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9. ABSTRACT
In the course of inquiry the author estimates manufacturing production functions for South Korean manufacturing industries. These estimates sheds light on the following questions:

1. Are there economies of scale in the production technologies of South Korea's manufacturing industries? If so, what is the potential and actual importance of the economies of scale in explaining output growth in South Korea's manufacturing industries?

2. What is the magnitude and extent of substitutability of factors in South Korea's manufacturing industries?

3. What is the extent of inter-industry variations of marginal products of factor?

4. Are the estimated production functions relevant for both small and large establishments?

5. Is the production process homothetic, i.e., are the output elasticities of inputs and the elasticity of substitution independent of the level of the factors of production?

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ECONOMIES OF SCALE AND PRODUCTION FUNCTIONS

IN SOUTH KOREAN MANUFACTURING

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA

By

CHONG HYUN NAM

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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CHAPTER I

INTRODUCTORY REMARKS

I-1. Introduction

Since the early 1960's South Korea has become one of the fastest growing economies among developing countries. Real GNP more than tripled during 1960-1973, rising from 1, 119.7 billion won in 1960 to 3, 534.3 billion won in 1973 measured at 1970 constant price. At the 1970 official exchange rate, that was equal to $3.54 billion for 1960 and $11.18 billion for 1973. That raised real per capita income from $140.9 to $337.0 in 1970 U. S. prices, despite population growth of 2.3 percent per year. One of the most significant features in the economic growth of South Korea is extremely fast growth in the manufacturing sector; the share of manufacturing in GNP rose from 10.8 percent in 1960 to 28.4 percent in 1973.

The South Korean experience is of great importance for other developing countries. This is especially so since the rapid growth of the South Korean manufacturing sector vividly illustrates the possibility of rapidly reducing reliance upon agriculture and primary commodities; the share of the agriculture, forestry and fishery sectors in GNP fell from 41.3 percent in 1960 to 22.6 percent in 1973, despite a real rate of growth of that sector of 3.8 percent. Although there have been some features special to South Korea's development -- e.g., large foreign aid flows until 1965, proximity to the rapidly growing Japanese market, etc. -- there is no particular reason for believing the Korean manufacturing sector was in any significant way different from that of other developing countries as of the mid-1960's. Since then its export-based rapid growth has, of course, distinguished it. However, the manufacturing sector was small, oriented toward import-substitution, and growing slowly in the late 1950's. In that sense, it was much like that of most other developing countries.

For that reason it is of great interest to examine South Korea's manufacturing sector in the expectation that South Korea's experience may shed some light on many questions of importance for developing countries.

In the course of inquiry we shall estimate manufacturing production functions for South Korean manufacturing industries. These estimates should shed light on the following questions:

1. Are there economies of scale in the production technologies of South Korea's manufacturing industries? If so, what is the potential and

actual importance of the economies of scale in explaining output growth in South Korea's manufacturing industries?

2. What is the magnitude and extent of substitutability of factors in South Korea's manufacturing industries?
3. What is the extent of inter-industry variations of marginal products of factor?
4. Are the estimated production functions relevant for both small and large establishments?
5. Is the production process homothetic, i.e., are the output elasticities of inputs and the elasticity of substitution independent of the level of the factors of production?

The purpose of this study is to present some statistical evidence on these questions along with some hypotheses testing relevant to developing economies. Essentially the empirical work is an investigation of production functions for South Korea's two-digit manufacturing industries.

In section 2 of the present chapter, the importance of the questions raised above are discussed, and in section 3 a brief economic background of South Korea is presented. The last section of this chapter indicates the plan of the thesis.

I-2. Importance of questions

One of the familiar arguments for industrialization in developing countries is the existence of external economies associated with industrialization, for example, the benefits to be derived from technical progress, training of labor and scale economies in production, etc. The externality arguments also constitute the backbone of the case for "infant industry" protection. The infant industry argument states that it is necessary for a pioneering firm in a new industry to invest in acquiring adequate technology and skills in the learning process, but the knowledge and skills acquired frequently become available free or at less cost to those who are potential competitors.[1] Therefore the pioneering firm may not find it profitable to enter an industry even though the activity is socially desirable. Government intervention is justified if it is aimed at correcting for such distortions. In any case of externality, it is well-known that the optimal policy will have to be applied at the point where the distortion arises.[2] For instance, the optimal policy for

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[1] If the pioneering firm can recoup all the costs for the acquisition of knowledge and on-the-job training of labor, then there is no externality problem. See Baldwin (5).

[2] For a careful analysis of externalities and optimal policies, see Bhagwati (10).

infant industry protection would be to subsidize directly the activities of acquiring knowledge and training labor.

Nonetheless, the main policies adopted in many developing countries to accelerate industrialization or to protect infant industries were trade policies: import-substituting policy by restriction of imports with high tariff and quota walls or export-promoting policy through a variety of subsidies and other incentives.[3] It is unclear how important such trade policies are in terms of industrialization or protection of infant industries. But it is clear that trade policies are not the optimal policy for infant industry protection, not only because they fail to reflect externalities correctly but also because the extent of infant industry protection is at best asymmetric among import, export, and nontraded goods sectors. The defects of trade policies in terms of resource allocation have now been studied in theory as well as in practice by numerous economists.[4] There appears to be widespread agreement among economists that the

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[3] For a fuller assessment of industrialization policies for seven developing countries, see Little, Scitovsky, and Scott (41), Chapter III.

[4] For theoretical arguments, see Bhagwati and Krueger (11), Bhagwati (10), Baldwin (5). For empirical work, see Little, Scitovsky and Scott (41), Krueger (39), and Balassa (3).

economic costs of incentives distorted toward export promotion are less serious than the cost of those distorted toward import substitution.[5] One important reason why export promotion may be the superior policy is that under export-promotion strategy, the handicap of small domestic market size is minimized and therefore firms in a small country can take advantage of whatever economies of scale are present.

The existence of scale economies in the firms' production technologies for an industry, however, can by no means be an argument for subsidizing firms through trade policies.[6] The reason is simple. If goods cannot be produced for the domestic market at a cost lower than c.i.f. import price, it is not worth bringing the industry into existence by tariff protection.[7] On the

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[5] See Keesing (35) and Bhagwati and Krueger (11).

[6] Of course, trade policy might be superior to no intervention if there were externalities which accrued to the output level of an industry though the socially optimal policy was domestic production subsidy. But we are dealing with only the economies of scale associated with the production technologies at the firm level.

[7] Of course, in the presence of economies of scale, one can consider a marginal case that domestic production can be more beneficial than imports, even when the average production costs exceed the price of imports at the level of demand for the product at the free trade import price. That is the case when the excess of consumers' valuations over social cost can be larger when it is produced at home with marginal cost pricing and subsidy program than when it is imported. Even then, the socially optimal policy is still domestic policy, not trade policy. See Corden (17).

other hand, if economies of scale can be foreseen and the production cost can be lower than f.o.b. export price at a certain scale or beyond, firms will be set up anyway and further export subsidy will be pointless.[8] Therefore, there is generally no need for government trade policy based on the firms' scale economies in production.

However, if the firms in industries producing nontraded goods (somewhere between c.i.f. and f.o.b. prices) or goods with prohibitive transport costs were subject to increasing returns to scale, special government intervention would be required to attain socially optimal output and price. If there were scale economies in production, economic theory suggests that the most likely outcome of market structure would be a monopoly. In such a case, the optimal policy is to eliminate the monopolistic waste of resources by enforcing marginal-cost pricing with appropriate subsidy on production to make up the loss.

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[8] A question arises again at the margin whether or not the firm should be brought into existence when the firm is subject to economies of scale and the export price covers marginal but not average costs. If we assume that a profit-maximizing firm can survive with price discrimination in a domestic market, then the existence of the firm is not only privately profitable but also socially desirable. But the socially optimal policy is still domestic, not trade, policy. That is, to subsidize the firm so that domestic price is equal to marginal receipts on the export and to marginal costs. See Pursell and Snape (51).

In many developing countries, however, even when there are clearly recognizable economies of scale among import-substitution industries, too many small-scale plants for the small domestic market are often established under high tariff or quota walls which permit non-economic size firms to be profitable.[9] This inefficient market structure can be introduced despite free entry and competition, suggesting that a few non-economic size firms enter a new industry at the same time under various protection measures and reach a sort of oligopolistic equilibrium where none wishes to expand at the expense of the other since each can play the same game.

Knowledge of economies of scale is therefore important, not only in providing a guide to achieving the most efficient allocation of resources but also in providing information as to which industries can successfully be developed into export industries in developing countries. Knowledge of elasticity of substitution is also necessary to evaluate the impacts of various government policies on the pattern of factor intensity and employment of labor.

Both economists and engineers generally agree that scale economies or indivisibilities in production exist at least

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[9] The automobile industry is a good example. See Little, Scitovsky, and Scott (41), Appendix to Chapter IV, p. 423.

up to a certain size of the firm or plant.[10] The principal basis of scale economies of production is the existence of indivisibilities in both men and capital equipment. In large firms a richer division of labor is possible than in small firms. An identical principle applies in the use of machinery. There are also great advantages in dealing with large quantities of inputs and in large machines and equipment.[11] In fact, many earlier studies on manufacturing industries in various advanced countries indicate that the firms' production processes are subject to increasing returns to scale in many industries.[12] Unless an industry's market structure is a monopoly with a fixed demand schedule, the firms with increasing return to scale would tend to expand over time whenever it is possible. The gains from economies of scale have the same potential importance as technical progress in explaining output growth. A few attempts have been made to measure the actual importance of economies

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[10]See Walters (56).

[11]For instance, it has been noted that the cost of an item is frequently related to its surface area, while its capacity of the item increases in accordance with its volume. See Moore (44).

[12]Among others see Griliches and Ringstad (29), Katz (34), and Hildebrand and Liu (31).

of scale in explaining output growth; for example, Griliches estimated that, for the United States post-war manufacturing sector, about 2 percent of output growth is explained by economies of scale. Hodgins finds about 7 percent for Canadian manufacturing sector.[13]

In view of the fact that economic growth has been the most urgent issue in developing countries, it is worthwhile to ask about the extent to which economies of scale have actually contributed to output growth in a rapidly growing economy like that of South Korea.

It was pointed out earlier that the existence of substantial scale economies in production could lead to monpolistic or oligopolistic market structure and hence cause a misallocation of resources in the absence of government intervention. It is therefore important to know the market structures as well as production technologies among industries to evaluate and improve the allocative efficiency of scarce resources. There are a few indications that the degree of departure from competitive-market-equilibrium conditions may be greater in developing countries compared with developed countries. First, for

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[13]See Griliches (28), and see Hodgins (32).

instance, in developing countries markets are often small and limited partly due to low income, lack of transport or communications, and partly due to the lack of open trade under restrictive trade regimes. The small domestic market, therefore, often precludes perfect competition in many industries in developing countries.[14] Second, factor markets are often considerably distorted in developing countries. Capital markets are rarely developed, and most of the financial institutions are owned and controlled by the government.[15] Governments often carry out large public investment, and credit rationing of insufficient loanable funds for private investment is a common phenomenon. In some countries the labor market is also distorted by trade union interventions or other government social legislations.[16] Third, in a rapidly growing or industrializing economy with substantial structural changes, one can hardly expect a long run equilibrium to be attained in output as well as in input markets. Under such circumstances, lags in market adjustment may be far greater in developing countries.

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[14]See Kindleberger (36).

[15]See McKinnon (43).

[16]See Harris and Todaro (30), and Eckaus (21).

Though it is admittedly important to investigate the market structure of industries, that is beyond the scope of the present study. Instead, the present study will examine the magnitude and extent of inter-industry variations in marginal products of factors.

In many earlier studies on manufacturing development in developing countries, observers report the existence of a whole range of technologies from modern to artisan establishments within an industry in cross section of developing areas. To reflect the coexistence of traditional and modern technologies, R. R. Nelson has applied a dualism model in his study of Columbian industries.[17] He assumes that larger firms tend to employ highly advanced modern technology, whereas small firms use the traditional craft technology, and that modern technology is in a diffusion process from large to small firms.[18] This dualism model abandons the neoclassical assumptions that factor markets are perfectly competitive and that all firms are on the same production surface. To test this dualism hypothesis, it is necessary to identify the craft and modern subsectors within

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[17]See Nelson (47), and Staley and Morse (54) for evidence of dualism in other developing countries.

[18]He further assumes that both modern and craft technology subsectors are subject to constant returns to scale but differ in efficiency parameters. This would be a testable hypothesis.

an industry and estimate separate production functions for each subsector. But it is difficult to identify an industry's craft and modern subsectors in a clear-cut way. Thus the dualism hypothesis will be tested in the present study by inquiring whether both small and large establishments within an industry are on the same production surface, assuming that small firms tend to use craft technology and large firms tend to use modern. There are at least two reasons why production functions of these two subsectors tend to differ if significant dualism exists.[19] First, one might expect that economies of scale are likely to be more important for modern technology than for craft technology, and, therefore, up to a certain scale of the firm, craft technology may even be superior to modern technology. Second, one would expect that modern technology tends to be more profitable at a higher capital intensity compared with craft technology.

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[19]It should be pointed out, however, that if the technology diffusion hypothesis holds true and if the diffusion occurs in a continuous process from large to small firms, then there is, instead a simple duality, a whole rainbow of technology gradations. In that case, the estimated returns to scale with cross-sectional firm data would not only reflect the scale economies in production (internal to the firm) but would also reflect the technology gradations across firm size (external to the firm). Thus to the extent that the technology diffusion exists and is important across firm size, the estimated inter-firm economies of scale would be greater than what might be called intra-firm economies of scale.

Among many developing countries in the process of industrialization, an interesting phenomenon has been observed: despite the rapid growth in output and capital, the growth in manufacturing employment has been extremely slow in some developing countries.[20] That is, capital deepening has occurred instead of capital widening in some developing countries where labor is considered to be in surplus. Among the hypotheses put forward to explain the paradox are: (i) Modern manufacturing technology tends to be capital intensive and does not permit much substitution between factors. Therefore, low elasticity of substitution limits the ability of the manufacturing sector to absorb labor.[21] (ii) The high capital intensity in production may be the result of the nonhomothetic production technology, which would tend to be more capital-intensive as the scale of production rises even in the context of unchanged factor prices.[22]

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[20]See Lewis (40), Reynolds (52), Baer and Herve (2), and Eckaus (21).

[21]Recently a few attempts have been made to estimate the elasticity of substitution in the manufacturing sector of developing countries to explain the paradox. However, those studies were based on the competitive-factor-market-equilibrium or profit maximizing conditions which are not particularly compelling in developing countries. See Clague (15), and Witte (58). Both authors provide estimates of the elasticities of substitution in Peruvian manufacturing industries, but with conflicting results. See the discussion in Witte (57).

[22]Empirical testing of this hypothesis would require estimation of alternative production functional forms and testing for the nonhomotheticity of production process.

(iii) Import-substituting policies, i.e., high tariffs or quotas on the imports which are likely to be more capital-intensive products, may have encouraged growth of capital-intensive industries while discouraging growth of labor-intensive industries. (iv) Imperfect factor markets may account for the tendency to adopt capital-intensive technologies in some developing countries. Unduly high wage rates in the manufacturing sector often result from strong industrial labor unions or extensive governmental minimum wage legislation in spite of the existence of high unemployment. There is also some evidence that rapidly expanding large firms face both a low cost of capital and high wage rates because of differential access to capital and labor markets. Sometimes overvalued exchange rates or low-cost foreign loans tied with imports of certain types of machinery can encourage importation of capital goods produced for capital-intensive technology.

Contrary to the paradox found in many developing countries, in South Korea manufacturing employment grew relatively rapidly, almost at the same rate as the rate of growth in value added, at least until the late sixties, and the real wage did not start rising until that time.[23] South Korea's factor markets

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[23]See Table 1.7 on page 38 in Chapter I-3.

appear to have worked relatively well. Therefore, it may be possible to test the importance of hypotheses (i) and (ii) raised above to explain the paradox.

I-3. Some Economic Background of South Korea

The purpose of this section is to acquaint readers with the economic background of South Korea, particularly with the manufacturing development in South Korea over the 1954 to 1973 period. We will place the manufacturing sector in the context of the entire South Korean economy, describe the major government policies influencing economic growth and manufacturing development, examine the structure and growth of manufacturing industries, and examine factor market conditions in South Korea.

Economic growth and manufacturing development

Table 1.1 provides basic data on the real gross national product and its composition by major sectors over the 1954 to 1973 period. Real GNP almost quadrupled between 1954 and 1973, for an average annual rate of growth of 7.51 percent. Real per capita income rose from $133.3 in 1956 to $337.0 in 1973 in terms of 1970 U. S. prices, for an average annual growth rate of 5.7 percent. The South Korean population was estimated to be 22.31 million in 1956 and 33.18 million in 1973; it has grown at an average annual rate of 2.36 percent over 1956-1973 period.

Table 1.1 GNP and Major Sectors, and Annual Growth
(1970 constant billion won)

Year	GNP[1] (Growth Rate) (1)	Value Added[1] in Mfg. (Growth Rate) (2)	Value Added[1] in Agric. (Growth Rate) (3)	(2)/(1), Share of[1] Mfg. in GNP (4)	(3)/(1), Share of[1] Agric. in GNP (5)	(Δ2)/(Δ1) Contribution of Mfg.[2] to GNP Growth (6)
1954	890 (5.5)	60.7 (18.6)	427.55 (7.6)	6.8	48.0	20.5
1955	938 (5.4)	74.6 (22.8)	438.60 (2.6)	7.9	46.7	28.9
1956	942 (0.4)	87.4 (17.3)	412.53 (-6.0)	9.3	43.8	324.2
1957	1014 (7.7)	94.7 (8.2)	450.15 (9.1)	9.3	44.4	10.0
1958	1067 (5.2)	103.3 (9.0)	478.12 (6.2)	9.7	44.8	16.3
1959	1108 (3.9)	112.8 (9.2)	472.53 (-1.2)	10.2	42.6	23.1
1960	1130 (1.9)	112.0 (8.1)	466.57 (-1.3)	10.8	41.3	43.1
1961	1184 (4.8)	125.8 (3.1)	522.20 (11.9)	10.6	44.1	25.6
1962	1121 (3.1)	142.3 (13.1)	492.17 (-5.8)	11.7	40.3	45.3
1963	1328 (8.8)	167.0 (17.2)	532.05 (8.1)	12.6	40.0	22.9
1964	1442 (8.6)	177.9 (6.5)	614.59 (15.5)	12.3	42.6	9.6

Table 1.1 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
1965	1530	213.4	602.65	13.9	39.4	40.4
	(6.1)	(19.9)	(-2.0)			
1966	1719	249.9	667.91	14.5	38.9	19.3
	(12.4)	(17.1)	(10.8)			
1967	1853	306.8	634.78	16.6	34.3	42.5
	(7.8)	(22.7)	(-5.0)			
1968	2087	389.7	650.08	18.7	31.1	35.4
	(12.6)	(27.0)	(2.4)			
1969	2400	473.0	731.48	19.7	30.5	26.6
	(15.0)	(21.3)	(12.5)			
1970	2589	560.0	724.59	21.6	28.0	46.1
	(7.9)	(18.3)	(-1.0)			
1971	2827	659.2	748.46	23.3	26.5	41.8
	(9.2)	(17.7)	(3.3)			
1972	3024	762.8	760.93	25.2	25.2	52.6
	(7.0)	(15.9)	(1.7)			
1973	3534	1002.0	801.15	28.4	22.6	46.9
	(16.9)	(31.4)	(5.3)			
53-74	(7.5)	(16.2)	(3.7)			
54-60	(4.3)	(13.3)	(2.4)			
61-73	(9.3)	(17.8)	(4.4)			

[1] Source: Bank of Korea, Economic Statistic Yearbook 1974, pp. 260, 300.

