the imported intermediate goods. Intermediate goods are classified into two groups by their properties: One is the base material. Major items

TABLE 3.6.

THE SHARE OF MAJOR IMPORTED INTERMEDIATE GOODS IN THE TOTAL SUPPLY[a]

(unit: %)

	1966	1970	1975	1980
Pig iron	61.4	97.4	49.9	24.3
Semi-final products of steel	17.6	3.6	11.3	19.9
Steel plate	63.3	48.3	33.3	10.8
Steel bar	7.7	2.4	4.9	3.3
General machinery parts	25.3	32.8	52.5	43.9
(Bearing)	(35.9)	(16.0)	(42.3)	(53.1)
Electric parts and components	16.6	44.5	35.8	53.2
Motor vehicle parts	N.A.	67.8	33.8	24.2
Parts of watches and clocks	N.A.	10.1	70.9	74.2

[a] The share is computed through dividing the value of imports by the sum of imports and domestic production.

Source : Same as table 3.4.

of this group are iron, steel, nonferrous metal, plastic, and rubber products. The other group is composed of the parts and the components of machinery. Each item in the latter group has a specific function after it is fixed in a machine, whereas the former is used to produce the latter. The iron and steel used in the various subsectors of the machinery industry are supplied by the steel industry. The Korean steel industry experienced fast growth in the 1970s, with the construction and capacity expansion of leading steel mills, such as the

Pohang Iron And Steel Co., the Dongkuk Steel Mill Co., and the Inchun Steel Co. Much of imported iron and steel products were replaced, as a result, by various products they supply. Some of the special products, such as angles and shapes of steel, wire rods of steel and iron, rails, medium- and heavy-steel plates and sheets, however, continued to be imported. The share of imports in total demand for iron and steel products decreased from 40 percent in 1960 to 20 percent in 1982.[4]

The portion of imports in total supply of general machinery parts had risen during the period of 1966-1975, from 25 percent to 53 percent, and had fallen to 44 percent by 1980 (see table 3.6). There are innumerable specific parts that are used in various machines. An important group of parts is that of the common parts that can be used interchangeably in different machines. Major items in this group are bolts, nuts, valves, bearings, springs, gears, clutches, etc. The supply of almost all of the items in this group has rapidly expanded, stimulated by a sharp increase in foreign and domestic demand. At the same time, the issue of quality improvement of the domestic common parts attracted more and more attention both from suppliers and from users.

For example, take the bearing. Its import share in total supply rose from 16 percent in 1970, to 53 percent in 1980. The main reason for the share change is a faster demand increase for high quality products than that for low quality products. Many companies in the machinery industry prefer imported bearings, they argued, because domestic bearings make noise when applied in revolving machines, and also because they were often distorted under high speed and high heat.

Another example shows the rate of domestic supply of some machinery parts is left behind compared to that of the demand for them, when quality of a final product is drastically improved. The introduction of the numeric controller (NC), a highly advanced automation system that is attached to various kinds of metal-working machine, opened a new horizon for the metal-working machinery industry. It was as late as 1977 that the Korean machinery industry first developed a domestic model of the NC lathe. It was followed by successive developments of the NC milling machine, and machining center. Domestic production of the NC machines required new, imported parts such as the numeric controller and the servo system. A bulk of these items were imported from the Japanese corporations, Toshiba and Fanuc.

The share of imports in the total supply of electronic parts also is rising. It amounts to over 50 percent in 1980. As for the black-and-white television sets, radio receivers, and sound amplifiers, of which domestic production has a relatively longer history, entire parts and components are supplied within the country. The import share is 10 percent for color television sets and 40 percent for the VCRs in 1983.[5] The bulk of magnetic heads, a crucial part in the audio and the video systems, are also imported. The import shares are different for different final products to which they are applied. For example, in the case of the magnetic heads used in the audio systems the share is 65 percent in 1982. In the case of those used in the video systems and the computers, the share rises to 100 percent.[6] Import dependency is greater in electronic machinery for industrial use than in household electronic appliances because production of the former requires more advanced technology than the latter.

For the Korean shipbuilding industry, expenditure on material inputs amounts to 70 percent of the total cost of a ship, and 30 to 40 percent of materials are imported.[7] Among the various intermediate goods, some items in iron plate, angles and shapes of iron and steel, small-size engines, paints, are supplied in the country. The reason for heavy dependency on foreign intermediate goods in the shipbuilding sector is that many domestic intermediate goods can not meet the waterproofing, durability and anti-corrosion standards.

A car consists of more than 20,000 parts and components. One way of looking at the short history of Korean automobile industry is to see how foreign parts have been replaced by domestic ones. The automobile parts sector increased its output greatly in the 1970s, encouraged by the rapid expansion of automobile industry. As a result, the share of the domestic intermediate goods in some car models rose dramatically.

For example, the share in a few domestic models of small cars had been raised to over 90 percent by the early 1980s, in striking contrast to 60 percent at the middle of the 1970s. The share is lower in medium- and large-size automobiles because makers of buses and trucks are quite cautious in using domestic parts. They argue that domestic parts of trucks and buses have a lower quality in terms of durability, safety and functional credibility. Moreover, many of them are not produced in the country partly because domestic demand for them falls short of economic size of production and partly because production technology and knowhow are not available in the country.

FOOTNOTES(CHAPTER III)

1. It is calculated based on the Input-Output Table 1980, The Bank Of Korea.

2. It is calculated based on The National Income of Korea, The Bank Of Korea.

3. Hirschman emphasizes the role of the intermediate goods in the economicc growth within the context of 'linkage effect'. He pointed out the fact that in many underdeveloped countries industrialization starts with the industries mainly transforming the imported semimanufactures in goods needed by final demands. The setting up of those industries brings with it the availability of a new expanding market for their inputs whether or not these inputs are supplied initially from abroad, which in turn stimulate the domestic production of inputs needed by the established industries. He called it the backward linkage effect. According to him, one way of maximizing economic growth rate is to maximize the linkage effect. Hirschman (1963) pp. 98-104.

4. Korean Industry 1984, Korean Development Bank, Vol.I, p. 176.

5. The Handbook of Korean Electronic Industry 1983, Electronic Industry Association of Korea. p. 127.

6. Ibid. p. 87.

7. Korean Industry 1984, Korean Development Bank. Vol. II, pp. 322-323

CHAPTER IV
THE GOVERNMENT POLICY AND FIRM BEHAVIOR

4.1 THE GOVERNMENT POLICY FOR THE PROMOTION OF THE MACHINERY INDUSTRY

The government policies that have had the greatest impact on the development in the whole industrial sectors for last two decades were various policy schemes for export promotion. Based on an export-led growth strategy, economic policy has paid primary attention to export activities. The annual export target was set up every year for each industrial sector. Export industries were encouraged by a variety of incentives, such as special export financing, preferential tax, insurance schemes, and other direct and indirect trade policies.

Special loans were given to export-related activities at the rate of one-half to two-third as low as the generally applied interest rates. The commodity tax on exportables, and the business tax for export-related business, had been completely exempted during 1961-1973. The special consumption tax on exportable goods was also exempted. In addition, tariffs were exempted, or refunded, on imported materials for use on the production of exportable commodities.

In a country like Korea, endowed with abundant labor and scarce natural resources and capital, above mentioned policy schemes had a more stimulating effect on the light industry producing consumer goods than on the heavy and chemical industries producing intermediate goods and capital goods. It was more lucrative for most firms to produce, say, textile final goods with imported materials than to develop new items in a machinery industry, because business activities in the latter field usually involved a longer time period and more capital cost for the production organization. One indicator showing a sectoral imbalance is the commodity structure of exports. The export value of light industry occupied 75 percent of total manufacturing exports.

In order to stimulate the heavy and chemical industries which received smaller benefits from the export promotion policy at the initial stage of industrialization, the Korean government began to place emphasis on the development of these sectors in late the 1960s. A series of laws promoting the heavy and chemical industries -- including petrochemicals, metal-working, shipbuilding, electronics, electrical machinery, transportation equipment -- had been promulgated during the Second and Third Five-Year Plan period (1967-1976).

The enactment of the Machinery Industry Promotion Law (1967) was followed by the Electronic Industry Promotion Law (1969), the Shipbuilding Industry Promotion Law (1969), the Development Plan for Automobile Industry (1970), the Long-Run Plan For Development of Machinery Industry (1973). The laws and development plans provide various incentives.

4.1.1. Protection of the Domestic Machinery Industry

One of the most effective measures for the protection of a domestic infant industry is quantity restriction on imports that are substitutable with domestic products. The import restrictions on machinery products were tightened in the early 1970s when the promotion of domestic machinery industry began to be emphasized.

Table 4.1 presents the percentage of restricted items of total import items calculated, based on CCCN 4-digit commodities.[1] Comparisons between the percentages in 1970 and 1972 show that the number of items in the restricted list has sharply increased. For example, almost all products in the automobile industry have been

TABLE 4.1

PROPORTIONS OF THE MACHINERY PRODUCTS

SUBJECT TO IMPORT RESTRICTION[a]

(unit: %)

	1968	1970	1972	1974	1978	1980	1982
Average of machinery industry	44	47	62	60	55	45	45
General machinery	33	38	62	59	59	53	53
Electric and electronic mach.	60	66	63	83	77	71	69
(electronic mach.)	(60)	(60)	(90)	(90)	(90)	(90)	(90)
Transportation equipment	30	33	41	41	41	41	41
(automobile)	(67)	(33)	(100)	(100)	(100)	(100)	(100)
Measuring,medical and optical instruments	39	39	58	61	55	55	55

[a] The proportions are calculated through dividing the number of items subject to import restriction by that of total imported commodities. The number of items is based on CCCN 4-digit commodities.

Source : Periodical Announcement Of Export And Import Commodities, 1968-1982. Ministry Of Commerce And Industry, Korea.

subject to import restriction since 1972. The tightened restriction seems to have stimulated not only the development of final products, but also semi-final products in machinery industry. It also has a negative effect on the machinery industry in the sense that entrepreneurs in a protected industry tend to neglect their efforts to improve the quality of their products. This is the reason why the trade policy turned towards import liberalization in the late 1970s. In order to enhance competitiveness of domestic machinery in the world market, the portion of restricted items was lowered from 62 percent in 1972 to 45 percent in 1980.

The tariff is another important policy instrument for protection of domestic infant industry. As for the Korean machinery industry, the tariff could not play a significant role. This is partly because most import items subject to a high tariff rate (such as household electronics, automobiles and watchs) have been on the list of

TABLE 4.2.

TARIFF RATE ON MANUFACTURING GOODS[a]

(unit: %)

	1975	1978	1980	1983
Intermediate goods	28.1	32.0	28.5	21.5
Total manufacturing goods	31.3	35.7	31.8	22.6

[a] The rates are simple arithmetic averages.

Source : Tariff Rate Schedule 1975, 1978, 1980, 1983. The Office of Tariff.

restricted items, and partly because many items have been imported free of tariffs under the export promotion schemes. The tariff structure in Korea is featured by its escalation system. As shown on table 4.2, higher rates are applied on final goods, and lower rates on raw materials and intermediate goods. In light of such a discriminating rate, the protection effect of tariffs on domestic intermediate goods was not of significance.

4.1.2 Preferential Loans

Since the late 1960s, various preferential credit schemes have been set up in order to help the machinery industry get easier access to industrial funds under favorable conditions. One of the most influential credit schemes is that of The National Investment Fund. It is based on The National Investment Fund Law promulgated in 1973. The main beneficiaries of various programs based on this law are machinery and chemical industries. There are several other funds directed toward the machinery industry, such as the Machinery Industry Promotion Fund, the Industry Rationalization Fund, and special funds of the Korean Development Bank and the Export-Import Bank.

