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CROSS-SECTIONAL ANALYSIS OF DEMAND FOR LABOR AND CAPITAL INPUTS IN MANUFACTURING INDUSTRIES: A CASE STUDY OF KOREA

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CROSS-SECTIONAL ANALYSIS OF DEMAND FOR LABOR AND CAPITAL INPUTS IN MANUFACTURING INDUSTRIES --A CASE STUDY OF KOREA--

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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By

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ABSTRACT

This study addresses questions concerning factor demand, labor-labor substitution, and labor-capital substitution in factor markets for overall manufacturing and 2-digit manufacturing industries of Korea. The objectives are twofold: 1) to analyze input demand, and labor-labor and labor-capital substitution where labor heterogeneity is captured by disaggregating labor by occupation, and 2) to test the null hypotheses of alternative specification of production structure on nonhomothetic model.

This study is different from other studies in that (1) it examines the input interrelationships for 2-digit industries, (2) it utilizes Korean cross-section by subindustries in studying aggregate manufacturing, and (3) it utilizes pre- and post-embargo data. The study is further differentiated from other studies in that the nonhomothetic production structure is postulated. Finally, it relates a developing economy. We know of no existing study for developing countries which explicitly disaggregates labor types.

The objectives of this study require the estimation of production relations such that there are no a priori constraints on the elasticities of substitution between factor inputs. Thus, translog cost functions are specified as quadratic approximations to the production process; where the relevant inputs are labor, disaggregated by occupation,

namely, production labor (blue collar workers) and nonproduction labor (white collar workers), and capital. As for the estimation procedure, Zellner's "seemingly unrelated regression" technique is employed to estimate the cost function coupled with the factor share demand equations, accounting for cross-equation disturbance correlations and adding-up parametric restrictions.

The features of production technology are characterized by the nonhomothetic production structures not only for overall manufacturing but also dominantly for 2-digit manufacturing industries in Korea. Our empirical results indicate that each factor input is a substitute for the other factor inputs in overall manufacturing and that capital is more substitutable for production labor than for nonproduction labor. When we proxy the amount of human capital embodied in labor by the occupation, the labor with a greater amount of human capital is less easily substitutable for physical capital. This finding is consistent with the Griliches hypothesis that, "skill or education is more complementary with physical capital than unskilled or raw labor." In addition, as labor has more human capital, the derived demand for labor becomes less elastic to its own prices. This implies that as a worker accumulates human capital, both the employer and the worker have a greater incentive to continue his employment regardless of possible minor wage fluctuations.

The low overall elasticity of substitution between capital and labor has an important employment-wage implication for Korean industrialization in that it has contributed to the rapid growth of employment and wages rather than impeding their growth. However, while the limited substitution among the factor inputs may temporarily moderate the effect of the wage increase on employment, it may not prevent the higher wage rate from forcing the producers toward labor-augmenting technologies in the long-run.

Investment tax credits will bring about a desired increase in capital accumulation, and there will be generated a substitution effect from labor to capital, reducing the demand for both types of workers given the level of output. Since the elasticity of substitution of production workers for capital is higher than that of nonproduction workers, production workers will be more adversely affected. In other words, employment of less skilled, young workers would suffer under investment incentives.

Finally, the own price elasticities of demand for production labor are quite sizable, while those for capital are smaller than those for labor. The evidence that demand for labor is relatively more price responsive than capital input suggests that greater attention be given to policy incentives, such as employment tax credits, which seek to stimulate employment by inducing movements along demand schedules.

TO MY LATE MOTHER

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TABLE OF CONTENTS

ABSTRACT. iii

ACKNOWLEDGEMENTS. vii

LIST OF TABLES. x

CHAPTER I. INTRODUCTION. 1

CHAPTER II. THE THEORETICAL FRAMEWORK 7

A. Introduction. 7
B. General Production Function 8
C. General Dual Cost Function. 9
D. Allen Partial Elasticities of Substitution and Price Elasticities of Input Demand 12
E. Choice of a Functional Form 16
F. Translog Cost Function. 18
G. Summary 24

CHAPTER III. MODEL SPECIFICATION, ESTIMATION PROCEDURES AND DATA 29

A. Specification of Empirical Model. . . 29
B. Method and Procedures of Estimation. 33
C. Test of Null Hypotheses on Nonhomothetic Translog Specification. 37
D. The Data. 40

CHAPTER IV. THE EMPIRICAL RESULTS 47

A. Empirical Results for All Manufacturing 47
B. Empirical Results for 2-Digit Industries. 56
C. Summary of Relevant Previous Studies 75

CHAPTER V. SUMMARY AND CONCLUSIONS 89

CHAPTER V. (continued)

A. Summary of the Findings 89

1. All Manufacturing 89

2. 2-Digit Manufacturing Industries. 90

B. Conclusions 92

BIBLIOGRAPHY. 97

LIST OF TABLES

Table		Page
3.1	Models for Alternative Specifications.	39
4.1	F-Test of Nonhomothetic Model for Alternative Specifications for All Manufacturing	49
4.2	Parameter Estimates for Translog Cost Function, Overall Manufacturing.	50
4.3	Estimates for Allen Elasticities of Substitution, Overall Manufacturing.	52
4.4	Estimates for Price Elasticities of Input Demand, Overall Manufacturing.	53
4.5	2-Digit Manufacturing Industries and Their Associated Short Titles.	58
4.6	Parameter Estimates for Translog Cost Function, 2-Digit Manufacturing Industries, 1973	60
4.7	Estimates for Allen Elasticities of Substitution, 2-Digit Manufacturing Industries, 1973	63
4.8	Estimates for Price Elasticities of Input Demand, 2-Digit Manufacturing Industries, 1973	64
4.9	Parameter Estimates for Translog Cost Function, 2-Digit Manufacturing Industries, 1978	67
4.10	Estimates for Allen Elasticities of Substitution, 2-Digit Manufacturing Industires, 1978	70
4.11	Estimates for Price Elasticities of Input Demand, 2-Digit Manufacturing Industries, 1978	71
4.12	F-Test of Nonhomothetic Model for Homotheticity Hypothesis for 2-Digit Industires, 1973.	79
4.13	F-Test of Nonhomothetic Model for Homogeneity Hypothesis for 2-Digit Industires, 1973.	80
4.14	F-Test of Nonhomothetic Model for Homotheticity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1973.	81

Table | Page

4.15 F-Test of Nonhomothetic Model for Homogeneity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1973. 82

4.16 F-Test of Nonhomothetic Model for Homotheticity Hypothesis for 2-Digit Industries, 1978. 83

4.17 F-Test of Nonhomothetic Model for Homogeneity Hypothesis for 2-Digit Industries, 1978. 84

4.18 F-Test of Nonhomothetic Model for Homotheticity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1978. 85

4.19 F-Test of Nonhomothetic Model for Homogeneity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1978. 86

CHAPTER I

INTRODUCTION

Substitutability between different types of labor inputs and that between labor and capital has become an important subject among economists interested in labor market and economic development policies. Empirical estimates of elasticities of substitution between pairs of factor inputs are essential for predicting the effect of changes in policy or other exogenous variables. First, let us consider how important our knowledge of factor substitutability is in our understanding of labor market behavior. The proposed reduction in minimum wage for production labor, which is intended to encourage employment of this type of workers, may bring about concurrent displacement of nonproduction labor. The extent of actual displacement will depend on substitutability between production and nonproduction labor.

Employment tax credits, which subsidize a certain fraction of employment costs of unskilled workers, would affect the employment of types of workers and also investment demand depending upon the substitutability among these factor inputs. Investment tax credits or accelerated depreciation allowances will decrease labor demand, assuming that capital and labor are substitutes. But their effects on demand for certain types of labor may be positive if capital is complementary with them in the production process. Employment and training programs convert low-skilled labor to high-skilled labor. Their effectiveness depends on how substitutable these human resources are in the production process.

Knowledge about the elasticity of substitution between capital and labor as well as the determinants of factor share demand is very important in our study of a developing economy, for such information will help visualize some of the basic characteristics of labor markets in this economy.

Second, empirical findings from the research on the behavior of utilization of factor services will be of great value to those engaged in the formulation of the country's industrial development plans. Development policies in most developing countries pursue both rapid industrialization and widespread distribution of its benefits by expanding the industrial employment opportunities. If we know that the elasticity of substitution between capital and labor is high, expansion of employment opportunities without sacrificing output growth is relatively easy by appropriately manipulating the relative factor prices (for this matter, e.g., by reducing the wage-rental ratio so as to change the factor intensities of output).

High elasticity of substitution would enable the economy to flexibly respond and adjust to the changes in external factors. For instance, a change in price of raw materials (or energy) in the international market can be absorbed by adopting more labor-intensive and material-saving production processes on the part of domestic business firms. In this case, the ease and speed of adaptation would also depend on the degree of substitutability between the pairs of different factor inputs.

The quantitative and qualitative information pertaining to the requirements of factor inputs and the analysis of the existing relationship between any of factor inputs and its determinants will contribute substantially toward securing consistency in formulating and implementing the policy instruments necessary to attain the desired targets and goals of an overall economy.

The purpose of this study is to estimate the factor share demand equations combined with the cost function for all manufacturing and 2-digit manufacturing industries of Korea using 1973 and 1978 cross-section data. These years are the most recent years of the mining and manufacturing census survey, which is statutorily conducted every five years in Korea. All the studies on the substitutability among factor inputs in developing economies employ the usual aggregate labor input. We take a modest step toward disaggregation by dividing labor into two categories, namely, production labor (blue collar workers) and nonproduction labor (white collar workers), where capital is the third input. It would be more desirable to disaggregate labor into several demographic characteristics such as age, education or sex. However, data limitations render this impossible. This study is very important because we know of no existing study for developing countries which explicitly disaggregate labor types. The main focus of this study will be on the statistical estimation of the following measures: (1) the Allen partial elasticities of substitution between factor inputs, and (2) the own-price elasticities of demand for the factor input.

To accomplish the objectives of this study it is desirable to estimate production relations via a model that does not impose a priori restrictions on the elasticities of substitution among factors of production, but that also permits the test of alternative specifications of production structure. The transcendental logarithmic function will provide such a model of production. This function is a member of the class of flexible functional forms, which are defined by the property that they can provide a second order approximation to any twice-differentiable function.

The following main research questions will be discussed throughout this study in accomplishing the aforementioned study objectives:

1. Do the parameter estimates for the translog cost function utilized in this study reveal that the underlying production function is significantly different from the Cobb-Douglass functional form?

2. Are the elasticities of substitution between pairs of factor inputs significantly different from zero?

3. Is the elasticity of substitution between production labor and capital significantly different from that between nonproduction labor and capital?

4. Are the factor demands price elastic?

5. Are the elasticity estimates significantly different across the different manufacturing industries?

6. Are there any substantial changes in input interrelations between 1973 and 1978?

7. What are the policy implications to be derived from the above discussions?

Chapter II develops the theoretical framework which enables us to estimate the parameters of factor share demand functions, and the Allen and price elasticity measures from the cost function facing overall manufacturing and each 2-digit industry. We also introduce the translog form as one of the flexible functional forms which are less restrictive than the conventional functional forms such as Cobb-Douglas, CES, and Leontief fixed proportions production functions. Chapter III presents the specification of empirical model for statistical estimation, followed by the discussions on the choice of estimation procedures and the test of null hypotheses for alternative specifications of production structure. Also described are the statistical data to be utilized for each variable in the empirical model. Chapter IV discussed the empirical results for overall manufacturing and 2-digit manufacturing industries in 1973 and

1978. Finally, Chapter V provides a summary of empirical findings and concludes this study.

CHAPTER II

THE THEORETICAL FRAMEWORK

A. Introduction

This chapter is intended to develop the theoretical framework which will be utilized to determine the input interrelations in production process in Korean overall manufacturing and 2-digit industries. The theoretical framework for the analysis of substitutability among the factors of production dates far back to Allen (1938).[1] However, it is only with relatively recent improvements in the theory of production, empirical techniques, and data that Allen's framework has been put to use. Empirical estimations of production relations from a multiple input production framework have only appeared since the seminal work of Griliches (1969) considering three inputs; low-skilled labor, high-skilled labor, and capital.[2]

The advent of estimable multiple input production functions and of improved data have recently led to empirical searches for appropriate or consistent aggregates of labor and capital for use in estimating substitution relations. Leontief (1947a, b) introduced the idea of what is now referred to as weak functional separability among inputs, thus providing a criterion for resource aggregation. Groups of inputs which are weakly separable from others may be formed into consistent aggregates in the sense that marginal changes in the level of use of other inputs outside the separable group do not alter the technical relations among inputs within the group.[3]

In the following sections, the general production function will be discussed first, followed by a discussion of general dual cost function. Then, in terms of the general dual cost function the Allen partial elasticities of substitution and price elasticities of input demand will be developed, which summarize the aforementioned input interrelationships in the production structure. In addition, a discussion of choice of functional form follows, and the elasticities and estimating factor share demand equations are derived in terms of the translog cost function.

B. General Production Function

Since the usage of any factor of production as an input in the production process is a derived input demand, we begin our discussion with the production function. Suppose that there exists the general production function for all manufacturing and for each 2-digit industry in the following form:

$$Y = F(X_1, X_2, \ldots, X_n) \tag{2-1}$$

where Y is quantity of output, and X_i is quantity of ith input. Here, the assumptions underlying this general production relation are; (i) there exists a positive, concave and twice-differentiable but unknown production function, and (ii) the production function is weakly separable in its empirically applicable aggregate input components.

The assumption (i) implies that the production function is well-behaved; i.e., marginal product of any input is decreasing with output but positive, and the production function satisfies certain minimal mathematical requirements. In other words, this assumption is simply a statement that the production function meets the minimum conditions implied by the economic theory.