[2] Source: Bank of Korea, National Income Statistic Yearbook 1973, p. 195.

As can be seen, the growth rate of GNP for the decade of the 1950's contrasts sharply with that of the 1960's and early 1970's. The GNP grew at an average annual rate of 9.25 percent between 1961-1973 but only 4.29 percent between 1954-1960. Nevertheless, the growth rate of manufacturing in value added has been sustained at a much higher rate than that of GNP over almost the entire period of 1954-1973, for a real average annual growth rate of 16.2 percent. Thus the share of manufacturing in the GNP increased from 6.8 percent in 1954 to 28.4 percent in 1973, while that of agriculture, forestry and fishery fell from 48.0 percent to 22.6 percent despite that sector's real annual growth rate of 3.74 percent. The share of the rest of the sectors in the GNP has risen somewhat over the period -- from 45.2 percent in 1954 to 49 percent in 1973. The importance of the manufacturing sector to GNP growth, measured by the ratio of the increase in value added in the manufacturing sector and the increase in GNP, is presented in the last column of Table 1.1.

Economic policies for development and industrialization in South Korea can also be divided into two periods; prior to and after 1960. Prior to 1960, there was little economic policy relating to development goals, except that emphasis was placed upon import-substitution through tariffs and quantitative restrictions of imports. Thus it was mainly import-substitution in nondurable consumer goods that contributed to the rapid growth of industrial production during the 1950's.[24] The decade of the 1960's, however, saw numerous reforms and economic plans, in a marked contrast to the decade of the 1950's. Two Five Year Economic Plans were formulated. The first (1962-1966) was immediately announced after the military coup in May 1961. The second (1967-1971) marked a continuation of planning for South Korean economic development.[25] Both plans have set a target rate of growth of 7 percent annually. The development of industry is stressed in each plan, with particular emphasis upon the expansion of key industries, and the modernization and diversification of industrial structure through development of such industries as chemicals, petroleum, and iron and steel.

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[24] Frank, Kim and Westphal estimated the direct contributions of export expansion and import substitution to the growth of manufactured output over the period of 1955-1968:

	1955-60	1960-63	1963-66	1966-68
Export expansion	5.1(%)	6.2	29.4	13.0
Import substitution	24.2	0.9	14.4	-0.1

See Chapter VI in Frank, Kim and Westphal (24).

[25] There was a Third Five Year Economic Plan (1972-1976) which started in 1972 but is not discussed in this study because the analysis was done mostly during 1973-1974.

Among important reforms and new economic policies that took place during the 1960's are: (1) the devaluation of Korean currency from 130 won to 255 won to the dollar in May 1964; (2) the interest rate reform which raised the maximum interest rate on ordinary loans of banking institutions from 16 percent to 26 percent per annum; (3) introduction of a comprehensive export promotion system which includes exemptions from various taxes, high wastage allowances on imported duty-free raw materials, preferential loans at a subsidized interest rate, an export-import linkage system, and frequent adjustment of the exchange rate with increases in the domestic price level; (4) gradual liberalization of import controls after the 1964 devaluation; and (5) encouragement of inflow of foreign loans by providing government or authorized banks' repayment guarantees on foreign loans.[26]

The 1964 devaluation was the most important reform and formed a basis for the development of export and import-substitution industries in subsequent years.[27] In addition, a comprehensive export promotion system introduced about the

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[26]For a further discussion and analysis of trade policies in South Korea, see Frank, Kim and Westphal (24).

[27]See footnote 24 on page 20.

same time greatly facilitated the unusually rapid expansion of exports for the next decade. As can be seen in Table 1.2, prior to 1964 exports were very small, ranging from 1.0 to 3.5 percent of the GNP. Thereafter, they rapidly rose to 29.7 percent of the GNP by 1973. Moreover, manufactures dominated the growth of exports during the 1960's; manufactured exports were only 18.1 percent of total exports in 1960, but accounted for more than 88 percent in 1973. Imports also grew substantially. As indicated in Table 1.2, there has been an import surplus over virtually the entire period, reaching a peak in the late sixties and early seventies. This for the most part reflects the fact that both import-substitution and export industries have become increasingly dependent upon imports of intermediate goods, and imports of capital goods financed by foreign loans have been large since 1965.

The 1965 interest rate reform not only enhanced the efficiency of domestic financial institutions and provided great incentives to save but also brought about large interest rate differentials between domestic and foreign loans and made low-cost foreign loans more attractive. Moreover, the government's or authorized banks' repayment guarantees were extended to almost all foreign loans so that foreign lenders could lend regardless of the individual borrower's credit condition. Thus the risk premium on foreign loans

Table 1.2 GNP, Exports and Imports
(1970 constant billion won)

Year	GNP (1)	Exports[1] (as percent of GNP) (2)	Growth of Exports (3)	Imports[1] (as percent of GNP) (4)	Growth of Imports (5)	Exports less Imports (6)	Share of Mfg.[2] in Exports (7)
1954	890	10.3 (1.1)	-39.4	78.1 (8.8)	-28.6	-67.8	
1955	938	12.9 (1.4)	25.2	104.8 (11.2)	34.2	-91.9	
1956	942	11.5 (1.2)	-10.9	122.4 (13.0)	16.8	-110.9	
1957	1014	15.6 (1.5)	35.7	144.8 (14.3)	18.3	-129.2	
1958	1067	19.7 (1.9)	26.3	125.3 (11.7)	-13.5	-105.6	
1959	1108	22.9 (2.1)	16.2	102.6 (9.3)	-18.1	-79.7	
1960	1130	27.4 (2.4)	19.7	117.5 (10.4)	14.5	-90.1	18.1
1961	1184	38.2 (3.2)	39.4	106.6 (9.0)	-19.3	-68.4	22.0
1962	1221	43.0 (3.5)	12.6	141.2 (11.6)	32.5	-98.2	27.0
1963	1328	46.2 (3.5)	7.4	179.2 (13.5)	26.9	-133.0	51.7
1964	1442	57.1 (4.0)	23.6	133.3 (9.2)	-25.6	-76.2	51.6

Table 1.2 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1965	1530 (5.2)	80.3 (5.2)	40.6	149.6 (9.8)	12.2	-69.3	62.3
1966	1719	122.3 (7.1)	52.3	237.9 (13.8)	59.0	-115.6	62.4
1967	1853	166.0 (8.9)	35.7	320.7 (17.3)	34.8	-154.6	70.1
1968	2087	235.0 (11.3)	41.6	468.0 (22.4)	45.9	-233.0	77.3
1969	2400	310.1 (12.9)	32.0	583.8 (24.3)	24.7	-273.7	79.0
1970	2589	381.2 (14.7)	22.9	642.4 (24.8)	10.0	-261.2	83.6
1971	2827	459.4 (16.3)	20.5	773.6 (27.4)	20.4	-314.2	86.0
1972	3024	643.3 (21.3)	40.0	801.2 (26.5)	3.6	-157.9	87.7
1973	3534	1049.5 (29.7)	63.1	1141.7 (32.3)	42.5	-92.2	88.2
54-73			26.6		15.3		
61-73			33.2		20.6		

[1]Source: Bank of Korea, Economic Statistics Yearbook, 1974, p. 262.
[2]Source: Economic Planning Board, Major Economic Indicators, 1974, p. 76.

was minimized. As can be seen in Table 1.3, the inflow of foreign loans remarkably accelerated beginning in 1966 -- from $218 million in 1966 to $739 million in 1973. The inflow of foreign loans was so rapid that South Korea has experienced an increase in foreign exchange holdings by the central bank, despite the large trade deficits since 1965.

The importance of foreign saving in domestic capital formation is indicated in Table 1.4. The bulk of the inflow of foreign saving came from foreign aid until 1964, mostly from the U. S. A. under reconstruction programs after the Korean war which ended in 1953. But after 1964, foreign commercial and public loans began to replace foreign assistance as the major source of foreign savings. It should be noted, however, that national saving has become increasingly important since 1962 as the GNP grew rapidly, despite the large influx of foreign loans; national saving rose from 12.1 percent in 1962 to 79.5 percent in 1973.

Changes in the industrial structure of the South Korean manufacturing sector are indicated in Table 1.5. A few notable features are evident from the data. First, there was a substantial structural change during the 1960's; the share of nondurable consumer goods declined sharply from 73.8 percent in 1960 to 55.6 percent in 1972, while the

Table 1.3 Balance of Payment
($ million)

Year	Commodity[1] Exports (1)	Commodity[1] Imports (2)	Services[1] Net (3)	Goods & Services (4)	Official[1] Grant Aid (5)	Net Loan[2] Capital Inflows (6)	Foreign[2] Exchange Holdings (7)
1954	24	241	37	-180	139	28	105
1955	18	327	43	-266	240	-3	95
1956	25	380	24	-331	298	14	97
1957	19	390	-17	-388	355	18	114
1958	17	344	16	-311	319	-7	145
1959	20	273	25	-228	229	-17	146
1960	33	305	10	-262	256	-1	155
1961	41	283	44	-198	207	19	205
1962	55	390	43	-292	200	-16	167
1963	87	497	7	-403	208	-104	130
1964	119	365	25	-221	141	-26	129

Table 1.3 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1965	175	420	46	-199	135	9	138
1966	250	680	107	-323	122	218	236
1967	335	909	157	-417	135	299	347
1968	486	1,322	170	-666	121	422	387
1969	658	1,650	198	-794	98	631	549
1970	882	1,804	119	-803	82	582	583
1071	1,132	2,178	28	-1,018	64	662	535
1072	1,676	2,250	33	-541	52	478	694
1973	3,266	3,817	84	-467	33	739	1,034

[1]Source: Bank of Korea, Economic Ststistics Yearbook, 1971, pp. 266-267 and 1974, pp. 224-225.

[2]Loan capital, both private and government, short term and long term, net of amortization payments.

[3]Source: Bank of Korea, Economic Statistics Yearbook, 1974, p. 221.

Table 1.4 Capital Formation
(in 1970 constant billion)

Year	Gross[1] Domestic Investment	GDI[1] as of percent GDI	National[1] Saving as percent of GDI	Foreign Saving as percent of GDI[1]	
				Net Transfer from Rest of World	Net Borrowing from Rest of World
1954	91.6	10.3	54.8	36.2	9.0
1955	94.0	10.0	41.1	47.0	11.9
1956	75.7	8.1	-14.4	122.3	-7.9
1957	135.3	13.4	36.1	63.6	0.3
1958	117.7	11.0	38.4	68.8	-8.2
1959	91.8	8.3	36.5	67.0	-3.5
1960	96.6	8.6	13.2	82.3	-4.0
1961	121.4	10.2	29.9	76.1	-10.9
1962	119.9	9.8	12.1	67.6	15.8
1963	225.1	16.9	33.8	37.4	20.6
1964	188.2	13.0	50.8	43.1	5.0
1965	197.3	12.9	49.6	44.2	-2.0
1966	317.5	18.4	54.6	26.5	12.5
1967	368.3	19.8	54.0	21.7	18.5
1968	509.1	24.4	51.0	14.6	28.5
1969	714.1	29.7	58.8	11.4	25.5
1970	704.7	27.2	60.0	8.0	27.4
1971	748.8	26.5	56.9	7.4	36.6
1972	667.9	22.1	71.7	8.3	18.4
1973	042.6	26.7	79.5	8.0	10.5

[1]Source: Bank of Korea, Economic Statistic Yearbook, 1974, p. 263.

Table 1.5 The Structure and Growth of Manufacturing Industries 1954-1972 (at 1970 constant prices)

	Composition as percet of[1] total manufacturing value added				Growth rate[1]			
	1954 (1)	1960 (2)	1966 (3)	1972 (4)	1954-1960 (5)	1961-1966 (6)	1967-1972 (7)	1954-1972 (8)
Nondurable consumer Goods	76.9	73.8	59.2	55.6				
20.Food	22.8	18.5	15.1	12.3	11.1	9.1	16.5	12.1
21.Beverage	9.5	14.9	9.2	6.9	17.9	5.3	15.2	13.1
22.Tobacco	10.5	6.4	8.3	8.1	4.1	17.8	20.2	13.5
23.Textile	20.7	20.1	14.8	16.2	14.4	7.6	22.3	14.8
24.Footwear & Clothing	6.5	7.7	6.6	9.6	19.3	10.6	28.9	19.6
26.Furniture	2.2	1.4	0.6	0.4	8.2	-0.7	15.3	7.6
28.Printing	4.7	4.8	4.6	2.1	13.6	16.4	5.5	12.0
Intermediate Goods	13.2	14.7	23.5	27.1				
25.Wood	3.2	2.6	2.7	2.4	16.3	15.9	19.4	17.1
27.Paper	1.1	1.4	2.6	2.0	22.9	24.4	16.0	21.2
29.Leather	1.2	0.8	0.6	0.8	9.4	5.9	48.8	20.7
30.Rubber	1.7	2.1	2.0	1.4	21.1	12.1	12.6	15.5
31.Chemicals	3.0	3.4	5.4	8.3	15.2	39.9	30.8	27.9
32.Petroleum and Coal	0.7	1.3	5.9	8.1	24.5	48.9	34.8	35.5
33.Caly	2.3	3.1	4.3	4.2	22.0	19.6	20.3	20.7

Table 1.5 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Metals and Machinery	8.0	9.7	15.1	12.9				
34.Basic Metal	0.5	1.8	2.4	2.3	36.7	19.1	20.2	25.9
35.Metal Prod.	1.5	1.7	1.8	0.9	14.8	14.6	7.4	12.4
36.Machinery	2.7	2.7	2.6	1.2	15.1	13.5	6.8	12.0
37.Elect. Mach.	0.7	1.1	3.3	4.6	32.0	31.7	27.8	30.6
38.Transp.Eq.	2.6	2.4	5.0	3.9	14.6	29.9	17.6	20.4
Other Manuf.	1.7	1.6	2.3	4.3				

[1] Source: Bank of Korea, National Income Statistics Yearbook, 1973, pp. 172-173.

share of intermediate goods and metals and machinery increased from 24.4 percent in 1960 to 40 percent in 1972. Second, among nondurable consumer goods, the share of exportable goods (23. Textile, 24. Clothing) remained stable; therefore all the decline in the share of nondurable consumer goods resulted from the slow growth of nontraded consumer goods (20. Food, 21. Beverage, 23. Tobacco, 26. Furniture, 28. Printing).[28] Third, the expansion of the production of intermediate products is largely due to the rapid growth of petroleum products and chemicals which have received special benefits. Fourth, although the share of metals and machinery industries as a whole increased during the 1960's, the shares of metal products and machinery (35. Metal Products, 36. Machinery) industries both declined sharply.[29]

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[28] Exportable goods are those whose exports are greater than 10 percent of total domestic production in 1968 and nontraded goods are those whose exports and imports are both less than 10 percent of domestic production.

[29] Balassa (4) pointed out that overvalued foreign exchange during the second half of the 1960's, and subsidies in the form of duty-free entry of machinery and materials used in export production and preferential credit facilities of their importation, may have induced domestic producers to use imported machinery and metal products and discouraged the domestic production of such products.

Factor markets

The capital-market structure in Korea appears to be highly distorted in violation of competitive-market principles. Before the 1965 interest rate reform, an unrealistically low interest rate was employed in South Korea (this is a common practice designed to encourage domestic capital formation in many developing economies).[30] In addition, a preferential loan scheme was adopted by providing loans at varying interest rates according to the purpose of the loans as well as the source of funds. The shortage of loanable funds through the organized money market resulted in credit rationing and an emergence of an inefficient curb market.

The 1965 interest rate reform was mainly intended to reflect the real cost of capital in Korea. It was also aimed at getting better distribution of scarce resources, as well as enhancing the efficiency of the financial institutions to transform savings into investments. Remarkable progress has been made since the 1965 interest rate reform; total loans from all domestic

[30] That low interest rate should be the target of monetary policy follows from the traditional Keynesian view that the interest rate is the only link between the financial market and the markets for real goods and services. Most of the simple Keynesian models, however, are demand-oriented, and ignoring the supply side of the economy often led policy makers to misuse of low interest policy. See Patinkin (50).

financial intermediaries leaped from 90.8 billion won in 1964 to 163.8 in 1966 and to 757.0 by 1969.[31] However, the uneconomic structure of interest rates has been persistent, because preferential loan rates by and large remained at their previous level while the ordinary loan rate was raised from 16 to 26 percent. For example, the loan rate for export-industry financing remained at 6.5 percent, the Korea Development Bank's rate on equipment loans stayed at 11 percent per annum, and other government-funded loan rates for key industries were almost unchanged.[32] As can be seen in Table 1.6, the annual rate of inflation averaged 13.7 percent by GNP deflator during 1965-1970 and 11.3 percent by Seoul consumer price index. Thus, on the one hand, the real rate of interest on ordinary bank loans, with a nominal rate of 26 percent, exceeded 12 percent during 1965-1970. On the other hand, the real rate of interest on preferential loans turned out to be negative. Those preferential loans comprised 63.6 percent (52 billion won) of the total loans of all domestic financial institutions in 1963, 52 percent (85.2 billion won) in 1966 and 44.4 percent (335.9

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[31] Source: Shim, Suh, Chee and Lee (53), p. 40.

[32] Source: Bank of Korea (7, 1973), pp. 49-52.