Such financial schemes raised the proportion of outstanding credits to the machinery sector. Table 4.3 shows that it rose from 15 percent in 1968, to 30 percent in 1980. The relative share of preferential loans in the sum of preferential and non-preferential loans is also higher for the loans to the machinery industry than for the loans to other industry sectors. Whereas the proportion of

TABLE 4.3.

PROPORTION OF OUTSTANDING LOANS TO THE MACHINERY INDUSTRY RELATIVE TO TOTAL LOANS TO MANUFACTURING[a]

(unit: %)

	1968	1972	1976	1980
Proportion of loans to machinery industry	14.9	15.7	20.3	30.0

[a] Annual proportions are calculated based on credit outstanding (sum of preferential and non-preferential loans) at the end of each year.

Source : Annual Economic Statistics, 1968, 1972, 1976, 1980. Bank Of Korea

preferential loans of the total loans is 31 percent for the loans to manufacturing as a whole, the proportion for machinery industry was 53 percent in 1980.

The interest rates applied to preferential loans are much lower than those applied to ordinary loans. The difference in interest rate between the two was more than 10 percentage points in the early 1970s. The gap has been reduced to 5 percentage points by 1979. One of special loans available in the National Investment Fund is a loan for purchases of domestic machinery products. The proportion of this loan fluctuates year by year at around 10 percent of the total loans from the National Investment Fund.

4.1.3 Tax Exemption

The machinery industry has been the main beneficiaries of the tax exemption policy scheme based on the Law For Regulation Of Tax Deduction And Exemption enacted in the early 1970s. The revised law in 1976 specified that fourteen major industries were eligible for tax exemption : oil refining, shipbuilding, machinery, electronics, processing of iron, steel, and nonferrous metals, mining, refining of some minerals, electricity, fertilizers, defense industry, aircraft and animal husbandry. By that law most sectors in the machinery industry could expect the following benefits.

(1) Exemption of the whole corporation's income tax for the initial three years and 50 percent of its income tax for the following two years.

(2) Deduction of 8 percent (10 percent in the case of domestic machinery users) of the investment amount.

(3) Special depreciation allowance.

As of 1979, the amount of tax deduction and exemption for the machinery industry occupied 32.5 percent of the total tax deduction and exemption for manufacturing.

The tax incentives, together with preferential loans, (the benefit of which is concentrated on machinery industry) seem to have played an important role in helping the development of the machinery industry. They also contributed to the expansion of the supply of, and the demand for, domestic machinery, including their intermediate goods. However, the assessments on the incentive schemes for the machinery industry were not always positive. Above all, the criteria for selection of the beneficiaries were often criticized. Since financial resources were limited and government's distribution of them was highly selective, the implementation of the incentive schemes necessarily led to a distortion of the resource allocation.

As a matter of fact, small- and medium-sized businesses benefited less from the incentive schemes than did the large firms. In view of the fact that the main products of most small- and medium-sized firms in the machinery industry are parts and components of machines, selective distribution of the benefits might lead to a relative underdevelopment of the parts and components sectors. With regard to the use of domestic intermediate goods, the government incentive policy has conflicting effects. Preferential loans and tax exemptions are conducive to expanding the use of domestic intermediate goods by inducing investments in the machinery sector. Particulary, special loans to the purchasers of domestic machines directly encourage it. On the other hand, the beneficiaries of this policy scheme are more likely to neglect their own efforts to survive by enhancing the productivity and improving the quality of their products. This in turn may lead to a greater quality gap between foreign and domestic intermediate goods.

4.2. FIRM BEHAVIOR UNDERLYING THE DEMAND FOR INTERMEDIATE GOODS

In a sense, the ratio of aggregate imported intermediate goods to domestic intermediate goods in an industry is ultimately determined by the input demand behavior of all firms in the industry. In other words, the ratio depends on, among other things, how firms respond to differences in price and quality between foreign and domestic intermediate goods. This section discusses a firms' demand behavior for imported and domestic intermediate goods based on information collected through the author's interview with businesmen and questionnaires surveys conducted by the Korea Institute For Economics And Technology (KIET).[2]

A survey on electronic machinery industry covers twenty three firms in the industry. All firms except one purchase both foreign and domestic intermediate goods. The remaining one uses only domestic intermediate goods. A question on the questionnaire asked "Why do you use imported parts or components of machinery?" Then it offers five possible reasons:

(1) Because it is not produced in the country.
(2) Because of limited supply of domestic products.
(3) Because the price of domestic parts is higher.
(4) Because the quality of domestic parts are inferior.
(5) Because the use of foreign parts is requested by buyer.

One of answers is checked for each imported items if a firm uses more than one imported part. The answer sheets show that the cumulative number of major foreign parts and components used by 22 firms totals up to 113. The distribution of them over different answers is:

Reason	Frequency	Percentage
(1) Not Produced	11	9.7
(2) Limited Supply	25	22.1
(3) Higher Price	15	13.3
(4) Lower Quality	55	48.7
(5) Buyer's Request	7	6.2
Total	113	100.0

The reason checked most frequently is the lower quality of domestic intermediate goods. 'Not Produced' (1) and 'Buyer's Request' (5) are least frequently cited reasons. We are particularly interested in sorting out the price-related reasons from the others. At first glance, the third reason, 'higher price of domestic intermediate goods', alone is supposed to represent the price-related reasons. It might lead to a misleading interpretation that the price difference plays a minor role in the firms' demand for parts and components, with the weight of 13 percent.

We must be careful not to overlook the close relationship between the third reason (high price) and the fourth (low quality). The quality element and the price element are so closely intermingled in a commodity that it is difficult for a firm to apply both criteria simultaneously to compare foreign and domestic goods. If a foreign product is higher in price, and superior in quality, compared to domestic product of the same function and of the same size, (as is common in developing countries) it is quite difficult to measure the quality gap relative to price gap between the two. Any argument by a firm that the price of a product is too high can be interpreted as to suggest that the quality of the product is low, taking its price into account. Likewise, any complaint about low quality of a product possibly imply that its price is high, taking its quality into account.

Hence, we conclude that the firms' choice between a foreign and a domestic part depend on the price-related reason to a greater extent than is suggested by the weight of the third reason, 13 percent. We cannot, of course, generalize the results of the survey over the electronic industry as a whole, because the sample in the survey covers only a small part of the industry.

The low quality of the domestic machinery parts is reconfirmed through the author's interview with businessmen from six companies. For example, K company uses domestic bolts, nuts, cast iron, electric appliances, electric motors and imported clutches and ball bearings to produce metal-drilling and metal-milling machines. It is argued by several companies that domestic clutches and ball bearings are inferior to imported ones, with regard to their function in a machine, preciseness, durability and quality of base metal. Five of the six companies which produce one or two kinds of metal-working machines such as lathe, milling, drilling machines are in agreement on the quality problems of domestic ball bearings, oil seals, clutches, numeric controllers and ball screws. According to them, some items of the domestic spindle boxes, gears, electric appliances, motor and oil pumps put in metal-working machines are of as good a quality as those imported from Japan and the U.S.

One of six companies produces radio receivers of several different kinds. Parts like transformers, mica-capacitators, and air-varicons are supplied in the domestic market, whereas some portions of electrolitic capacitators, ceramic capacitators, variable resistors, silicon transistors, diodes and integrated circuits are imported from Japan. For two items, the diode and integrated circuit, more than half of them are imported. The company believes that if the imported parts are replaced by domestic parts, the present quality of their products could not be maintained. One important finding obtained through interviews is that all companies place greater emphasis on the quality gap than on the price difference in their choice of foreign or domestic parts and components.

Another survey by KIET covers 133 firms producing general machinery parts and components. Two questions on the questionnaire are concernd with how producers of parts assess quality and price level of their own products The questions and answers are as follows.

"What do you think about the quality and price of your products compared to the same item made in Taiwan?"

Answer	No. of firms	percentage
(1) Lower price, lower quality	3	3.3
(2) Lower price, higher quality	9	9.8
(3) Same price, same quality	29	31.4
(4) Higher price, lower quality	25	27.2
(5) Higher price, higher quality	26	28.3
Total answered	92	100.0

The highest percentage of respondents selected the third answer (same price, same quality). With regard to price, 55 percent of them (sum of answer 4 and answer 5) believed the price of their products was higher than Taiwan products, whereas 13 percent regarded it lower. With respect to quality, 38 percent of respondents (sum of answer 2 and 5) believed that their products were superior, whereas 31 percent had an opposite view. Comparisons between Korea and Taiwan, based on combined criteria of the price and quality, indicated that parts of general machinery made in Korea were tightly competitive with those made in Taiwan on the world market.

Another question of the same survey requests comparison between Japanese and Korean machinery parts. The majority of the respondents

(80 percent of 104 respondents) admitted the superiority of Japanese parts.

We find that the quality factor is a very important criterion for a firm's choice on intermediate goods that are to be assembled into the final product. Since final products of the machinery industry are durable goods, the users expect their production services will last for a long time. This is the main reason why the quality of machines, in general, is given serious consideration by demanders, relative to the quality of non-durable goods such as textile goods. And since the quality of machines depends on the quality of their parts and components, the behavior of final demanders for machines is reflected by a firms' attitude of derived demand for parts and components. We explained in section 3.1 how fast the output and export of Korean machinery expanded during the 1970s. The output growth has been accompanied by a diversification of machinery items. Such developments in the machinery industry seem to have given most firms in it a strong motive to pay more and more attention to the quality of intermediate goods.

FOOTNOTES(CHAPTER IV)

1. Restricted items are composed of items subject to special import licensing and banned items. The portion of the latter is very small.

2. KIET has conducted several surveys recently in order to analyze firms' activities in machinery industry and to assess government policy relating to it. Three of the surveys contain questions about the firms' behavior regarding intermediate goods and their views on price and quality of foreign and domestic intermediate goods. Fortunately, author was accessible to answer sheets of the surveys.

CHAPTER V

THEORETICAL FRAMEWORK AND FORMULATION OF EMPIRICAL MODEL

5.1 DECOMPOSITION OF CHANGES IN INPUT SHARE AND IN INPUT RATIO.

In this section, we try to formally incorporate technical change in the most general form of cost function, in order to show how technical change is related to a change in input share and in input ratio.

What is to be noted here is that the concept of 'factor augmentation' (growth of an input's quantity in terms of 'efficiency unit') cannot always be used interchangeably with that of 'quality improvement' of input. Suppose that the quality of a worker who operates a machine improves and that the underlying production function is of fixed proportions in inputs. The worker will be able to produce more output per machine-hour and per man-hour than before. Both the capital-output and labor-output ratios are reduced, not just the latter. Both factors are augmented. Likewise, any quality change resulting from an innovation causes one or more inputs to be augmented, though the rate of augmentation is not uniquely related to the rate of quality improvement of inputs.

There are numerous sources of input augmentation. Innovating firms may invest in new capital goods. The productivity of labor can be increased through more schooling or training of workers. A firm's organizational change is another source of innovation. Inter-firm, inter-industry, and inter-country transfer of technology can also contribute to innovation in production. Adoption of improved intermediate goods also leads to an augmentation of one or more inputs. As discussesd in the preceding chapter, the quality level and its change rate of imported intermediate goods are different from those of domestic intermediate goods.