The assumption (ii) of weak separability in inputs insures the existence of consistent aggregate indices of such inputs. For example, the weak separability of equipment and structures in the capital aggregate means that the marginal rate of substitution between equipment and structures is independent of the levels of the other inputs. Thus, two heterogeneous forms of capital such as equipment and structures may be added up to form a consistent aggregate index. Clearly, the presupposition of such indices is necessary in the formulation of a production function, although it is not evident that such indices actually exist. Berndt and Christensen (1973) found that equipment and structures could be aggregated for U.S. total manufacturing in a three-input production function where the third input was labor.[4] In short, this assumption is necessary in any empirical study using aggregate input data.

C. General Dual Cost Function

Now turn to the general cost function. Duality theory[5] allows us to restate Y in terms of its dual cost function.

Shephard (1953, 1970) and Diewert (1971) have demonstrated that input demand and substitution relations can also be investigated by means of cost functions.[6] Assume that production of alternative levels of output takes place according to a general cost function:

$$C = G(\ Y,\ P_1, \ldots, P_n) \tag{2-2}$$

where C is total cost, Y is output and P_i is the price of services of the ith input. Further, assume that C is (i) a positive, real valued function in Y which approaches infinity, as Y approaches infinity, (ii) homogeneous of degree one in input prices P_i, (iii) a concave function in P_i for all positive levels of output.

Given these assumptions, Shephard (1953, 1970) and Diewert (1971) have demonstrated that (iv) if C is a continuously differentiable function of P_i and is minimized with respect to $Y > 0$, and all input markets are competitive, then there exists a well defined production function that is dual in relation to the cost function.[7] This dual production function may not be explicitly expressible in parametric form, but the technological relations among inputs in production can be determined from the cost function alone.[8] It is important to point out that the dual to a translog cost function is not necessarily a translog production function.

The model formulation in this study will be based on the duality relationship that exists between production and cost functions. Duality theory implies that if producers minimize input costs of producing given output, and if factor prices are exogenous, then the cost function that satisfies the usual regularity conditions[9] contains sufficient information to completely describe the corresponding production technology, and vice versa. Thus, rather than specifying a functional form for the production function and deriving the input demand functions therefrom, we can directly formulate a cost function and then apply Shephard's Lemma[10] to obtain the input demand functions.

The application of a cost function rather than a production function for estimating the production parameters has several advantages. For instance, in the production function estimation, high multicollinearity among the input variables often causes problems. Since there is usually little multicollinearity among factor prices, this problem does not arise in the cost function estimation. In addition, the choice of cost function or production function specification affects the computational ease of the elasticity estimates. In the cost function approach the Allen partial elasticities of substitution can be obtained directly from the estimated parameters of a single equation. Derivation of any Allen partial elasticity from the production function specification, however, involves inversion of an n x n matrix of estimated coefficients. If any one estimated coefficient in the system has a large standard error, this will be reflected in all the estimates derived from the production function specification.[11] The most important criterion for choosing a cost function or production function approach is whether input prices or input quantities can be assumed to be exogenous to the unit under observation.[12]

D. Allen Partial Elasticities of Substitution and Price Elasticities of Input Demand

R. G. D. Allen (1938) defined the Allen partial elasticity of substitution between inputs i and j as:

$$A_{ij} = \frac{\sum_{k=1}^{n} X_k f_k}{X_i X_j} (\bar{f}^{-1})_{ji}; \qquad (2\text{-}3)$$

where $f_i = \partial Y/\partial X_i$, $f_{ij} = \partial^2 Y/\partial X_i \partial X_j$, X_i is quantity of the ith input, $\bar{f}$ is the bordered Hessian matrix of production function (2-1)

$$\bar{f} = \begin{bmatrix} 0 & f_1 & \cdots\cdots & f_n \\ f_1 & f_{11} & \cdots\cdots & f_{1n} \\ \vdots & \vdots & f_{ij} & \vdots \\ f_n & f_{n1} & \cdots\cdots & f_{nn} \end{bmatrix} \qquad (2\text{-}4)$$

and $(\bar{f}^{-1})_{ij}$ is the ijth element of the inverse of the bordered Hessian matrix $\bar{f}$. According to the Young's theorem, it is apparent that

$$A_{ij} = A_{ji} \qquad (2\text{-}5)$$

The Allen partial elasticity of substitution, A_{ij}, measures the effect on the relative quantity of factor i of a change in the relative price of factor j, holding output and other input prices constant. Inputs i and j are substitutes in production if $A_{ij} > 0$, and are complements in production if $A_{ij} < 0$.[13]

The price elasticity of input demand, E_{ij}, of input X_i given a change in the relative price of input X_j is defined as:

$$E_{ij} = \partial \ln X_i / \partial \ln P_j \tag{2-6}$$

where output and all other input prices remain unchanged. Allen (1938) has demonstrated that the Allen partial elasticities of substitution are related to the price elasticities of input demand in the following manner:[14]

$$E_{ij} = M_j A_{ij} \tag{2-7}$$

where M_j is the factor share of the jth input in the total production cost. Therefore, even though $A_{ij} = A_{ji}$, in general $E_{ij} \neq E_{ji}$.

What follows presents how the Allen partial elasticities of substitution can be easily derived in terms of cross derivatives of the general dual cost function. First, we assume that there exists a dual minimum cost function, C*, corresponding to the following cost minimization problem subject to a given production technology expressed in the general form (2-9) which is postulated to be a well-behaved production function:

$$\text{Minimize } C = \sum_{i=1}^{n} X_i P_i \qquad (i=1,2,\ldots,n) \qquad (2\text{-}8)$$

subject to

$$Y = F(X_1, X_2, \ldots, X_n) \qquad (2\text{-}9)$$

where C denotes cost, X_i and P_i denote the quantity and the price of ith input, and Y denotes output.

$$C^* = G(Y, P_1, \ldots, P_n) \qquad (2\text{-}10)$$

This function, C*, assigns to every combination of input prices the minimum cost corresponding to the cost minimizing input levels X_i^*.[15] C* is homogeneous of degree one in factor prices.

Shephard's Lemma[16] holds for the cost function

$$\frac{\partial C^*}{\partial P_j} = X_j \qquad (2\text{-}11)$$

The first order conditions of the cost minimizing problem (2-8) and (2-9) are:

$$F(X_1, \ldots, X_n) - Y = 0 \qquad (2\text{-}12)$$

$$P_i - \lambda f_i = 0 \qquad i = 1, \ldots, n \qquad (2\text{-}13)$$

where λ denotes the Lagrangean multiplier. Writing the total differential of the above first order conditions and rearranging the terms in the following bordered Hessian matrix form;

$$\lambda \begin{bmatrix} 0 & f_1 \cdots\cdots f_n \\ f_1 & f_{11} \cdots\cdots f_{1n} \\ \vdots & \vdots \quad f_{ij} \quad \vdots \\ f_n & f_{n1} \cdots\cdots f_{nn} \end{bmatrix} \begin{bmatrix} d\lambda/\lambda \\ dX_1 \\ \vdots \\ dX_n \end{bmatrix} = \begin{bmatrix} \lambda dY \\ dP_1 \\ \vdots \\ dP_n \end{bmatrix} \tag{2-14}$$

Solving for the vector of endogenous variables,

$$\begin{bmatrix} d\ln\lambda \\ dX_1 \\ \vdots \\ dX_n \end{bmatrix} = \frac{1}{\lambda}\bar{f}^{-1} \begin{bmatrix} dY \\ dP_1 \\ \vdots \\ dP_n \end{bmatrix} \tag{2-15}$$

This implies

$$\frac{\partial X_j}{\partial P_i} = \frac{1}{\lambda}(\bar{f}^{-1})_{ji} \tag{2-16}$$

Substituting from (2-16) into (2-3) and substituting $f_k = \frac{P_k}{\lambda}$ from (2-13),

$$A_{ij} = \frac{\sum_{k=1}^{n} X_k f_k}{X_i X_j} \lambda \frac{\partial X_j}{\partial P_i} = \frac{\sum_{k=1}^{n} X_k P_k}{X_i X_j} \frac{\partial X_j}{\partial P_i} \tag{2-17}$$

Taking the derivative of (2-11) with respect to P_i,

$$\frac{\partial^2 C^*}{\partial P_i \partial P_j} = \frac{\partial X_j}{\partial P_i} \tag{2-18}$$

Combining (2-17), (2-18) and (2-5),

$$A_{ij} = A_{ji} = \frac{\sum_{k=1}^{n} X_k P_k}{X_i X_j} \frac{\partial^2 C^*}{\partial P_i \partial P_j} \qquad (2\text{-}19)$$[17]

Multiplying and dividing the righthand side of (2-19) by $\frac{P_j}{X_i}$,

$$A_{ij} = A_{ji} = \frac{E_{ij}}{M_j} \qquad (2\text{-}20)$$

where $E_{ij} = \frac{\partial X_i}{\partial P_j} \frac{P_j}{X_i}$ which indicates price elasticity of input demand, and $M_j = \frac{X_j P_j}{\sum_{k=1}^{n} X_k P_k}$ which represents the share of factor j in total costs. When the parameters of specific functional form of a cost function have been estimated, the equation (2-19) can be used to derive the Allen partial elasticities of substitution. Thus far we have shown that in the case of cost function approach, estimates of elasticities of substitution can be obtained directly from the parameters of the cost function.

E. Choice of a Functional Form

As more than two factors are used in this analysis, the application of the constant elasticity of substitution (CES) production function is particularly objectionable since it not only implies that the cross-elasticities of substitution between any pair of factors are all constant but also that they are all equal to the same constant. In addition, the other two conventional forms of production functions, namely, Cobb-Douglas and Leontief (fixed factor proportion) production functions, both impose also a priori restrictions on the elasticities of substitution in that the former restricts the elasticities of substitution among inputs to unity whereas the latter postulates no substitutability at all among factor inputs. Multi-factor Cobb-Douglas and CES functions assume strong separability, which is equivalent to assuming that the conditions for consistent aggregate labor and capital indexes are satisfied. These characteristics may severely limit the ability of the conventional functions to describe an arbitrary production technology.

The recognition of the severe limitations of the conventional forms of production has motivated substantial research to specify more general forms of production function. Such vigorous research effort has culminated in the development of the new functional forms, in early 1970's, which are flexible and general in that they impose no a priori restrictions on the elasticities of substitution as well as on the separability of inputs.

Diewert (1971) proposed a flexible form which is called the Generalized Leontief Production Function.[18] This function is a quadratic form in an arbitrary number of factor inputs. It reduces to the Leontief (fixed factor proportion) production function as a special case. Diewert (1973) also introduced what he has called the Generalized Cobb-Douglas Production Function, which also imposes no a priori restrictions.[19] On the other hand, Christensen, Jorgenson and Lau (1971, 1973) proposed the Transcendental Logarithmic Production Function (translog, for short).[20] This functional form has both linear and quadratic terms with any arbitrary number of factor inputs. It reduces to the multi-input Cobb-Douglas form as a special case. Separability can be imposed on the translog form by testable parametric restrictions.

As mentioned above, all three flexible functional forms do not impose a priori restrictions on the price and Allen partial elasticities. Recently, Berndt, Darrough and Diewert (1977) examined these three functional forms and concluded that the translog functional form is preferable on theoretical and econometric grounds.[21] Among the three functional forms, we arbitrarily choose the translog cost function in this study.

F. Translog Cost Function

The translog functional form is chosen to describe the general cost function in (2-10) for several reasons. First, it imposes no a priori restrictions on the values of the Allen partial elasticities of substitution and the price elasticities of factor demand, the estimations of which are the primary purpose of this study. Second, the translog functional form is flexible in that it can be interpreted as a second order approximation to any arbitrary, twice-differentiable analytic function. In other words, the translog functional form can be viewed as a second order logarithmic Taylor series expansion, where the point of expansion is the means of data. Finally, the translog functional form is econometrically desirable since it facilitates the derivation of the factor share demand equations which are linear in parameters and therefore relatively easy to estimate. In short, the choice of the translog cost function is arbitrary, but it is convenient and desirable for the estimation of Allen partial elasticities of substitution which are not imposed with any particular a priori restrictions on their values.

Here, we will introduce the translog cost function first by rewriting the general cost function (2-10) in natural logarithms:

$$\ln C^* = G(\ln Y, \ln P_1, \ldots, \ln P_n) \tag{2-21}$$

where P_i denotes price of ith input.

Then, using the Taylor series expansion to the second term, we obtain a translog cost function for the second order approximation to the logarithmic Taylor series expansion as shown below:

$$\ln C^* = a_0 + a_y \ln Y + \sum_i a_i \ln P_i + 1/2 r_{yy} (\ln Y)^2 + \sum_i r_{yi} \ln Y \ln P_i + 1/2 \sum_i \sum_j r_{ij} \ln P_i \ln P_j \tag{2-22}$$

where a_0, a_y, a_i, r_{yi}, r_{yy} and r_{ij} are technologically determined parameters, and $r_{ij} = r_{ji}$ is the symmetry constraint. This translog cost function represents nonhomothetic production structure.

The linear homogeneity in input prices of general cost function (2-10) is defined as the equation (2-23) below:[22]

$$G(Y, mP_1, \ldots, mP_n) = mG(Y, P_1, \ldots, P_n); \qquad (2\text{-}23)$$

And this implies the following parametric restrictions on the translog cost function (2-22):

$$\sum_i a_i = 1;$$

$$\sum_i r_{ij} = \sum_j r_{ij} = \sum_i \sum_j r_{ij} = 0; \text{ and}$$

$$\sum_i r_{yi} = 0 \qquad (2\text{-}24)$$

With the assumption of competitive factor markets, input prices may be considered given. Then, for a given level of output, factor share demand equations subject to cost minimization can be derived directly from the partial logarithmic derivatives. Sufficient conditions for Shephard's Lemma, $\frac{\partial C^*}{\partial P_i} = X_i$, are also met for this translog cost function, and this implies

$$\frac{\partial \ln C^*}{\partial \ln P_i} = \frac{\partial C^*}{\partial P_i} \; \frac{P_i}{C^*} = \frac{P_i X_i}{C^*} = M_i \qquad (2\text{-}25)$$

where M_i denotes the factor share of ith input in total production cost. The set of factor share demand equations is derived from partial logarithmic differentiation of translog cost function (2-22) as follows:

$$M_i = a_i + r_{yi}\ln Y + \sum_j r_{ij}\ln P_j \qquad (2\text{-}26)$$

The set of estimating factor share demand equations, (2-26), are linear in logarithms and have proper exogenous variables on the right hand side if the analysis pertains to firms or an industry.