Table 1.6 Major Price Indices[1]
(1970 = 100)

Year	GNP[2] Deflator	GNP Deflator[3] for Mfg. Industry	GNP Deflator for[3] fixed capital formation in Mfg. Industry	Whole Sale Price Index	Seoul Consumer Price Index
1954	7.5	12.7	10.5	10.5	10.2
1955	12.4	17.4	14.7	19.1	17.3
1956	16.2	19.7	18.3	25.1	21.2
1957	19.5	23.1	18.8	29.2	26.1
1958	19.4	25.2	21.0	27.3	25.3
1959	19.9	27.5	24.8	28.0	26.4
1960	21.8	27.5	25.6	31.0	28.6
1961	25.1	31.6	34.3	35.1	30.9
1962	28.6	35.6	36.3	38.4	32.9
1963	36.8	43.8	42.3	46.3	39.7
1964	48.6	62.5	56.4	62.3	51.4
1965	52.6	67.4	64.9	68.5	58.4
1966	60.1	76.4	79.3	74.6	65.4
1967	68.5	78.0	86.0	79.4	72.5
1968	76.6	84.0	88.9	85.8	80.6
1969	86.7	91.1	90.6	91.6	88.7
1970	100.0	100.0	100.0	100.0	100.0
1971	111.5	103.9	108.7	108.6	112.3
1972	127.7			123.8	125.6
1973	138.2			132.4	129.5

[1] Middle of year.
[2] Source: Bank of Korea, Economic Statistic Yearbook, 1974, pp. 4, 264-267.
[3] Source: Bank of Korea.

billion won) in 1969.[33] Another source of uneconomic interest rate structure in South Korea is the low cost of foreign loans. As was seen in Table 1.4, South Korea has increasingly relied upon foreign loans to finance her ambitious investment projects since 1965; annual foreign loans averaged about 22 percent of total domestic investment or 5.4 percent of the GNP during 1966-1973. Frank, Kim and Westphal calculated nominal and real interest rates on the foreign loans; the weighted average of nominal interest on foreign loans ranges from the lowest of 5.6 percent in 1965 to the highest of 7.1 percent in 1969 for the period 1965 to 1970, and the real private costs of interest on foreign loans were estimated at from 0.3 percent in 1965 to 1.8 percent in 1969 for the same period.[34]

Economic theory would predict a high rate of return to capital for an economy such as that of Korea, where labor is relatively abundant and capital is scarce. The inference regarding high rates of return is supported by the observation that the amount of funds demanded by borrowers far exceeds the amount of funds supplied for ordinary bank loans even

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[33] See Shim, Suh, Chee and Lee (53), p. 22.

[34] See Frank, Kim and Westphal (24), Chapter VII.

after the 1965 interest rate reform. From national income data, Gilbert Brown[35] has estimated the real marginal rate of return on capital. The estimates reveal that the average marginal rate of return on new investments in the private non-farm sector was between 20 and 30 percent during 1962-1967.

The direct control of interest rates by the government and the presence of a wide spectrum of interest rates both suggest that capital markets in Korea may be far from a perfectly competitive equilibrium. The average or marginal cost of capital can vary from the highest curb market rate to the lowest preferential loan rate, depending upon the capital structure or ability of the firm to finance its capital stock. Thus low-cost domestic preferential or foreign loans might have contributed to a worsening of factor market distortion and possibly led to misallocation of resources in Korea.

Unlike the capital market, the labor market in Korea appears to have been highly market-oriented. The government did not intervene with unrealistic social legislation, nor was labor well organized into unions. Thus wage rates are largely left to be set by the market forces in Korea. Unlike

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[35] See Brown (13).

frequent reports of the failure of rapidly growing manufacturing sectors to absorb a significant amount of labor in many developing countries,[36] in Korea manufacturing employment grew relatively rapidly, at least until the very late sixties. As can be seen in Table 1.7, the rapid growth rate of value added was matched by a rapid growth rate in manufacturing employment and a steady decline in the rate of unemployment in the non-farm sector until 1968. After 1968, however, the growth rate in manufacturing employment began to drop sharply, although the growth rate of value added remained high. On the other hand, real monthly wages, which showed a mild decline in the early sixties, tended to rise sharply beginning in 1967. Thus both the sharply rising real wages and the sharp drop in the growth of employment in the late sixties suggest that Korea may have been experiencing a transitional period from labor surplus to labor market tightening in the late sixties.

I-4. Plan of the Thesis

In Chapter II we review various forms of production functions relevant to the questions to be studied and discuss a number of estimation problems. The burden of that chapter

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[36] See footnote 20 on page 14.

Table 1.7 Employment and Wage Rates in Manufacturing

Year	Employment in Mfg. (in thousands) (1)	Growth Rate of Mfg. Empl. (2)	Growth Rate of Value Added in Mfg. (3)	Non Farm Labor Force (in millions) (4)	Growth Rate of Non Farm Labor (5)
1960	454		8.1	2.92	
1961	462	1.8	3.1	3.22	10.3
1962	529	14.3	13.1	3.21	-0.3
1963	631	19.3	17.2	3.37	5.0
1964	671	6.3	6.5	3.45	2.4
1965	800	19.2	19.9	3.76	9.0
1966	851	7.1	17.1	3.90	3.7
1967	1043	21.7	22.7	4.19	7.4
1968	1181	13.2	27.0	4.34	3.6
1969	1222	3.5	21.3	4.59	5.7
1970	1260	3.1	18.3	4.91	7.0
1971	1288	2.1	17.7	5.24	6.9
1972	1372	6.5	15.9	5.36	2.1

Table 1.7 (Continued)

Year	Non-farm Household Unemployment Rate (%) (6)	Total Household Unemployment Rate (%) (7)	Monthly Earnings of Prod. Worker in Mfg.(won) (8)	Price Deflated Earnings in Mfg.(won in 1970 Seoul Cons. Prices) (9)	Growth Rate of Price Deflated Earnings (10)
1960	n.a.	7.5	2330	8007	
1961	n.a.	7.9	2610	8286	3.5
1962	n.a.	8.3	2780	8274	-0.1
1963	16.4	8.1	3180	7910	-4.4
1964	14.4	7.7	3880	7548	-4.6
1965	13.5	7.4	4600	7877	4.4
1966	12.8	7.1	5420	8287	5.2
1967	11.1	6.2	6640	9159	10.5
1968	8.9	5.1	8400	10422	13.8
1969	7.8	4.8	11270	12706	21.9
1970	7.5	4.5	14561	14561	14.6
1971	7.8	4.5	17349	15449	6.1
1972	7.6	4.5	20104	16006	3.6

Source: Bank of Korea, Economic Statistic Yearbook, various issues, and Economic Planning Board, Major Economic Indicators, various issues.

is to evaluate the viability of various regression equations for estimating key parameters in production functions. Estimates of the various production functions are presented in Chapter III along with discussions of those results. In Chapter IV we further investigate the implications of our cross section production function results, and in Chapter V our summary and conclusions are presented.

CHAPTER II

PRODUCTION FUNCTIONS AND SAMPLE PROPERTIES

II-1. Introduction

The empirical problem of this study is concerned with statistical estimation of production functions which confront firms in the 18 two-digit industries composing the manufacturing sector of the South Korean economy. The production function expresses the relation between the maximum quantity of output and the inputs required to produce it and the relation among inputs themselves. The estimates of production functions will provide us with information on such technical characteristics as: (i) elasticities of output with respect to inputs; (ii) the elasticity of scale or the elasticity of output with respect to a proportional change in all inputs; (iii) the elasticity of substitution; and (iv) homotheticity of the production technology, that is, whether the form of isoquants is independent of scale.

The scope of the empirical work in this study is very much conditioned by the availability of a particular body of data: cross section data from the 1966 and 1968 Manufacturing Surveys in South Korea. This report provides cross section data classified both by region and firm size. Thus the basic units used in this study are per-establishment averages of the cross section data classified by region and firm size.

The major purposes of this chapter are (1) to review alternative production functions with respect to estimation of the key parameters of production functions in section 2; (2) to discuss the problems of aggregation in the data in section 3; (3) and to describe the properties of the data used and the limitations of the empirical work of this study.

II-2. Production Functions

A wide choice of algebraic forms can be used to represent production functions. Probably the most popular production function is the Cobb-Douglas function which can be written in its best known form as

$$(2.1) \quad V = AK^{\alpha}L^{\beta} \quad \text{or} \quad \ln V = a_0 + a_1 \ln K + a_2 \ln L$$

where V measures output, K the quantity of capital input, and L the labor input.[1] The properties of the Cobb-Douglas function are:

(i) The α and β are the elasticities of output with respect to capital and labor, respectively.

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[1]See Cobb and Douglas (16).

(ii) The function is homogeneous of degree $\alpha + \beta$. There are increasing, constant, or decreasing returns to scale, depending upon whether the elasticity of scale, $\alpha + \beta$, is above, equal to, or below unity, respectively.

(iii) The marginal rate of substitution is $\beta K / \alpha L$, and the elasticity of substitution, σ, is unity.

While the Cobb-Douglas function allows us to estimate elasticities of output with respect to inputs and the elasticity of scale, it imposes strong assumptions on the data, which would require empirical verification. These assumptions are constancy in output elasticities of inputs, in the elasticity of scale, and in the elasticity of substitution regardless of the levels of inputs employed. Further, the elasticity of substitution is not only constant but is assumed to be unity.

The Cobb-Douglas function was challenged in 1961 by a more general function called the constant elasticity of substitution (the CES function), pioneered by Arrow, Chenery, Minhas and Solow (ACMS).[2] The basic change introduced by ACMS is to allow the elasticity of substitution to be constant at a value other than

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[2] See Arrow, Chenery, Minhas, and Solow (1).

unity (Cobb-Douglas) or zero (input-output of Leontief type).

A general form of the CES function can be written as

$$(2.2) \quad V = B \left[\theta K^{-\delta} + (1-\theta)L^{-\delta}\right]^{-\lambda/\delta}$$

where

θ = distribution parameter

δ = elasticity of substitution parameter

λ = scale parameter.

Although the CES function has some attractive theoretical merits over the Cobb-Douglas function, it has had rather limited empirical application. This lack of use is because the CES function cannot be transformed to a function linear in its parameters and is therefore difficult to estimate directly.

A major emphasis in work involving CES functions has focused on estimating σ, the elasticity of substitution. The conventional procedure of estimating the elasticity of substitution has been indirect through marginal productivity relation. The regression equation to estimate the elasticity of suostitution usually takes the following form:

$$(2.3) \quad \ln(V/L) = a + \sigma(W/L) + \mu$$

where

W = total labor compensation

μ = random disturbance.

The derivation or interpretation of this equation as yielding evidence about σ requires, however, many underlying a priori assumptions. These assumptions are: (1) perfectly competitive factor and output market equilibrium; (2) profit maximizing conditions; and (3) constant returns to scale.[3]

Relaxing the assumption of constant returns to scale, we can derive a similar form from the labor marginal productivity relation, which can be written:[4]

$$(2.4) \quad \ln(V/L) = a + b\ln(W/L) + c\ln(L) + \mu$$

where

$$a = -\lambda/(\lambda+\delta)\ln\lambda(1-\theta)$$

$$b = \lambda/(\lambda+\delta)$$

$$c = -(1-b)(1-\lambda).$$

Hence $\lambda-1 = c/(1-b)$ and $\sigma = b/(1+c)$.

Since we are particularly interested in the possibility of non-constant returns to scale, the regression equation 2.4 is better suited to our purpose. But the problem with the

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[3] Of course, certain discrepancies from these assumptions can be admitted without affecting the validity of the estimate, σ. For instance, a proportional discrepancy between the marginal revenue product and the value of the marginal product would affect only the constant term in equation 2.3.

[4] Hodgin's (32) study on Canadian Manufacturing is based on this equation.

equation 2.4 is that it still relies on the assumption of marginal productivity relation which may not hold true. Furthermore, Griliches points out that exactly the same regression equation can be derived from a slightly different specification.[5] Therefore a "significant" coefficient for the ln(L) term may not be the result of the elasticity of scale being different from unity.

An alternative procedure which does not rely on the marginal productivity relation is the direct estimation of the CES function through the use of an approximation suggested by Kmenta.[6] This is based on a Taylor expansion of the logarithm of the function around $\delta = 0$, and, ignoring third and higher order terms, it can be written as:

$$\ln(V/L) = \ln(B) + h\ln(L) + \lambda\theta \ln(K/L) - 1/2\, \lambda\theta\, (1-\theta) [\ln(K/L)]^2 \quad (2.5)$$

where

$h = \lambda - 1,$

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[5]For instance, Griliches indicates that if the production function were of the generalized ACMS form proposed by Mukerji, that is

$$V = A[\theta K^{-\delta_1} + (1-\theta)L^{-\delta_2}]^{-1/\delta_0}$$

the marginal productivity relation implicit in this function leads to

$$\ln(V/L) = B + C\ln(W/L) + C(\delta_2 - \delta_0)\ln(L)$$

where $C = 1/(1+\delta_0)$, which is therefore statistically indistinguishable from the equation 2.4. See Griliches and Ringstad (29), p. 13, and Mukerji (45).

[6]See Kmenta (38).

or

$$\ln(V/L) = a_0 + a_1\ln(L) + a_2\ln(K/L) + a_3[\ln(K/L)]^2.$$

The closer the elasticity of substitution is to unity, the better this approximation is; it deteriorates as the elasticity of substitution departs from unity, which is an undesirable property. However, this approximation allows a direct test of the Cobb-Douglas form, because it reduces itself to the Cobb-Douglas form when the elasticity of substitution is unity. If a_3 is not significantly different from zero, one cannot reject the hypothesis of a Cobb-Douglas form; otherwise one accepts the hypothesis of a CES form. But this test is rather weakly grounded due to following reasons:

(i) The ignored higher order terms in the approximation by Taylor expansion can affect a_3 in an unpredictable way.

(ii) The acceptance of the hypothesis can be misleading in the sense that a_3 being significantly different from zero could also be the result of a more general production function.

(iii) Since a_3 is a product of many parameters, the fact that a_3 is not significantly different from zero does not necessarily imply that δ is not significantly different from zero.

A technique for direct estimation of the CES function by nonlinear least squares is also available. This is based on the first order Taylor expansion, but it iterates until the estimates converge to certain values with a specified rate of change. However, the estimates are not likely to be terribly sharp due to the omission of terms higher than the first order in the Taylor expansion and due to the presence of collinearity in the first order differentials with respect to parameters.

As a consequence, there is no fully satisfactory procedure to estimate the CES function. But we will attempt to estimate the elasticity of substitution by the various ways considered above and compare the results.

Although the CES function does not require such a priori assumptions as the unitary elasticity of substitution and constancy in output elasticities with respect to inputs, it still assumes both the elasticity of scale and the elasticity of substitution to be constant, regardless of the scale or combination of inputs, and hence production technology is assumed to be homothetic. These assumptions require further empirical support.

Recent studies, directed mostly to generating more generalized production functions, have produced a number of new forms of production functions. Among others, two potentially useful functional forms for empirical application are worth noting here. One is the transcendental logarithmic production function (or translog production function) developed by Christenson, Jorgenson, and Lau,[7] and independently by Griliches.[8] The other was developed by Diewert.[9] Both the translog form and the Diewert formulation are characterized by linear, second order local approximation to an arbitrary twice differentiable transformation function. Whereas the translog function is presented as a general second order polynomial form in the logarithms of the variables, the Diewert formulation is an expansion of a second order polynomial in terms of the square roots of the variables. Both have the property of being linear in the parameters so that linear regression techniques can be employed in estimation. Furthermore, neither needs any a priori assumptions regarding elasticity of scale, elasticity of substitution or homotheticity. The Diewert formulation can be reduced to a linear transformation function as a special case, whereas the translog function reduces to a Cobb-Douglas function

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[7]See Christensen, Jorgenson, and Lau (14). For an application of the translog production function, see Berndt and Christensen (9).

[8]See Griliches and Ringstad (29).

[9]See Diewert (19). Parks (49) has applied the Diewert formulation to estimating substitution possibilities in Swedish manufacturing.

as a special case.[10] Though these new functional forms are claimed to be much more general than the Cobb-Douglas or CES function, the estimates of these new functions may not be very sharp because they suffer from a relatively large number of parameters to be estimated and the presence of multicollinearity among independent variables. However, they do provide us with the grounds to test some of the properties assumed a priori in the Cobb-Douglas or CES function. Since the translog function contains the Cobb-Douglas function as a special case, it attracts our interest more and hence will be fitted to the data in the present study. We can write the translog function as:

$$\text{(2.6)} \quad \ln(V) = a_o + a_1\ln(K) + a_2\ln(L) + a_3[\ln(K)]^2 + a_4[\ln(L)]^2 + a_5[\ln(K)][\ln(L)].$$

As will be immediately apparent from the above equation, when $a_3=a_4=a_5=0$, the translog function reduces to the Cobb-Douglas

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[10] In a simple case of two factors and one output, the Diewert function can be written as

$$V = a_0 + a_1K^{1/2} + a_2L^{1/2} + a_3L + a_4K + a_5K^{1/2}L^{1/2}.$$

Note that when $a_1 = a_2 = a_5 = 0$, this function reduces itself to a linear transformation function.

form. When $a_3 = a_4 = -(\frac{1}{2})a_5$, the translog function reduces to the Kmenta approximation of the CES function. Thus one can directly test the translog form against the Cobb-Douglas or the Kmenta approximation of the CES function.

In the translog function, output elasticities of inputs can be derived from equation 2.6:

$$(2.7) \quad \alpha = \frac{\partial \ln(V)}{\partial \ln(K)} = \frac{\partial V}{\partial K}\frac{K}{V} = a_1 + 2a_3\ln(K) + a_5\ln(L)$$

$$(2.8) \quad \beta = \frac{\partial \ln(V)}{\partial \ln(L)} = \frac{\partial V}{\partial L}\frac{L}{V} = a_2 + 2a_4\ln(L) + a_5\ln(K)$$

where the α and β denote the output elasticity of capital and labor, respectively. Note that these elasticities are not constant but depend upon the levels of inputs employed. The elasticity of substitution is also a variable in the translog function. The elasticity of substitution can be expressed in terms of output elasticities of inputs and the coefficients of the variables in the translog function as follows:[11]

$$(2.9) \quad \sigma = \frac{\alpha\beta\ (\alpha+\beta)}{\alpha\beta\ (\alpha+\beta) + 2[a_5\alpha\beta - a_3\beta^2 - a_4\alpha^2]}$$

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[11]In Appendix A, the properties of the translog function along with the derivations of the elasticity of substitution are presented.

Thus the elasticity of substitution is in general no longer constant but a function of output elasticities of inputs, which are in turn determined by the amount of factors employed. Note that if the coefficients of second order terms in the translog function are equal to zero, the production function reduces to the Cobb-Douglas and the elasticity of substitution becomes unity.

II-3. Aggregation Problem

From a microeconomic point of view, the production function should represent a technological relationship confronting individual firms, because they are the basic units who make all the decisions on the allocation of production resources and level of outputs. Thus the data one would like to work with for estimating the firms' production functions are those of individual microunits -- firms or establishments -- within a well-defined industry. In the bulk of earlier econometric studies on production functions in manufacturing industries, however, it appears that the basic statistics used have frequently been inappropriate because they are at various levels of aggregation. For instance, the cross section data classified by individual industries have often been used as a sample base.[12]

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[12]For example, see Douglas and Gunn (20), and Griliches (28).

The economic meaning of a production function estimated from these data is obscure, because it is assumed in the procedure used that factor inputs are homogeneous across industries and that production functions for various industries are the same. Second, sometimes production functions have been inferred from such cross section data as state or regional totals, which seem to have little relevancy to the scale of individual firms or plants.[13] Third, in other cases, per-establishment data have been taken as "representative establishment," thus permitting a production function to be estimated for a given industry on the basis of the differences between representative establishments of different states or regions.[14] As we shall show below, these are also subject to a bias in sampling and tend to cause a loss of precision in estimation due to aggregation. Surprisingly, only a few studies have actually dealt with the data of microunits or at least average cross section data classified by relevant firm size.[15]

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[13]For example, see Bronfenbrenner and Douglas (12), Dhrymes (18), and Katz (34).