We can not list all the sources of input augmentation completely, and it is extremely complicated to trace the transmission mechanism through which an initial quality change of an input finally results in augmentation of one or more inputs. Our main aim is to elucidate the effect of input augmentation or technical progress on the input ratio, regardless of the sources of input augmentations.

Once the technical change is allowed we can postulate three different ways by which the optimal input ratio are influenced. The observed ratio changes or share changes might have come about through biased technical change and through ordinary input substitution in response to changes in the relative price of inputs. In addition, the non-homothetic nature of the production function is another source of change in the optimal input ratio. In general, there is no a priori rationale for assuming the homothetic production function. Hence, a given increase in output is not necessarily related to a simple proportionate expansion of all inputs. Instead, the ratio of one input to another will change as output increases, accompanied by the economies of scale.

The problem now is to sort out to what extent the input share or the input ratio changes are due to the biased technical change, to the price change, and to the scale effect. To the best of our knowledge, no one has attempted to mathematically decompose a change in input ratio or input share into its components accruing to different sources, using most general form of cost function.

A formal relationship between the share change and their sources can be conveniently derived from the use of the cost function. The cost function approach has many advantages for this purpose since the input share can be defined in terms of cost, first derivatives of cost function and input prices. We begin with the assumption that any technical change augments one or more inputs of production.

Let us define cost function as dual of production function in input augmenting form.

$$C=C[p_1/r_1(t), \ldots, p_n/r_n(t), Y] \qquad (5.1.1)$$

where C=minimized cost, p_i=price of i-th input, r_i=augmentation index of i-th input, t=time or technical knowledge, Y=optimal quantity of output. $r_i(t)$ implies that augmentation index is a function of time or technical knowledge. The cost function is derived on the basis of the firm's behavior of cost minimization constrained by production technology. The underlying production function is,

$$Y=F[r_1(t)X_1, \ldots, r_n(t)X_n] \qquad (5.1.2)$$

where X_i=quantity of i-th input.

A rise in r_i raises proportionately the number of efficiency units of X_i in the production function and reduces the price of efficiency unit of it in cost function. Here, we assume that perfect competition is preserved in product and input markets and that our cost function is well behaved. No restrictions are imposed with regard to the economies of scale, elasticity of substitution and the nature of technical change.

Cost function gives following share equation.

$$s_i = C_i p_i / C \qquad i=1, \ldots\ldots, n \qquad (5.1.3)$$

where s_i=share of i-th input, $C_i = \partial C / \partial p_i = X_i$ = optimal quantity of i-th input as is shown by Shephard lemma. Taking first derivatives of logarithm of the share equation produces,

$$d \ln s_i = d \ln C_i + d \ln p_i - d \ln C, \quad i=1, \ldots, n \qquad (5.1.4)$$

By using the nature of cost function and applying Allen-Uzawa partial elasticity of substitution, we can decompose share change of i-th input, $d \ln s_i$, into three parts (See detailed mathematical procedures in Appendix).

$$d \ln s_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} (1 - \sigma_{ij}) s_j \, d \ln(p_i/p_j) + \sum_{\substack{j=1 \\ j \neq i}}^{n} (1 - \sigma_{ij}) s_j \, d \ln(r_j / r_i)$$

$$+ (E_{iy} - E_{cy}) \, d \ln Y \qquad i=1, \ldots, n \qquad (5.1.5)$$

where σ_{ij}=Allen-Uzawa partial elasticty of substitution(AUES),

E_{iy}=demand elasticity of i-th input with regard to output,

E_{cy}=cost elasticity with regard to output.

The first term of RHS in the equation 5.1.5 shows the component of total share change caused by a change in relative price of input. This component represents the changes in input ratio due to a pure price effect. If the underlying production function is homothetic, the percent changes in inputs accompanying output expansion are equivalent across all inputs such that $E_{iy}-E_{cy}=0$. Any arbitrary assumption of homotheticity is, of course, not justified in general.

The share change resulting from non-neutral technical change is explained by the second term of equation 5.1.5. It shows that the extent of the share change is controlled by difference in augmentation rates between inputs ($d \ln r_j / r_i$), initial share of input, and elasticity of substitution. This term can be used to construct a bias index of technical change (B_i). As discussed in the section 2.1.1, one variant of Hick's definition of technical bias is expressed in terms of input ratio change with constant input prices and output level.

$$B_i=[d \ln s_i]_{p^\circ, y^\circ} = (\partial s_i / \partial t)(1/s_i)$$

$$=\sum_{\substack{j=1 \\ j\neq i}}^{n} (1-\sigma_{ij})s_j \, d \ln (r_j / r_i) \qquad (5.1.6)$$

Technical change is said to be i-using, neutral, or i-saving as B_i is greater than, equal, or less than zero, respectively.

Likewise, a change in the input ratio is decomposed into three components such that (See more detailed mathematical procedure in Appendix),

$$d \ln (X_i/X_j) = [d \ln (X_i/X_j)]_{y^\circ t^\circ} + [d \ln (X_i/X_j)]_{p^\circ y^\circ} + [d \ln (X_i/X_j)]_{p^\circ t^\circ}$$

$$= [\sum_{\substack{j=1 \\ j \neq i}}^{n} E_{ij} \, d \ln(p_j/p_i) - \sum_{\substack{i=1 \\ i \neq j}}^{n} E_{ji} \, d \ln(p_i/p_j)]$$

$$+ [\sum_{\substack{j=1 \\ j \neq i}}^{n} E_{ij} \, d \ln(r_i/r_j) - \sum_{\substack{i=1 \\ i \neq j}}^{n} E_{ji} \, d \ln(r_j/r_i) - d \ln(r_i/r_j)]$$

$$+ [(E_{iy} - E_{jy}) \, d \ln Y] \qquad (5.1.7)$$

where E_{ij}=demand elasticity of i-th input with regard to the price of j-th input. E_{iy} and E_{jy} is the elasticity of i-th input and j-th input with regard to output.

It shows that the optimal input ratio can be changed without a change in the relative price if a technical change is non-neutral. The effect of the technical change on the input ratio is implied by the second bracket term of equation 5.1.7. This term is identical to the the second definition of technical bias discussed in the section 2.1.[1] Thus a technical bias index(B_{ij}) is expressed as,

$$B_{ij} = [d \ln (X_i/X_j)]_{p^\circ y^\circ} = [\ \partial(X_i/X_j)/\ \partial t][\ 1/(X_i/X_j)]$$

$$= [\sum_{\substack{j=1 \\ j \neq i}}^{n} E_{ij}(\hat{r}_i - \hat{r}_j) - \sum_{\substack{i=1 \\ i \neq j}}^{n} E_{ji}(\hat{r}_j - \hat{r}_i) - (\hat{r}_i - \hat{r}_j) \qquad (5.1.8)$$

where ^ denotes the growth rate of relevant variable.

Using the formula 5.1.8, technical change is said to be i-using (j-saving), neutral, or i-saving (j-using) as B_{ij} is greater than, equal, or less than zero, respectively. Bias index 4.1.8 expressed in terms of input ratio is more general than that expressed in share change of a single input. If there are more than two inputs, and if we are interested in technical bias for each input pair, the B_{ij} index is more meaningful than the B_i in the equation 5.1.6. The RHS in the equation 5.1.8 indicates that the extent of technical bias depends on cross- price-elasticities of the relevant inputs, as well as augmentation rates of all inputs.

Estimation of the relationship shown by the equation 5.1.5 or by the equation 5.1.7 requires a specific form of the production or the cost function. The two formulas, B_i and B_{ij}, shown in the equation 5.1.6 and 5.1.8 can be utilized to calculate the bias indexes and to interpret the estimates of time coefficients that are obtained using a specific form of the cost function.

5.2 CHOICE OF FUNCTIONAL FORM

In order to take into account all the components of a change in the input ratio and in the input share, a functional form used in estimation should be free from the restrictions with regard to the elasticity of substitution, the economies of scale, and the technical change. Several functional forms satisfy these requirements. The translog function (Christensen, Jorgenson and Lau (1973)), generalized Leontief (Diewert (1971)), and generalized Cobb-Douglas (Diewert (1973)) are examples of flexible functional forms.

These functional forms have been followed by the more flexible forms called generalized quadratic (Denny (1974)) and generalized Box-Cox (Berndt and Khaled (1979)). In spite of their richness in parameters estimated, the last two forms are not intensively applied by economists mainly because of their mathematical and econometric difficulties. Specifically, both of them are nonlinear in unknown parameters and computation of partial elasticity of substitution is highly complicated.

The majority of the empirical studies on input substitution and technical bias have adopted the translog or the generalized Leontief functional form. Berndt, Darrough, and Diewert (1977) analyzed differences among the three flexible functional forms, the translog, the generalized Leontief and the generalized Cobb-Douglas, in their estimation of the indirect utility function. They find the translog form preferable, since it does not reject the Slutsky symmetry restrictions and it fits their data best. They conclude that when a Slutsky type of symmetry restrictions are imposed, the empirical results obtained from three functional forms are reasonable and similar. In an analysis of the global properties of the flexible functional forms, Caves and Christensen (1980) conclude that for the non-homothetic case a comparison of the translog and the generalized Leontief specifications reveals the superiority of the latter with respect to the satisfaction of monotonicity and concavity conditions.

For the purpose of this study, we opt for an extension of the generalized Leontief functional form. As far as the impact of technical change on input demand is concerned, the coefficient of the time variable in the generalized Leontief cost function gives a more straightforward meaning than in the translog form.[2] Another advantage of the generalized Leontief over the translog form is the fulfilment of the homogeneity condition by the generalized Leontief cost function without restrictions on parameters. But an estimation using the translog form must impose homogeneity restrictions together with other necessary restrictions.

The generalized Leontief cost function is sufficiently rich in parameters for the present problem and has conveniences for econometric work. Diewert's (1971) original form is the second-order Taylor expansion of the cost function in powers of square roots of input prices such that,

$$C=h(Y)\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}(p_i p_j)^{1/2} \qquad (5.2.1)$$

where b_{ij} matrix is symmetric. The multiplicative separability of output from price indicates the homothetic nature of the underlying production function. An extended version of it was proposed by Parks (1971). It allows for the non-homothetic production process and technical change. Equation 5.2.1 then becomes,

$$C= Y\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}(p_i p_j)^{1/2} + Y^2\sum_{i=1}^{n} g_i p_i + Yt\sum_{i=1}^{n} a_i p_i \qquad (5.2.2)$$

The function must satisfy following conditions.

(1) Linear homogeneity in prices: It is satisfied always without imposing any additional restrictions

(2) Monotonicity in input prices: It is satisfied if $\partial C/\partial p_i > 0$, $i=1,\ldots,n$

(3) Concavity in input prices : It is satisfied if the principal minors of Hessian matrix, $\partial^2 C/\partial p_i\,\partial p_j$, alternate in sign beginning with negative sign such that,

$$H_1 = C_{11} \leqslant 0, \qquad H_2 = \begin{vmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{vmatrix} \geqslant 0, \quad H_3 = \begin{vmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{vmatrix} \leqslant 0, \ldots$$

5.3 FORMULATION OF THE ESTIMATING MODEL

Since the direct estimation of cost function involves so many parameters in a single equation to be estimated and frequently raises multi-collinearity problem, it must be transformed to more manageable form. Applying Shephard lemma to the generalized cost function produces a derived demand function for each input.

$$\partial C/\partial p_i = X_i = Y\Big[\sum_{j=1}^{n} b_{ij}(p_j/p_i)^{1/2} + g_i Y + a_i t\Big] \qquad i=1,\ldots,n \qquad (5.3.1)$$

Dividing both sides of equation 5.3.1 by output, Y, gives input-per-unit-of-output equation,

$$X_i/Y = \sum_{j=1}^{n} b_{ij}(p_j/p_i)^{1/2} + g_i Y + a_i t \qquad i=1,\ldots.,n \qquad (5.3.2)$$

A derived form like the equation 5.3.2 directly shows the decomposition of the input demand into three sources, price substitution, scale effect and innovation effect. There is a close correspondence between the equation 5.3.2 and the equations derived in the section 5.1 to show the decomposition of share change and of input ratio change.