The parametric restrictions (2-24) of linear homogeneity in input prices clearly indicate that the system of equations in (2-26) is singular. The parameter estimates of any single factor share demand equation can be derived from the parameter estimates of the remaining (n-1) equations, and these parameter estimates are identical regardless of the equation chosen to be deleted. Thus, with the symmetry and linear homogeneity in factor prices constraints imposed, a non-singular set of factor share demand equations would be:

$$M_i = a_i + r_{yi}\ln Y + \sum_{j-1}^{n-1} r_{ij}\ln(P_j/P_n) \qquad (2\text{-}27)$$

$$i = 1, 2, \ldots, n-1;$$

where the parameters of the arbitrary nth equation are determined from the parameters of the remaining (n-1) equations.

The parameters, r_{ij}, have little economic meaning of their own. It will be shown that they are related to variable elasticities of substitution and of factor demand. Under the translog cost function specification the Allen partial elasticities of substitution are easier to determine. Uzawa (1962) has derived these elasticity measures from the general cost function (2-10) as:

$$A_{ij} = C^* \frac{\partial^2 C^*}{\partial P_i \partial P_j} \frac{\partial P_i}{\partial C^*} \frac{\partial P_j}{\partial C^*} \tag{2-28}$$

With the translog specification the Allen partial elasticities are determined as normalized elasticities which can be stated in terms of the cost function parameters, r_{ij}, and appropriate cost shares as follows, using Uzawa's formulation:[23]

$$\begin{aligned} A_{ii} &= \frac{r_{ii} + M_i^2 - M_i}{M_i^2} \quad ; \quad i = 1, 2, \ldots, n \\ A_{ij} &= \frac{r_{ij} + M_i M_j}{M_i M_j} \quad ; \quad i \neq j \end{aligned} \tag{2-29}$$

Two factor inputs are said to be substitutes if Allen partial elasticities of substitution, A_{ij}, are positive, while two factor inputs are complements if Allen partial elasticities of substitution are negative. A priori, the own elasticities of substitution should be negative, which will be ascertained later by our empirical results.

The conventional price elasticity of demand for factor input, E_{ij}, is defined as the relative change in usage of factor input i due to a relative change in the price of input j holding output and the prices of all other inputs constant, but allowing all factor input substitutions to occur.

$$E_{ij} = \frac{\partial X_i}{\partial P_j} \frac{P_j}{X_i} = \frac{\partial \ln X_i}{\partial \ln P_j} \qquad (2\text{-}30)$$

Using Shephard's Lemma, the price elasticities of demand for factor input can also be restated in terms of derivatives of the translog cost function and the resultant cost shares as follows:

$$E_{ii} = \frac{r_{ii} + M_i^2 - M_i}{M_i} = M_i A_{ii} \quad ; \quad i = 1, 2, \ldots, n$$

$$E_{ij} = \frac{r_{ij} + M_i M_j}{M_i} = M_j A_{ij} \quad ; \quad i \neq j \qquad (2\text{-}31)$$

The price elasticities of factor demand differ from the Allen partial elasticities of substitution in only one respect. Price elasticities are sensitive to the ordering of the factors, i.e., $E_{ij} \neq E_{ji}$, whereas Allen partial elasticities of substitution are not, i.e., $A_{ij} = A_{ji}$. Since the cost shares are positive, the price elasticities all have the same signs as the corresponding Allen partial elasticities of substitution, and thus the determination of factor inputs as substitutes or complements remains the same. Also, it is noted that the own price elasticity of demand should be negative, which measures the effect on the relative change in usage of an input due to a relative change in its own price.

G. Summary

A general production function was postulated to exist for all manufacturing and each 2-digit industry subject to the assumptions that (i) it is well-behaved; and (ii) it is weakly separable in its applicable aggregate input components which are used in our empirical model. Then, applying the duality theory, which requires the additional conditions of cost minimization and exogeneity of input prices, it is assumed there exists a general dual cost function which reflects the same production structure and the conditions imposed thereon. So far, all of the conditions mentioned are minimal in that they are either required in any econometric study or necessitated by data limitations.

The Allen partial elasticities of substitution and price elasticities of factor demand were developed in terms of the general dual cost function, based on the assumptions of the cost minimization behavior and the exogeneity of input prices. Following the discussion on the choice of functional form, the translog cost function was arbitrarily chosen as a flexible and general functional form, because of its several desirable properties. It is flexible and reasonably easy to estimate the functional parameters, and imposes no a priori restrictions on the price and Allen partial elasticities, which are the main focus of this study.

In addition, using Shephard's Lemma and various parametric restrictions implied by economic theory a non-singular set of factor share demand equations were derived from the partial differentiation of the translog cost function. Finally, the Allen partial elasticities of substitution and the price elasticities of input demand were derived in terms of the relevant cost shares and the parameters of translog cost function.

CHAPTER II—NOTES

[1]See Allen, R. G. D., 1938, Mathematical Analysis for Economists, New York, Macmillan and Co Ltd., 1969, pp. 503-509.

[2]See Griliches, Zvi, 1969, "Capital-Skill Complementarity," Review of Economics and Statistics, vol. 51, no. 5 (November), pp. 465-468.

[3]See Leontief, W. W., 1947a, "A Note on the Interrelations of Subsets of Independent Variables of a Continuous First Derivatives," Bulletin of the American Mathematical Society, vol. 53, no. 4, pp. 343-350; also see Leontief, W. W., 1947b, "Introduction to a Theory of the Internal Structure of Functional Relationships," Econometrica, vol. 15, pp. 361-373.

[4]Berndt, Ernst R., and Laurits R. Christensen, 1973, "The Translog Function and the Substitution of Equipment, Structures, and Labor in U.S. Manufacturing 1929-68," Journal of Econometrics, vol. 1, no. 1 (March), pp. 81-114.

[5]For a short, yet complete survey of duality theory, see Diewert, W. E., 1974, "Applications of Duality Theory," Frontiers of Quantitative Economics, vol. 2, M. D. Intriligator and D. Kendrick, eds., Amsterdam, North-Holland Publishing Company, pp. 107-171.

[6]See Shephard, Ronald W., 1953, Cost and Production Functions, New Jersey, Princeton University Press, pp. 10-17; and Shephard, Ronald W., 1970, Theory of Cost and Production Functions, New Jersey, Princeton University Press, pp. 159-177. Also see Diewert, W. E., 1971, "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," Journal of Political Economy, vol. 79, no. 3 (May/June), pp. 481-507.

[7]See ibid.

[8]For an extended discussion, see Humphrey, D. B., and J. R. Moroney, 1975, "Substitution among Capital, Labor and Natural Resource Products in American Manufacturing," Journal of Political Economy, vol. 83, no. 1 (February), pp. 57-82.

[9]The regularity conditions for a cost function that are required to uniquely determine the corresponding production function are that the cost function be increasing, linearly homogeneous and quasi-concave in the input prices.

[10]For the development of Shephard's Lemma, see Shephard, Ronald W., 1953, Cost and Production Functions, New Jersey, Princeton University Press, p. 11; also see Shephard, Ronald W., 1970, Theory of Cost and Production Functions, New Jersey, Princeton University Press, p. 171.

[11]The inversion of a matrix of estimates has the tendency to exaggerate estimation errors to an unknown extent and, because inversion is a nonlinear transformation, econometric properties of estimated Allen partial elasticities of substitution cannot be found even if such properties of the production function parameters are known.

[12]For a more detailed discussion of the advantages of a cost function approach over a production function approach for the measurement of elasticities of factor demand and elasticities of substitution, see Binswinger, Hans P., 1974, "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution," American Journal of Agricultural Economics, vol. 56, no. 2 (May), p. 377.

[13]See Allen, op. cit., pp. 504-509 for a more detailed development.

[14]See ibid., pp. 508-509.

[15]While C of (2-8) is the cost of production under any feasible factor combination, C* refers to the cost of production when the cost minimizing input combination is used. Since the optimal input combination is a function of factor prices, the minimum cost is also a function of the factor prices.

[16]For the mathematical proof of the Shephard's Lemma, see Diewert, W. E., 1971, "An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function," Journal of Political Economy, vol. 79, no. 3 (May/June), p. 496.

[17] Alternatively, Uzawa (1962) has shown that the Allen partial elasticities of substitution can be derived in the following manner:

$$A_{ij} = \frac{GG_{ij}}{G_i G_j}$$

where G denotes cost function, $G_i = \frac{\partial G}{\partial P_i}$ and $G_{ij} = \frac{\partial^2 G}{\partial P_i \partial P_j}$.

[18] See Diewert, 1971, _op. cit_.

[19] Diewert, W. E., 1973, "Separability and the Generalized Cobb-Douglas Utility Function," Department of Manpower and Immigration, Ottawa (January), mimeo.

[20] Christensen, Laurits R., Dale W. Jorgenson, and L. J. Lau, 1971, "Conjugate Duality and the Transcendental Logarithmic Function," _Econometrica_, vol. 39, no. 4 (July), pp. 255-256; and 1973, "Transcendental Logarithmic Production Frontiers," _Review of Economics and Statistics_, vol. 55, no. 1 (February), pp. 28-45.

[21] See Berndt, Ernst R., M. N. Darrough, and W. E. Diewert, 1977, "Flexible Functional Forms and Expenditure Distributions: An Application to Canadian Consumer Demand Functions," _International Economic Review_, vol. 18 (October), pp. 651-675.

[22] Given the conditions noted earlier, a proportionate increase in factor prices (P_i) will result in total cost (C*) increasing in the same proportion, assuming the output (Y) is held constant. This behavior indicates that the cost function must be homogeneous of degree one in factor prices. Homogeneity of degree one in input prices does not impose the homogeneity of degree one of the production function in inputs, which, if ever assumed, implies a very strong assumption of constant return to scale on the production technology.

[23] See Uzawa, Hirofumi, 1962, "Production Functions with Constant Elasticities of Substitution," _Review of Economic Study_, vol. 29, no. 81 (October), p. 293.

CHAPTER III

MODEL SPECIFICATION, ESTIMATION PROCEDURES AND DATA

The purpose of this chapter is to detail all the procedures necessary to implement the nonhomothetic translog cost function model developed in Chapter II. This requires the specification of our empirical model for statistical estimation subject to data limitations, the choice of estimation procedures, the discussion of the test of null hypotheses on the nonhomothetic translog specification, and the description of statistical data to be utilized for each variable in the empirical model.

A. Specification of Empirical Model

In this study, we postulate more than two factors of production. Instead of having the usual aggregate labor and capital inputs, we take a modest step toward disaggregation by dividing labor into two categories, namely, production labor and nonproduction labor. Though it would be also desirable to disaggregate physical capital into at least two categories, data limitations render this difficult. Here, it is assumed that three primary factor inputs are used in the production process; these factor inputs are (1) production labor, (2) nonproduction labor, and (3) capital.

We will employ the translog cost function for estimating the Allen partial elasticities of substitution and the price elasticities of factor demand for overall manufacturing and each of 2-digit industries in Korea analyzing cross-section data, 1973 and 1978, respectively. This translog function is a highly flexible and general functional form that imposes no a priori restrictions on the Allen partial elasticities of substitution between pairs of factor inputs. We also postulate that the cost function parameters are the same for sub-industries within the relevant industry group, but they may differ across different industry groups.[1]

Now, we assume that there exists in the Korean manufacturing industries a twice-differentiable aggregate production function relating the flow of gross output Y to the services of three primary factor inputs; production labor (p), non-production labor (n), and capital (k). Corresponding to such a production function, we postulate a translog cost function which can be interpreted as a second order approximation to an arbitrary twice-differentiable analytic function.

We write this three-input cost function with symmetry ($r_{ij} = r_{ji}$) in the following form, which represents nonhomothetic production technology:

$$\begin{aligned} \ln C = {} & a_0 + a_y \ln Y + a_p \ln P_p + a_n \ln P_n + a_k \ln P_k + 1/2 r_{yy} (\ln Y)^2 \\ & + 1/2 r_{pp} (\ln P_p)^2 + r_{pn} \ln P_p \ln P_n + r_{pk} \ln P_p \ln P_k \\ & + 1/2 r_{nn} (\ln P_n)^2 + r_{nk} \ln P_n \ln P_k + 1/2 r_{kk} (\ln P_k)^2 \\ & + r_{yp} \ln Y \ln P_p + r_{yn} \ln Y \ln P_n + r_{yk} \ln Y \ln P_k \qquad (3\text{-}1) \end{aligned}$$

where p denotes production labor, n refers to nonproduction labor, and k is capital input. This translog cost function model represents a nonhomothetic production structure which does not impose any of the restrictions of homotheticity, homogeneity and unitary elasticities of substitution (Cobb-Douglas type) on the production technology. These null hypotheses will be statistically tested later.