[14]For example, see Hildebrand and Liu (31), and Griliches (28).

[15]For example, Eisner's (23), Hodgin's (32), and Griliches and Ringstad's (29) studies are based on data for individual companies or plants.

A systematic treatment of the general aggregation problems in production function was pioneered by Klein and Nataf.[16] Nataf has shown that, for sensible aggregation, the production function must be additively separable. Particularly if the production function for the microunits were of Cobb-Douglas type, Klein and Nataf have shown that aggregate data should be logarithmic sums or geometric averages of microunits in order for the aggregate data to remain on the same production function as that of the microunits.[17] However, census data are often presented only in the form of arithmetic averages or totals. Thus economists are often forced to use cross section data of state or regional totals, or at best arithmetic averages, hoping that arithmetic means may not differ significantly from the geometric means. A natural question to ask then is what are the errors introduced by these aggregate data? The most serious drawback of the aggregate data of state or regional totals is that they do not

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[16] See Klein (37), and Nataf (46).

[17] Suppose that for each microunit i, we have the Cobb-Douglas function in the logarithmic form: $\ln(V_i) = \alpha \ln(K_i) + \beta \ln(L_i)$, $i = 1, \ldots, N$. Then the Klein-Nataf condition for aggregate variables to have the same function is: $\ln(V) = \alpha \ln(K) + \beta \ln(L)$, where $\ln(V) = (1/N) \Sigma \ln(V_i)$, $\ln(K) = (1/N) \Sigma \ln(K_i)$, and $\ln(L) = (1/N) \Sigma (L_i)$.

reflect individual firm size but instead represent largeness of states or regions. Therefore, the aggregate data may deviate from the production surface of individual firms. The deviation could be particularly serious when the true production function is subject to other than constant returns to scale and when the number of firms aggregated in each sample point becomes large. In a simple case of Cobb-Douglas function, it can be shown that the aggregate data of arithmetic sums tend to fall under the true production surface when the elasticity of scale is greater than unity and tend to fall above when it is less than unity.[18] Thus per-establishment averages of cross section data

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[18]A simple example will demonstrate the likely deviation of the aggregate data from the true production surface. Suppose the true production function is $V = K^{\alpha} L^{\beta}$ or $V = k^{\alpha} L^{\lambda}$, where $k = (K/L)$ and $\lambda = \alpha + \beta$. Assume there are two firms, firm 1 and 2, who employ the same capital-labor ratios but may differ in scale. The aggregate output observed would then be $V_1 + V_2$ for the inputs of $(L_1 + L_2)$ and $(K_1 + K_2)$, where $V_1 + V_2 = k^{\alpha} L_1^{\lambda} + k^{\alpha} L_2^{\lambda} = k^{\alpha}(L_1^{\lambda} + L_2^{\lambda})$. However the true output level, at the scale of $(L_1 + L_2)$ and $(K_1 + K_2)$, would have been $V_{1+2} = k^{\alpha}(L_1 + L_2)^{\lambda}$. Thus the aggregation bias can be written as

$$(V_1+V_2) - V_{1+2} = k^{\alpha} [(L_1^{\lambda} + L_2^{\lambda}) - (L_1 + L_2)^{\lambda}] \gtreqless 0. \quad \text{if } \lambda \lesseqgtr 1.$$

Therefore the aggregate output will underestimate the true output when the production function is subject to increasing returns to scale and overestimate in case of decreasing returns to scale. Of course, this is not a proof that the elasticity of scale estimated with the aggregate data of arithmetic sums is necessarily biased toward unity. But one can easily see that if all the firms are identical and observations differ only in number of firms aggregated in each sample point, then the elasticity of scale estimated with these data tends to be constant returns to scale regardless of the true elasticity of scale of individual firms.

appear to be the more relevant data to estimate the elasticity of scale or production functions, because they at least reflect the average size of establishments in different states or regions. But still they suffer from being arithmetic means, whereas aggregation requires geometric means in the case of Cobb-Douglas function. If the deviations from the mean value of a variable are relatively small, it can be shown that the geometric mean $\bar{G}$ is related to the arithmetic mean $\bar{A}$ by formula:[19]

$$\bar{G} = \bar{A}\,(1 - \frac{\sigma_A^2}{\bar{A}}),$$

where σ_A^2 is the variance of the variable. This formula indicates that the larger the relative variance, the larger is the divergence between the arithmetic mean and the geometric mean. Therefore, an aggregation over a wide range of firm size in one sample point may give rise to a large deviation between the arithmetic means and the geometric means of the variables.[20] For that reason, if individual establishment data

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[19]See Walters (56), p. 10.

[20]The formula suggests, however, that as long as the relative variances of the variables, output, capital, and labor are approximately equal across sample points, the bias due to arithmetic averages in the estimates of the factor-output elasticities may not be serious in case of a Cobb-Douglas form, because any fixed deviation in the variables across sample points would affect only the constant term. But the formula depends on (continued next page)

are lacking, the closest approximation to the required micro-data or geometric means can be obtained by using cross section data classified by some relevant firm size.

It is well known that, even when grouped data with no aggregation bias (such as geometric means for the Cobb-Douglas function) are used in the multiple regressions, a loss of precision resulting from grouping is unavoidable in estimation of the parameters. The loss of precision depends upon the relative variations of independent variables from their mean within a group to those between groups.[21] Thus the loss of precision is clearly minimized when the data are grouped so that the values of independent variables are little different within a group. This is another important reason why per-establishment averages derived from cross section data classified by some relevant size of firms are preferred to those derived from simple cross section data.

(footnote 20 continued)
the assumption of only relatively small deviations of the variables from mean values, and this assumption may not be satisfied if the variances of the variables get too large.

[21]See Malinvaud (42), pp. 281-285.

II-4. Data and Limitations of the Work

All the data used to estimate production functions in this study were obtained from the Report on Mining and Manufacturing Survey, published jointly by the Korea Development Bank and Economic Planning Board. This data source covers all the establishments with five or more employees. One of the most serious shortcomings of the data is that the capital stock data are available only for 1966 and 1968. However, the report provides cross section data for each of 18 two-digit manufacturing industries, classified by eleven regions and twelve divisions by size of the firms for each region in 1966 and seven divisions by size of the firms for each region in 1968. Thus, at maximum, 209 sample observations could be obtained for each industry. Each sample point includes the data for value added (V), capital stock (K), number of workers (L), number of establishments (N), and total labor compensation (W). The basic units used in this study are per-establishment averages of cross section data classified both by regions and firm size.

These data, however, are subject to limitations in a number of respects. The capital stock represents the total "book value" of tangible fixed assets as of the end of the year. This measure of capital stock as an input suffers from many shortcomings: (i) it measures the stock of capital rather than the flow of services from it; (ii) it ignores vintages and heterogeneity of capital stocks; and (iii) capital stocks are not adjusted for capacity utilization.[22]

The labor input is measured as the average number of employees during the twelve months and the number of working proprietors and unpaid workers as of the end of the year. Perhaps the most important drawback in the measure of labor is the lack of information on the characteristics (age, sex, skills, etc.) of the labor force in the various sample points. Thus no adjustment can be made to account for quality differences of labor among sample points. Moreover, the procedure used assumes that the flow of labor services has some constant relationship with the stock of labor input.

The measure of output as the main dependent variable in this study is value added derived by subtracting the cost of production from the value of gross output. The production cost refers to direct charges actually paid or payable for materials and services consumed or put into production during

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[22]Capacity utilization appears to be an important variable in time-series analysis but not so seriously important in cross section analysis. For empirical evidence, see Eisner (23).

the reporting year. The value added, therefore, includes depreciation charges, domestic consumption duties, income tax and other indirect business expenditures, in addition to the actual payments to factors, labor and capital. Thus, to the extent that the fraction of actual returns to factors in the measure of value added differs from sample to sample, the output data should suffer from measurement error.

Besides the errors of measurement in the variables, our estimation procedures may be subject to a number of possible biases. In particular, the aggregation to the two-digit level of industries and the specification errors should be noted. We assume a unique production function for a two-digit industry in which hundreds of different products and different technologies may exist. We fail to include the "entrepreneurship" factor in the production function. Hence, the estimated elasticities of labor and capital may be biased in some unknown way because of this omission. It can be shown, however, that if the omitted variable is positively correlated with one factor, then the bias in the elasticity of that factor would be upward. The omission bias on the overall returns to scale depends on how the omitted input changes in the sample when the other inputs are varied to scale. On the average, we shall overestimate if the omitted input varies more than proportionally with the included inputs, and we shall underestimate in the opposite case.[23] We also ignore the simultaneity between factor employments and output determination decision, and we use the single-equation, least square method. This method is subject to the well-known "simultaneous equation bias." To deal adequately with the simultaneous model, we would have to have good price data for inputs and output. In the aggregate cross section analysis, however, the good price data are hardly available; this lack of data forced us to rely on the single-equation estimation method.

Before we estimate and interpret the parameters of the production function, one basic question should be answered. That is, what are the sources of differences in K and L among establishments within the industry? If all the establishments in an industry are subject to an identical production function and are faced with the same factor and output markets, why should they produce different levels of output with different combinations of inputs? There may be several explanations for that: (1) there may be some fixed inputs which can change only slowly over time; (2) there may be regional differences in wages; (3) different firms may have differential access to capital markets; and (4) different firms may have different price expectations.

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[23]Reference is made to Griliches (27), and Theil (55), p. 551.

CHAPTER III

RESULTS OF ESTIMATION AND HYPOTHESIS TESTING

III-1. Introduction

The main results of estimating production functions for South Korean manufacturing industries are presented in this chapter. Prior to investigation of two-digit level industries, preliminary experiments were conducted with the cross section data for the total manufacturing sector. These preliminary experiments are primarily intended to reveal some of the important properties of the data and production functions for total manufacturing, and to illustrate the estimation procedures used for the follow-up estimation of production functions in two-digit level industries. Care should be taken, therefore, in interpreting the estimates of various elasticities derived from total manufacturing, because the data are aggregated across industries and a unique production function is assumed for average firms in total manufacturing. Having estimated production functions of individual industries at the two-digit level, of course, more relevant factor-output elasticities for total manufacturing may be constructed by finding weighted averages of the factor-output elasticities of individual industries, the weights being the shares of respective industries in total magnitude of relevant inputs.[1]

We shall present all the results of preliminary tests and estimates of production functions for total manufacturing in section 2 of this chapter. In section 3, we report all findings concerning 18 two-digit industries and hypothesis testing regarding the characteristics of production technologies for each of the 18 industries. We chose to delete two two-digit industries -- tobacco and miscellaneous industries -- in the present study, because the former, being a monopoly owned by the government, lacks degrees of freedom and the latter lacks homogeneity in outputs.

III-2. Overview: Total Manufacturing

At the outset we examined the importance of the per-establishment cross section data in contrast with the cross section totals in making inferences on the output elasticities

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[1]Output-elasticity with respect to a factor for total manufacturing can be interpreted as the percentage increase in output in the manufacturing sector measured in value added if the factor input increased by 1 percent. The weighted averages of the output elasticities across industries mean assuming that all firms in the manufacturing sector increase the factor by 1 percent.

of inputs or the elasticity of scale.[2] A simple Cobb-Douglas function was fitted to each set of data. The estimating equation and the regression result for the data of cross section totals are:

$$(3.1) \quad \ln V^* = a_o + dD + a_1 \ln K^* + a_2 \ln L^*$$

$\hat{a}_o = -0.974(-3.720)$ $\hat{d} = 0.076(0.973)$

$\hat{a}_1 = 0.573(9.955)$ $\hat{a}_2 = 0.458(6.664)$

$R^2 = 0.888$ SSR = 49.789 Sample = 202

where "*" refers to the data of cross sectional totals which are not divided by the number of establishments in each observation, "^" refers to the estimates of the coefficients, and D denotes time dummy, 0 for 1966 and 1 for 1968. The numbers in parentheses by the coefficients represent t-values of the estimates. The coefficient of the time dummy variable should not be interpreted as an estimate of technical change, since the values of the dependent variable are not deflated for price changes. R^2 represents the coefficient of determination adjusted by degrees of freedom and SSR, the sum of the squares of residuals. The estimation result indicates that the

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[2] See page 55.

elasticity of scale is very close to unity. Thus the hypothesis that $a_1 + a_2 = 1$ was tested by estimating the constrained equation. It gave an F-ratio of 1.045 which is not significant at the 10 percent level. As discussed in the preceding Chapter II-3, however, the above estimates of the output elasticities of inputs may be subject to serious biases due to aggregation of the data and neglect of the actual size of the microunits. Thus in order to look at the possible influence of the number of firms aggregated in each sample point, we added another independent variable, that is, the number of firms which constitutes each sample point, to the equation 3.1. The regression result is:

$$(3.2) \quad \ln V^* = a_o + dD + a_1 \ln K^* + a_2 \ln L^* + a_3 \ln N^*$$

$$\hat{a}_o = -1.971(-7.781) \quad \hat{d} = 0.155(2.309)$$

$$\hat{a}_1 = 0.437(\ 8.490) \quad \hat{a}_2 = 0.773(11.230)$$

$$\hat{a}_3 = -0.172(-8.732)$$

$$R^2 = 0.919 \quad SSR = 35.897 \quad Sample = 202$$

where N^* is the number of firms in each sample point. The result clearly indicates that the equation 3.1 is seriously misspecified in not having reflected the number of firms aggregated in each sample point.[3] The more economically meaningful way to reflect the number of firms in each sample point would be to take per-establishment averages of the cross section data as "the representative firms" for the sample points. Using the per-establishment data, the estimate of the Cobb-Douglas function is:

$$(3.3) \quad \ln V = a_o + dD + a_1 \ln K + a_2 \ln L$$

$$\hat{a}_o = -1.656(-12.646) \quad \hat{d} = 0.181(2.791)$$

$$\hat{a}_1 = 0.447(8.762) \quad \hat{a}_2 = 0.723(12.045)$$

$$R^2 = 0.956 \quad SSR = 36.291 \quad Sample = 202$$

where V, K, and L are the average values which correspond to V^*/N^*, K^*/N^*, and L^*/N^*, respectively.[4] Comparing the estimates in equation 3.1 with those in equation 3.3, two

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[3] The auxillary equation, $\ln N^* = b_o + dD + b_1 \ln K^* + b_2 \ln L^*$, was estimated at: $\hat{b}_1 = -0.795(4.486)$, and $\hat{b}_2 = 1.835(8.679)$, implying that if equation 3.2 had been a correct specification, then the estimate of a_1 would have been overestimated and that of a_2 underestimated in equation 3.1.

[4] Equation 3.3 is, in fact, equivalent to constraining equation 3.2 by $a_3 = 1 - (a_1 + a_2)$. Analysis of variance for the null hypothesis of $a_3 = 1 - (a_1 + a_2)$ gave an F-ratio of 2.2 which is not significant at the 10 percent significance level.

characteristic observations are evident: (i) the elasticity of scale is substantially greater than unity in equation 3.3, whereas it is not significantly different from unity in equation 3.1. This is not too surprising because the aggregate data of arithmetic sums tend to reflect the number of firms aggregated in each sample point rather than the size of individual firms;[5] (ii) the failure to take per-establishment data gave rise to an overestimation of a_1 and an underestimation of a_2 in equation 3.1.

Since OLS (ordinary least squares) is used in the estimation procedure, it would be desirable to check the assumption of homoscedasticity of the disturbance in regression equation. Plotting the residuals from equation 3.3 against the logarithm of employment per-establishment (lnL) shows a mildly increasing tendency as employment rises, implying that the residuals may be subject to some degree of heteroscedasticity. Thus the heteroscedasticity was tested by the method of Goldfeld and Quandt, estimating equation 3.3, separately using the first 74 samples and the last 74 samples when the whole

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[5] See footnote 18 on page 55.

202 samples were placed in order of the size of employment (lnL).[6] Denoting the SSR_1 and SSR_2 the sum of the squares of the residuals from the regression based on the relatively small and large values of lnL respectively, we form:

$$F_{70,70} = \frac{SSR_2}{SSR_1}$$

under the null hypothesis of homoscedasticity.

The test gave an F-ratio of 6.8 which is significant at the 1 percent level. Thus we divided equation 3.3 by the logarithm of the employment term and got:

$$(3.4) \quad \frac{\ln V}{\ln L} = a_0 \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1\frac{\ln K}{\ln L} + a_2$$

The test of homoscedasticity of the residuals of equation 3.4 using the same procedure as described before gave an F-ratio of 1.5 which is not significant at the 5 percent level. Thus homoscedasticity of the transformed equation is not rejected. There is another traditional source from which the heteroscedasticity may come. Heteroscedasticity may arise as a result of aggregation. That is, if error terms of all the microunits show constant variances, then the different

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[6]According to the best experimental result obtained by Goldfeld and Quandt (26), we left out 54 samples.

number of microunits aggregated in each sample may give rise to heteroscedasticity. Thus a new regression equation was derived from equation 3.3 by multiplying $\sqrt{N^*}$ assuming that all microunits before aggregation were initially subject to homoscedasticity in their logarithmic Cobb-Douglas form. That is:

$$(3.5)\quad \sqrt{N^*}\ \ln V = a_o \sqrt{N^*} + d\sqrt{N^*}D + a_1\sqrt{N^*}\ \ln K + a_2\sqrt{N^*}\ \ln L$$

The test of homoscedasticity of equation 3.5 gave an F-ratio of 9.0, rejecting the null hypothesis of homoscedasticity at the 1 percent significance level.[7] Both attempts to correct heteroscedasticity rest upon ad hoc assumptions, but the specification of equation 3.4 appears to be better than that of equation 3.5. Hence we attempted to use Cobb-Douglas and other functional forms divided by lnL in order to estimate coefficients of the production functions by OLS in the following estimations.

Since the cross section data for two years, 1966 and 1968, are to be used together with the time dummy variable (D)

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[7] The same procedure as in the previous test was used except that SSR_2 was referred to small firms and SSR_1 to large firms in calculation of the F-ratio, for the data show an correlation coefficient of -0.8 between firm size and number of firms in observations.

in the present study, it should be checked whether the factor-output elasticities remain unchanged between 1966 and 1968. Thus the null hypothesis of the same coefficients between 1966 and 1968 was tested by estimating the Cobb-Douglas function separately for each year. The resulting F-ratio was 0.234 which is not significant at almost any level.

By rearranging equation 3.4, we can derive a new equation by which the returns to scale can be easily tested. That is, by subtracting 1 from both sides of equation 3.4, we get:

$$(3.6)\quad \frac{\ln(V/L)}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 \frac{\ln(K/L)}{\ln L} + (a_1 + a_2 - 1).$$

Thus the constant term $(a_1 + a_2 - 1)$ in equation 3.6 measures the scale coefficient $(h = \lambda - 1)$, i.e., the extent of departure from constant returns to scale.