In this study, inputs are classfied into four groups, labor (L), capital (K), foreign intermediate goods (F), and home-produced intermediate goods (D). We assume the existence of an aggregate cost function (C) consisting of the four inputs which are weakly separable from energy and other input such that,

$$C^*=C^*[C(p_L,p_K,p_D,p_F),\ p_E,\ p_O\ ]$$

where subscripts L, K, D, F, E, and O denote labor, capital, domestic intermediate goods, foreign intermediate goods, energy and other inputs, respectively. This restrictive condition was necessitated by the lack of consistent data on energy and other inputs.[3]

Observation units are sixteen industrial subsectors in the Korean machinery industry over three different years, 1975, 1978, and 1980. Assuming that for subsectors of machinery industry there exists a twice differentiable aggregate cost function, we define two different estimating models.

Model I employs equations in 5.3.3 which exclude a possible intercept- and slope-difference among the different subsectors of the machinery industry such that,

$$(L/Y)_{s\ t} = b_{LL} + b_{LK}(p_K/p_L)^{1/2}_{s\ t} + b_{LD}(p_D/p_L)^{1/2}_{s\ t} + b_{LF}(p_F/p_L)^{1/2}_{s\ t} + a_L t + g_L Y + u_{L\ s\ t} \qquad (5.3.3.a)$$

$$(K/Y)_{s\ t} = b_{KK} + b_{KL}(p_L/p_K)^{1/2}_{s\ t} + b_{KD}(p_D/p_K)^{1/2}_{s\ t} + b_{KF}(p_F/p_K)^{1/2}_{s\ t} + a_K t + g_K Y + u_{K\ s\ t} \qquad (5.3.3.b)$$

$$(D/Y)_{s\ t} = b_{DD} + b_{DL}(p_L/p_D)^{1/2}_{s\ t} + b_{DK}(p_K/p_D)^{1/2}_{s\ t} + b_{DF}(p_F/p_D)^{1/2}_{s\ t} + a_D t + g_D Y + u_{D\ s\ t} \qquad (5.3.3.c)$$

$$(F/Y)_{s\ t} = b_{FF} + b_{FL}(p_L/p_F)^{1/2}_{s\ t} + b_{FK}(p_K/p_F)^{1/2}_{s\ t} + b_{FD}(p_D/p_F)^{1/2}_{s\ t} + a_F t + g_F Y + u_{F\ s\ t} \qquad (5.3.3.d)$$

$s=1,\ldots, 16, \qquad t=0, 3, 5.$

where subscripts s and t denote s-th subsector and t-th year respectively.

Model II relaxes the assumption of the same intercept over machinery subsectors while maintaining the assumption of the same slope coefficient. Thus, Model II allows for possible differences in input demand that may be resulted from some sources, if any, other than input price, technical change and output level. By estimating two different models we can test the Model I's assumption of the same intercept for 16 machinery subsectors.[4]

5.4. ESTIMATION METHOD AND HYPOTHESES TO BE TESTED

Since four equations defined in the Model I and Model II originate from a single cost function and the quantities of four inputs are determined jointly, it is reasonable to assume that there is a correlation between the disturbance terms in one equation and those in other equations, as Zellner (1962) suggested. If there are no autocorrelation and no heteroscedasticity among disturbance terms within equation, the relationship of residuals in our model can be expressed as,

$$E(u_{i,s,t})=0 \quad \text{for all } i=L, K, D, F, \quad s=1,\ldots,16, \quad t=0,3,5. \qquad (5.4.1)$$

$$E(u_i u_i')=\sigma_{ii} I, \quad \sigma_{ii} \neq \sigma_{jj}, \quad i \neq j, \quad i,j=L, K, D, F. \qquad (5.4.2)$$

$$E(u_i u_j')=\sigma_{ij} I, \quad i \neq j, \quad i,j=L, K, D, F. \qquad (5.4.3)$$

where u_i, u_j=disturbance vector in i-th and j-th equation respectively, and I is identity matrix.

Equation 5.4.2 implies the assumption of no autocorrelation and no heteroscedasticity within the equation and equation 5.4.3 implies that there are a cross-equation relationship of disturbances and the covariances of them are constant over observation units. Equations 5.4.1 to 5.4.3 are integrated into a single expression such that,

$$E(uu')=E\left(\begin{bmatrix} u_L \\ u_K \\ u_D \\ u_F \end{bmatrix} [u_L' \ u_K' \ u_D' \ u_F']\right)= \Sigma \otimes I \qquad (5.4.4)$$

where $$\Sigma = \begin{bmatrix} \sigma_{LL} & \sigma_{LK} & \sigma_{LD} & \sigma_{LF} \\ \sigma_{KL} & \sigma_{KK} & \sigma_{KD} & \sigma_{KF} \\ \sigma_{DL} & \sigma_{DK} & \sigma_{DD} & \sigma_{DF} \\ \sigma_{FL} & \sigma_{FK} & \sigma_{FD} & \sigma_{FF} \end{bmatrix}$$

Thus, our complete estimating model is provided by equations 5.3.3.a through 5.3.3.d and 5.4.4. Since the off-diagonal elements of the disturbance covariance matrix, E(uu'), are nonzero, greater efficiency in estimation may be attained by taking the estimated covariance into account. In order to estimate coefficients, Iterative Zellner-Efficient method (Zellner (1962)) is applied.[5]

Our two models are useful for testing several hypotheses. First we can test for the existence of technical change ($a_i \neq 0$, for all i). Coefficients, a_i, are used to identify the direction of technical bias, i-using or i-saving technical change. Indexes of technical bias can be calculated based on the formula derived in the section 5.1. Second, tests for the non-homotheticity of the producton process, can be conducted. If the null hypothesis ($g_i = 0$, for all i) is accepted we can conclude that the underlying production function is homogeneous of degree one.

Third, substitutability between any pair of inputs, $b_{ij} \neq 0$, all $i \neq j$, can be tested. Elasticity of substitution (σ_{ij}) is given by the formula,

$$\sigma_{ij} = CY\, b_{ij}/[2X_i X_j (p_i p_j)^{1/2}] \qquad \text{if } i \neq j,$$

$$\sigma_{ii} = [\, -CY \sum_{\substack{j=1 \\ j \neq i}}^{n} b_{ij} p^{-3/2} p^{1/2}]/2X^2 \qquad \text{if } i = j,$$

and elasticity of input demand is given by,

$$E_{ij} = [\; Y\, b_{ij} (p_j/p_i)^{1/2}]/2X_i \qquad \text{if } i \neq j,$$

$$E_{ii} = [-Y \sum_{\substack{j=1 \\ j \neq i}}^{n} b_{ij} (p_j/p_i)^{1/2}]/2X_i \qquad \text{if } i = j$$

The own elasticity of substitution and the own demand elasticity is expected to have negative sign. Cross-elasticity of substitution and cross-demand elasticity may have either sign, positive or negative.

Fourth, the hypothesis of the fixed coefficient production function can be tested. If $b_{ij}=0$ for all $i \neq j$, then equation 5.3.2 takes a form like,

$$X_i/Y = b_{ii} + g_i Y + a_i t \quad \text{for all } i,$$

which is the system of derived demand equations corresponding to Leontief production function.

Finally, by combining all the information obtained from the sign and magnitude of the estimated coefficients, we can analyze the relative effect of the price substitution, the scale economies and the technical change on the change of input share or input ratio. Meaningful policy implications can be derived from this analysis.

FOOTNOTES(CHAPTER V)

1. See footnote 2 in CHAPTER II.

2. Dependent variable in GL estimation equation is input-output coefficient whereas that in TL form is cost share of input. Hence, coefficient of time variable in two forms have slightly different meanings. In case of GL, the time coefficient in the i-th equation, a_i, is expressed as,

   $$a_i = \partial (X_i/Y)/\partial t$$

   where X_i=i-th input, Y=output, t=time or technology.
   The value of a_i gives direct information about a change in input per unit of output which is caused by technical change. In TL form, however, time coefficient is,

   $$a_i = \partial s_i/\partial t = \partial (p_i X_i/pY)/\partial t$$

   where p_i=price of i-th input, p=price of output, s_i=cost share of i-th input. Hence, we can estimate the effect of t on X_i/Y only after eliminating p_i/p.

3. Regardless of being inevitable, the assumption of weak separability ignores possible difference in substitutability among input pairs, K-E, L-E, D-E, and F-E. The assumption has some limited empirical support in the empirical literature. Although Berndt-Wood (1975) reject weak separability, Humphrey-Moroney (1975) find it holds in five of the seven manufacturing sectors of the U.S. Though the validity of weak separability is not yet conclusive many models such as K-L models K-L-M (M = materials) models either implicitly or explicitly assume weak separability without testing for it. Almost all of energy demand research has proceeded with similar assumption, focusing on interfuel substitution rather than on the substitution between fuel and other inputs.

4. We can construct more general model that allows for sectoral difference not only in intercept but also in slope. However, to apply it, separate GL function must be estimated for each subsector with the use of data that cover sufficient time periods.

5. Following Iterative Zellner-Efficient procedure (IZEF), coefficient estimates obtained by separate OLS are used to compute starting value of the elements in residual covariance matrix. Next, new coefficient estimates based on the starting value of residual covariance matrix, gives another value of covariance matrix. This procedure is repeated until the trace of the covariance matrix is minimized. Estimators of IZEF are proved equivalent to maximum likelihood estimators.

CHAPTER VI

EMPIRICAL RESULTS

This chapter covers the data description and analysis of the empirical results. Data sources and methods of constructing aggregate price indexes are described in the section 6.1. Remaining sections of the chapter present results and interpretations of coefficient estimates.

Estimations of the generalized Leontief cost function in Model I and Model II and hypothesis tests are conducted in the following order.

(1) Preliminary check on disturbance relationship. (No evidence of autocorrelation and heteroscedasticity in transformed equations)

(2) Test for sectoral difference in intercept using Iterative Zellner-Efficient (IZEF) procedure. (Rejection of the validity of the Model II)

(3) System estimation of Model I with and without output variable, Y. (Acceptance of the hypothesis that coefficients of Y are jointly zero)

(4) System estimation of Model I with and without price terms. (Rejection of fixed coefficient production function)

(5) Estimation of partial elasticity of substitution and demand elasticity using the results of system estimation with symmetry restrictions.

(6) Check on monotonicity and concavity of cost function.

(7) System estimation of Model I with and without time variable, t.

(Rejection of the hypothesis that coefficents of t are jointly zero)

(8) Calculation of technical bias index using the results of system estimation with symmetry restrictions.

The results of (1) through (4) are presented in the section 6.2. Coefficient estimates are reported in the section 6.3. Because of the evidence that the underlying production function happens to be that of constant returns to scale, the reported coefficient estimates are those obtained from the estimation without Y term and with symmetry restrictions. Elasticities of substitution and demand elasticities are also reported in this section, followed by a discussion about their implications. Finally, section 6.4 discusses bias in technical change. Indexes of technical bias in terms of input ratio are computed for each pair of input.