Assuming competitive factor markets, we treat input prices as exogenous. Given the level of output and input prices, cost minimizing factor share demand equations are derived. We logarithmically differentiate (3-1),

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{\partial C}{\partial P_i}\,\frac{P_i}{C} = a_i + \sum_j r_{ij}\ln P_j + r_{yi}\ln Y \qquad (3\text{-}2)$$

where j = p, n, k; and then, using Shephard's Lemma (2-11),

$$X_i = \frac{\partial C}{\partial P_i} \qquad i = p,\ n,\ k \qquad (3\text{-}3)$$

Accordingly, we obtain the three factor share demand equations as follows:

$$M_p = \frac{P_p p}{C} = a_p + r_{pp}\ln P_p + r_{pn}\ln P_n + r_{pk}\ln P_k + r_{yp}\ln Y$$

$$M_n = \frac{P_n n}{C} = a_n + r_{pn}\ln P_p + r_{nn}\ln P_n + r_{nk}\ln P_k + r_{yn}\ln Y$$

$$M_k = \frac{P_k k}{C} = a_k + r_{pk}\ln P_p + r_{nk}\ln P_n + r_{kk}\ln P_k + r_{yk}\ln Y$$

(3-4)

Linear homogeneity of the cost function in factor prices imposes the following parametric restrictions on both the cost function (3-1) and the factor share demand equations (3-4):

$$a_p + a_n + a_k = 1$$

$$r_{pp} + r_{pn} + r_{pk} = 0$$

$$r_{pn} + r_{nn} + r_{nk} = 0$$

$$r_{pk} + r_{nk} + r_{kk} = 0$$

$$r_{yp} + r_{yn} + r_{yk} = 0 \qquad (3\text{-}5)$$

As mentioned earlier in the previous chapter, the system of equations in (3-4) is singular in that the parameter estimates of any single equation can be derived from the parameter estimates of the remaining two equations. The parameter estimates are identical regardless of the equation chosen to be deleted, and thus, the M_n equation is arbitrarily deleted.[2]

If we impose the above parametric restrictions on the cost function (3-1) and the remaining two factor share demand equations in (3-4), i.e., M_k and M_p, and appropriately substitute the parameters into these equations, we obtain a complete non-singular set of estimating equations (3-6) with the error terms appended which represent random errors in cost minimizing behavior.

$$\ln(C/P_n) = a_0 + a_y \ln Y + 1/2 r_{yy} (\ln Y)^2 + a_p \ln(P_p/P_n) +$$
$$1/2 a_k \ln(P_k/P_n) + 1/2 r_{pp} [\ln(P_p/P_n)]^2 +$$
$$1/2 r_{kk} [\ln(P_k/P_n)]^2 + r_{pk} \ln(P_p/P_n) \ln(P_k/P_n) +$$
$$r_{yp} \ln Y \ln(P_p/P_n) + r_{yk} \ln Y \ln(P_k/P_n) + u_c$$
$$M_p = a_p + r_{pp} \ln(P_p/P_n) + r_{pk} \ln(P_k/P_n) + r_{yp} \ln Y + u_p$$
$$M_k = a_k + r_{kk} \ln(P_k/P_n) + r_{pk} \ln(P_p/P_n) + r_{yk} \ln Y + u_k \quad (3\text{-}6)$$

where the remaining parameters, a_n, r_{yn}, r_{pn}, r_{nk}, r_{nn}, are determined by the linear homogeneity constraints. A priori, given that input prices are fixed and exogenous, it is reasonable to assume that the error terms (u_c, u_p, u_k) are random and normally distributed within equations, although error terms across equations are likely to be correlated because random errors in the cost minimizing behavior should affect all the cost shares. Thus, a constrained estimation procedure is required to account for this cross-equation error correlation as well as the cross-equation parametric equality. This will be discussed in detail in the next section.

B. Method and Procedures of Estimation

It is feasible to estimate the parameters of translog cost function (3-1) using ordinary least squares. This technique may be certainly attractive from the point of view of simplicity. However, it neglects the additional information contained in the factor share demand equations (3-4), which are also estimable. Furthermore, even for a modest number of factors of production, the translog cost function has a large number of regressors which, aside from the terms involving output, do not vary greatly across observation units. Hence, multicollinearity may be a problem, resulting in imprecise parameter estimates.

An alternative estimation procedure, followed by Berndt and Wood (1975), may be to estimate the factor share demand equations (3-4) as a multivariate regression system. This procedure was satisfactory for their purposes, since they assumed constant return to scale on the production structure as a maintained hypothesis.[3] Thus, their factor share demand equations included all the parameters of the cost function except for the neutral shift intercept, and no economic information was lost by not including the cost function in the estimation procedure. This approach is, however, not satisfactory when constant return to scale is not imposed, and particularly objectionable for our approach, in which a nonhomothetic production structure is postulated.

We infer that the optimal procedure is to jointly estimate the cost function and the factor share demand equations as a multivariate regression system. Inclusion of the factor share demand equations in the estimation procedure has the effect of adding many additional degrees of freedom without adding any unrestricted regression coefficients. A constrained regression technique is required to estimate our model to account for the fact that error terms across equations for corresponding observations are likely to be correlated in addition to the constraints of cross-equation parametric equality. Thus, Zellner's "seemingly unrelated regression" approach is appropriate for obtaining asymtotically efficient parameter estimates.[4] This will result in more efficient parameter estimates than would be obtained by applying ordinary least squares to the cost function alone.

The choice of Zellner's technique is based primarily on the study of Kmenta and Gilbert (1968) who investigated the properties of the Zellner's technique for both small samples of sizes 10 and 20 and large samples of size 100 under a variety of simulated conditions implementing Monte Carlo experiments.[5] They conclude that Zellner's procedure is preferable to either ordinary least squares or maximum likelihood method. As they state,

> ...the results do, in general, favor Zellner's two-stage Aitken estimator over the ordinary least squares and the maximum likelihood estimator. The ordinary least squares estimator is, for the most part, less efficient than the two-stage Aitken estimator. This appears to be true not only asymtotically but also in small samples. Further, the two-stage Aitken estimator does as well as the maximum likelihood estimator on average, even when the model is substantially misspecified.[6]

In small samples, the only case in which ordinary least squares was preferable to the Zellner's technique was one when there was no error correlation across equations. The only case in which a maximum likelihood procedure was preferable to the Zellner's technique occurred when the cross-equation error correlation was high and the correlation of the explanatory variables was very low. In practical applications, Kmenta and Gilbert found the differences in the Zellner estimates and the maximum likelihood estimates to be quite small.

Since the factor share demand equations are derived by differentiation, they do not contain the disturbance term from the cost function. We assume that the disturbances have a joint normal distribution. Following Zellner (1962), we allow nonzero correlation for a particular observation but impose zero correlations across observations. However, his proposed estimation procedure is not operational for our model. The estimated disturbance covariance matrix required to implement Zellner's procedure is singular because the disturbance on the factor share demand equations must sum to zero for each observation. Zellner's procedure can be made operational by deleting one of the factor share demand equations from the system. However, the estimates so obtained may not be invariant to which equation is deleted.

Barten (1969) has shown that maximum likelihood estimates of a system of share equations with one equation deleted are invariant to which equation is dropped.[7] In this connection, our estimation procedure will be the extension of his result to our multivariate system which includes the cost function with the factor share demand equations. Besides Kmenta and

Gilbert, Dhrymes (1970) has also shown that iteration of Zellner's estimation procedure until convergence results in maximum likelihood estimates.[8] We will employ the iteration of Zellner's procedure for estimating our empirical model, since it is a computationally efficient method for obtaining maximum likelihood estimates.

In addition, given that the parameters in our multivariate system (3-6) are estimated, with the M_n equation arbitrarily deleted, the values of the parameters not included in the estimating equations can be computed by using the adding-up parametric restrictions in (3-5). However, this does not provide direct estimates of the asymtotic standard errors for all parameters, so an alternative procedure is used in which an additional combination of the factor share demand equations (with M_p equation arbitrarily deleted this time) are estimated with the cost function. The only advantage of this procedure is to obtain the direct estimates of the asymptotic standard errors for all parameters.

C. Test of Null Hypotheses on Nonhomothetic Translog Specification

As previously mentioned, our empirical model represents a nonhomothetic production structure. This translog specification does not constrain the structure of production to be homothetic or homogeneous, nor does it impose restrictions on the elasticities of substitution. However, this specification is convenient in that the alternative specification of null hypotheses can be statistically tested by imposing the relevant parametric restrictions on it.

A cost function corresponds to a homothetic production structure if and only if the cost function can be written as a separable function in output and factor prices. A homothetic production structure is further restricted to be homogeneous if and only if the elasticity of cost with respect to output is constant.[9] The Allen partial elasticities of substitution can all be restricted to unity by eliminating the second-order terms in factor prices from the translog cost function. The homotheticity and other restrictions for the translog cost function are summed up in the following:

$r_{yi} = 0$	Homothetic restrictions	(3-7)
$r_{yi} = 0$; $r_{yy} = 0$	Homogeneous restrictions	(3-8)
$r_{ij} = 0$	Unitary elasticities of substitution restrictions	(3-9)

We will perform the joint F-test of our nonhomothetic model for the null hypotheses of four alternative specifications. As shown in the table 3.1, we consider four alternative models in addition to the nonhomothetic Model I. Model II imposes homotheticity, and Model III imposes homogeneity. Models II' and III' correspond to Models II and III, respectively, with unitary elasticities of substitution imposed in each case. The test statistic is, then, the weighted change in the residual sum of squares (restricted minus unrestricted) divided by the weighted unrestricted residual sum of squares accounting for degrees of freedom as appropriate. The calculated test statistic is asymtotically distributed as $F(v_1,v_2)$, where v_1 is the number of restrictions and v_2 is the number of residual degrees of freedom.

In addition, we will ascertain the estimated elasticity measures in view of a priori expectations. There are no a priori expectations for the signs of the estimated parameters in the system of estimating equations. However, the own price and Allen elasticities are expected to be negative based on our a priori expectations.

Table 3.1

Models for Alternative Specifications

Models	Production Structures	Restrictions
Model I	Nonhomotheticity	———
Model II	Homotheticity	$r_{yi}=0$
Model III	Homogeneity	$r_{yi}=0$, $r_{yy}=0$
Model II'	Homotheticity and Unitary Elasticities of Substitution	$r_{yi}=0$, $r_{ij}=0$
Model III'	Homogeneity and Unitary Elasticities of Substitution	$r_{yi}=0$, $r_{yy}=0$, $r_{ij}=0$

If one or more of the A_{ii} are significantly positive, then our translog specification is questionable. Furthermore, if all $A_{ij} = 1$, $i \neq j$, then that implies a Cobb-Douglas specification. If all $A_{ij} = 0$, $i \neq j$, then that implies the Leontief fixed proportions specification. And finally, if all $A_{ij} = k$, $i \neq j$, then that implies a CES specification.

The price and Allen elasticities are computed by cost shares and estimated parameters using the formulas in (2-29) and (2-31). Clearly, these elasticities vary over the sample as the cost shares vary. However, only the elasticities at the means of the data are reported in this study. The associated standard errors for the elasticities are calculated using the same formulas, since they are functions of the standard errors of relevant parameters and the corresponding cost shares.

D. The Data

In this study, statistical data from Report on Mining and Manufacturing Census of Korea will primarily be used for the cross-sectional analysis of the demand for factor inputs for total manufacturing and each of 2-digit manufacturing industries in Korea. The years 1973 and 1978 are the most recent years of the mining and manufacturing census survey, which is statutorily conducted every five years by the National Bureau of Statistics, Economic Planning Board of the Government of Republic of Korea. This census covers all the establishments that are operating with five or more workers engaged as of the end of the corresponding years.

Each of the 2-digit industries is divided up to 5-digit subindustries by the industry number. We will use these subindustries as the observation units for the present study, assuming that the cost function parameters are the same for subindustries within a 2-digit industry, but may differ across different industries. The data is available for (1) number of establishments; (2) number of workers,[10] (3) number of employees, production workers and nonproduction workers, (4) employees' remunerations,[11] (5) value added, (6) direct production cost,[12] (7) gross output,[13] (8) value of shipments, (9) fixed capital stock which is broken down into land, buildings and structures, machinery and equipment, tools and furniture, and vehicles and transport equipment, (10) average hours worked per employee for each 2-digit industry. What follows provides a brief description of the data to be utilized for each variable in our empirical model:

1. Output(Y): Gross output will be employed to proxy the quantity of output, with data utilized from the Report on Mining and Manufacturing Census. Unless otherwise mentioned hereafter, all data are available from this source.
2. Capital Inputs: It is assumed that capital service flows are proportional to the capital stocks. Thus, the amount of fixed capital stock (net of land) will proxy the corresponding capital service flows.

3. Labor Inputs: We will calculate the amount of labor services in terms of manhours, combining the data on number of workers for each observation unit and the average hours worked per employee by 2-digit industry. The average hours worked per employee is available from Report on Monthly Labor Survey published by the Ministry of Labor. Since the workers include working proprietors and unpaid family workers as well as employees, we here assume not only that the working proprietors and unpaid family workers work the same average hours as the employees, but also that the average hours worked per employee is the same for subindustries within a 2-digit industry but may differ across different industries. We include working proprietors and unpaid family workers in the category of nonproduction workers who are defined as those engaged in the administrative and other nonproduction activities.

4. Prices of Factor Inputs

   A) Prices of Labor Input: Since data on number of production workers and nonproduction workers, employees' remunerations for each category of workers, and average hours worked per employee are readily available, we will be able to construct the effective hourly money wage rate, based on the assumption as postulated to calculate the amount of labor input in the previous paragraph. Prices of labor input are computed by dividing total remunerations for each category of workers by corresponding total manhours.

B) Prices of Capital Input: The inadequacy of available data precludes us from following the procedures outlined by Christensen and Jorgenson (1969). We will use the familiar concept of value added which has been employed by the national income accountants as a device for allocating the origins of national income to the services of the primary inputs, capital and labor. Nominal value added, $P_v V$, is composed of labor share and capital share,

$$P_v V = P_k K + P_l L$$

where V is real value added and P_v is the price deflator of value added. Several economists employ the definition of value added to construct the price data of capital services especially for the purpose of analyzing cross-section data.[14] Virtually all empirical studies of investment demand and capital-labor substitutability have assumed a value added specification of technology. Thus, the capital service prices data are constructed as value added minus total labor compensation divided by the amount of fixed capital stock.

CHAPTER III——NOTES

[1]Humphrey and Moroney (1975) have made this assumption in their study of American manufacturing industries.