The estimates of equation 3.4 and 3.6 for the total manufacturing sector are summarized below:

$\hat{a}_o$ = -1.624(-15.688)	$\hat{d}$ = 0.211(4.665)
$\hat{a}_1$ = 0.420(7.714)	$\hat{a}_2$ = 0.732(12.113)
$\hat{h}$ = 0.152(9.383)	Sample = 202
R^2 = 0.896	SSR = 1.617

In order to verify the assumption of unitary elasticity of substitution imposed on the data in the Cobb-Douglas function, the Kmenta approximation of CES function (equation 2.5) was fitted to the data. The regression equation and the result are:

$$(3.7)\quad \frac{\ln(V/L)}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 + a_2\frac{\ln(K/L)}{\ln L} + a_3\frac{[\ln(K/L)]^2}{\ln L}$$

$\hat{a}_o$ = -1.625(-14.844) $\hat{d}$ = 0.163(3.411)

$\hat{a}_1$ = 0.152(8.824) $\hat{a}_2$ = 0.419(4.489)

$\hat{a}_3$ = -0.0005(-0.012) Sample = 202

R^2 = 0.896 SSR = 1.617

The result indicates that adding the square of the logarithmic capital-labor ratio term to the Cobb-Douglas form does not affect the other coefficients much at all. The estimate of $h(a_1)$ remains at 0.152 and R^2 also remains unchanged.

As mentioned in Chapter II-2, the translog function has merits in that it does not impose any a priori assumptions such as constancy in the elasticities or homotheticity onto the data. Furthermore, it contains the Cobb-Douglas or the Kmenta approximation of the CES form as special cases and hence can provide us with direct tests against the restricted forms. The estimate of the translog function is presented below:

$$(3.8)\quad \frac{\ln V}{\ln L} = a_0\frac{1}{\ln L} + d\frac{D}{\ln L} + a_1\frac{\ln K}{\ln L} + a_2 + a_3\frac{(\ln K)^2}{\ln L} + a_4\ln L$$

$$+ a_5\ln K.$$

$\hat{a}_0 = -1.722(-5.109)$ $\hat{d} = 0.177(3.623)$

$\hat{a}_1 = 0.164(0.672)$ $\hat{a}_2 = 0.917(2.859)$

$\hat{a}_3 = -0.025(-0.534)$ $\hat{a}_4 = -0.48(-0.655)$

$\hat{a}_5 = 0.088(0.787)$

$R^2 = 0.897$ SSR = 1.581   Sample = 202

The result indicates that the coefficients of the first order logarithmic capital and labor terms lose much of their sharpness due to the relatively large number of independent variables and the presence of multicollinearity among them. Moreover, none of the coefficients of the quadratic terms is statistically significant. The test of the null-hypothesis of a Cobb-Douglas form against a translog form gave an F-ratio of 1.480 which is not significant at the 5 percent level. Thus one can infer that the Cobb-Douglas function may not be a bad approximation of the production process for the total manufacturing sector in South Korea.[8]

In order to double check the earlier finding that the elasticity of substitution is not significantly different from unity, we have further attempted to estimate the elasticity of

[8]The results for total manufacturing, however, do not guarantee that the same conclusion will follow in two-digit industries because of the aggregations made in total manufacturing.

substitution in two more ways: one through the marginal productivity relation and the other by direct estimation of the CES function by nonlinear least squares method. Allowing for non-constant returns to scale, the estimable equation can be derived from the marginal productivity condition (equation 2.4). The estimating equation and the result are:

$$(3.9) \quad \frac{\ln(V/L)}{\ln L} = a_0 \frac{1}{\ln L} + d \frac{D}{\ln L} + a_1 \frac{\ln(W/L)}{\ln L} + a_2.$$

$\hat{a}_0 = 1.026(3.491)$ $\hat{d} = -0.039(-0.809)$

$\hat{a}_1 = 1.006(11.450)$ $\hat{a}_2 = 0.079(4.818)$

$R^2 = 0.919$ SSR = 1.265 Sample = 202

This result yields the estimate of the elasticity of substitution of 0.932 with approximate standard error of 0.09, which is somewhat lower than unity but not significantly different from unity at the conventional level.[9] The calculation of the scale coefficient h (or λ - 1), however, led to the nonsense result of -13.2 with the approximate standard error of 194.8.

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[9]In equation 3.9, we find $\sigma = a_1/(1 + a_2)$ and h (or λ - 1) $= a_2/(1 - a_1)$. The approximate standard error of σ and h can be calculated according to the Goldberger's suggestion. That is, suppose y is a differentiable function of a where a is a vector of a_i's; then approximately σ_y^2 (variance of y) can be expressed as $\sigma_y^2 = A'MA$ where $A = \partial y/\partial a$, and M is the covariance matrix of a. See Goldberger (25), p. 125.

This is not too surprising because, even if the marginal productivity condition were to hold true, the estimate of h becomes extremely unstable when the estimate of a_1 approaches unity. Thus it appears that equation 3.9 may not be an appropriate one from which the economies of scale can be inferred, at least for the manufacturing sector in Korea with the data available.

Another attempt at direct estimation of the CES function was made using nonlinear least squares method. The estimating equation and the result are:

$$(3.10) \quad \frac{\ln V}{\ln L} = a_o \frac{1}{\ln L} + d \frac{D}{\ln L} - \frac{\lambda}{\delta} \frac{\ln [\theta K^{-\delta} + (1-\theta) L^{-\delta}]}{\ln L}$$

$\hat{a}_o = -1.625(-1.844, -1.406)$ $\hat{d} = 0.163(0.067, 0.258)$

$\hat{\theta} = 0.364(0.197, 0.531)$ $\hat{\lambda} = 1.152(1.117, 1.186)$

$-\hat{\delta} = -0.004(-0.649, 0.644)$ or $\hat{\sigma} = 0.996(0.606, 2.809)$

$R^2 = 0.896$ Sample = 202

where the elasticity of substitution σ is derived by $1/(1+\delta)$. The numbers in parentheses by the coefficients are the approximate lower and upper bounds of the 95 percent confidence interval. Both the estimates and the confidence limits on the estimates are based on a linear approximation of equation 3.10 by Taylor expansion.[10] The results indicate that the estimate of the elasticity of substitution is subject to a large standard error but is not significantly different from unity. The estimate of the elasticity of scale turns out to be 1.152 which is not different from those obtained by the Cobb-Douglas function and the Kmenta approximation of the CES function.

In order to test the dualism hypothesis that the production technology for large firms may differ from that of small firms, we divided our sample into two parts by a somewhat

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[10] Let us have a nonlinear regression model:

$$V_i = f(X_i;\pi) + \mu_i \qquad i = 1, \ldots, n$$

where X_i denotes a vector of independent variables for i^{th} observation giving rise to V_i while π is a vector of unknown parameters. The estimation of π by nonlinear least squares is to minimize $S(\pi) = \Sigma[V_i - f(X_i;\pi)]^2$. The first order Taylor expansion at π_o as certain initial values for π will be given by

$$V_i - f(X_i;\ \pi_o) = (\pi - \pi_o)\frac{f(X_i;\ \pi_o)}{\pi}\bigg|_{\pi = \pi_o} + \mu_i + R_i$$

where R_i is the remainder of the Taylor expansion. Using OLS we estimate $(\pi - \pi_o)$. Then we correct initial values π_o by the new estimates of π and repeat the process until k^{th} iteration converges to the criterion given by

$$\left|\frac{\pi_k - \pi_{k-1}}{\pi_k}\right| = \gamma \qquad \text{where } \gamma \text{ is specified a priori.}$$

arbitrary standard -- into establishments with fewer than or more than 100 employees.[11] Then separate regressions for estimating the Cobb-Douglas function (equation 3.4) were run for each part. The results are:

	fewer than 100 employees	more than 100 employees
$\hat{a}_o$:	-1.641(-12.338)	-1.772(-4.078)
$\hat{d}$:	0.200(4.222)	0.036(0.273)
$\hat{a}_1$:	0.333(3.995)	0.449(5.654)
$\hat{a}_2$:	0.773(9.031)	0.750(6.360)
R^2:	0.884	0.486
SSR:	0.696	0.873
Sample:	110	92

The hypothesis testing for the null hypothesis of the same production functions for small and large establishments gave an F-ratio of 1.484 which is not significant at the 5 percent level. Thus the dualism hypothesis is not supported statistically. However, it is interesting to note that the elasticity of scale is greater for large firms ($\lambda = 1.199$) than for small firms ($\lambda = 1.106$), and the elasticity of output with respect to capital is greater for larger firms than for small firms.

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[11]We chose to divide at the level of 100 employees per establishment because the share of employment with fewer than 100 employees in total manufacturing employment has declined since 1966, whereas that with more than 100 employees has increased. See Table 4.4 on page 107.

In conclusion, we may summarize the findings as follows:

(1) There is a significant indication of increasing returns to scale at the establishment level as opposed to the constant returns to scale which result from cross sectional totals for total manufacturing. Moreover, the estimate of the elasticity of scale is invariant regardless of the estimation procedures or production functions used.

(2) There is no indication that the elasticity of substitution differs significantly from unity.

(3) There is no indication that the production technology is not homothetic.

(4) The dualism hypothesis is not supported by the data.

These observations, however, should be taken only as indicative for individual manufacturing industries, because of the aggregation of data involved in total manufacturing. We now proceed to investigate two-digit level industries and discuss the findings in the following section.

III-3. Individual Industry Results and Hypothesis Testing

We have fitted the Cobb-Douglas and other related production functions to the data for each of the 18 two-digit industries, according to the procedures described for total manufacturing in the previous section. All the regression results are presented in Appendix B, and we shall present only the summary o' these results in this section. In Table 3.1 the results of estimating a Cobb-Douglas function (equation 3.4) separately for each of the 18 industries are reported. The estimates of the output elasticities with respect to factors turn out to be reasonably good statistically with all the expected signs. The weighted average of factor-output elasticities across two-digit industries turns out to be 0.425 for capital and 0.741 for labor (the weights being the share of each industry in total manufacturing capital stock and employment for respective elasticity). It is interesting to compare these weighted averages with those estimated directly from total manufacturing; the output elasticity was 0.420 for capital and 0.732 for labor, respectively.[12]

In Table 3.2 we present the F-ratios for testing hypotheses regarding alternative forms of production functions: (i) the null hypothesis of a Cobb-Douglas form against the Kmenta approximation of a CES form; (ii) the null hypothesis of the Kmenta approximation against a translog form; and

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[12] See page 70.

Table 3.1 Estimates of Cobb-Douglas Function (Equation 3.4)[1] for Individual Industries

Industry(n)[2]	Coefficients				
	$\hat{a}_0$ (t-value)	$\hat{d}$ (t-value)	$\hat{a}_1$ (t-value)	$\hat{a}_2$ (t-value)	R^2 (SSR)
20.Food	-1.212	.043	.655	.625	.428
(152)	(-8.472)	(.551)	(10.437)	(9.591)	(3.473)
21.Beverage	- .208	.350	.507	.827	.392
(121)	(-1.229)	(3.732)	(6.188)	(8.826)	(3.562)
23.Textile	- .471	.194	.380	.740	.379
(175)	(-5.732)	(2.998)	(7.483)	(11.828)	(2.425)
24.Footwear &	.244	.343	.232	.750	.431
Apparel(104)	(2.092)	(4.136)	(3.729)	(10.508)	(1.912)
25.Wood	- .005	.240	.342	.759	.525
(94)	(- .027)	(2.805)	(5.416)	(12.269)	(1.952)
26.Furniture	- .475	.408	.298	.892	.355
(82)	(-2.767)	(4.679)	(2.580)	(8.178)	(1.553)
27.Paper	- .186	.023	.502	.595	.504
(116)	(-1.400)	(.233)	(8.560)	(6.037)	(3.631)
28.Printing	- .337	.242	.288	.845	.130
(102)	(-1.564)	(2.068)	(2.700)	(7.447)	(3.975)
29.Leather	.335	.169	.247	.768	.175
(41)	(.995)	(.905)	(1.810)	(4.479)	(1.692)
30.Rubber	- .757	.162	.503	.682	.357
(76)	(-3.984)	(1.196)	(5.354)	(6.865)	(2.246)
31.Chemicals	- .276	.130	.441	.716	.341
(133)	(-1.824)	(1.478)	(6.434)	(9.878)	(3.056)
32.Petroleum &	- .663	.190	.553	.740	.538
Coal(105)	(-5.383)	(2.452)	(7.588)	(8.986)	(1.359)
33.Caly	.034	.056	.552	.488	.504
(143)	(- .403)	(-.760)	(9.841)	(8.072)	(3.151)
34.Basic Metal	- .189	.115	.315	.854	.217
(100)	(-1.193)	(1.067)	(4.950)	(9.984)	(2.666)
35.Metal Prod.	- .158	.185	.291	.795	.202
(117)	(-1.250)	(2.281)	(3.315)	(8.506)	(2.098)
36.Machine	.014	.279	.132	.941	.420
(122)	(.108)	(3.271)	(1.540)	(10.922)	(2.840)
37.Elec. Mach.	- .151	.010	.361	.726	.172
(89)	(- .798)	(.179)	(4.387)	(7.558)	(3.145)
38.Transp. Eq.	- .270	.175	.260	.900	.219
(128)	(-2.246)	(2.456)	(2.456)	(4.146)	(1.943)

[1] (3.4) $\frac{\ln V}{\ln L} = a_0 \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 \frac{\ln K}{\ln L} + a_2$.

[2] n indicates the number of observations.

Table 3.2 Hypotheses Testings for Alternative Production Functions for Individual Industries

Industry	$F_{1,n-5}$ [1]	$F_{2,n-7}$ [2]	$F_{3,n-7}$ [3]
20.Food	.042	1.929	1.301
21.Beverage	8.044*	.763	3.179
23.Textile	7.847*	.109	2.661
24.Footwear & Appr.	.416	1.796	1.338
25.Wood	.921	1.275	1.159
26.Furniture	.000	.539	.359
27.Paper	.584	9.664*	6.667*
28.Printing	.000	1.063	.709
29.Leather	.193	.173	.177
30.Rubber	5.300*	.226	1.883
31.Chemicals	9.929*	1.385	4.253*
32.Petro. & Coal	2.334	.560	1.144
33.Caly	4.898*	2.215	3.138*
34.Basic Metal	8.039*	.828	3.222*
35.Metal Prod.	.268	1.017	.767
36.Machine	16.607*	4.702*	9.021*
37.Elect. Mach.	.027	.934	.631
38.Transp. Equ.	.063	.503	.356

[1] F-ratios for the null hypothesis of $a_3 = 0$ in equation 3.7.

[2] F-ratios for the null hypothesis of $a_3 = a_4 = -\frac{1}{2}a_5$ in equation 3.8.

[3] F-ratios for the null hypothesis of $a_3 = a_4 = a_5 = 0$ in equation 3.8.

*The F-ratio is significant (rejection of the null hypothesis) at the 5 percent level.

(iii) the null hypothesis of a Cobb-Douglas form against a translog form. First, we find that in 7 industries (21, 23, 30, 31, 33, 34, and 36) out of the 18 two-digit industries, the Cobb-Douglas function is rejected against the Kmenta approximation, indicating that the assumption of unitary elasticity of substitution may not be appropriate for these 7 industries. Second, the Kmenta approximation is rejected only in two industries (27 and 36) when tested against a more general translog form, implying that the homothetic assumption tends to be violated with statistical significance in these two industries. It is interesting to note that a Cobb-Douglas form is not rejected against the Kmenta approximation for the paper industry (27), but both the Cobb-Douglas and the Kmenta approximation are rejected against a translog form, implying that the elasticity of substitution may not be far from unity but that production technology tends to be nonhomothetic. For the machine industry (36), however, it appears that both assumptions of the unitary elasticity of substitution and the homotheticity are violated, since the hypothesis of a Cobb-Douglas form is rejected against the Kmenta approximation and the Kmenta approximation is again rejected against a translog form. Thus the estimation results of the Cobb-Douglas and the CES function should be interpreted with care for these two industries.[13]

We have summarized the alternative estimates of the scale coefficient ($h = \lambda - 1$) in Table 3.3. The estimate of the scale coefficient is in fact equivalent to the hypothesis testing of constant returns to scale. Indications of economies of scale are predominant, with the elasticity of scale being significantly greater than unity in 13 out of the 18 industries at the conventional 5 percent significance level. It is interesting to note that the estimates of the scale coefficient yield almost the same values regardless of the form of production functions and estimation methods employed, even for the seven industries where the null hypothesis of a Cobb-Douglas form was rejected against the Kmenta approximation of a CES function. Thus only in 5 industries (24, 27, 29, 33, and 37) are we unable to reject the hypothesis of constant returns to scale. Only in industry (24) do the estimates of the scale coefficient show a negative sign, but not significantly so.

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[13] We did not attempt, however, to draw estimates of various elasticities from the estimation results of the translog function because a number of coefficients turned out to be insignificant even for these two industries. See Table B.2.

Table 3.3 Alternative Estimates of the Scale Coefficient by Industry

		CES Function Approximations	
	Cobb-Douglas	Kmenta	nonlinear
Industry	$\hat{h}$(t-value)	$\hat{h}$(t-value)	$\hat{h}$(95% Conf. int.)
20.Food	.280 (8.273)	.277 (7.531)	.276 (.203, .350)
21.Beverage	.334 (7.209)	.[illegible]93 (7.928)	.404 (.305, .502)
23.Textile	.120 (5.018)	.1[illegible]7 (5.354)	.125 (.077, .172)
24.Footwr. & Appr.	-.018* (-.474)	-.024* (-.604)	-.026* (-.105, .052)
25.Wood	.101 (2.004)	.105 (2.082)	.105 (.104, .206)
26.Furniture	.189 (3.395)	.189 (3.152)	.189 (.069, .309)
27.Paper	.097* (1.891)	.087* (1.656)	.088* (.017, .193)
28.Printing	.134 (2.219)	.133 (2.065)	.133 (.004, .262)
29.Leather	.014* (.136)	.000* (.001)	.001* (-.224, .226)
30.Rubber	.185 (3.513)	.185 (3.615)	.187 (.084, .289)
31.Chemicals	.157 (4.387)	.213 (5.474)	.212 (.137, .287)
32.Petro. & Coal	.292 (7.872)	.288 (7.139)	.288 (.208, .369)
33.Clay	.040* (1.503)	.011* (.371)	.005* (.054, .064)
34.Basic Metal	.168 (3.562)	.182 (3.970)	.174 (.081, .266)
35.Metal Prod.	.086 (2.386)	.091 (2.423)	.091 (.016, .165)
36.Machine	.072 (3.133)	.087 (3.979)	.076 (.030, .112)
37.Elec. Mach.	.087* (1.592)	.085* (1.50[illegible])	.085* (-.028, .198)
38.Transp. Eq.	.160 (5.126)	.158 (4.959)	.159 (.095, .222)

*$\hat{h}(=\hat{\lambda} - 1)$ is not significantly different from zero at the 5 percent level.