6.1. DATA AND CONSTRUCTION OF PRICE AND QUANTITY INDEXES

We used as a main source of data, The Input-Output Tables compiled by The Bank Of Korea. Our sample consists of 16 subsectors of machinery industry over three different years, 1975, 1978 and 1980. In The 1978 Input-Output Tables, the machinery industry is composed of 19 subsectors in 164 sector classification table, as shown on table 3.1. Three of them are excluded from our sample because the reorganization of the industrial classification system makes it difficult to match them consistently over the different years. Excluded subsectors account for a meager fraction of total output of machinery industry.

Hence, the result of empirical study based on our sample can be interpreted as a valid representative of the machinery industry as a whole. The Input- Output Tables give the value of output and input only in terms of current prices. Therefore, price data were collected from various sources.

Labor : The quantity and price indexes of labor are obtained straightforwardly using the the annual sum of wage expenditures and the number of workers in each industrial subsector, which are provided by The Input-Output Tables.

Capital: Quantity and price indexes of capital services are computed following the line suggested by Jorgenson and Griliches (1967). They warn against the confusion of price of capital stock with that of the productive services of capital. According to them, the price of capital service is expressed as,

$$p_k = q_k(r + d_k - \dot{q}_k/q_k),$$

where q_k is the price of k-th capital goods, r is the rate of return of all capital, d_k is depreciation rate of the capital stock, and $\dot{q}_k/q_k$ is the rate of increase in q_k.

This formula is based on the concept of opportunity cost of capital goods. However, since the market for the used capital goods is not so much developed in Korea, the term $\dot{q}_k/q_k$ in the formula is not relevant for our study. We computed the service price of k-th capital goods using the expression like,[1]

$$p_k = q_k(r, + d_k)$$

Our calculation of p_k uses the price index of buildings and structures, machinery and equipment, and vehicles which are available from The National Income Of Korea-1980 published by The Bank Of Korea; rate of return on all capital goods from Financial Statement Analysis 1975, 1978 and 1980 by The Bank Of Korea; and a sectoral depreciation rate of each kind of captial goods from The Report on Mining and Manufacturing Census, 1975, 1978, 1980 by The Economic Planning Board, Korea. After obtaining the service price index of each group of capital goods, we constructed aggregate capital service price using the Divisia price index formula.[2]

The total expenditure on capital services is given by subtracting the renumeration on labor services from total value added, both of which are available in The Input-Output Tables. Dividing it by the aggregate price index gives an aggregate quantity index of capital services.

Domestic Intermediate Goods: The Input-Output Tables classify whole items of intermediate goods into 103 commodity groups in 164 sector classfications. The Tables give the value of imported and domestic intermediate goods for each sector. Price indexes of domestic intermediate goods are provided by Price Statistics Summary 1977 and 1982 compiled by The Bank Of Korea.

The Divisia aggregate price indexes for each of 16 subsectors are constructed by taking the average share of each commodity group in 1978 as a scaling factor. Fortunately, by using the information of transportation cost for each industrial subsector available in The Input-Output Tables, we could give more elaborate treatment to the price index by allowing for the transportation cost.

Imported Intermediate Goods : Aggregate price indexes of imported intermediate goods are constructed through a much more complicated procedure. Since there are no consistent import price indexes for individual items, or for commodity groups appropriate for this study, we have to construct them with laboriously gathered data. In view of the fact that a lion's share of the intermediate goods for the Korean machinery industry comes from U.S. and Japan, we begin with aggregating price indexes of the U.S and of Japan for each group of imported intermediate goods. At this first step, we used wholesale price indexes of individual commodity groups available in Wholesale Prices and Price Indexes, Supplement 1976 by U.S. Department of Labor, Producer Prices and Price Indexes, (Supplement 1979 and 1981 by U.S. Department of Labor) and Price Indexes Annual 1976, 1979 and 1981 by The Bank of Japan. The shares of imports from U.S. and from Japan in the total imports for each commodity group are calculated based on the Annual Trade Statistics 1975, 1978, 1980, The Office Of Tariff, Korea. Exchange rates of Korean won against yen, and won against dollar, are allowed for at this step.

After obtaining the import price indexes of the individual commodity groups purchased by each industrial sector in each year, they were aggregated into Divisia indexes for each sector each year. Finally, import taxes and tariffs were allowed for. Since tariffs are refunded or exempted on materials that are used to produce exportable goods, as discussed in the section 4.1, the ratios of exports in the total output given by The Input-Output Table were allowed for in such a manner as,

$$TR_s = LTR\ (1- Exp_s/Y_s)$$

where TR_s=tariff rate actually applied to s-th sector's total imports of intermediate goods, LTR=average of legal tariff rate on intermediate goods, Exp_s=value of exports of s-th sector, and Y_s= value of output of s-th sector. Information of export ratio, and import tax are available in The Input-Output Tables. And the average legal tariff on intermediate goods is calculated, based on the Tariff Rate Schedule 1975, 1978 and 1980 by The Office Of Tariff.

We admit that our aggregate price index of imported intermediate goods should be given a more elaborate treatment. Specifically, the price of individual imported goods must be estimated based on the CIF price rather than the FOB price by including insurance and shipping cost if data allow it. However, the exclusion of insurance and shipping cost is not supposed to significantly distort our price index, because the share of them in the CIF price is relatively small (it is often approximated to be 10 percent of CIF price), and change rates of them are not so much different from that of aggregate commodity price.

6.2 THE PROPERTIES OF ESTIMATED COST FUNCTION

Preliminary Check on Disturbance Relationship : As mentioned in section 5.4, we must confirm non-autocorrelation and homoscedasticity

TABLE 6.1

D-W STATISTICS FROM IZEF

Equation	L/Y	K/Y	D/Y	F/Y	k^a	critical D_L, D_U
1. Model I						
a. Estimation with Y	1.7343	1.8055	1.7951	1.9365	6	D_L=1.335 D_U=1.771
b. Estimation without Y	1.7456	1.8397	1.7931	1.8979	5	D_L=1.378 D_U=1.721
2. Model II						
a. Estimation with Y	1.9582	2.3346	2.0252	2.1728	10	D_L=1.156 D_U=1.986
b. Estimation without Y	1.9802	2.2562	1.9908	2.1479	9	D_L=1.201 D_U=1.930

[a] k=number of independent variables including intercept.

among the disturbance terms in each of the four equations. Even though our sample consists of the pooled data of time-series and cross-section, the iterative Zellner-Efficient method requires satisfaction of the conditions in the same manner as for simple time-series or simple cross-section data.

First, we checked Durbin-Watson statistics for each equation obtained by the iterative Zellner-Efficient method.[3] Estimating Model I and II, each with and without the Y term, gives four sets of D-W statistics. Estimation without the Y term is conducted because the coefficients of the Y were found to be jointly zero, as will be discussed in the last part of this section.

Looking at the table 6.1, D-W statistics from the estimation of Model I with Y strongly reject the possibility of autocorrelation for the equations, K/Y, D/Y and F/Y. The test result for the L/Y equation is inconclusive with regard to autocorrelation. However, the value of D-W statistic is close to the upper bound of critical value. D-W statistics based on the estimation of the Model I, without the Y term, all exceed critical upper bound.

Hence we cannot reject the null hypothesis of no autocorrelation. The estimation of Model II gives D-W statistics, all of which are between the critical lower and upper bound, except for the L/Y and D/Y equations obtained from the estimation without Y. Since Model II is rejected, as will be shown later, we can proceed to further estimation without being disturbed by possibility of autocorrelation.

With regard to heteroscedasticity, we assume that the variance of disturbances associated with the input demand is proportional to the squared output level. The notion that the absolute error in input demand, X_i, should be associated positively with the output level, is quite reasonable. Adding the disturbance term to the input demand equation, defined by the equation 5.3.1, the estimation form of it is expressed as,

$$X_{i,s,t} = Y_{s,t}\sum_{j=1}^{n} b_{ij}(p_j/p_i)_{s,t} + g_i Y_{s,t}^2 + a_i Y_{s,t} t + v_{i,s,t} \qquad (6.2.1)$$

where $X_{i,s,t}$=quantity for i-th input demanded for by s-th sector in t-th year. Our assumption associated with residual term is,

$$\mathrm{Var}(v_{i,s,t})=Y_{s,t}^2\ \sigma_i^2 \qquad (6.2.2)$$

We checked this assumption using Goldfeld-Quandt test technique. The test results presented on table 6.2 support our assumption. All of the four equations turn out to have heteroscedastic disturbances. It justifies a transformation of the equation 6.2.1. If equation 6.2.1 is divided by $Y_{s\ t}$ we can get ,

$$(X_i/Y)_{s,t}=\sum_{j=1}^{n} b_{ij}(p_j/p_i)_{s,t}+ g_i Y_{s,t}+ a_i t + u_{i,s,t} \qquad (6.2.3)$$

We applied the Goldfeld-Quandt test technique to this transformed equatons. Now the null hypothesis that the disturbance terms are homoscedastic is not rejected, as shown on table 6.2. This confirms that the equation 6.2.3 has the dosturbance term, $u_{i,s,t}$, with, $E(u_{i,s,t})=0$ and $Var(u_{i,s,t})=Var(v_{i,s,t}/Y_{s,t})= \sigma_i^2$. Hence, the estimation equation like 6.2.3 can be considered as a variant of the

TABLE 6.2

THE RESULTS OF TEST FOR HETEROSCEDASTICITY[a]

1.Estimation of demand equation.		2.Estimation of transformed equation	
Dependent variable	F statistic	Dependent variable	F statistic
L	56.8757	L/Y	1.3381
K	15.0293	K/Y	1.6067
D	34.9433	D/Y	1.2834
F	24.2666	F/Y	1.3380

[a] Critical value of $F_{.05}(13,13) = 2.57$.

input demand equation that is transformed, so as to overcome the problem of heteroscedastic disturbances.

Choice between Model I and Model II : In order to check the validity of Model I and Model II, we estimated both systems separately. We used four intercept dummies in the Model II to allow for possible difference in intercept over sixteen different subsectors. Sixteen different combinations of zero and one are obtained by specifying dummy sets in following way[4]

Sector	Dummy1	Dummy2	Dummy3	Dummy4
1	1	1	1	1
2	1	1	1	0
3	1	1	0	1
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
15	0	0	0	1
16	0	0	0	0

A test for the null hypothesis that the coefficients of the four dummies are jointly zero was conducted using the likelihood ratio.[5]

TABLE 6.3

LOG-LIKELIHOOD RATIO TEST FOR SECTORAL DIFFERENCES IN THE INTERCEPT COEFFICIENT(IZEF)

	Estimation with Y	Estimation without Y
Chi-square	24.78	22.72

Critical value of $\chi^2_{.05}$(16 d.f.)=26.2962

The system estimations of the Model I and the Model II are conducted with and without the Y term. The null hypothesis is accepted in both of the two estimations. It implies that the intercepts defined in our estimation equations are not significantly different among subsectors of machinery industry. Hence, we reject Model II and the following estimations are based solely on Model I. Contrary to our results, the hypothesis of different intercept over the cross-section observation units is sometimes acceptedfor the pooled data. For example, the empirical results of Griffin and Gregory (1976) support the different country intercept for their intercountry translog model of energy substitution.