[2]To avoid the problems created by singularity of the contemporaneous covariance matrix, we delete one of the factor share demand equations before carrying out the Zellner's iteration procedure of "seemingly unrelated regressions." The resulting estimates are asymptotically equivalent to maximum likelihood estimates, as well as invariant to which equation is deleted.

[3]See Berndt, Ernst R., and David O. Wood, 1975, "Technology, Prices, and the Derived Demand for Energy," Review of Economics and Statistics, vol. 57, no. 3 (August), pp. 259-268.

[4]See Zellner, Arnold, 1962, "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias," Journal of American Statistical Association, vol. 57, no. 298 (June), pp. 348-368.

[5]See Kmenta, Jan, and Roy F. Gilbert, 1968, "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions," Journal of American Statistical Association, vol. 63, no. 324 (December), pp. 1180-1200.

[6]ibid., p. 1199.

[7]See Barten, A. P., 1969, "Maximum Likelihood Estimation of a Complete System of Demand Equations," European Economic Review, vol. 1, no. 1 (Fall), p. 16.

[8]Dhrymes, Phoebus J., 1969, "Equivalence of Iterative Aitken and Maximum Likelihood Estimates for a System of Regression Equations," Unpublished, University of Pennsylvania.

[9]See Diewert, 1974, for formal statements and derivations of the restrictions for homotheticity and homogeneity.

[10]Total workers cover working proprietors, unpaid family workers and employees (production and nonproduction workers).

[11]Total employees' remunerations are divided into those for production workers and nonproduction workers.

[12]Direct production cost here indicates those intermediate input costs covering raw materials, fuels, electricity purchased, water purchased, contract work, and repair and maintenance.

[13]Gross output is defined as the sum of value added and direct production cost.

[14]For one, Kwon and Williams (1982) follow this method for the calculation of price data of capital services for each observation unit in their cross-section analysis applying the translog cost function. Also, Kwon recommended in correspondence with the author that this is a useful one in cross-section studies.

CHAPTER IV

THE EMPIRICAL RESULTS

This chapter presents the results of estimating the translog cost function model for overall manufacturing and 2-digit manufacturing industries of Korea in 1973 and 1978. Among the empirical results of interest to be discussed are (1) the test of null hypotheses for alternative specification of production technology on the nonhomothetic translog cost function model, (2) the Allen partial elasticities of substitution between pairs of three primary factor inputs; production labor, nonproduction labor and capital input, and (3) the own price elasticities of demand for each of the three factor inputs.

A. Empirical Results for All Manufacturing

The translog cost function model in (3-6) was estimated for overall manufacturing, respectively, for 1973 and 1978 cross-section data. As mentioned previously, the specification of our empirical model does not restrict the production structure to be homothetic or homegeneous, nor does it constrain the Allen partial elasticities of substitution. We performed the joint F-test on the nonhomothetic model against the null hypotheses corresponding to four alternative specifications of production technology; (i) homotheticity (Model II), (ii) homogeneity (Model III), (iii) homotheticity and unitary elasticities of substitution (Model II'), and (iv) homogeneity and unitary elasticities of substitution (Model III').

The test results are shown for both cross-section data in Table 4.1. The calculated F-values for each null hypothesis that our nonhomothetic model can be actually reduced to the corresponding alternative specification of production technology ranges from 19.5 to 86.5, far exceeding the critical values at .01 significance level, which account for the appropriate degrees of freedom.[1] It is evident that all of the null hypotheses are rejected at any reasonable confidence interval. The very high test statistics strongly imply that the preferred model is actually nonhomothetic.

The comparison of the test results from both cross-section data sets indicates also that, basically, there has not been any noticeable structural change in the technology of production in Korean overall manufacturing industry during the period under review. It is inappropriate to adequately describe the features of technology of Korean manufacturing as a whole with the homothetic, homogeneous or Cobb-Douglas production functions.

In Table 4.2, the estimated parameters and standard errors of the preferred nonhomothetic model are reported for 1973 and 1978 data. Almost all the parameter estimates in our system of estimating equations are significantly different from zero in both cross-section data. Only one

Table 4.1

F-Test of Nonhomothetic Model for Alternative Specifications for All Manufacturing

Hypotheses	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
1973 Data						
(HT)	2	738	28.911	4.66	.01	Rejected
(HG)	3	738	19.525	3.83	.01	Rejected
(HT-UE)	5	738	83.678	3.06	.01	Rejected
(HG-UE)	6	738	69.909	2.85	.01	Rejected
1978 Data						
(HT)	2	1050	86.489	4.62	.01	Rejected
(HG)	3	1050	58.864	3.80	.01	Rejected
(HT-UE)	5	1050	60.599	3.04	.01	Rejected
(HG-UE)	6	1050	51.244	2.82	.01	Rejected

Note: We denote the homothetic restriction by (HT); homogeneity restriction by (HG); homotheticity and unitary elasticity of substitution by (HT-UE); and homogeneity and unitary elasticity of substitution by (HG-UE).

Table 4.2

Parameter Estimates for Translog Cost Function, Overall Manufacturing

Parameters	1973	1978
a_k	-.24185 (.095282)	-.18591 (.073001)
a_p	.91226 (.078392)	.76825 (.067758)
a_n	.32959 (.038421)	.41766 (.027641)
r_{yk}	.033507 (.004408)	.033729 (.003100)
r_{yp}	-.025173 (.003631)	-.021016 (.002873)
r_{yn}	-.008334 (.001771)	-.012714 (.001163)
r_{kk}	.090978 (.006648)	.037156 (.007368)
r_{pp}	.057660 (.007937)	.024708 (.008351)
r_{nn}	.043040 (.006262)	.047808 (.006785)
r_{kp}	-.052799 (.005604)	-.007028 (.006445)
r_{kn}	-.038179 (.002567)	-.030128 (.003003)
r_{pn}	-.004861 (.006313)	-.017680 (.006387)
Number of observations	249	353

Note: The numbers in parentheses represent asympototic standard errors.

parameter estimate (r_{pn}) is statistically insignificant at .95 confidence interval in 1973, while all the parameter estimates except one (r_{kp}) are significant in 1978.

The estimated Allen elasticities of substitution and price elasticities of input demand are illustrated for the preferred nonhomothetic translog cost function in Tables 4.3 and 4.4 respectively. Let's examine the results of estimated elasticities for 1973 first. All the estimates for Allen elasticities of substitution and price elasticities of input demand are statistically significant at any reasonable confidence interval. Moreover, all the own price elasticities (E_{ii}) and Allen elasticities of substitution (A_{ii}) are significantly negative as expected. The diversity of Allen partial elasticities of substitution also implies a rejection of the Cobb-Douglas, fixed proportions, and CES specifications.

As the results show, the Allen partial elasticities of substitution have all positive signs. This implies that each factor input is a substitute for all the other factor inputs. Consequently, changes in relative prices of one factor will cause the substitution toward all the other inputs. The Allen partial elasticity of substitution between production labor and nonproduction labor is the highest (A_{pn} = .81) but less than one. The elasticity of substitution between production labor and capital (A_{kp} = .67) is greater than the corresponding elasticity between nonproduction labor and capital (A_{kn} = .43). This is to say that an increase in the

Table 4.3

Estimates for Allen Elasticities of Substitution, Overall Manufacturing

Elasticities	1973	1978
A_{kk}	-.317562 (.015578)	-.465812 (.017834)
A_{pp}	-2.133861 (.133804)	-2.618848 (.134792)
A_{nn}	-4.649166 (.588310)	-4.157222 (.571832)
A_{kp}	.668153 (.035224)	.956071 (.040285)
A_{kn}	.433537 (.038079)	.567328 (.043129)
A_{pn}	.806543 (.251229)	.344299 (.236892)

Note: The numbers in parentheses indicate asymptotic standard errors.

Table 4.4

Estimates for Price Elasticities of Input Demand, Overall Manufacturing

Elasticities	1973	1978
E_{kk}	-.207456 (.010176)	-.299415 (.011463)
E_{pp}	-.519702 (.032588)	-.651831 (.033550)
E_{nn}	-.479654 (.060696)	-.450352 (.062629)
E_{kp}	.162729 (.008579)	.237966 (.010027)
E_{pk}	.436491 (.023011)	.614543 (.258943)
E_{kn}	.044728 (.003929)	.061459 (.004672)
E_{nk}	.283221 (.024876)	.364667 (.027723)
E_{pn}	.083211 (.025919)	.037298 (.025663)
E_{np}	.196434 (.061187)	.085696 (.058962)

Note: The numbers in parentheses show asymptotic standard errors.

relative prices of capital has greater effect on the quantity of production labor used than the quantity of nonproduction labor.

The transformation from A_{ij} to E_{ij} is sign preserving, and therefore the general relations of substitutes or complements between inputs identified from the Allen partial elasticities of substitution remain the same. The cross price elasticity of demand for labor input given a change in the price of capital is lower for nonproduction labor (E_{nk} = .28) than for production labor (E_{pk} = .44). The cross price elasticity of demand for capital given the change in the price of nonproduction labor is the lowest (E_{kn} = .045) among all the corresponding elasticities of input demand.

The own price elasticity of demand for a factor input measures the relative change in the quantity of the factor input demanded due to a relative change in its own price. We find that the factor share demand functions are downward sloping, all showing the negative signs of E_{ii}. The estimated own price elasticity of demand is higher for production labor (E_{pp} = -.52) than for nonproduction labor (E_{nn} = -.48), while that for capital input (E_{kk} = -.21) is the lowest.

Now let's turn to discuss the results of estimated elasticities for 1978 data. All the estimated Allen elasticities and price elasticities are statistically significant except three (A_{pn}, E_{pn} and E_{np}). As expected, the own price elasticities (E_{ii}) and Allen elasticities of substitution (A_{ii})

are all significantly negative. The estimated Allen partial elasticities of substitution are consistent with those for 1973 in that each factor input is a substitute for the other factor inputs. The elasticity of substitution between production labor and capital (A_{kp} = .96) is also higher than that between nonproduction labor and capital (A_{kn} = .58).

When compared to those in 1973, capital input became more substitutable with both production and nonproduction workers. The estimated A_{kp} was increased by .29, whereas A_{kn} registered an increase of .13 during the period under review. Contrary to the results in 1973, production and nonproduction labor became the lowest substitutes with the corresponding elasticity (A_{pn}) which substantially decreased from .81 in 1973 to .34 in 1978, though the latter estimate is statistically insignificant.

The estimated own price elasticities show that production labor and capital become more responsive to their own prices than 1973. The production labor is also more own price elastic (E_{pp} = -.65) than nonproduction labor (E_{nn} = -.45) and capital (E_{kk} = -.30). Capital is also calculated to be the least elastic input to its own prices. The cross price elasticity of demand for labor input due to a change in the relative prices of capital is also estimated to be lower for nonproduction labor (E_{nk} = .36) than for production labor (E_{pk} = .61), although both cross price elasticities increased over time.

In summarizing the above results of all manufacturing for both cross-section data sets, we have observed two interesting results. We allow the approximation of occupation that nonproduction labor (white collar workers) is embodied with more human capital than production labor (blue collar workers.) The first result is that labor with a greater amount of human capital, although approximated by the occupation, is less easily substitutable for physical capital.

The second interesting result appears from the estimated own price elasticities. As labor acquires more human capital as approximated by occupation, the deirved demand for labor becomes less elastic with respect to its own prices. As our results show, $|E_{nn}| < |E_{pp}|$. It is a tenet of the theory of human capital that as a worker accumulates human capital specific to his occupation, both the employer and the worker have an increased incentive to continue his employment regardless of possible minor wage fluctuations.[2] This implies that the demand for labor having much specific human capital will be less wage elastic than will the demand for labor with less specific human capital. The disaggregation of labor by occupation in our model may provide the best approximation for human capital ownership. For example, white collar professionals require a great deal of specific training, compared to blue collar workers.

B. Empirical Results for 2-Digit Industries

In this section we present the empirical results for 2-digit manufacturing industries using both 1973 and 1978 cross-section data. To facilitate the exposition, each of 2-digit industries is given a short title as indicated in Table 4.5. Hereafter, specific reference to each of the industries is made by the short title only.

The nonhomothetic translog cost function model in (3-6) was tested against the null hypotheses corresponding to four alternative specifications of production structure. The test results are provided in Tables 4.12 through 4.19. As results show, all of the hypotheses are rejected at .05 significance level for each industry in 1973. However, the nonhomothetic model did not converge in the case of basic metals industry (37), in performing the Zellner's iteration procedure. The test statistics reported for this industry are those from the Model II (homothetic model). We can tell that in 1973 the homothetic translog function model is the most preferred one for this industry that we can obtain, since the other null hypotheses are rejected.

As for the test results of the 1978 cross-section, all of the null hypotheses are rejected for all the 2-digit industries except the paper industry (34). In the paper industry, none of the null hypotheses can be rejected at .05 significance level. This implies that this industry is representing the production structure of Model III' which is characterized by the homogeneity and the unitary elasticities of substitution. However, we will use the parameter estimates of Model III (homogeneous model) purely for the

Table 4.5

2-Digit Manufacturing Industries and Their Associated Short Titles

SIC Code	SIC Industry	Short Title
31	Food, Beverages and Tobacco	Food
32	Textile, Wearing Apparel and Leather	Textile
33	Wood and Wood Products including Furniture	Wood
34	Paper and Paper Products; Printing and Publishing	Paper
35	Chemicals and Petroleum, Coal, Rubber and Plastic Products	Chemicals
36	Non-metallic Mineral Products, except Petroleum and Plastic Products	Non-metallic Minerals
37	Basic Metal Industries	Basic Metals
38	Fabricated Metal Products, Machinery and Equipment	Machinery

estimation purpose of elasticities in this industry. Thus, the nonhomothetic model is preferred for seven out of the eight 2-digit industries. To sum, the Cobb-Douglas functional form is not an appropriate production or cost function specification for 2-digit industries, as was the case for overall manufacturing.