Alternative estimates of the elasticity of substitution are summarized in Table 3.4. The estimates of the elasticity of substitution through marginal productivity relation (equation 3.9) turn out to be reasonably good in terms of statistics, showing that they are significantly different from zero in all of the 18 industries, but significantly different from unity only in 5 industries (23, 25, 33, 36, and 37).[14] Among these 5 industries, elasticity of substitution in 4 industries (23, 25, 33 and 36) is significantly below one and in 1 industry (37) is above one. It turns out, however, that the various direct estimates of the elasticity of substitution, σ, from the production function result only in estimates with large variances. The major reason for that is that we are relying on the linearized CES function by Taylor expansion. We would, perhaps, need larger samples or greater dispersions in capital-labor ratios in order to detect the deviations from unitary elasticity of substitution with any degree of statistical significance. The last two columns in Table 3.4 report on alternative estimates of σ based on the production

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[14] It should be pointed out, however, that the estimates of σ tend to be biased towards unity to the extent that there are significant differences in the quality of labor and in the product prices. See Griliches and Ringstad (29), p. 197, and Nerlove (48).

Table 3.4 Alternative Estimates of the Elasticity of Substitution by Industry

Industry	ACMS[1] (Appr. Stand. Error)	Kmenta	Nonlinear (95 % Conf. Int.)
20.Food	1.061(.076)	1.067	1.068 (.672, 2.591)
21.Beverage	1.179(.162)	.471[b]	.392[c](.246, .956)
23.Textile	.429(.067)[a]	.556[b]	.540 (.367, 1.024)
24.Footwear & Appr.	1.145(.122)	1.359	1.727 (.620, ∞[d])
25.Wood	.425(.138)[a]	.799	.791 (.548, 1.416)
26.Furniture	1.008(.111)	.993	.992 (.280, ∞[d])
27.Paper	.888(.098)	1.263	1.274 (.746, 4.386)
28.Printing	.689(.173)	1.019	1.016 (.357, ∞[d])
29.Leather	.821(.270)	2.632	1.653 (.563, ∞[d])
30.Rubber	1.113(.192)	.413[b]	.407 (.223, 2.404)
31.Chemicals	.997(.103)	.436[b]	.372[c](.234, .191)
32.Petro. & Coal	1.044(.187)	.969	.969 (.606, 2.404)
33.Clay	.754(.080)[a]	3.984[b]	[d](.835, ∞[d])
34.Basic Metal	.987(.152)	∞[b,d]	10.753 (.826, ∞[d])
35.Metal Prod.	.896(.139)	.715	.700 (.313, ∞[d])
36.Machine	.237(.039)[a]	.371[b]	.159 (.058, ∞[d])
37.Elec. Mach.	1.410(.145)[a]	1.081	1.071 (.569, 9.090)
38.Transp. Eq.	.995(.120)	1.314	1.174 (.545, ∞[d])

[1]The elasticity of substitution in equation 3.9 is calculated by $\hat{\sigma} = \hat{a}_1/(1 + \hat{a}_2)$, and the approximate standard error is calculated according to the procedure described in footnote 9 on page 64.

[a]The elasticity of substitution is significantly different from unity.

[b]The coefficient a_3 in equation 3.7 is significant at the 5 percent level.

[c]The estimate of δ in equation 3.10 is significantly different from zero at the 5 percent level.

[d]Estimates set to ∞ when $\hat{\delta} < -1$.

functions one via the Kmenta approximation (equation 3.7) and the other via direct nonlinear estimation (equation 3.10). In the Kmenta case, it was shown before that in 11 out of the 18 industries we could not reject the null hypothesis of a Cobb-Douglas form at the 5 percent significance level. In the remaining 7 industries, the elasticity of substitution in 5 industries (21, 23, 30, 31, and 36) is below one, in one industry (33) is above one, and for one industry (34) wrong curvature for the isoquants ($\sigma < 0$) is implied. In the non-linear case, the elasticity of substitution in 2 industries (21 and 31) is significantly different from one, both below one. In a number of industries, there appears to be little relationship between the estimates of σ based on the marginal productivity relation (ACMS) and those based on the production function. However, the estimates of σ across industries through the Kmenta approximation rank almost in the same order as those estimated by nonlinear least squares.

In order to test the dualism hypothesis at the two-digit industry level, separate regressions for estimating the Cobb-Douglas function (equation 3.4) were run for each part of establishments with fewer or greater than 100 employees for each individual industry. The summary of the estimation results is presented in Table 3.5. One industry (26) has no large

Table 3.5 Dualism Hypothesis Test for Individual Industries

Industry	Establishments with fewer than 100 employees					Establishments with more than 100 employees					Hypothesis test[1]
	n_S	$\hat{a}_1$ (t-value)	$\hat{a}_2$ (t-value)	$\hat{a}_1+\hat{a}_2$	R^2 (SSR)	n_L	$\hat{a}_1$ (t-value)	$\hat{a}_2$ (t-value)	$\hat{a}_1+\hat{a}_2$	R^2 (SSR)	F_{4,n_S+n_L-8}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
20.Food	106	.609	.648	1.257	.371	46	.722	.685	1.407	.497	.409
		(7.824)	(7.525)		(2.300)		(6.374)	(2.915)		(1.134)	
21.Beverage	96	.418	.902	1.320	.308	25	.739	1.223	1.962	.690	1.390
		(4.035)	(7.347)		(3.053)		(6.534)	(4.457)		(.342)	
23.Textile	103	.390	.746	1.136	.405	72	.320	.861	1.181	.196	.242
		(6.123)	(8.448)		(1.781)		(3.364)	(5.988)		(.630)	
24.Footwear & Appr.	78	.206	.847	1.053	.354	26	.233	1.078	1.311	.393	1.507
		(2.801)	(8.592)		(1.571)		(2.085)	(4.344)		(.228)	
25.Wood	81	.339	.797	1.136	.498	13	.549	.431	.980	.324	.484
		(4.784)	(11.118)		(1.725)		(2.442)	(1.512)		(1.184)	
27.Paper	84	.472	.510	.982	.468	32	.878	.046	.924	.428	4.142*
		(7.684)	(4.691)		(2.670)		(4.994)	(.157)		(.478)	
28.Printing	85	.266	.796	1.062	.124	17	.289	1.044	1.333	.418	.582
		(2.097)	(5.850)		(3.781)		(2.527)	(4.283)		(.098)	
29.Leather	34	.242	.815	1.057	.080	7	.286	.516	.802	.672	.099
		(1.540)	(3.542)		(1.662)		(1.811)	(2.832)		(.009)	
30.Rubber	54	.550	.611	1.161	.385	22	.289	.637	.926	.185	.759
		(4.936)	(4.366)		(1.922)		(1.528)	(2.590)		(.228)	
31.Chemicals	89	.365	.794	1.159	.276	44	.577	.502	1.079	.406	.604
		(3.955)	(8.496)		(2.118)		(4.953)	(2.008)		(.880)	

Table 3.5 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
32.Petro. & Coal	92	.514	.758	1.272	.472	13	.449	1.254	1.703	.898	1.081
		(5.611)	(7.365)		(1.264)		(3.809)	(3.876)		(.037)	
33.Caly	94	.470	.515	.985	.450	49	.599	.536	1.135	.722	1.152
		(5.366)	(5.902)		(2.664)		(10.288)	(3.291)		(.383)	
34.Basic Metal	72	.312	.824	1.136	.229	28	.295	.630	.925	.180	.684
		(4.297)	(7.057)		(2.324)		(1.622)	(2.900)		(.265)	
35.Metal Prod.	92	.265	.845	1.110	.118	25	.123	.441	.564	.177	.763
		(2.728)	(7.421)		(1.697)		(.436)	(1.675)		(.344)	
36.Machine	92	.111	.934	1.045	.452	30	.318	.891	1.209	.204	1.094
		(1.049)	(8.554)		(2.432)		(2.460)	(4.332)		(.303)	
37.Elect. Mach.	63	.358	.620	.978	.213	26	.291	.908	1.199	-.015	.672
		(3.828)	(5.071)		(2.369)		(1.481)	(2.808)		(.675)	
38.Transp. Eq.	97	.262	.875	1.137	.238	31	.254	.831	1.085	.032	.264
		(3.579)	(10.445)		(1.623)		(1.928)	(4.175)		(.303)	

[1]The null hypothesis is that a_o, d, a_1, and a_2 are the same for small and large establishments in equation 3.4: $\frac{\ln V}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 \frac{\ln K}{\ln L} + a_2$. The F-ratio is calculated by using SSR's in Table 3.1 and Table 3.5.

*The null hypothesis is rejected at the 5 percent level.

firm and so is excluded from estimation. In general, the fitting for large firms turns out to be relatively poor. The fact that the sample size is much less for large firms than for small firms may be partly responsible for that. The null hypothesis of the same production functions for small and large firms was tested for each of the 17 industries. The F-ratios were calculated and are reported in the last column in Table 3.5. Only in one industry (27) did the production functions prove to be significantly different between small and large firms at the 5 percent level.

We may summarize our findings as follows:

(1) The single most important finding is that fairly substantial economies of scale exist in most of the Korean manufacturing industries. The estimates are almost invariant, regardless of the type of production functions and estimation methods employed. Only in 5 out of the 18 industries are we unable to reject the null hypothesis of constant returns to scale.

(2) It appears that there is no satisfactory procedure for estimating the elasticity of substitution directly from the CES function with the data available. The estimates of the elasticity of substitution based on the marginal productivity relation appear to be much better in terms of statistics,

but they tend to differ from those based on the production function in a number of industries, particularly in such industries as beverages (21), leather (29), rubber (30), chemicals (31), clay (33), and basic metals (34). Since both methods are subject to a number of drawbacks, these results are not so surprising. But one conclusion emerges from the results with reasonable certainty -- that is, σ is not close to zero.

(3) There are only two industries (27 and 36) where the assumption of homotheticity in production technology tends to be violated with statistical significance.

(4) The findings (2) and (3) above may be of some importance in explaining the paradox observed in some developing countries, that is, that the growth of manufacturing employment has been extremely slow despite the rapid growth in output and capital.[15] The traditional explanation of this paradox involves the assertion of low elasticity of substitution and nonhomotheticity in the production function. But our findings for South Korea do not seem to confirm that

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[15] For a fuller discussion about the paradox, see pages 14 and 15.

assertion. Thus to the extent that structure and production technologies in the manufacturing sector of South Korea are not significantly different from those of other developing countries where the paradox is observed, our findings suggest that perhaps there are more important reasons than the traditional explanation of production technology for the paradox.

(5) Our data do not seem to support the dualism hypothesis that R. R. Nelson proposed. It is recognized that a sharp distinction between the craft and modern subsectors within an industry is almost impossible to make. It should be noted, however, that our sample may be too small to detect any difference in production technology between large and small firms. It should also be pointed out that technology diffusion may occur in a continuous fashion from large to small firms and the estimated elasticity of scale may pick up much of the efficiency differentials over the size distribution.

CHAPTER IV

FURTHER IMPLICATIONS OF THE ESTIMATION RESULTS

IV-1. Introduction

In the preceding chapter, we have presented estimates of production functions for manufacturing industries of the South Korean economy. Despite a number of limitations encountered in the estimation procedure, the results throw considerable light on the characteristics of the underlying production technologies, particularly on the factor-output elasticities and the elasticity of scale.

The purpose of this chapter is to present some interesting implications of these results. Section 2 of this chapter will be devoted to examining and comparing static allocative efficiency in capital and labor utilization across industries. In section 3, we will examine the actual importance of the economies of scale in explaining output growth in the South Korean manufacturing sector. In section 4, we will explore linkages between the pattern of trade development and the characteristics of underlying production technologies across industries.

IV-2. Marginal Products of Factors and Actual Returns to Factors

In the neoclassical theory of the firm, it is customary to assume that factor and goods markets are characterized by perfect competition and furthermore that firms operate under constant returns to scale. Our empirical results, however, indicate that at least the latter assumption tends to be violated in a number of industries in the South Korean manufacturing sector. For instance, the firms in 13 industries out of the 18 two-digit industries are subject to significantly increasing returns to scale. Furthermore, the manufacturing sector of South Korea was growing rapidly during the 1960's, and hence all firms could have been on the way to equilibrium or in the process of adjustment. Under these circumstances, one can hardly expect a long-run equilibrium to prevail in factor as well as output markets. As a consequence, it appears risky to employ the marginal productivity assumption in factor payments or the income-share approach in approximating factor-output elasticities. Having estimated the factor-output elasticities at the two-digit industry level, it is of some interest to know the actual magnitude of marginal products of factors and the extent of their variations across industries. It would also be interesting to compare the marginal products of factors based on the production function and actual returns to the respective factors.

Using the estimates of the Cobb-Douglas function (equation 3.4) for total manufacturing, we calculated the marginal products of capital and labor over the 12 size groups for 1966 and the 7 size groups for 1968. The marginal products of capital and labor for total manufacturing were then calculated by finding the weighted averages of the marginal products over the size groups (the weights were the shares of respective size groups in total value added). The results are presented in Table 4.1. Actual return to labor was measured as the labor compensation per unit of labor employed. Actual rate of return on capital was measured as the ratio of residual after deduction of labor compensation and consumption duty from the value added to the capital stock.

As can be seen in Table 4.1, the weighted average of the marginal product of capital declined from 0.342 in 1966 to 0.273 in 1968, whereas the value of the marginal product of labor increased from 199.7 thousand won in 1966 to 292.0 in 1968.[1] This is not too surprising, because

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[1]These values are not adjusted for price changes. The GNP deflator for manufactures went up about 10 percent during 1966-1968. See Table 1.6 on page 34.

Table 4.1 marginal Products of Factors and Average Returns on Factors by Firm Size for Total Manufacturing

Firm Size	Marginal Product of K	Average[1] Rate of Return on K	(2)/(1)	Value of[2] Marg.Prod. of L	Ave. Wage[2] Rate per Worker	(5)/(4)
1966						
5-9workers	.238	.382	1.607	1.039	.461	.444
10-19	.523	.415	1.641	1.259	.535	.425
20-19	.229	.379	1.654	1.524	.552	.417
30-49	.280	.463	1.657	1.342	.557	.415
50-74	.313	.509	1.624	1.431	.621	.434
75-99	.389	.654	1.682	1.653	.663	.401
100-149	.343	.591	1.721	1.677	.635	.379
150-199	.407	.698	1.715	1.699	.649	.382
200-299	.422	.765	1.813	2.246	.732	.326
300-499	.319	.582	1.827	2.660	.846	.318
500-999	.382	.661	1.729	2.287	.856	.374
100 or more	.390	.706	1.809	2.577	.846	.328
Weighted Average	.342			1.997		
1968						
5-9workers	.263	.413	1.571	1.353	.629	.465
10-19	.263	.405	1.541	1.714	.826	.482
20-49	.270	.426	1.578	1.824	.841	.461
50-99	.314	.509	1.622	2.117	.921	.435
100-199	.206	.322	1.565	2.181	1.021	.468
200-499	.300	.519	1.731	3.141	1.171	.373
500 or more	.271	.481	1.777	3.725	1.292	.347
Weighted Average	.273			2.920		

[1]Average rate of return on K is measured by (V-T-W)/K, where V represents value added, T consumption duty and W labor compensation.

[2]The measurement unit is 100,000 won per worker.

during the same period the number of employees in total manufacturing increased by only 23 percent from 566,665 to 748,307, whereas capital stock more than doubled from 178,548 million won to 414,667.[2]

One of the puzzles that emerges from Table 4.1, however, is the fact that there are large discrepancies between the marginal products of factors and the actual rates of return on factors. The ratios between the average returns and the marginal products are well above one for capital and well below one for labor, suggesting that capital gets over-paid and labor underpaid. This puzzle may be explained largely by the fact that our measure of value added is overvalued to a large extent. Recall that our measure of value added is derived by subtracting the direct charges for materials or services consumed in production from the value of gross output, and thus it includes depreciation, taxes and other indirect business expenses in addition to actual payments to factors, labor and capital. For instance, the share of labor compensation in our measure of value added for total manufacturing turns out to be 0.24 for 1966 and 0.26 for 1968, but the share of

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[2]The value of capital is not adjusted for price changes.

labor compensation in actual returns on capital and labor is reported to be 0.42 for 1966 and 0.45 for 1968 in the Financial Statement Analysis, published by the Bank of Korea.[3] This suggests that our measure of value added might exceed the actual payments to factors by almost 100 percent. Thus the marginal products of capital and labor, and the average rate of return on capital in Table 4.1, might have been exaggerated by almost 100 percent of the true values. Even if these over-valuations were taken into consideration, however, the conclusion that capital gets overpaid and labor underpaid remains unchanged. This means that the capital intensity in manufactur industries of the South Korean economy may be unduly high from a social welfare point of view. Not enough work has been done to explain the causes of the high returns on capital relative to marginal products and of the low wage rates relative to value of marginal products; however, there seems to be several possible explanations.

i) If production functions are subject to increasing returns to scale, which is observed in our

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[3] The return on capital is derived by summing up the net profits, payable interests, and rents. The Financial Statement Analysis (6) is based on sample observations of firms with mor than 10 employees.

estimation, the factor payments according to the marginal products will more than exhaust the total output. Under this circumstance, bargaining power may determine how the product will be divided among the factors. Should both factors have approximately equal bargaining power, one might expect that the actual returns to factors would be proportionally less than their respective marginal products. In most of the South Korean industries, however, labor is not unionized enough to exercise much power in collective bargaining. Furthermore, the managers of firms, even in large scale firms, are often identified with the owners of the firms. Thus capital may be able to pay labor less than its marginal product, while capital itself gets more than its marginal product.

ii) According to the data, capital grows much faster than labor does. In the period of such an unbalanced growth of factors, perhaps lagged response in wage adjustment may be partly responsible for such a gap between the value of marginal product of labor and the average wage rate. Recall that wages were rising rapidly during the sample period of 1966-1968 after declining mildly in the early sixties in South Korea (see Table 1.7).

iii) Up to this point we assumed a riskless economy. In the real world, however, most of the economic decisions of firms are subject to some degree of uncertainty regarding output price, demand or acquisition of intermediate goods, etc. Thus the risk premium on capital might have required a target value of rate of return on capital higher than its marginal product. The reverse would be true for labor.

iv) As mentioned in Chapter II-4, our measure of capital stock as an input suffers from a number of shortcomings and is therefore undoubtedly subject to relatively large measurement error. It is well known that if independent variables are subject to measurement error, OLS estimates of the coefficients will not only be biased but will also be inconsistent.[4] Particularly when the true coefficients are positive

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[4] For a proof, see Johnston (33), p. 281.

values, OLS estimates will be negatively biased. Therefore, our estimates of the capital-output elasticity could have been biased negatively by some unknown magnitude.[5]

v) Another possibility is that output markets may not be perfectly competitive. In this circumstance, labor will be employed and paid according to the marginal revenue product instead of the value of marginal product.

The arguments made above may explain in some part but we believe much remains to be answered.