<u>Hypothesis Test for Properties of Underlying Production Function</u> : Test results for two different hypotheses are presented on table 6.3. The first test is associated with the effect of production scale on input ratio. The null hypothesis that the coefficients of output variable are jointly zero in four equations is accepted. It implies that underlying production function happens to have the property of constant returns to scale. It seems that every output level in the Korean machinery industry data belongs to the horizontal interval of average cost curve.

The chi-square value for the test of the hypothesis of zero input substitution against the alternative hypothesis of non-zero input substitution is presented in the second column of table 6.4. The null hypothesis is rejected for the Korean machinery industry data. It implies that input prices can not be ignored in the determination of

TABLE 6.4

LOG-LIKELIHCOD RATIO TESTS FOR CRTS AND FIXED-COEFFICIENT

	Constant returns to scale(CRTS)	Fixed-coefficient production function
χ^2	4.36	94.72
critical $\chi^2_{.05}$ (d.f)	9.4877 (4)	21.0261 (12)

input demand.

An extreme situation is where the input-output coefficients are independent of the input prices, indicating that the elasticities of substitution between the inputs are zero. Our data rejects this special case where $\sigma_{ij}=0$ (i,j=L,K,D,F., $i \neq j$). Since we find that input demands are, in general, responsive to changes in the relative input prices, the studies using fixed cofficients of production can not be regarded as providing good answers.

6.3. EFFECT OF INPUT PRICES ON INPUT DEMAND

In view of the evidence that the underlying production function is of constant returns to scale, the equation system in Model I is estimated without the Y term in order to obtain the elasticity of substitution. The results of the coefficient estimation with symmetry restriction are presented on table 6.5. The conventional goodness of fit statistic, R^2, for each equation is also presented. However, in

TABLE 6.5

COEFFICIENT ESTIMATES WITH SYMMETRY RESTRICTIONS[a]

(IZEF WITHOUT Y TERM)

Dependent variables	Estimates of coefficient					R^2
L/Y	b_{LL}	b_{LK}	b_{LD}	b_{LF}	a_L	.7810
	.1587	-.1002	.4209	-.2680	-.0232	
	(4.2694)	(2.3352)	(6.3970)	(3.7268)	(6.3052)	
K/Y	b_{KL}	b_{KK}[b]	b_{KD}[c]	b_{KF}	a_K[b]	.4490
	-.1002	-.1781	-.1932	.7049	-.0123	
	(2.3352)	(1.9641)	(1.6077)	(5.3889)	(1.8330)	
D/Y	b_{DL}	b_{DK}[c]	b_{DD}	b_{DF}	a_D	.3646
	.4209	-.1932	-.9481	1.2616	-.0511	
	(6.3970)	(1.6077)	(2.9765)	(4.2404)	(6.1974)	
F/Y	b_{FL}	b_{FK}	b_{FD}	b_{FF}	a_F	.4778
	-.2680	.7049	1.2616	-1.4919	.0233	
	(3.7268)	(5.3889)	(4.2404)	(4.4978)	(2.5872)	

[a] The values in the parenthesis are absolute values of asymptotic t-ratios.

[b] Significant at 10 % significance level.

[c] Insignificant even at 10 % significance level.

system estimation, the ordinary R^2 does not have so much meaning because it does not necessarily have the value between one and zero.

All coefficients of relative prices are significant except b_{KD} ($=b_{DK}$). The price coefficients in table 6.5 contain the information about the input substitution, but they are somewhat difficult to iterpret in raw form. Using the value of coefficients, Allen-Uzawa

TABLE 6.6

ELASTICITIES OF SUBSTITUTION IN MACHINERY INDUSTRY[a]

	Labor(L)	Capital(K)	Domestic intermediate goods(D)	Foreign intermediate goods(F)
Labor	-1.5062 (2.3247)	-1.8623 (2.3352)	3.9936 (6.3970)	-3.5276 (3.7268)
Capital		-6.0425 (4.4678)	-1.3745 (1.6077)	6.9597 (5.3889)
Domestic intermediate goods			-5.4884 (4.7280)	6.3590 (4.2404)
Foreign intermediate goods				-11.5250 (4.9696)

[a] The values in the parenthesis are the absolute values of asymptotic t-ratio.

partial elasticities of substitution and price elasticities are computed based on the formula defined in the section 4.4. We present those elasticities calculated at the mean values of the relevant variables for the entire machinery industry as representative results on table 6.6 and 6.7.

Important findings from these results are as follows.

(1) All of the own-price elasticities are negative as expected and significantly so at the conventional significance levels. The results therefore do not violate the postulates of cost-minimizing input demand theory. It is interesting to find that the labor demand is inelastic to the own-price change and capital demand is roughly unit-elastic, whereas the own price elasticities of domestic and foreign intermediate

TABLE 6.7

PRICE ELASTICITIES OF INPUT DEMAND IN THE MACHINERY INDUSTRY[a]

	L	K	D	F
Labor(L)	E_{LL}	E_{LK}	E_{LD}	E_{LF}
	-.2237 (2.3247)	-.3241 (2.3352)	1.4791 (6.3970)	-.9313 (3.7268)
Capital(K)	E_{KL}	E_{KK}	E_{KD}	E_{KF}
	-.2766 (2.3352)	-1.0516 (4.4678)	-.5091 (1.6077)	1.8373 (5.3889)
Domestic intermediate goods(D)	E_{DL}	E_{DK}	E_{DD}	E_{DF}
	.5932 (6.3970)	-.2392 (1.6077)	-2.0327 (4.7280)	1.6787 (4.2404)
Foreign intermediate goods(F)	E_{FL}	E_{FK}	E_{FD}	E_{FF}
	-.5240 (3.7268)	1.2112 (5.3889)	2.3552 (4.2404)	-3.0424 (4.9696)

[a] The values in the parenthesis are absolute values of asymptotic t ratio.

goods are as high as two and three, respectively. Relatively low own-price elasticities of labor and capital demand are consistent with the facts observed in the real world. It is easier for firms to adjust the quantities of materials in face of relative price changes than to adjust labor and capital inputs. We can conclude that the relative rigidity of demand for labor and capital is higher than that for intermediate goods in the Korean machinery industry.

(2) An overall impression is that the cross-substitution or cross

-complementarity among L, K, D, F, is considerable; all elasticties of substitution are greater than unity and significantly so, except for the K-D pair.

For the data of this study, the input pairs, L-K, L-F, K-D, are complements, while the input pairs, L-D, K-F, and D-F are substitutes. The nature of the relationship between capital and labor services is generally determined by two opposing forces. One stimulates the replacement of capital (labor) by labor (capital) services in face of the rising price of capital (labor) service. The other encourages diminution or expansion of workers employed accompanying the diminution or expansion of production capacities. We conclude that the latter is dominant for our data. In general, it is reasonable to assume that services of the workers equipped with job skills and special knowledge are complements with capital services rather than substitutes. Considering the fact that the ratio of skilled workers in the total employment is higher in the machinery industry than in other industries, it is not surprising that the capital and the labor services are complements in the Korean machinery industry.

Manufacturing data from the U.S. and other countries show that capital and labor services are substitutes. There are some exceptions that support the complementarity of the two. For example, Kwon and Williams (1982) report the complementarity of capital with labor services for three among seven 2-digit industry sectors of which cost functions they estimate.[6]

The positive σ_{KF} implies a rising price of imported intermediate goods stimulate firms in the machinery industry to expand the employment of capital services. It is plausible to infer that domestic firms are encouraged to produce more intermediate goods with expanded production capacities when they see a rising price of foreign intermediate goods.

One of the main concerns of present study is the nature of the relationship between domestic and foreign intermediate goods. We find that they are strong substitutes as expected and significantly so. The variation of total intermediate goods with constant output is subject to a certain limit. Even though relative price of material to capital or to labor sevice undergoes extremely great change, there are a certain upper limit and lower limit, above and below which the quantity of material could not be increased and decreased. Taking this into consideration, we can expect that an increase in one subgroup of material, say foreign intermediate goods, would accompany a decrease of other subgroup of material, say domestic intermediate goods.

Another way of looking at the evidence of substitutability between foreign and domestic intermediate goods is as follows. When we disaggregate foreign intermediate goods (F) and domestic intermediate goods (D) at the lowest level, we find numerous items ($D_1, D_2, \ldots, D_m$) in the bundle of domestic intermediate goods (D) and those ($F_1, F_2, \ldots, F_n$) in the bundle of foreign intermediate goods (F). We can safely argue that one item from bundle D (D_i), and the other item of the same kind from bundle F (F_i), are substitues. However, if D_i from D and F_j from F are of different kinds of machinery parts, they are not always substitutes. Taking automobile parts for instance, an imported car engine and a domestic car engine are undoubtedly substitutes. On the contrary, imported engine and domestic brake system are rather complementary. The relationship between the aggregate D and F is interpreted as the total sum of the individual pairwise relationships between D_i and F_j (i=1, 2,..., m and j=1, 2,..., n). Hence our evidence is interpreted as to indicate the dominance of pairwise substitutability between numerous domestic items and foreign items over pairwise complementarity between them.

Without correct information about the nature of their relationship, any policy concerning import substitution of intermediate goods or a production promotion policy for domestic industry could not be based on solid foundations. Suppose that D and F are complementary. Then, any policy devised to encourage the demand for domestic intermediate goods, say, increase in the exchange rate, will dampen it on the contrary to the policy intention. In addition, overall production activities would be discouraged with the reduced demand, not only for foreign intermediate goods, but for domestic ones.

(3) There are different elasticities for different subsectors in machinery industry. Table 6.8.1 and 6.8.2 present elasticities of substitution and price elasticities of domestic and foreign intermediate goods. Looking at the respective elasticity of substitution for each machinery subsector, we find that intersectoral variations are substantial. The results shown on the table 6.8.1 and 6.8.2 imply that the possibilities of substitution between domestic and foreign intermediate goods are stronger in the subsectors 1, 3, 4, 5, 12, 14

TABLE 6.8.1

ELASTICITIES OF SUBSTITUTION AND PRICE ELASTICITIES OF DOMESTIC AND FOREIGN INTERMEDIATE GOODS FOR THE MACHINERY SUBSECTORS[a]

	E_{DD}	E_{DF}	E_{FF}	E_{FD}	DF
1.Prime movers	-2.5385 (4.5282)	2.2121 (4.2404)	-3.9780 (5.3175)	3.0276 (4.2404)	9.9925 (4.2404)
2.Agricultural machinery	-1.5640 (4.6854)	1.3124 (4.2404)	-4.7169 (5.0015)	3.6452 (4.2404)	8.0181 (4.2404)
3.Metal and wood-working machinery	-2.2325 (4.8723)	1.7898 (4.2404)	-5.1814 (4.7755)	4.1932 (4.2404)	11.3977 (4.2404)
4.Special industrial machinery	-1.6826 (4.8157)	1.3680 (4.2404)	-5.8582 (4.8831)	4.5969 (4.2404)	10.0540 (4.2404)
5.Household electric appliances	-1.5215 (4.6359)	1.2868 (4.2404)	-7.2129 (5.0542)	5.5161 (4.2404)	11.0541 (4.2404)
6.Electrical industrial apparatuses	-1.7009 (4.9116)	1.3558 (4.2404)	-3.4206 (4.7867)	2.7286 (4.2404)	6.4726 (4.2404)
7.Other electrical equipment	-1.7337 (4.7577)	1.4395 (4.2404)	-3.2770 (4.9219)	2.5725 (4.2404)	6.3213 (4.2404)
8.Household electronic appliances	-1.8141 (4.3193)	1.6330 (4.2404)	-2.7563 (5.3479)	2.0108 (4.2404)	5.6944 (4.2404)

[a] Values in parenthesis are asymptotic t ratios.

and 15, than in the subsectors 6, 7, 8, 9, 10, 11, 13 and 16. A policy implication can be derived from this intersectoral difference that any interference with relative price of foreign to domestic intermediate goods through manipulation of foreign exchange rate or tariff rate may have different effect on input ratio of the two over different industrial subsectors.