In the following discussion, we will start with the review of the estimated results for 1973 cross-section data. The parameter estimates and their standard errors of the preferred translog cost functions for 2-digit industries in 1973 are reported in Table 4.6. Almost all the parameter estimates of the cost function are significantly different from zero in each 2-digit industry except two industries; the paper (34) and the basic metals (37) industries. Out of six r_{ij} parameter estimates, only three estimates are statistically significant at .95 confidence interval in either paper (34) or basic metals industry (37). This is not a "bad" result because $r_{ij} = 0$, when $i \neq j$, implies the elasticity of substitution is equal to the Cobb-Douglas value of 1. However, our test results previously discussed indicate that none of the 2-digit industries is consistent with the Cobb-Douglas production structure. In addition, it should be noted here that the degrees of freedom are calculated as 3 times the actual number of observations minus the number of unrestricted regression parameters, since the same data are stacked up 3 times to jointly estimate the cost

Table 4.6

Parameter Estimates for Translog Cost Function, 2-Digit Manufacturing Industries, 1973

Parameter	Industry (31)	(32)	(33)	(34)
a_k	-.13182 (.17223)	-.76456 (.23855)	-.22079 (.13499)	.062704 (.32255)
a_p	.76596 (.12664)	1.30280 (.18592)	.81480 (.15129)	.86438 (.21970)
a_n	.36586 (.06662)	.46174 (.076653)	.40598 (.096527)	.072912 (.20749)
r_{yk}	.030436 (.007786)	.051154 (.010693)	.025150 (.006144)	.017194 (.015251)
r_{yp}	-.021741 (.005727)	-.036567 (.008339)	-.016638 (.006950)	-.025933 (.010297)
r_{yn}	-.008695 (.003015)	-.014587 (.003433)	-.008514 (.004459)	.008739 (.009691)
r_{kk}	.10306 (.013519)	.10864 (.017422)	.16718 (.014317)	.15002 (.034687)
r_{pp}	.045235 (.011076)	.075701 (.01477)	.089086 (.010819)	-.003063 (.020313)
r_{nn}	.030133 (.007761)	.005483 (.007969)	.074865 (.008717)	.088337 (.018818)
r_{kp}	-.059082 (.009866)	-.08943 (.013642)	-.090699 (.010924)	-.029312 (.019887)
r_{kn}	-.043981 (.005148)	-.019212 (.005683)	-.076478 (.004525)	-.12071 (.020182)
r_{pn}	.013847 (.00823)	.013729 (.009342)	.001613 (.008883)	.032373 (.018930)
Number of observations	41	38	10	20

Note: 1) The numbers in parentheses indicate asymptotic standard errors.

2)*The parameter estimates for homothetic translog cost function are illustrated for the Basic Metals Industry (37), since Zellner's iteration was not done for the nonhomothetic model.

Table 4.6 (continued)

Parameter Estimates for Translog Cost Function,
2-Digit Manufacturing Industries, 1973

Parameter	Industry (35)	(36)	(37)*	(38)
a_k	-.21670 (.22879)	-.51677 (.43920)	.86461 (.048066)	.071153 (.17610)
a_p	.91412 (.19271)	1.22065 (.29363)	.10105 (.034074)	.66571 (.14909)
a_n	.30258 (.070966)	.29612 (.17331)	.03434 (.017297)	.26314 (.059667)
r_{yk}	.034842 (.010688)	.042673 (.020763)	———	.018996 (.008173)
r_{yp}	-.026461 (.009016)	-.037584 (.013914)	———	-.011286 (.006947)
r_{yn}	-.008380 (.003281)	-.005089 (.008160)	———	-.007710 (.002792)
r_{kk}	.088341 (.018764)	.138537 (.017532)	-.029109 (.024334)	.079513 (.007754)
r_{pp}	.087462 (.018937)	.063482 (.018919)	.003257 (.013416)	.11158 (.011706)
r_{nn}	.064639 (.015163)	.034795 (.016827)	.032366 (.001304)	.089696 (.009801)
r_{kp}	-.055582 (.016181)	-.083612 (.013220)	.034959 (.015561)	-.050697 (.006940)
r_{kn}	-.032759 (.005879)	-.054925 (.006409)	.00585 (.009144)	-.028815 (.002842)
r_{pn}	-.031880 (.014080)	.020130 (.016219)	-.038216 (.010447)	-.060881 (.009877)
Number of observations	42	23	8	66

Note: 1) The numbers of parentheses indicate asymptotic standard errors.
2)*The parameter estimates for homothetic translog cost function are illustrated for the Basic Metals Industry (37), since Zellner's iteration was not done for the nonhomothetic model.

function and the two factor share demand equations. The number of unrestricted regression coefficients is 9 in the nonhomothetic model and 7 in the homothetic model. For example, the degree of freedom is calculated to be 17 for the preferred homothetic model of the basic metals industry (37), which has 8 actual observations.

The estimates for Allen elasticities of substitution and price elasticities of input demand in 1973 are reported in Tables 4.7 and 4.8 respectively. Almost all the elasticity estimates are significantly different from zero at .95 confidence interval in any 2-digit industry. The own price and Allen elasticities have the correct negative signs, which ascertain our a priori expectations. Further, the diversity of Allen partial elasticities of substitution also casts doubt on Cobb-Douglas, fixed proportions, or CES specifications.

The review of estimated elasticities of substitution in 2-digit industry classification in 1973 shows little difference in outcomes from those in all manufacturing. In all the industries, production labor and capital are substitutes, with the Allen partial elasticity of substitution (A_{kp}) ranging from .45 to 1.31. Nonproduction labor and capital are complements in only two industries, namely, the wood (A_{kn} = -.16) and the paper (A_{kn} = -.35) industries; the estimated A_{kn} is insignificant in the latter industry. In the meantime, production labor and nonproduction labor are

Table 4.7

Estimates for Allen Elasticities of Substitution, 2-Digit Manufacturing Industries, 1973

Elasticities	Industry (31)	(32)	(33)	(34)
A_{kk}	-.1459 (.0238)	-.4014 (.0518)	-.1597 (.0355)	-.2974 (.1080)
A_{pp}	-3.6010 (.4722)	-1.3798 (.1432)	-1.5236 (.1588)	-2.6651 (.2669)
A_{nn}	-6.2458 (.8864)	-8.5445 (.8136)	-1.6753 (.8128)	-1.7877 (.7599)
A_{kp}	.4879 (.0855)	.5198 (.0733)	.4532 (.0659)	.8125 (.1272)
A_{kn}	.3761 (.0730)	.6653 (.0990)	-.1623 (.0688)	-.3534 (.2263)
A_{pn}	1.9663 (.5743)	1.4319 (.2939)	1.0597 (.3286)	1.7457 (.4360)

Elasticities	Industry (35)	(36)	(37)	(38)
A_{kk}	-.2281 (.0369)	-.2705 (.0475)	-.2817 (.0372)	-.4012 (.0200)
A_{pp}	-1.8368 (.5160)	-1.7648 (.2421)	-5.8935 (.6679)	-1.1633 (.1559)
A_{nn}	-2.3617 (1.6822)	-5.1310 (1.3229)	-6.0454 (.5229)	-.2842 (.9160)
A_{kp}	.5934 (.1184)	.5078 (.0778)	1.3051 (.1358)	.7028 (.0407)
A_{kn}	.5164 (.0868)	.1985 (.0935)	1.1449 (.2266)	.5525 (.1003)
A_{pn}	-.7527 (.7741)	1.6385 (.5144)	-4.4003 (1.4763)	-1.1478 (.3484)

Note: The numbers in parentheses represent asymptotic standard errors.

Table 4.8

Estimates for Price Elasticities of Input Demand,
2-Digit Manufacturing Industries, 1973

	Industry			
Elasticities	(31)	(32)	(33)	(34)
E_{kk}	-.1099 (.0179)	-.2328 (.0300)	-.1015 (.0225)	-.1685 (.0612)
E_{pp}	-.5515 (.0723)	-.4431 (.0460)	-.3977 (.0414)	-.7352 (.0736)
E_{nn}	-.5844 (.0829)	-.8456 (.0805)	-.1735 (.0842)	-.2813 (.1196)
E_{kp}	.0747 (.0131)	.1669 (.0235)	.1183 (.0172)	.2242 (.0351)
E_{pk}	.3675 (.0644)	.3014 (.0425)	.2879 (.0419)	.4605 (.0721)
E_{kn}	.0352 (.0068)	.0658 (.0098)	-.0168 (.0071)	-.0556 (.0356)
E_{nk}	.2833 (.0550)	.3858 (.0574)	-.1031 (.0437)	-.2003 (.1282)
E_{pn}	.1840 (.0537)	.1417 (.0291)	.1097 (.0340)	.2747 (.0686)
E_{np}	.3011 (.0880)	.4599 (.0944)	.2766 (.0858)	.4816 (.1203)

Note: The numbers in parentheses represent asymptotic standard errors.

Table 4.8 (continued)

Estimates for Price Elasticities of Input Demand,
2-Digit Manufacturing Industries, 1973

Elasticities	Industry (35)	(36)	(37)	(38)
E_{kk}	-.1627 (.0263)	-.1644 (.0289)	-.2277 (.0301)	-.2498 (.0125)
E_{pp}	-.3519 (.0988)	-.4934 (.0677)	-.8353 (.0947)	-.3188 (.0427)
E_{nn}	-.2242 (.1597)	-.5787 (.1492)	-.3018 (.0261)	-.0294 (.0948)
E_{kp}	.1137 (.0227)	.1420 (.0218)	.1850 (.0193)	.1926 (.0111)
E_{pk}	.4233 (.0845)	.3086 (.0473)	1.0550 (.1098)	.4375 (.0253)
E_{kn}	.0490 (.0082)	.0224 (.0105)	.0572 (.0113)	.0572 (.0104)
E_{nk}	.3684 (.0619)	.1206 (.0568)	.9255 (.1831)	.3439 (.0275)
E_{pn}	-.0715 (.0735)	.1848 (.0580)	.2197 (.0737)	-.1187 (.0360)
E_{np}	-.1442 (.1483)	.4580 (.1438)	.6237 (.2092)	-.3145 (.0955)

Note: The numbers in parentheses represent asymptotic standard errors.

estimated to be substitutable except in three industries; chemical (A_{pn} = -.75), basic metals (A_{pn} = -4.40), and machinery (A_{pn} = -1.15). The estimate for A_{pn} is significant except for the chemicals industry (35). The fact that conforms to the results of overall manufacturing is that capital is more easily substitutable with production labor than with nonproduction labor in all the industries except for the textile industry (32).

The estimated own price elasticities also indicate that capital is the least elastic with respect to its own price in each industry. Production labor is more responsive to its own prices than nonproduction in five industries. In the meantime, nonproduction labor is more own price elastic than production labor in the remaining three industries; food (31), textile (32), and non-metallic minerals (36) industries. The estimated cross price elasticity of demand for labor input due to a change in the prices of capital is also lower for nonproduction labor than for production labor, except for the textile industry (32).

Now, let us turn to examine the results for 1978 cross-section data. The estimated parameters and their standard errors for the preferred translog cost function model are reported for 2-digit industries in Table 4.9, while the associated Allen and price elasticities are illustrated in Tables 4.10 and 4.11 respectively. Since homogeneity cannot be rejected for the paper industry (34), the homogeneous

Table 4.9

Parameter Estimates for Translog Cost Function, 2-Digit Manufacturing Industries, 1978

	Industry			
Parameter	(31)	(32)	(33)	(34)*
a_k	-.52418 (.20857)	-.11002 (.17172)	-.10902 (.24506)	.66423 (.04654)
a_p	.94300 (.15717)	.78248 (.14605)	.73411 (.21751)	.17753 (.046546)
a_n	.58119 (.10371)	.32754 (.070046)	.37491 (.06435)	.15824 (.028007)
r_{yk}	.046842 (.008934)	.025296 (.007333)	.021556 (.010174)	———
r_{yp}	-.027810 (.006702)	-.016909 (.006267)	-.013322 (.008864)	———
r_{yn}	-.019032 (.004355)	-.008387 (.002980)	-.008234 (.002690)	———
r_{kk}	.086046 (.014417)	.095824 (.017431)	.15006 (.047459)	-.049200 (.027023)
r_{pp}	.062959 (.013910)	.054337 (.017084)	.063837 (.047509)	-.11859 (.046961)
r_{nn}	.008525 (.014979)	.048982 (.010578)	.053876 (.010302)	-.11832 (.051442)
r_{kp}	-.070240 (.010815)	-.050590 (.015442)	-.080011 (.044103)	.024733 (.026752)
r_{kn}	-.015806 (.007080)	-.045235 (.004765)	-.070051 (.011024)	.024468 (.019430)
r_{pn}	.007281 (.012976)	-.003747 (.010513)	.016174 (.012179)	.093852 (.044005)
Number of observations	42	56	19	25

Note: 1) The numbers in parentheses represent asymptotic standard errors.

2)*The parameter estimates for homogeneous translog cost function are reported for the Paper Industry (34), since the null hypotheses of homotheticity and homogeneity cannot be rejected at .05 significance level.