Another puzzle which can be observed in Table 4.1 is the fact that the wage rate tends to rise as firm size gets bigger. It appears that there are a number of causes to which these wage differentials can be attributed. One extreme view could be that all the variation in wage rates is due to differences in the quality of labor and hence reflects a return on investment in human capital. If this were the only reason, then our

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[5] Griliches and Ringstad (29) believed that the measurement error in capital input was mainly responsible for the relatively low estimates of the capital-output elasticity. The median capital-output elasticity was about 0.18 for Norwegian manufacturing industries. See Griliches and Ringstad (29), p. 70.

data for labor input could be very disappointing because the measurement for labor input does not reflect the quality differences. There seem to be, however, a number of other reasons which might be equally responsible for the wage differentials. First, one could imagine a spectrum of labor markets which might exist between urban and rural areas with limited inter-market labor mobility. Thus firms in different locations may be faced with different wage rates which reflect differences in the cost of living, differences in the cost of moving from one place to another, and the extent of immobility of labor for other cultural reasons. In order to look at the possible wage differentials between urban and rural workers, we have further disaggregated the wage rates per worker (formerly classified by firm size for total manufacturing in 1968) by 11 cross regions (2 cities and 9 provinces). The results are presented in Table 4.2. The wage rates at the disaggregated level are quite revealing. For instance, the wage differentials across firm size in Seoul and Busan (South Korea's first and second largest cities, respectively) turn out to be much more moderate than those aggregated over cross regions in Table 4.1. Furthermore, there is no indication of a tendency for wage rates to increase across firm size in Jeju province, a small rural island which is

Table 4.2 Average Wage Rates by Firm Size and by Region, 1968

Regions	Wage Rates: 5-9 Workers	10-19 Workers	20-49 Workers	50-99 Workers	100-199 Workers	200-499 Workers	500 or more Workers
Seoul city	.819	1.191	1.073	1.110	1.225	1.270	1.341
Busan city	.773	.876	.923	1.001	1.030	1.092	1.129
Gyunggi	.591	.768	.837	.735	.930	1.379	1.521
Gangwon	.634	.692	.656	.662	.522	1.412	1.316
Chungbug	.573	.694	.661	.677	.589	.985	1.739
Chungnam	.561	.632	.684	.739	.596	1.242	1.253
Jeonbug	.537	.560	.656	.647	.576	.807	1.203
Jeonnam	.499	.605	.575	.792	.811	.866	1.079
Gyungbug	.590	.697	.738	.747	.902	.962	1.096
Gyungnam	.628	.660	.618	.880	.793	1.079	1.493
Jeju	.605	.721	.419	.523	.797	.427	—

Data source: Korea Development Bank and Economic Planning Board, Report on Mining and Manufacturing Survey, 1968. The measurement unit is 100,000 won per worker.

probably the least industrialized province. The important point is, however, that wage differentials between the same size firms in Seoul and Jeju are approximately the same order of magnitude as those between the largest and smallest size firms in Table 4.1.[6] It is therefore not unreasonable to say that the sharp wage differentials across firm size in other provinces may reflect, to a large extent, the fact that most small firms are likely to be in rural areas and that an increasing proportion of large firms tends to be located in urban areas within each province. Second, if the production functions are, indeed, of increasing returns to scale, profitability will be positively related to the firm size. A high rate of economic profit attained from economies of scale may then be divided into higher returns on capital and labor. Under increasing returns to scale, generally, large firms would bid labor away from small firms, and only large firms would exist at long-run equilibrium. Third, rapidly growing firms or firms being newly established on a large scale will inevitably have to pay higher wages to draw labor from other firms or other sectors of the economy. Fourth, although trade unions are

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[6] Of course, one could suspect again that the quality of labor may be different between Seoul and Jeju for the same size firms.

not well-developed enough to affect the wage rate in any significant way in South Korea, it is true that large firms are under heavier government or social pressure to pay their employees a decent wage than are small firms.

Careful investigation is necessary to answer the question of wage differentials in any meaningful way, particularly in the context of human capital. Obviously, this is beyond the scope of the present study. Our study, however, suggests a number of important factors other than the quality of labor which could cause the wage differentials in South Korea.

Table 4.3 presents the marginal product of capital and the value of the marginal product of labor obtained by finding weighted averages over the firm size groups for each of the 18 two-digit industries. It should be borne in mind, however, that these figures could have been exaggerated by almost 100 percent, because our measure of value added far exceeds the actual payments on factors, labor and capital. But the ranking of the different industries with respect to the marginal product of capital or labor probably would not have been affected. Thus we believe that this ranking, together with the estimating results of the elasticity of scale across industries, can provide an important guide for evaluating future investments in terms of efficient

Table 4.3 Marginal Product of Capital and Value of Marginal Product of Labor for Individual Industries

	1966		1969	
	Marginal Product of K (ratio)	Value of Marginal Prod. of L	Marginal Prod. of K	Value of Marg. Prod. of L
20.Food	.570(2)[1]	1.690(13)	.530(3)	2.416(11)
21.Beverage	.592(1)	4.479(1)	.726(1)	5.849(2)
23.Textile	.257(12)	1.210(16)	.201(15)	1.773(18)
24.Footwear & Apparel	.256(13)	1.207(17)	.290(9)	1.901(15)
25.Wood	.214(17)	1.984(10)	.269(12)	2.826(8)
26.Furniture	.312(10)	1.366(15)	.305(8)	1.905(14)
27.Paper	.514(3)	3.971(3)	.336(6)	3.563(6)
28.Printing	.246(14)	2.422(8)	.275(11)	3.210(7)
29.Leather	.241(15)	1.730(12)	.192(16)	2.329(12)
30.Rubber	.465(6)	1.056(18)	.567(2)	1.891(16)
31.Chemicals	.470(5)	4.111(2)	.247(13)	6.892(1)
32.Petro. & Coal	.464(7)	3.416(5)	.448(4)	3.928(3)
33.Clay	.370(8)	2.224(9)	.348(5)	1.884(17)
34.Basic Metal	.342(9)	3.427(4)	.279(10)	3.681(5)
35.Metal Prod.	.265(11)	1.503(14)	.242(14)	2.175(13)
36.Machine	.136(18)	1.975(11)	.102(18)	2.680(10)
37.Elec. Mach.	.494(4)	2.956(6)	.324(7)	2.696(9)
38.Transp. Eq.	.231(16)	2.734(7)	.184(17)	3.804(4)

[1]The numbers in parentheses indicate the ranking across industries.

allocation of resources.

IV-3. Industry Growth and Gains from Economies of Scale

In industry growth, aggregate output increases over time, partly due to increases in factor employment of the existing firms, partly due to the birth of new firms, and partly due to technical change over time. If the firms' production processes are characterized by increasing returns to scale in an industry, a typical firm in the industry would tend to expand over time, and new firms entering the industry would tend to be relatively large scale. Thus the size distribution of establishments should be shifting toward larger firms over time. The pattern of growth in the South Korean manufacturing sector is revealing. Table 4.4 shows that firms of over 200 employees, which in 1966 accounted for 39.8 percent of total employment in the manufacturing sector, accounted for 53.8 percent in 1971. The increase in employment by firms of over 200 employees accounts for more than 82 percent of the total increase in employment by the manufacturing sector between 1966 and 1971. During the same period, there was a significant relative decline in employment in small firms. Employment in firms of under 100 fell from 50.02 percent of the total in 1966 to 35.89 in 1971.

Table 4.4 Distribution of Labor Force by Firm Size for Total Manufacturing, 1966-1971

Year	Employees by Firm Size (As Percent of Total Manufacturing) 5-9 Workers	10-19 Workers	10-49 Workers	50-100 Workers	100-199 Workers	100-499 Workers	500 or more Workers	Total
1966	76,880 (13.6)	67,783 (12.0)	78,847 (13.92)	59,541 (10.50)	58,371 (10.30)	78,291 (13.81)	146,935 (25.94)	566,665 (100.0)
1967	91,353 (14.08)	73,187 (11.28)	84,173 (12.97)	66,212 (10.21)	66,798 (10.30)	88,462 (13.63)	178,626 (27.53)	648,811 (100.0)
1968	85,689 (11.45)	79,305 (10.60)	95,630 (12.78)	70,673 (9.44)	73,606 (9.84)	109,525 (14.64)	233,876 (31.25)	748,307 (100.0)
1969	103,620 (12.50)	59,586 (7.18)	99,104 (11.95)	77,114 (9.30)	89,994 (10.86)	125,868 (15.18)	273,758 (34.97)	829,044 (100.0)
1970	85,483 (9.93)	72,612 (8.43)	102,720 (11.93)	75,075 (8.72)	85,665 (9.95)	138,371 (16.07)	301,112 (34.97)	861,041 (100.0)
1971	80,729 (9.52)	68,410 (8.07)	87,229 (10.28)	68,054 (8.02)	87,396 (10.30)	154,301 (18.19)	302,075 (35.61)	848,194 (100.0)

Data source: Korea Development Bank and Economic Planning Board, Report on Mining and Manufacturing Survey, 1966-1971.

In view of the fact that the estimated elasticity of scale is greater than unity in 13 out of the 18 two-digit industries, it is of great interest to know the extent to which economies of scale have actually contributed to growth in South Korean manufacturing industries. To assess this precisely, one would have to have time-series data of establishments for each industry. But this is simply unavailable. Instead, we have aggregate data of inputs and output for only two years, 1966 and 1968, for each industry. Thus we would have to make some ad hoc assumptions about the data in order to make even a very rough approximation of the extent of output growth due to realizing economies of scale. This can be done using an approach developed by Griliches.[7] Assuming that firms within an industry are identical, we can write aggregate value added as the product of value added by individual firms and by number of firms in the industry:

(4.1) $V^* = N \cdot V$

where

V^* = aggregate value added

N = number of firms in the industry

V = value added by the typical firm.

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[7]Refer to Griliches (28), p. 317.

The growth rate of aggregate output is then obtained by differentiating V^* with respect to time and dividing by V^*. That is:

$$(4.2) \quad \frac{\dot{V}^*}{V^*} = \frac{\dot{N}}{N} + \frac{\dot{V}}{V}$$

where dots over variables indicate differentiation with respect to time. The first term on the right-hand side represents growth due to net birth of new firms; the second term represents growth due to an increase of output of the typical firm. Let the production function for the typical firm be a Cobb-Douglas function, $V = AK^{\alpha} L^{\beta}$. Then we have:

$$(4.3) \quad \frac{\dot{V}}{V} = \frac{\dot{A}}{A} + \alpha\frac{\dot{K}}{K} + \beta\frac{\dot{L}}{L}$$

This is the form conventionally used to measure disembodied technical change (the residual method). But it should be noted that we are dealing with the typical firm's production function instead of approximating α and β by income shares of capital and labor. We can rewrite equation 4.3 as follows:

$$(4.4) \quad \frac{\dot{V}}{V} = \frac{\dot{A}}{A} + \theta_o \frac{\dot{K}}{K} + (1 - \theta_o) \frac{\dot{L}}{L} + (\lambda - 1)\left[\theta_o \frac{\dot{K}}{K} + (1 - \theta_o) \frac{\dot{L}}{L}\right]$$

where $\theta_o = \alpha/(\alpha+\beta), \lambda = \alpha + \beta$.

The last term in equation 4.4 is a measure of output growth due to the fact that the elasticity of scale is other than unity.

If there were constant returns to scale, the last term would vanish. Substituting equation 4.4 into equation 4.2 yields a growth form of aggregate value added derived from the typical firm's production function for an industry. That is:

$$(4.5) \quad \frac{\dot{V}^*}{V^*} = \frac{\dot{N}}{N} + \frac{\dot{A}}{A} + \theta_o \frac{\dot{K}}{K} + (1 - \theta_o) \frac{\dot{L}}{L} + (\lambda - 1) \left[\theta_o \frac{\dot{K}}{K} + (1 - \theta_o) \frac{\dot{L}}{L} \right]$$

The ratio of the last term on the right-hand side to the growth of aggregate value added on the left-hand side in equation 4.5 was calculated for each of the 13 industries in which economies of scale are significant at the 5 percent level. The results are summarized in Table 4.5. The gains from economies of scale range from 1.4 percent in the machine industry (36) to 24.2 percent of the growth in the basic metal industry (34). The calculation for total manufacturing indicates that about 11 percent of total growth is the result of gains from economies of scale during 1966-1968. This contrasts sharply with the earlier reports of 2 percent for the United States post-war manufacturing sector and 7 percent for the Canadian manufacturing sector,[8] suggesting that economies of scale may be a more important source of productivity growth in rapidly industrializing economies like South Korea than in

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[8] See footnote 13 on page 10.

Table 4.5 Gains from Economies of Scale for Total Manufacturing and by Industry

Industry	$\frac{\dot{V}^*}{V^*}$ (1)	$\frac{\dot{N}}{N}$ (2)	$\theta_o \frac{\dot{K}}{K}+(1-\theta_o)\frac{\dot{L}}{L}$ (3)	$(\lambda-1)x(3)$ (4)	$\frac{(4)}{(1)}x100$ (5)
20.Food	.303	-.008	.175	.049	16.2
21.Beverage	.313	.029	.036	.012	3.8
23.Textile	.375	.034	.250	.030	8.0
25.Wood	.503	.029	.297	.303	6.0
26.Furniture	.385	.105	.069	.013	3.4
28.Printing	.266	.023	.075	.010	3.8
30.Rubber	.397	-.021	.141	.126	6.5
31.Chemicals	.858	-.080	1.064	.167	19.5
32.Petroleum & Coal	.504	.092	.349	.102	20.2
34.Basic Metal	.248	.026	.357	.060	24.2
35.Metal Prod.	.345	.025	.140	.012	3.5
36.Machine	.211	.029	.042	.003	1.4
38.Transp. Eq.	.291	.058	.256	.041	14.1
Total Manuf.	.377	.030	.263	.040	10.6

Data source: Korea Development Bank and Economic Planning Board, Report on Mining and Manufacturing Survey, 1968. Value added and capital stock are measured in 1966 constant prices.

advanced countries. We feel, however, that our results should be taken only as indicative, because our data cover only two years and are by no means adequate to draw conclusive results about growth problems.

IV-4. Trade Development and Production Technology

After the end of the Korean war, the relatively small manufacturing sector of the South Korean economy began to grow rapidly, mainly the import substitution in nondurable consumer goods and their intermediate goods. By the late fifties, however, most of these imports had been replaced by domestic production, and the relatively rapid growth of the manufacturing sector began to slow down in late fifties.[9] Unlike many countries which concentrated further on import substitution in intermediate goods, machinery and durable consumer goods at that stage of industrialization, South Korea began to emphasize an export promotion strategy. Certain changes in policies along with a devaluation were made in 1961, but the major policy shift began with the exchange rate reform in 1964. Gradual liberalization of import controls and a variety of export promotion measures were introduced

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[9] Refer to Table 1.1.

in subsequent years. The major effect of this policy has been rapid expansion of foreign trade, particularly rapid expansion in exports of labor-intensive manufactured goods. Exports began to grow about 1961 and growth accelerated sharply after 1964. The rapid expansion in foreign trade was reflected in a high growth rate of the manufacturing sector, which grew at an annual rate of 17.8 percent during 1961-1973.[10]

Having estimated production functions at the two-digit industry level, it is of interest to examine the pattern of trade development in the context of the underlying production technologies. For that purpose, we have classified the 18 two-digit industries by export, import-substitution, and home-goods industries. Although most industries at the two-digit level are subject to two-way trade, we adopted the following rules: (1) export industries are classified as those industries whose average export ratio (ratio of exports to domestic production) exceeds 10 percent in both the years 1966 and 1970; (2) similarly, import-substitution industries are defined as those showing an import ratio (ratio of imports to domestic

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[10] Refer to Table 1.1 and 1.2.

production) higher than 10 percent; and (3) the rest of the industries are classified as home-goods industries. The industries whose export and import ratios are both higher than 10 percent are classified as export industries.[11] Table 4.6 presents export and import ratios, along with a few characteristics of the underlying production technologies for each of the two-digit industries classified by the three sectors. The table also reports weighted averages of the elasticities of scale, capital-labor ratios in 1968, and marginal products of capital in 1968 for each of the three sectors (the weights are the share of each industry's capital stock in each sector).

A few interesting points may be seen in Table 4.6. First, exports appear to be relatively more labor-intensive than imports. This implies that the basic pattern of trade in South Korea is conforming with the simple Heckscher-Ohlin model; South Korea is relatively abundantly endowed with labor in comparison with her major trading countries.[12] Thus

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[11] We did so on the ground that most of the industries initially started from import-substitution industries in South Korea and then some of them have gradually transformed into home-goods or export industries.

[12] For instance, in 1968, 81.7 percent of total exports of South Korea went to Japan, Europe and U.S.A., and 83.8 percent of total imports came from those countries. See Major Economic Indicator (22, 1970), p. 72.

Table 4.6 Trade and Production Technology by Industry

Export Industries	Export-ratio[1] (%) 1963 (1)	1966 (2)	1970 (3)	Import ratio[1] (%) 1963 (4)	1966 (5)	1970 (6)	Elasticity of scale (7)	Capital-labor[2] ratio(in Mil. won/worker) (8)	Marg. prod. of capital, 1968 (9)
25.Wood	11.1	31.6	38.6	2.4	1.0	1.1	1.101	.513	.269
24.Footwear & Apparel	1.1	17.8	28.9	.3	.5	1.2	.982*	.198	.290
23.Textile	5.8	13.6	25.0	6.2	5.0	11.4	1.120	.450	.201
30.Rubber	3.2	17.4	23.1	1.1	1.1	3.2	1.185	.239	.567
37.Elect. Mach.[3]	3.5	10.3	22.7	53.8	33.8	63.4	1.087*	.409	.324
35.Metal Prod.[3]	1.7	10.2	13.1	15.6	49.9	53.3	1.086	.334	.242
Weighted Ave.							1.105	.418	.244
Import-Sub Industries									
36.Machine	3.0	8.8	3.3	43.2	189.9	327.8	1.072	.391	.102
38.Transp. Eq.	2.2	1.6	1.9	27.9	27.9	58.4	1.160	.551	.184
31.Chemicals	.8	.8	3.1	49.3	64.2	46.9	1.157	1.476	.247
34.Basic Metal	18.5	9.7	5.4	33.6	32.2	48.8	1.168	.510	.279
27.Paper	.1	1.6	2.4	4.1	10.1	29.7	1.097*	.730	.336
Weighted Ave.							1.145	1.054	.239

Table 4.6 (Continued)

Home-goods Industries	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20.Food	3.4	7.1	5.6	4.5	5.9	9.4	1.280	.456	.530
21.Beverage	.4	1.3	.6	.2	.4	.6	1.334	.420	.726
26.Furniture	2.8	1.8	11.5	.1	.1	.7	1.189	.228	.305
28.Printing	.6	1.0	1.3	1.6	1.6	1.8	1.134	.404	.275
29.Leather	.2	4.5	6.5	.3	2.8	4.5	1.014*	.713	.192
32.Petroleum & Coal	.0	4.6	6.7	.7	9.2	2.3	1.292	1.015	.448
33.Clay	1.5	5.7	3.9	14.6	7.2	5.3	1.040*	1.329	.348
Weighted Ave.							1.150	.947	.416

[1]Sources: Bank of Korea, Input-Output Tables, 1963, 1966, 1970.