TABLE 6.8.2

ELASTICITIES OF SUBSTITUTION AND PRICE ELASTICITIES OF DOMESTIC AND FOREIGN INTERMEDIATE GOODS FOR MACHINERY SUBSECTORS[a] (continued)

	E_{DD}	E_{DF}	E_{FF}	E_{FD}	DF
9.Communication equipment	-2.0445 (4.7524)	1.6618 (4.2404)	-3.0172 (4.9666)	2.3055 (4.2404)	6.7985 (4.2404)
10.Electronic components	-2.4963 (4.4355)	2.1746 (4.2404)	-2.4589 (5.2552)	1.8093 (4.2404)	6.3173 (4.2404)
11.Ships	-2.7941 (4.8066)	2.2309 (4.2404)	-2.3131 (4.9152)	1.7901 (4.2404)	6.4421 (4.2404)
12.Railroad transportation equipment	-.1.8484 (4.9661)	1.4585 (4.2404)	-5.3089 (4.7337)	4.2971 (4.2404)	9.9072 (4.2404)
13.Motor vehicles	-1.9447 (4.8776)	1.5613 (4.2404)	-3.3825 (4.8218)	2.6793 (4.2404)	6.4362 (4.2404)
14.Other transportation equipment	-1.5005 (9.8718)	1.2016 (4.2404)	-6.8313 (4.7380)	5.5523 (4.2404)	10.9548 (4.2404)
15.Measuring,medical, optical instruments	-2.3464 (4.7135)	1.9346 (4.2404)	-4.7141 (4.9837)	3.6467 (4.2404)	10.2221 (4.2404)
16.Watches and clocks	-2.7412 (4.4142)	2.3670 (4.2404)	-2.0195 (5.2950)	1.4538 (4.2404)	5.5705 (4.2404)

[a] The values in parenthesis are asymptotic t ratios.

Another conclusion emerging from the intersectoral comparison is that the absolute value of E_{FF} is greater than that of E_{DD} in most subsectors (except subsectors 10, 11, and 16). It implies that the own-price elasticities of the foreign intermediate goods are higher than those of domestic intermediate goods in the majority of subsectors.

(4) It is interesting to inquire whether our estimated GL cost

function satisfies the properties that the economic theory imposes. Two such properties which may be checked are (i) monotonicity of cost with regard to input prices and (ii) concavity of cost function with regard to input prices. First, to satisfy the monotonicity condition, the function must be an increasing function of input prices, i.e.,

$$\partial C/ \partial p_i > 0, \quad i=L, K, D, F.$$

We check it and find that the estimated cost function satisfies the condition at each observation point. The concavity is checked at each observation point by computing the principal minors of the Hessian matrix as discussed in the section 5.2. Concavity is never attained for all observation point because the third principal minor, H_3, violates the condition of non-positivity. It means that our estimated cost function is not well behaved. Although such deviations from the second-order theoretical reqirements are quite common for empirical studies,[7] it suggests that our results must be interpreted with caution.

6.4 EFFECT OF TECHNICAL CHANGE ON INPUT RATIO

In order to check the direction of biased technical change, we test two sets of hypotheses. First, we test the null hypothesis that the coefficients of the time variable are jointly zero across four different equations against the alternative hypothesis that they are non-zero. A joint hypothesis test for the zero coefficient of time variable, $a_i=0$(for all i), indicates that the null hypothesis of non-existence of technical change should be rejected. When we test for it with the results from the estimation with the Y term the null hypothesis is also rejected. It implies that input demand in the Korean machinery industry is influenced not only by the input prices but also by the biased technical change.

As shown on table 6.9, three of the four time coefficients, a_i, are significant at the 0.01% significance level, while a_K is significant at 0.10% significance level. It is interesting to note that signs of all time coefficients except a_F are negative. Thus, we can argue that the Korean machinery industry experienced labor-, capital-, and domestic-intermediate-goods-saving but foreign-intermediate-goods-using technical change in absolute terms. In the context of productivity change, the productivity growth have economized on three inputs, labor, capital and domestic intermediate goods. It implies that quantities of the three inputs employed to produce a unit of output have decreased while more and more foreign intermediate goods are required, after the impact of input price changes are eliminated.

Most empirical studies adopting the translog or the generalized Leontief cost function define technical bias simply by referring to the sign of time coefficient. By doing so, they restrict their discussions to technical bias only in absolute terms. When the sign of time coefficients for two inputs are same, how can we define the direction of technical bias in the relative sense? For the purpose of a rigorous discussion about this problem, the decomposition formula 5.1.7 and the bias index 5.1.8 we derived in the section 5.1 are especially

TABLE 6.9.

ESTIMATES OF TECHNICAL PARAMETERS AND STATISTICS OF HYPOTHESIS TESTS (IZEF)[a]

1.Estimates of time coefficients, a_i

a_L	a_K	a_D	a_F
-.0232 (6.3052)	-.0123 (1.8330)	-.0511 (6.1974)	.0233 (2.5872)

2.Joint test for existence of technical change.

$H_0 : a_i = 0 \quad i = L, K, D, F$

$\chi^2 = 31.50 \qquad [\ \chi^2_{.05}(4df) = 9.4877]$

3.Estimates of pairwise bias index.

B_{LK}	-.1111	(K-using)
B_{LD}	-.0333	(D-using
B_{LF}	-.2569	(F-using)
B_{KD}	.0769	(K-using)
B_{KF}	-.3429	(F-using)
B_{DF}	-.2596	(F-using)

[a]The values in the parenthesis are asymptotic t-ratio.

insightful. The estimates of the time coefficients in their raw form give information of bias only in absolute terms. Therefore, we have to estimate the bias index for each pairwise combination of inputs using time coefficients in the same manner as we estimate elasticity of substitution using coefficients of relative price.

In the context of the generalized Leontief cost function, technical bias index (B_{ij}) is expressed as

$$B_{ij}=[d \ln (X_i/X_j)]_{p^{\circ} y^{\circ}}= Y(a_i/X_i - a_j/X_j)$$

The bias indexes of all pairs of inputs based on the formula are presented in table 6.9. We find that the labor-saving bias and the foreign-intermediate-goods-using bias are invariable when labor and foreign intermediate goods are matched respectively to any other inputs. The labor-saving (capital-using) bias is in agreement with the common impression of increased capital intensity of production. And it is also in agreement with the results of most other studies.

Here we are particularly interested in the technical bias of domestic intermediate goods (D), relative to the foreign intermediate goods (F). The evidence of D-saving (F-using) bias confirms the firms' deep-rooted preference for foreign intermediate goods in the Korean machinery industry as discussed in the section 4.2. Another source of this bias can be explained with the use of the innovation possibility curve (IPC) suggested by Ahmad (1966). The lower quality of many domestic intermediate goods relative to imported ones is fundamentally caused by the lack of the scientific knowledge in the importing society. It is also the case for the intermediate goods that domestic firms cannot produce. Borrowing Ahmad's terminology, we can argue that the innovation possibility curve itself is biased toward foreign intermediate goods in the Korean machinery industry.

The comparison of the effect of price change with that of technical bias on input ratio gives another insight to our problem.

The value of elasticity of substitution between D and F (σ_{DF}) means a percentage change in quantity ratio of the two inputs, due to a one percent change in price ratio. The value of σ_{DF} given by our empirical results is 6.36. Our technical bias index B_{DF} (-.26) implies that the technical change in a year raises the F-D ratio by 26 percent. Thus, the effect of the technical bias occuring over a year is roughly identical to the effect of a 4 percent rise in relative price of domestic intermediate goods to foreign intermediate goods. In other words, 4 percent rise in the relative price of foreign intermediate goods tends to result in the constancy of D-F ratio, if all other things are constant. The comparison of two effects in this way reveals how strong the effect of technical change on the D-F ratio is.

FOOTNOTES(CHAPTER VI)

1. Parks (1971) used the same expression in his study on input substitution of Swedish manufacturing.

2. The Divisia price index in t-th period (D_t), relative to the period, t-1 (D_{t-1}), is expressed as,

   $$\log (D_t/D_{t-1}) = 1/2 \sum_{i=1}^{n} (s_{i,t} + s_{i,t-1}) \log (p_{i,t}/p_{i,t-1})$$

   where $s_{i,t}$ = share of i-th item in t-th period, and $p_{i,t}$=price index of i-th item in t-th period. Richter (1966) discusses several desirable properties of Divisia index.

3. Durbin (1957) and Malinvaud (1966) have suggested that conventional single-equation Durbin-Watson statistic be used to check for autocorrelation of disturbances in the multivariate and simultaneous equations setting. Malinvaud (1966) pp. 424-425.

4. Such a dummy specification helps us save much degrees of freedom. Dummy techniques like this are discussed in Pindyck and Rubinfeld (1981), pp. 111-114.

5. The likelihood ratio, r, is the ratio of maximum value of the likelihood under the null hypothesis to the maximum value of the likelihood under the alternative hypothesis. It is defined as,

   r= Constrained maximum likelihood/Unconstrained maximum likelihood

   Asymptotically, minus twice the logarithm of this likelihood ratio has a chi-square distribution which may, therefore, be used to carry out hypothesis tests

6. Kwon and Williams (1982) estimate TL cost function for the cross-section data of Korean manufacturing. Their model employ three inputs, capital, labor and materials.

7. Many empirical studies on cost function report the violations of concavity condition. Examples are Parks (1971), Duncan and Binswanger (1974), Lynk (1982), Woodland (1975) and Magnus (1979).

CHAPTER VII

CONCLUSION

The primary focus of this study is to elucidate the determinants of changes in input ratio, particularly the ratio of domestic intermediate goods to foreign intermediate goods in the Korean machinery industry. The development process of the Korean machinery industry was overviewed and historical trends of the ratio of the two inputs were discussed. Then a few surveys were analyzed to find out information about a firm's behavior on the input demand. Finally, major determinants of input demand were estimated using the generalized Leontief cost function.

One of the major problems is constructing a precise aggregate price index of foreign intermediate goods. The indexes used in this study are by no means ideal and leave room for improvement. Another shortcoming in our study is that the estimated cost function does not satisfy the concavity condition. Subject to these qualifications, our study yields several important findings and provides meaningful policy implications.

7.1. SUMMARY OF MAJOR FINDINGS

(1) The major determinants of input ratio for the Korean machinery industry are the relative price of inputs and the biased technical change. On the contrary, the scale effect on input ratio is negligible.

(2) The model justifies the disaggregation of intermediate goods into two components, domestic and foreign intermediate goods. The results show that domestic and foreign intermediate goods respond differently to the price change of other inputs, capital and labor. If we employ an alternative model that incorporates domestic and foreign itermediate goods to a single bundle, say material input, then we are forced to assume that each component of material interacts with other input price changes to the same extent, as well as in the same way. This assumption is rejected by our study.

(3) Our finding of moderate complementarity between capital and labor (E_{LK}=-.32, E_{KL}=-.28) differs from those of most empirical studies for manufacturing data. The complementarity of the two is supported by a high ratio of skilled workers in the machinery industry compared to other industrial sectors. It is reasonable to assume that the more capital services are employed, the more technicians and specialists are needed. We have other empirical evidence that shows capital and skilled workers are complementary.