Table 4.9 (continued)

Parameter Estimates for Translog Cost Function, 2-Digit Manufacturing Industries, 1978

	Industry			
Parameter	(35)	(36)	(37)	(38)
a_k	.26137 (.17273)	.11767 (.28782)	.73540 (.55669)	-.12392 (.09422)
a_p	.35891 (.15299)	.51758 (.27700)	-.11566 (.46130)	.67977 (.08986)
a_n	.37972 (.05893)	.36475 (.08823)	.38026 (.14596)	.44415 (.04600)
r_{yk}	.020966 (.007132)	.023177 (.011897)	.003549 (.021395)	.028587 (.004073)
r_{yp}	.008832 (.006302)	-.011765 (.011520)	.009749 (.017742)	-.014956 (.003863)
r_{yn}	-.012134 (.002398)	-.011412 (.003681)	-.013298 (.005506)	-.013631 (.001944)
r_{kk}	-.035670 (.016976)	.009238 (.025150)	-.11474 (.057185)	.077399 (.011766)
r_{pp}	-.021302 (.019718)	.005939 (.022848)	-.047553 (.045912)	.059613 (.014487)
r_{nn}	-.004940 (.016483)	.062346 (.015459)	.050085 (.035812)	.095096 (.012638)
r_{kp}	.026016 (.014807)	.023585 (.021645)	.10619 (.046773)	-.020958 (.010691)
r_{kn}	.009654 (.006471)	-.032823 (.008739)	.008549 (.017816)	-.056441 (.005618)
r_{pn}	-.004714 (.015574)	-.029523 (.014055)	-.058634 (.031877)	-.038655 (.011501)
Number of observations	60	26	13	112

Note: 1) The numbers in parentheses represent asymptotic standard errors.
2)*The parameter estimates for homogeneous translog cost function are reported for the Paper Industry (34), since the null hypotheses of homotheticity and homogeneity cannot be rejected at .05 significance level.

model is preferred for this industry, as indicated by an asterick in Table 4.9. The parameter estimates of the translog cost function are generally significant except for three industries; paper (34), chemicals (35), and basic metals (37) industries. These results are not so good as those of 1973 cross-section data, but acceptable for our practical purpose of estimating the elasticites.

As shown in Tables 4.10 and 4.11, the estimated Allen elasticities of substitution and price elasticities of input demand are generally significant at the .95 confidence interval in each industry. The own price and Allen elasticities have the correct negative signs, again conforming to our a priori expectations. The diversity in the values of the Allen partial elasticities of substitution also implies a rejection of conventional production specifications. It is here noted that, as mentioned earlier, the null hypotheses for alternative technology specifications cannot be rejected only in the paper industry (34), which is resultantly characterized by a homogeneous production structure with unitary elasticities of substitution.

Reviewing the Allen partial elasticities of substitution, the results are generally similar to those of 1973 data. Production labor and capital are also substitutes in each of 2-digit industries. The Allen partial elasticities of substitution between production labor and capital (A_{kp}) range from .43 to 1.76. Nonproduction labor and capital are

Table 4.10

Estimates for Allen Elasticities of Substitution, 2-Digit Manufacturing Industries, 1978

Elasticities	Industry (31)	(32)	(33)	(34)
A_{kk}	-.2096 (.0271)	-.4103 (.0493)	-.2917 (.1458)	-.7060 (.0677)
A_{pp}	-2.7131 (.4873)	-1.6953 (.1838)	-1.5156 (.4709)	-5.0056 (.7723)
A_{nn}	-7.9982 (1.4445)	-4.1013 (1.0519)	-3.6342 (.8238)	-15.2278 (3.4795)
A_{kp}	.4299 (.0878)	.7210 (.0851)	.5585 (.2434)	1.1587 (.1717)
A_{kn}	.7871 (.0954)	.2417 (.0799)	-.0979 (.1728)	1.3185 (.2529)
A_{pn}	1.4232 (.7542)	.8774 (.3439)	1.4554 (.3429)	4.1304 (1.4677)

Elasticities	Industry (35)	(36)	(37)	(38)
A_{kk}	-.4492 (.0324)	-.5008 (.0583)	-.6154 (.1109)	-.4652 (.0334)
A_{pp}	-5.4503 (.6512)	-2.8389 (.3530)	-1.3894 (1.1891)	-1.7774 (.1788)
A_{nn}	-9.2840 (1.5858)	-2.3457 (1.9681)	-3.8448 (4.8962)	-.8027 (.8509)
A_{kp}	1.2065 (.1175)	1.1411 (.1295)	1.7527 (.3315)	.8759 (.0633)
A_{kn}	1.1308 (.0877)	.4363 (.1501)	1.1392 (.2901)	.2196 (.0777)
A_{pn}	.7343 (.8779)	-.3094 (.6233)	-2.4892 (1.8968)	-.1143 (.3315)

Note: The numbers in parentheses represent asymptotic standard errors.

Table 4.11

Estimates for Price Elasticities of Input Demand, 2-Digit Manufacturing Industries, 1978

Elasticities	Industry (31)	(32)	(33)	(34)
E_{kk}	-.1528 (.0198)	-.2441 (.0293)	-.1664 (.0832)	-.4461 (.0428)
E_{pp}	-.4584 (.0823)	-.5169 (.0560)	-.4814 (.1496)	-1.2343 (.1904)
E_{nn}	-.8145 (.1471)	-.4113 (.1055)	-.4064 (.0921)	-1.8515 (.4231)
E_{kp}	.0726 (.0148)	.2198 (.0260)	.1774 (.0773)	.2857 (.0423)
E_{pk}	.3135 (.0640)	.4289 (.0506)	.3186 (.1389)	.7321 (.1085)
E_{kn}	.0802 (.0097)	.0242 (.0080)	-.0109 (.0193)	.1603 (.0308)
E_{nk}	.5740 (.0695)	.1438 (.0475)	-.0558 (.0986)	.8330 (.1598)
E_{pn}	.1449 (.0768)	.0880 (.0345)	.1628 (.0383)	.5022 (.1785)
E_{np}	.2405 (.1274)	.2675 (.1048)	.4623 (.1089)	1.0185 (.3619)

Note: The numbers in parentheses represent asymptotic standard errors.

Table 4.11 (continued)

Estimates for Price Elasticities of Input Demand,
2-Digit Manufacturing Industries, 1978

	Industry			
Elasticities	(35)	(36)	(37)	(38)
E_{kk}	-.3252 (.0234)	-.3290 (.0383)	-.4418 (.0796)	-.2761 (.0198)
E_{pp}	-.9484 (.1133)	-.7222 (.0898)	-.2730 (.2336)	-.5059 (.0509)
E_{nn}	-.9465 (.1617)	-.2079 (.1744)	-.3288 (.4187)	-.0978 (.1037)
E_{kp}	.2099 (.0205)	.2903 (.0329)	.3444 (.0651)	.2493 (.0180)
E_{pk}	.8735 (.0851)	.7497 (.0851)	1.2584 (.2380)	.5199 (.0376)
E_{kn}	.1153 (.0089)	.0387 (.0133)	.0974 (.0248)	.0268 (.0095)
E_{nk}	.8187 (.0635)	.2866 (.0986)	.8180 (.2083)	.1304 (.0461)
E_{pn}	.0749 (.0895)	-.0274 (.0552)	-.2129 (.1622)	-.0139 (.0404)
E_{np}	.1278 (.1528)	-.0787 (.1586)	-.4891 (.3727)	-.0325 (.0944)

Note: The numbers in parentheses represent asymptotic standard errors.

also substitutable each other, except for only the wood industry (33), where the A_{kn} estimated at -.098 is statistically insignificant. On the other hand, production labor is estimated to be substitutable for nonproduction labor in all industries except three industries; non-metallic minerals (A_{pn} = -.31), basic metals (A_{pn} = -2.49), and machinery (A_{pn} = -.11) industries. However, the estimated A_{pn} is insignificant in all of these three industries. Capital input is also a better substitute for production labor than for nonproduction labor in six out of eight industries.

The factor share demand functions are all downward sloping with respect to their own prices as expected. In all the industries capital is less responsive to its own prices than production labor and nonproduction labor. Production labor is more own price elastic than nonproduction labor in five industries, while nonproduction labor is reported to be more responsive to its own prices than production labor in the remaining three industries; food (31), paper (34), and basic metals (37) industries.

As shown earlier in the results for all manufacturing and 1973 2-digit industry data, each factor input was reported to be inelastic to its own prices with an elasticity of demand which is less than one. The own price elasticity of demand for each input in 1978 cross-section is also less than unity in all the industries except the paper industry (34). In the paper industry, E_{pp} and E_{nn} are estimated to be -1.23 and -1.85 respectively, both estimates being statistically significant. Besides, the cross price elasticity of demand for labor input due to a change in the prices of capital is also lower for nonproduction labor than for production labor except in two industries; food (31) and paper (34) industries.

When compared to the estimated results of 1973, substitutability among factor inputs has been generally increased over time. The elasticity of substitution between production labor and capital has increased over the period under review in seven industries, whereas that between nonproduction labor and capital has grown during the same period in five industries. In addition, production labor and nonproduction labor also became more substitutable for each other in five industries than the previous period.

The own price elasticity of demand for each input has also been generally expanded over time. Capital became more responsive to its own prices in all the industries, and production labor became more elastic in six industries, whereas nonproduction labor became more own price responsive in five industries. The cross price elasticity of demand for production labor with respect to the prices of capital has been enlarged in seven industries, while the direction of change in the corresponding elasticity for nonproduction labor is relatively less clear-cut.

C. Summary of Relevant Previous Studies

It is instructive to compare the results discussed above with those of others. In recent years, many studies on both labor-labor and labor-capital substitution in the manufacturing sector of developed economies have appeared. Few of the studies, however, share similar methodologies. They are different in one or more of the following ways. First, studies differ according to the criterion chosen for labor force disaggregation. Second, they are different by choosing to estimate a cost function, treating factor prices as exogenous, or a production function, treating factor quantities as exogenous. Third, they are separated by their chosen data; estimates based on the time series data versus estimates from cross-section data. Finally, they may also differ in the choice of functional form and estimation procedures.[3] It should be noted that we know of no existing study for developing countries which explicitly disaggregates labor types that would allow us to draw comparison. Since all the previous studies are based on data for developed economies as opposed to a developing economy, the comparison of our results must be more qualitative than quantitative.

All the studies unanimously find that production labor and capital are substitutes, while almost all the studies estimate that nonproduction workers and production workers are substitutes. The studies of Denny and May (1978b), and Dennis and Smith (1978) are the only exceptions as to the substitutable relation between the two types of workers. Denny and May disaggregate capital into equipment and structures in their time series study of Canadian manufacturing, and show that production labor and nonproduction labor are very inelastic complements with the corresponding elasticity which ranges from -.500 in 1970 to -.28 in 1950.[4] In addition, Dennis and Smith (1978) report, including the real cash balances as an additional input, that two types of workers are complements in seven out of eleven selected disaggregated U.S. manufacturing sectors.[5] As shown in our discussion of the empirical results, production labor and nonproduction labor were also complements in three out of eight 2-digit industries. These may be possible, not surprising, results when we deal with disaggregated set of industry data.

In the meantime, the relationship between capital and nonproduction labor is relatively less clear-cut. The only cross-section studies of U.S. manufacturing by Freeman and Medoff (1982)[6] and Grant (1979) appropriately assuming wages exogenous indicate they are substitutes. However, most time series studies of U.S. manufacturing using either a cost function or (inappropriate) production function specification have estimated nonproduction labor and capital to be complements. Our results indicate the substitutability between capital and nonproduction workers.

The only time series study of U.S. manufacturing that reports the substitutability between capital and nonproduction workers is that of Dennis and Smith. Denny and May (1978b) also show that both types of capital, namely, equipment and structures, are substitutable with production and nonproduction workers in Canadian manufacturing. Likewise, in the time series study of Irish manufacturing which is disaggregated into 40 sectors, Boyle and Sloane (1982) find that nonproduction labor and capital are substitutes in almost every sector.[7]

Our findings indicate that the elasticity of substitution between production workers and capital is relatively high but generally less than one. It is interesting to note that captial is more substitutable with production workers than with nonproduction workers, which is in almost unanimous agreement with the previous studies. Denny and May (1978b) estimate that both equipment and structures are more easily substitutable with production labor than with nonproduction labor in Canadian manufacturing, while Boyle and Sloane (1982) also report that capital is generally a better substitute for production workers than for nonproduction workers in the Irish manufacturing industries. The only study that shows the greater substitutability between capital and nonproduction labor than between capital and production labor in the U.S. manufacturing industries is that by Dennis and Smith (1978).

The estimates for own price elasticities of factor demand in the previous studies are in close agreement with our findings. Almost all the studies estimate the own price elasticities of factor inputs to be less than one. Only the study of Berndt and Christensen (1974) reports them to be greater than one. In addition, production workers are calculated to be more own price elastic than nonproduction workers in all the previous studies except the studies of U.S. manufacturing by Berndt and Christensen (1974), and Freeman and Medoff (1982).

Table 4.12

F-Test of Nonhomothetic Model for Homotheticity Hypothesis for 2-Digit Industries, 1973

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	2	114	7.688	4.80	.01	Rejected
Textile(32)	2	105	11.831	4.82	.01	Rejected
Wood(33)	2	21	9.134	5.78	.01	Rejected
Paper(34)	2	51	4.059	3.18	.05	Rejected
Chemicals(35)	2	117	5.537	4.79	.01	Rejected
Non-metallic Minerals(36)	2	60	5.940	4.98	.01	Rejected
Basic Metals(37)*	—	—	—	—	—	—
Machinery(38)	2	189	4.213	3.06	.05	Rejected

Note: *As for the Basic Metals Industry(37), Zellner's iteration could not be done for the nonhomothetic model. So F-statistics is not reported in this table.

Table 4.13

F-Test of Nonhomothetic Model for Homogeneity Hypothesis for 2-Digit Industries, 1973

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	3	114	5.175	3.97	.01	Rejected
Textile(32)	3	105	7.917	3.98	.01	Rejected
Wood(33)	3	21	11.246	4.87	.01	Rejected
Paper(34)	3	51	2.815	2.79	.05	Rejected
Chemicals(35)	3	117	4.261	3.96	.01	Rejected
Non-metallic Minerals(36)	3	60	4.110	2.76	.05	Rejected
Basic Metals(37)*	1	17	27.257*	8.40	.01	Rejected
Machinery(38)	3	189	3.390	2.65	.05	Rejected

Note: *As for the Basic Metals Industry(37), F-statistics of homothetic model against the relevant hypothesis is reported in this table, because Zellner's iteration could not be performed for the nonhomothetic model.

Table 4.14

F-Test of Nonhomothetic Model for Homotheticity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1973

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	5	114	20.890	3.97	.01	Rejected
Textile(32)	5	105	16.137	3.98	.01	Rejected
Wood(33)	5	21	67.738	4.87	.01	Rejected
Paper(34)	5	51	10.398	4.20	.01	Rejected
Chemicals(35)	5	117	14.142	3.96	.01	Rejected
Non-metallic Minerals(36)	5	60	19.856	4.13	.01	Rejected
Basic Metals(37)*	3	17	23.297*	5.18	.01	Rejected
Machinery(38)	5	189	50.249	3.91	.01	Rejected

Note: *As for the Basic Metals Industry(37), F-statistics of homothetic model against the relevant hypothesis is reported in this table, because Zellner's iteration could not be performed for the nonhomothetic model.

Table 4.15

F-Test of Nonhomothetic Model for Homogeneity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1973

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	6	114	17.436	2.98	.01	Rejected
Textile(32)	6	105	13.465	2.99	.01	Rejected
Wood(33)	6	21	62.632	3.81	.01	Rejected
Paper(34)	6	51	8.882	3.18	.01	Rejected
Chemicals(35)	6	117	12.488	2.97	.01	Rejected
Non-metallic Minerals(36)	6	60	16.555	3.12	.01	Rejected
Basic Metals(37)*	4	17	26.767*	4.67	.01	Rejected
Machinery(38)	6	189	42.043	2.92	.01	Rejected

Note: *As for the Basic Metals Industry(37), F-statistics of homothetic model against the relevant hypothesis is illustrated in this table, because Zellner's iteration could not be performed for the nonhomothetic model.

Table 4.16

F-Test of Nonhomothetic Model for Homotheticity Hypothesis for 2-Digit Industries, 1978

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	2	117	14.273	4.79	.01	Rejected
Textile(32)	2	159	6.609	4.75	.01	Rejected
Wood(33)	2	48	4.764	3.19	.05	Rejected
Paper(34)*	2	66	1.719*	3.14	.05	Not Rejected*
Chemicals(35)	2	171	12.935	4.73	.01	Rejected
Non-metallic Minerals(36)	2	69	5.521	4.92	.01	Rejected
Basic Metals(37)	2	30	5.741	5.39	.01	Rejected
Machinery(38)	2	327	36.628	4.68	.01	Rejected

Note: *The null hypothesis cannot be rejected at .05 significance level.

Table 4.17

F-Test of Nonhomothetic Model for Homogeneity Hypothesis for 2-Digit Industries, 1978

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	3	117	9.580	3.98	.01	Rejected
Textile(32)	3	159	7.092	3.91	.01	Rejected
Wood(33)	3	48	3.928	2.80	.05	Rejected
Paper(34)*	3	66	1.224*	2.75	.05	Not Rejected*
Chemicals(35)	3	171	8.682	3.90	.01	Rejected
Non-metallic Minerals(36)	3	69	3.694	2.74	.05	Rejected
Basic Metals(37)	3	30	4.345	2.92	.05	Rejected
Machinery(38)	3	327	27.749	3.85	.01	Rejected

Note: *The null hypothesis cannot be rejected at .05 significance level.

Table 4.18

F-Test of Nonhomothetic Model for Homotheticity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1978

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	5	117	23.138	3.18	.01	Rejected
Textile(32)	5	159	24.042	3.14	.01	Rejected
Wood(33)	5	48	23.124	3.42	.01	Rejected
Paper(34)*	5	66	2.160*	2.36	.05	Not Rejected*
Chemicals(35)	5	171	6.920	3.13	.01	Rejected
Non-metallic Minerals(36)	5	69	5.712	3.29	.01	Rejected
Basic Metals(37)	5	30	6.855	3.70	.01	Rejected
Machinery(38)	5	327	46.285	3.08	.01	Rejected

Note: *The null hypothesis cannot be rejected at .05 significance level.

Table 4.19

F-Test of Nonhomothetic Model for Homogeneity with Unitary Elasticities of Substitution Hypothesis for 2-Digit Industries, 1978

Industry	Degree of Freedom df1	df2	Calculated F-Value	Critical F-Value	Significance Level	Remarks
Food(31)	6	117	19.291	2.98	.01	Rejected
Textile(32)	6	159	22.975	2.92	.01	Rejected
Wood(33)	6	48	19.270	3.20	.01	Rejected
Paper(34)*	6	66	1.859*	2.24	.05	Not Rejected*
Chemicals(35)	6	171	5.813	2.91	.01	Rejected
Non-metallic Minerals(36)	6	69	4.900	3.07	.01	Rejected
Basic Metals(37)	6	30	5.781	3.47	.01	Rejected
Machinery(38)	6	327	41.264	2.87	.01	Rejected

Note: *The null hypothesis cannot be rejected at .05 significance level.

CHAPTER IV—NOTES

[1]As noted earlier in Chapter III, the calculated test statistic is asymptotically distributed as $F(v_1, v_2)$, where v_1 is the number of restrictions and v_2 is the number of residual degrees of freedom. In our case, the former indicates the number of parametric restrictions, on the nonhomothetic model, corresponding to each alternative production structure, and the latter is computed as 3 times the actual number of observations minus the number of unrestricted regression coefficients on the cost function because the same data are stacked up 3 times to jointly estimate the cost function and the two factor share demand equations.

[2]See Becker, G. S. 1975, Human Capital A Theoretical and Empirical Analysis with Special Reference to Education, 2nd edition, National Bureau of Economic Research, pp. 16-37, specifically p. 34.

[3]For a thorough review of the literature on the studies of labor-labor and labor-capital substitution in U.S. manufacturing, see Hamermesh, Daniel S., and James Grant, 1979, "Econometric Studies of Labor-Labor Substitution and Their Implications for Policy," Journal of Human Resources, vol. 14, no. 4 (Fall), pp. 518-555.

[4]See Denny, Michael, and J. Douglas May, 1978b, "A Representation of Canadian Manufacturing Technology," Applied Economics, vol. 10, no. 4 (December), pp. 305-317.

[5]See Dennis, Enid, and V. Kerry Smith, 1978, "A Neoclassical Analysis of the Demand for Real Cash Balances by Firms," Journal of Political Economy, vol. 86, no. 5 (October), pp. 793-813.

[6]Freeman and Medoff (1982) further decompose labor into union and nonunion groups in their cross-section study of U.S. manufacturing. For further details see Freeman, Richard B., and James L. Medoff, 1982, "Substitution between Production Labor and Other Inputs in Unionized and Non-Unionized Manufacturing," Review of Economics and Statistics, vol. 64, no. 2 (May), pp. 220-233.

[7]See Boyle, G., and P. D. Sloane, 1982, "The Demand for Labour and Capital Inputs in Irish Manufacturing Industries," Economic and Social Review, vol. 13, no. 3 (April), pp. 153-170.

CHAPTER V

SUMMARY AND CONCLUSIONS

A. Summary of the Findings

1. All Manufacturing

Since all the null hypotheses for alternative specification of production structure are rejected for both 1973 and 1978 cross-section data, the nonhomothetic model is the most preferred one for overall manufacturing. This also implies that basically there has not been any noticeable structural change in the production technology in Korean overall manufacturing between 1973 and 1978.

Almost all the parameter estimates for the factor share demand functions are significantly different from zero. In addition, all the estimates for Allen elasticities of substitution and price elasticities of input demands are statistically significant at a reasonable confidence interval. Furthermore, all the own price elasticities and Allen elasticities of substitution are significantly negative as expected.

Each factor input is a substitute for all the other factor inputs with Allen partial elasticities of substitution which are less than one. Capital is relatively more substitutable for production labor than for nonproduction labor. This implies that a change in the relative prices of capital has a greater effect on the quantity of production labor used than the quantity of nonproduction labor.

The cross price elasticity of demand for labor input given a change in the prices of capital is higher for production labor than for nonproduction labor. Each factor input is responsive to its own prices. Production labor is more elastic to its own prices than nonproduction labor. Capital is the least elastic factor input.

When comparing the empirical results for 1973 and 1978 cross-section data, capital input became more easily substitutable with both production and nonproduction workers, while production workers became considerably less substitutable with nonproduction workers. With respect to its own prices, every factor input became more elastic in 1978 than in 1973. The cross price elasticity of labor demand with respect to the change in the prices of capital is also estimated to have increased over time for both production labor and nonproduction labor.

2. <u>2-Digit Manufacturing Industries</u>

In 1973, the nonhomothetic translog cost function model was the most preferred one for all the 2-digit manufacturing industries except for the basic metals industry, for which the Zellner's procedure of iterating the nonhomothetic model could not converge. The homothetic model is, however, the best model for the basic metals industry, since the other null hypotheses against homotheticity were rejected. As for

1978 cross-section data, the most preferred model was the nonhomothetic one for seven out of eight 2-digit industries, whereas only the paper industry represents a production structure characterized by homogeneity with unitary elasticities of substitution.

Generally, the estimates for the parameters of the cost function, and the Allen and price elasticities are statistically significant at .95 confidence interval for both cross-section data sets. The own price and Allen elasticities are all significantly negative as expected. Production workers and capital are estimated to be substitutes in all the industries. In 1973 nonproduction workers and capital are reported to be relatively good substitutes in six industries, and relatively weak complements in wood and paper industries, while in 1978 both inputs are substitutes in seven industries and weak complements only in the wood industry.

In the meantime, production and nonproduction workers are calculated to be complementary to each other in chemicals, basic metals and machinery industries in 1973, and in nonmetallic minerals, basic metals and machinery industries in 1978. Capital input is shown to be more substitutable with production labor than with nonproduction labor in almost all the industries. The substitutability between pairs of factor inputs has been generally increased over time.

Cross price elasticity of demand for labor input due to a change in the prices of capital is generally higher for production workers than for nonproduction workers. Each factor input is responsive to its own prices in every industry. Capital is the least elastic input to its own prices in all the industries, while production labor is more own price elastic than nonproduction labor except in the food, paper and basic metals industries. The own price elasticity of demand for each input has been generally expanded over the period under review.

B. Conclusions

In this study, we presented Zellner's "seemingly unrelated regression" estimates for the parameters of the translog cost function coupled with factor share demand equations to estimate the Allen elasticities of substitution and the price elasticities of factor demand. Our estimates for elasticities and parameters are generally significant at a reasonable confidence interval and the estimated own elasticities all conform to our a priori expectations. Thus, we may conclude that our translog function may be considered to be a reasonable approximation to a well-behaved analytic cost function.

The features of technology are characterized by nonhomothetic production structures not only for all manufacturing but also dominantly for 2-digit manufacturing industries in Korea. Accordingly, this fact casts doubt on the application of conventional production functional forms to analyze the input interrelations in Korea's manufacturing production processes.

Our study indicates that each factor input is a substitute for the other factor inputs in all manufacturing and that capital is more substitutable for production labor than for nonproduction labor. When we proxy the amount of human capital embodied in labor by occupation, we can approximate that nonproduction labor is embodied with more human capital relative to production labor. Therefore, it is inferred that the labor with greater amount of human capital is less easily substitutable for physical captial.

In his seminal work, Griliches (1969) set forth the hypothesis that, "skill or education is more complementary with physical capital than unskilled or raw labor." (See Griliches, 1969, p. 465). Our model provided in this study, which disaggregate labor by occupation, derived the estimates of the Allen partial elasticities of substitution which are consistent with the Griliches hypothesis. However, in our model the appropriate factor inputs are not estimated to be complements.

The other interesting result appears from the estimated own price elasticities of input demand. Our empirical results show that production labor is more elastic to its own prices than nonproduction labor. As labor has more human capital as approximated by occupation, the derived demand for labor becomes less elastic to its own prices. This implies that as a worker accumulates human capital, both the employer and the worker have a greater incentive to continue his employment regardless of possible minor wage fluctuations.

Based on the estimates for the elasticities of substitution for all manufacturing as shown in Table 4.3, we may safely conclude that the overall elasticity of substitution between capital and labor is considerably less than one. This low elasticity of substitution has an important employment-wage implication for Korean industrialization in that it has contributed to the rapid growth of employment and wages rather than impeding their growth. However, while the limited substitution among the factor inputs may temporarily moderate the effect of the wage increase on employment, it may not prevent the higher wage rate from forcing the producers toward labor-augmenting technologies in the long run. The displaced workers can be absorbed only through the rapid expansion of exports.

Investment tax credits or accelerated depreciation allowances will decrease the cost of implementing new capital and bring about a desired increase in capital accumulation. As each factor input is a substitute for the other inputs, there will be generated a substitution effect from labor to capital, reducing the demand for both types of workers given the level of output. Since the Allen partial elasticity of substitution of production workers for capital is higher than that of nonproduction workers, the production workers will be more adversely affected. In other words, the employment of less skilled, young workers would suffer under investment incentives as physical capital is substituted for these workers. The severity of such repercussions is measured by the estimated elasticity of substitution between physical capital and labor. However, it should be noted that, in view of the relatively inelastic demand for capital, the impact of these policy instruments on the factor mix between capital and labor will be moderate.

From our results we can conclude that the factor prices do play a role in the determination of the demand for factor inputs and the factor mix in production, though their role is relatively modest. The own price elasticities of demand for production labor are quite sizable, while the corresponding elasticities for capital are smaller than for labor. The evidence that demand for labor is relatively more responsive to its own prices compared to capital input suggests that greater attention be given to policy incentives, such as employment tax credits, which seek to stimulate employment by inducing movements along demand schedules.

As our empirical results show, the input interrelations are not homogeneous, though not substantially heterogeneous, across industries in the 2-digit classification. Under these circumstances, policy instruments uniformly applied to all the manufacturing industries may not result in desired outcomes in certain industries. Thus, it is recommended that the policy incentives should be differentiated according to the characteristics of input interrelations for disaggregated industry level. For example, as capital and nonproduction workers are shown to be complements in wood industry, the investment tax credits may be also desirable in an attempt to encourage the employment of nonproduction workers. Finally, the improvement of data is suggested which enables us to disaggregate labor input more desirably into several demographic characteristics for the more useful policy applications. Future research should concentrate on substitution among workers disaggregated by age, education, or sex rather than by the blue-collar-white-collar distinction.

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