(4) Domestic and foreign intermediate goods are found to be substitutes as expected. The substitutability between them is strong and significantly so. The relationships of individual items between the two groups are divergent. Some pairs are complements and others are substitutes. We find that the force of substitutability between individual items in foreign intermediate goods and those in domestic intermediate goods are dominant over the complementarity between them. This is the first empirical evidence that they are substitutes.

(5) The price elasticities and elasticities of substitution are significantly different across the subsectors in the machinery industry.

(6)The Korean machinery industry experienced foreign-intermediate-goods-using and domestic-intermediate-goods-saving technical change. It implies that if prices of all inputs vary equiproportionately the ratio of F to D tends to rise.

7.2. POLICY IMPLICATIONS

The information obtained from this study can be useful for making decision relating to the policies of stimulating the development of the machinery industry and of the domestic intermediate goods industries.

Our finding of moderate complementarity between labor and capital services supports the view that any efforts by the government to expand the production capacity to a great extent must be accompanied by a corresponding increase in the supply of skilled workers. This is in agreement with the criticism directed at the government policy for development of the heavy and chemical industries. The government policy was not as successful as was expected because it did not take into account the limited availability of skilled workers who were complements to the capital services, when the government initiated the campaign to expand investment in the large projects of the machinery and chemical industries in the early 1970s.

As far as the ratio between domestic and foreign intermediate goods is concerned, the government employed conflicting policy instruments simultaneously: One had the stimulating effect on the use of domestic intermediate goods and the other had opposite effect. Various benefits such as favorable conditions of financing and tax reduction provided to the use of domestic machinery stimulated the demand for domestic intermediate goods. On the contrary, tariff exemptions on the import of materials (raw material and intermediate goods) for exports production as well as rigid foreign exchange rate encouraged the demand for foreign intermediate goods. During the period 1975-1980 covered by our data, the price of intermediate goods in Korea rose faster than that in the U.S. and Japan. However, the adjustment of foreign exchange rate was so slow that it could not sufficiently allow for the change in the price ratio between domestic and foreign intermediate goods. Our finding of high elasticity of substitution between domestic and foreign intermediate goods indicates that such policy instruments played significant role in determining the ratio between the two groups of intermediate goods.

Elasticities of substitution that are significantly different across the machinery subsectors provide policy-makers with a useful guideline with regard to the choice of policy instruments. In a country like Korea with a heavy foreign debt, a chronic trade deficit and a fast increasing labor force, the policy goal of stimulating the use of domestic intermediate goods seems desirable. Hence, it is important to select the most efficient policy instrument. Possible candidates are tariffs, import taxes, and exchange rates. A change of exchange rates leads to a change in the relative price of domestic to foreign intermediate goods by the same proportion for all machinery subsectors. Nevertheless, the extent of reaction by each sector is determined by its elasticity of substitution. The rates of import tax or tariff can be manipulated to encourage the use of a specific item of domestic intermediate goods in a specific subsector. In either case, information about the elastictity of substitution for each industrial subsector is necessary.

The technical change biased toward foreign intermediate goods imposes a limit to the effectiveness of the policies that manipulate only relative prices. When there is a strong tendency to use foreign intermediate goods in the machinery industry, the sources of this tendency must be identified. In the case of the Korean machinery industry, one of the most important sources of it is the technological backwardness in the production of domestic intermediate goods.

In order to substitute for an foreign input where the price has risen, domestic production of that item qualitatively identical to foreign item must be supported by accumulation of technology. The limited availability of production technology makes the innovation possibility curve (IPC) itself biased toward foreign intermediate goods. This line of reasoning is in agreement with the results of questionnaire survey discussed in the section 4.2. The frequent complaints by businessmen about the low quality of domestic intermediate goods are an indicator of the nature and bias of IPC which fundamentally restricts the extent of import substitution of intermediate goods.

APPENDIX MATHEMATICAL DECOMPOSITION OF A CHANGE IN INPUT SHARE AND IN INPUT RATIO-A COST FUNCTION APPROACH

A production function which takes technical progress into account is expressed in most general form as,

$$Y = F[X_1, \ldots\ldots, X_n, t] \qquad (1)$$

where Y=output, X_i=i-th input, t=time or technological knowledge. If we assume that technical change has input augmenting form, t enter the production function as a determinant of input augmentation parameter such that,

$$Y = F[r_1(t)X_1, \ldots, r_n(t)X_n] \qquad (2)$$

where r_i=augmentation parameter of i-th input.

Equation 2 yields, as its dual, a unique minimized cost function, C, such that,

$$C = C[p_1/r_1(t), \ldots\ldots, p_n/r_n(t), Y] \qquad (3)$$

Now let,

$$P_i = p_i/r_i(t),\ C_i^* = \partial C/\partial P_i,\ C_i = C/p_i,\ C_y = \partial C/\partial Y,\quad C_{ij}^* = \partial^2 C/\partial P_i \partial P_j$$

$$C_{ij} = \partial^2 C/\partial p_i \partial p_j, \text{ and } C_{iy}^* = \partial^2/\partial P_i \partial Y$$

where P_i=price of a efficiency unit of input, p_i=price of a physical unit of i-th input.

1. DECOMPOSITION OF SHARE CHANGE.

The share of i-th input and the growth rate of the share are

$$s_i=C_i^*P_i/C=C_ip_i/C \tag{4}$$

$$\hat{s}_i=\hat{C}_i^* + \hat{P}_i - \hat{C} \tag{5}$$

where growth rate of each variable is denoted by ^. For example,

$$\hat{s}_i=d \ln s_i=d\, s_i/s_i.$$

Our present problem is to decompose each RHS term in equation (5) into three sources of change in input share, i.e., change in relative price of inputs, biased technical change, and scale effect. By taking total differentials of $C_i^*(P_1,\dots,P_n, Y)$ and $C(P_1,\dots,P_n, Y)$, and then by substituting them into equation (5), we get,

$$\begin{aligned}\hat{s}_i &=(C_{i1}^*dP_1 +\dots+ C_{in}^*dP_n + C_{iy}^*dY)/C_i^* + \hat{P}_i\\ &\quad - (C_1^*dP_1 + \dots + C_n^*dP_n + C_ydY)/C\\ &= (C_{i1}^*P_1/C_i^* - C_1^*P_1/C)\hat{P}_1 + \dots + (C_{ii}^*P_i/C_i^* - C_i^*P_i/C + 1)\hat{P}_i\\ &\quad + \dots + (C_{in}^*P_n/C_i^* - C_n^*P_n/C)\hat{P}_n + (C_{iy}^*Y/C_i^* - C_yY/C)\hat{Y}\end{aligned} \tag{6}$$

Using Allen-Uzawa partial elasticity of substitution expressed as, $\sigma_{ij}=C_{ij}C/C_iC_j$, linear homogeneity of cost function in input prices which yields $\sum_{j=1}^{n}\sigma_{ij}s_j=0$, and $\hat{P}_i=\hat{p}_i-\hat{r}_i$, we can obtain,

$$\hat{s}_i=\sum_{\substack{j=1\\ j\neq i}}^{n}(1-\sigma_{ij})s_j(\hat{p}_i-\hat{p}_j)+\sum_{\substack{j=1\\ j\neq i}}^{n}(1-\sigma_{ij})s_j(\hat{r}_j-\hat{r}_i)+(E_{iy}-E_{cy})\hat{Y} \tag{7}$$

Suppose that there are only two inputs, labor (L) and capital (K). Then, equation (7) reduces to,

$$\hat{s}_K=(1-\sigma_{KL})s_L(\hat{p}_K-\hat{p}_L)+(1-\sigma_{KL})s_L(\hat{r}_L-\hat{r}_K)+(E_{Ky}-E_{cy})\hat{Y} \tag{8}$$

2.DECOMPOSITION OF INPUT RATIO CHANGE.

From the cost function (3), we derive i-th input demand equation such that,

$$X_i=C_i=\partial C/\partial p_i=(1/r_i)\ C_i^*(P_1,\ldots,P_n,\ Y) \tag{9}$$

Since X_i is the function of $p_1,\ldots,p_n$, $r_1,\ldots,r_n$, and Y, total differentiation of it gives,

$$dX_i=\sum_{j=1}^{n}(\partial X_i/\partial r_j)\,d\,r_j+\sum_{j=1}^{n}(\partial X_i/\partial p_j)d\,p_j+(\partial X_i/\partial Y)\,d\,Y \tag{10}$$

Equation (10) shows that a change in input quantity can be decomposed into threee components. The first term of RHS is the component of input increment resulting from technical change, the second term is that resulting from price change, and third term is that resulting from a change in output level. The first term is rewritten in terms of price elasticities and rate of input augmentation:

$$\sum_{j=1}^{n}(\partial X_i/\partial r_j)d\,r_j = \sum_{\substack{j=1\\ j\neq i}}^{n}(\partial X_i/\partial r_j)d\,r_j + (\partial X_i/\partial r_i)\,d\,r_i$$

$$=(1/r_i)\sum_{\substack{j=1\\ j\neq i}}^{n} C^{*}_{ij}(\partial P_j/\partial r_j)d\,r_j$$

$$+[\,\partial(1/r_i)/\partial r_i\cdot C^{*}_{i} + (\partial C^{*}_{i}/\partial r_i)(1/r_i)\,]\,d\,r_i$$

$$= -\sum_{\substack{j=1\\ j\neq i}}^{n} r_j C_{ij} p_j - [(1/r_i^2)r_i C_i + (p_i/r_i^2)r_i^2 C_{ii}(1/r_i)]d\,r_i$$

$$= -\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}\hat{r}_j X_i - \hat{r}_i X_i(1-\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}) \tag{11}$$

The second term of equation (10) gives,

$$\sum_{j=1}^{n}(\partial X_i/\partial p_j)d\,p_j = \sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}\hat{p}_j X_i + E_{ii}\hat{p}_i X_i \tag{12}$$

The third term of equation (10) is expressed as,

$$(\partial X_i/\partial Y)d\,Y = E_{iy}\hat{Y}X_i \tag{13}$$

where E_{iy} is elasticity of i-th input with regard to output. Substituting equation (11), (12) and (13) into equation (10) and rearranging it yield,

$$\hat{X}_i = d\ln X_i = [\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}(\hat{p}_j-\hat{p}_i)] + [\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}(\hat{r}_i-\hat{r}_j)-\hat{r}_i] + E_{iy}\hat{Y} \tag{14}$$

The second bracket term of input growth eqaution (14) is the input growth component resulting from technical change. We can decompose $\hat{X}_j$ in the same manner. Then, the growth rate of input ratio is decomposed like,

$$\begin{aligned} d \ln (X_i/X_j) &= \hat{X}_i-\hat{X}_j \\ &=[\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}(\hat{p}_j-\hat{p}_i)-\sum_{\substack{i=1\\ i\neq j}}^{n} E_{ji}(\hat{p}_i-\hat{p}_j)] \\ &+ [\sum_{\substack{j=1\\ j\neq i}}^{n} E_{ij}(\hat{r}_i-\hat{r}_j)-\sum_{\substack{i=1\\ i\neq j}}^{n} E_{ji}(\hat{r}_j-\hat{r}_i)-(\hat{r}_i-\hat{r}_j)] \\ &+[(E_{iy}-E_{jy})\hat{Y}] \qquad (15) \end{aligned}$$

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