[2]Sources: Korea Development Bank and Economic Planning Board, Report on Mining and Manufacturing Survey, 1968.

[3]Industries whose export and import ratios are both higher than 10 percent.

*Indicates that the elasticity of scale is not significantly different from unity.

her comparative advantage should lie in exporting labor-intensive products and in importing capital-intensive ones. Second, it appears that the elasticity of scale tends to be somewhat smaller in the export sector than in the import-substitution sector; the weighted average of the elasticities of scale yields 1.105 for the export sector but 1.145 for the import-substitution sector. The elasticity of scale, however, varies widely across individual industries within each sector. It turns out that the elasticity of scale is not significantly different from unity in two export industries (24, 37) and in one import-substitution industry (27). Industry (27), however, revealed that the production functions differ significantly between small and large firms, requiring more capital-intensive technology for large firms (see Table 3.5). Third, among home-goods industries, food (20), beverage (21), and furniture (26) industries are characterized by both the presence of scale economies in production and relatively labor intensive production methods. The petroleum and coal industry (32) also indicates the presence of scale economies in production but requires relatively capital-intensive production methods. It turns out that the firms' scale economies are not significantly different from constant returns to scale in the leather (29) and clay (33) industries, but both industries require relatively capital-intensive production methods. Fourth, the marginal products of capital are not much different between the export and the import-substitution sector but are sharply different from the home-goods sector; the weighted average of marginal products of capital was 0.416 for the home-goods sector in 1968, whereas it was 0.244 for the export sector and 0.239 for the import-substitution sector. This result is not entirely surprising, because one would have little doubt that markets for traded goods are more competitive than those for home goods, particularly in a small country. Therefore, the monopolistic nature of domestic markets for home goods may give rise to higher marginal products of factors than would occur under perfect competition. Another reason for the higher marginal products may be that domestic preferential and foreign loans at subsidized interest rates probably have been concentrated more on export and import-substitution industries than on home-goods industries, and hence the cost of capital has been higher in home-goods industries than in export or import-substitution industries.[13]

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[13]For instance, a very rough approximation indicates that the ratio of preferential loans to capital stock was 0.42 for the export sector, 0.45 for the import-substitution sector, and 0.33 for the home-goods sector. The preferential loans are roughly measured as the sum of domestic equipment loans and foreign loans. The data were obtained from Economic Planning Board and Bank of Korea.

CHAPTER V

CONCLUDING REMARKS

In this study we have examined the manufacturing sector of the South Korean economy, particularly focusing on the production technologies of two-digit level industries. The major limiting factor facing us was the availability and reliability of basic data. Quite aside from the measurement errors associated with the variables used in estimating production functions, we are aware of the specification errors and problems involved in aggregation up to the two-digit level of industry. While there is much to be improved in our results when more refined data become available, we did learn something about the structure of the underlying production technologies in South Korean manufacturing industries.

Our principal finding is the evidence of increasing returns to scale for total manufacturing, as well as for most of individual industries at the two-digit level. The estimate of the Cobb-Douglas function for total manufacturing yields the elasticity of scale of 1.152, and in 13 of the 18 two-digit industries the elasticity of scale turns out to be significantly greater than unity at the 5 percent level (see Table 3.3). Surprisingly, these estimates of the elasticities of scale are almost invariant, regardless of the type of production functions and estimation methods employed.

It is worthwhile to emphasize that these results are based on observations that are per-establishment averages of cross section data classified both by region and firm size. Thus, they are a more relevant measure of microunits than regional totals or simple regional averages used frequently in many earlier studies on production functions.

However, this study is unable to draw any substantive conclusions about the elasticity of substitution. Different methods of estimating the elasticity of substitution give differing results in a number of industries (see Table 3.4). The estimates of the elasticity of substitution based on the marginal productivity relation appear to be statistically satisfactory but suffer from the underlying assumption of labor market equilibrium conditions. Our data are not too informative about the possible curvature of the underlying isoquants. Direct estimates of the CES function yield only estimates with large variances. The only thing that is certain is that the elasticity of substitution differs significantly from zero in all industries. In 7 of the 18 industries, the null hypothesis of a Cobb-Douglas function is rejected against the Kmenta approximation of a CES function, suggesting that the assumption of unitary elasticity of substitution may be wrong in those 7 industries. In 2 industries, the null hypothesis of the Kmenta approximation is rejected against a translog function, implying that the assumption of homotheticity may be violated in these 2 industries (see Table 3.2). The knowledge about the elasticity of substitution and homotheticity found in this study may be of some importance in explaining the paradox observed in some developing countries that the growth of manufacturing employment has been extremely slow despite the rapid growth in output and capital. To the extent that the structure of, and production technologies in, the manufacturing sector of South Korea are not significantly different from those of other developing countries where the paradox is observed, our findings suggest that perhaps there are more important reasons for the paradox -- for instance, trade policies or imperfect factor markets, etc. -- than the traditional explanation through low elasticity of substitution and non-homotheticity in the production function.

Our data do not seem to support the classic dualism hypothesis. Only in one industry do we find statistically significant evidence that the production functions differ between small and large firms. Of course, much care should be taken in interpreting this result, because it is difficult to make a sharp distinction between the craft and modern sub-sectors within an industry and because our sample size may be too small to detect any difference in production technology.

While it is hard to judge the validity of our estimation results, we have drawn some interesting implications from our cross-section production function results. First, we find that ratios between the average returns and the marginal products are well above one for capital and well below one for labor, indicating that capital gets overpaid and labor gets underpaid. This finding remains unchanged even if overvaluation of our measure of value added is taken into consideration. Perhaps the fact that wages were rapidly rising during the sample period of 1966-1968 can be partially explained by a lagged response in wage adjustment (see Table 1.7). Second, the actual importance of economies of scale in output growth is quite evident in most of the manufacturing industries in South Korea. It turns out that economies of scale explain about 11 percent of the growth of total manufacturing output during 1966-1968. Third, it appears that the outward-looking development strategy adopted in early 1960's in

South Korea has resulted in a relatively efficient pattern of trade development through exporting labor-intensive manufactured goods and importing capital-intensive products. Thus the rapid expansion of exports seems to have contributed significantly to the fairly rapid growth in employment in the manufacturing sector, hence reducing the pressure of underemployment or unemployment in the agricultural sector. Our production function results further indicate that elasticity of scale tends to be smaller in export industries than in import-substitution and home-goods industries. This suggests that the products which can be produced efficiently on a relatively small scale may be more easily developed into exports at the early stage of manufacturing development. This also suggests that the government's protective measures for some import-substitution industries may foster inefficient operation of firms and an inefficient market structure by permitting non-economic size firms to be profitable, whereas the absence of appropriate government policy in some home-goods industries may allow a monopolistic market structure because of the economies of scale.

APPENDIX A

TRANSLOG FUNCTION

A production function is usually considered to be well behaved if it is monotonically increasing function of inputs and concave. Because of the quadratic nature of the translog function, one cannot expect these conditions to be satisfied globally. But the range where these conditions are met may be large enough to cover all the sample points. One can easily check the monotonicity and concavity condition for a specified translog function. The monotonicity condition requires that the marginal products of inputs are positive. This condition can also be satisfied if the logarithmic marginal products are positive. The logarithmic marginal products are nothing but the output elasticities of inputs in the translog function. In our simple case of equation 2.6, i.e.,

$$\ln(V) = a_0 + a_1\ln(K) + a_2\ln(L) + a_3[\ln(K)]^2 + a_4[\ln(L)]^2 + a_5[\ln(K)][\ln(L)],$$

the logarithmic marginal products can be written as

$$(1) \qquad \alpha = \frac{\partial \ln(V)}{\partial \ln(K)} = \frac{\partial V}{\partial K}\frac{K}{V} = a_1 + 2a_3\ln(K) + a_5\ln(L)$$

$$(2) \qquad \beta = \frac{\partial \ln(V)}{\partial \ln(L)} = \frac{\partial V}{\partial L}\frac{L}{V} = a_1 + 2a_4\ln(L) + a_5\ln(K)$$

where α denotes the output elasticity of capital and β the output elasticity of labor. Note that these elasticities depend upon the level of inputs employed. The concavity condition is satisfied if the Hessian matrix of second order partial derivatives is negative definite. Thus the monotonicity and concavity conditions can be evaluated at each sample point for an estimated translog function.

The elasticity of substitution is also a variable in the translog function. To show that, let a production function be $V = f(K, L)$. Then the elasticity of substitution can be written as:

$$(3) \qquad \sigma = \frac{d\ln(K/L)}{d\ln(f_L/f_K} = \frac{d(K/L)(K/L)}{d(f_L/f_K)/(f_L/f_K)}$$

where f_L and f_K are the partial derivatives of the production function with respect to labor and capital, respectively. For computational purposes, we can rewrite:

$$d\ln(K/L) = d[\ln(K) - \ln(L)] = dK/K - dL/L$$

$$\begin{aligned} d\ln(f_L/f_K) &= d[\ln f_L - \ln f_K] \\ &= df_L/f_L - df_K/f_K \\ &= \frac{f_{LL}dL + f_{LK}dK}{f_L} - \frac{f_{LK}\,dL + f_{KK}dL}{f_K} \end{aligned}$$

$$= \left(\frac{f_{LL}}{f_L} - \frac{f_{KL}}{f_K}\right) dL + \left(\frac{f_{LK}}{f_L} - \frac{f_{KK}}{f_K}\right) dK.$$

Thus we have,

$$\sigma = \left(\frac{dK}{K} - \frac{dL}{L}\right) / \left[\left(\frac{f_{LL}}{f_L} - \frac{f_{KL}}{f_K}\right)dL + \left(\frac{f_{LK}}{f_L} - \frac{f_{KK}}{f_K}\right)dK\right]$$

Since $dK/dL = -f_L/f_K$ along an isoquant, substituting this in the above equation and simplifying yields:

(4) $$\sigma = \frac{f_K f_L (f_K K + f_L L)}{KLD}$$

where $D = \begin{vmatrix} f_{KK} & f_{KL} & f_K \\ f_{LK} & f_{LL} & f_L \\ f_K & f_L & 0 \end{vmatrix} = 2 f_{KL} f_K f_L - f_{KK} f_L^2 - f_{LL} f_K^2.$

By rearranging equation (1) and (2), we can write the marginal products of capital and labor as:

(5) $$f_K = \alpha \frac{V}{K}$$

(6) $$f_L = \beta \frac{V}{L}.$$

Differentiating (5) and (6) with respect to capital and labor and simplifying, we get the second order partial derivatives as:

(7) $$f_{KK} = \left[\alpha(\alpha - 1) + 2a_3\right] \frac{V}{K^2}$$

(8) $$f_{LL} = [\beta(\beta - 1) + 2a_4] \frac{V}{L^2}$$

(9) $$f_{LK} = f_{KL} = (\alpha\beta + a_5) \frac{V}{KL}$$

By substituting (5), (6), (7), (8), and (9) into the equation (4) and simplifying, we get

(10) $$\sigma = \frac{\alpha\beta(\alpha + \beta)}{\alpha\beta(\alpha + \beta) + 2[a_5 \alpha\beta - a_3 \beta^2 - a_4 \alpha^2]}$$

Thus the elasticity of substitution is in general no longer constant but a function of output elasticities of inputs which are again determined by the amounts of factors employed. Note that if the coefficients of second order terms in the translog function are equal to zero, the production function reduces to the Cobb-Douglas and the elasticity of substitution becomes unity.

APPENDIX B

Table B.1 Estimates of the Kmenta Approximation of the CES Function (Equation 3.7[1]) for Individual Industries

Industry (n)	$\hat{a}_o$ (t-value) (1)	$\hat{d}$ (t-value) (2)	$\hat{a}_1$ (t-value) (3)	$\hat{a}_2$ (t-value) (4)	$\hat{a}_3$ (t-value) (5)	R^2 (SSR) (6)
20.Food	-1.196	.042	.277	.634	.010	.424
(152)	(-7.402)	(.036)	(7.531)	(5.587)	(.219)	(3.472)
21.Beverage	-.483	.325	.393	.878	-.183**	.426
(121)	(-2.532)	(3.544)	(7.928)	(5.738)	(-2.840)	(3.330)
23.Textile	-.470	.212	.127	.478	-.110**	.403
(175)	(-5.832)	(3.320)	(5.354)	(7.851)	(-2.799)	(2.318)
24.Footwear &	.244	.335	-.024*	.242	.024	.428
Apparel (104)	(2.083)	(3.974)	(-.604)	(3.770)	(.652)	(1.904)
25.Wood	-.009	.247	.105	.395	-.032	.524
(94)	(-.050)	(2.874)	(2.082)	(4.716)	(-.959)	(1.932)
26.Furniture	-.476	.408	.189	.298	.000	.346
(82)	(-2.557)	(4.551)	(3.152)	(1.646)	(-.006)	(1.553)
27.Paper	-.189	.023	.087*	.486	.028	.502
(116)	(-1.422)	(.234)	(1.656)	(7.811)	(.762)	(3.612)
28.Printing	-.355	.242	.133	.284	.002	.121
(102)	(-1.369)	(2.057)	(2.065)	(1.322)	(.021)	(3.975)
29.Leather	.391	.154	.000*	.172	.044	.157
(41)	(1.070)	(.799)	(.001)	(.777)	(.433)	(1.683)
30.Rubber	-.783	.237	.185	.787	-.188**	.393
(76)	(-4.238)	(1.751)	(3.615)	(5.130)	(-2.304)	(2.090)

Table B.1 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
31.Chemicals	-.632	.145	.213	.851	-.164**	.383
(133)	(-3.415)	(1.701)	(5.474)	(5.831)	(-3.147)	(2.836)
32.Petroleum &	-.655	.179	.288	.562	-.005	.534
Coal (105)	(-4.499)	(2.324)	(7.139)	(4.682)	(-.098)	(1.328)
33.Caly	.086	-.049	.011*	.372	.088**	.517
(143)	(.864)	(-.670)	(.371)	(3.788)	(2.219)	(3.043)
34.Basic Metal	-.245	-.068	.182	.166	.137**	.270
(100)	(-1.587)	(-.554)	(3.970)	(2.053)	(2.839)	(2.458)
35.Metal Prod.	-.181	.199	.091	.345	-.047	.197
(117)	(-1.341)	(2.311)	(2.423)	(2.446)	(-.497)	(2.093)
36.Machine	-.121	.302	.087	.528	-.230**	.487
(122)	(-.978)	(3.768)	(3.979)	(4.183)	(-4.072)	(2.487)
37.Elec. Mach.	-.149	.007	.085*	.355	.009	.163
(89)	(-.781)	(.059)	(1.502)	(3.904)	(.175)	(3.144)
38.Transp. Eq.	-.244	.169	.158	.216	.021	.214
(128)	(-1.807)	(2.318)	(4.959)	(1.771)	(.420)	(1.940)

[1] (3.7) $$\frac{\ln(V/L)}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 + a_2 \frac{\ln(K/L)}{\ln L} + a_3 \frac{[\ln(K/L)]^2}{\ln L} .$$

* $\hat{a}_1(=\hat{h})$ is not significantly different from zero at the 5 percent level.

** $\hat{a}_3$ is significantly different zero at the 5 percent level.

Table B.2 Estimates of the Translog Function (Equation 3.8)[1] for Individual Industries

Industry	$\hat{a}_o$ (t) (1)	$\hat{d}$ (t) (2)	$\hat{a}_1$ (t) (3)	$\hat{a}_2$ (t) (4)	$\hat{a}_3$ (t) (5)	$\hat{a}_4$ (t) (6)	$\hat{a}_5$ (t) (7)	R^2 (SSR) (8)
20.Food	-.464	.048	.277	.698	.020	-.036	.045	.431
	(-1.130)	(.626)	(1.125)	(2.859)	(.457)	(-.570)	(.476)	(3.382)
21.Beverage	-.053	.328	.485	.796	-.142	-.226	.368	.424
	(-.100)	(3.574)	(1.373)	(2.073)	(-1.949)	(-2.909)	(2.809)	(3.287)
23.Textile	-.483	.215	.432	.713	-.122	-.144	.262	.396
	(-2.377)	(3.329)	(3.695)	(3.837)	(-2.537)	(-1.716)	(2.137)	(2.315)
24.Footwear & Apparel	.075	.345	-.093	1.226	.005	-.084	.004	.437
	(.242)	(4.124)	(-.447)	(4.366)	(1.219)	(-1.227)	(.046)	(1.836)
25.Wood	.136	.253	.105	1.018	.004	-.083	.064	.527
	(.262)	(2.930)	(.394)	(4.778)	(.095)	(-1.800)	(.941)	(1.877)
26.Furniture	-1.164	.356	1.740	-.345	-.249	.137	.111	.382
	(-1.913)	(3.958)	(2.789)	(-.637)	(-1.403)	(.869)	(.389)	(1.431)
27.Paper	.434	.120	.238	.426	-.095	-.160	.311	.570
	(1.550)	(1.276)	(1.456)	(1.229)	(-1.884)	(-1.197)	(2.032)	(3.068)
28.Printing	.498	.273	-.185	.922	.048	-.023	.016	.123
	(.782)	(2.236)	(-.387)	(1.748)	(.467)	(-.166)	(.080)	(3.888)
29.Leather	-.175	.158	.263	1.084	.047	.032	-.125	.116
	(-.156)	(.780)	(.521)	(1.910)	(.356)	(.113)	(-.309)	(1.666)
30.Rubber	-1.068	.235	.916	.430	-.203	-.182	.367	.380
	(-2.333)	(1.695)	(3.009)	(1.385)	(-2.361)	(-1.756)	(2.168)	(2.076)
31.Chemicals	-.143	.157	.557	.513	-.161	-.224	.390	.387
	(-.357)	(1.874)	(2.317)	(1.792)	(-3.000)	(-3.276)	(3.511)	(2.775)

Table B.2 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
32. Petroleum & Coal	-.343	.192	.570	.371	-.034	-.010	.076	.530
	(-1.029)	(2.304)	(2.494)	(1.369)	(-.594)	(-.127)	(.625)	(1.313)
33. Clay	.419	-.007	.316	.446	.065	.087	-.114	.526
	(2.048)	(-.089)	(2.274)	(2.941)	(1.534)	(1.446)	(-1.138)	(2.947)
34. Basic Metal	-.101	-.074	.006	1.141	.117	.033	-.158	.268
	(-.246)	(-.606)	(.039)	(4.234)	(2.240)	(.355)	(-1.169)	(2.415)
35. Metal Prod.	-.426	.213	.217	1.076	-.033	-.092	.093	.197
	(-1.047)	(2.464)	(.788)	(3.938)	(-.344)	(-.899)	(.489)	(2.055)
36. Machine	-.119	.220	.612	.359	-.243	-.209	.481	.518
	(-.366)	(2.668)	(2.035)	(1.622)	(-3.761)	(-3.441)	(4.383)	(2.299)
37. Elect. Mach.	.405	-.010	.300	.449	.015	.047	-.017	.161
	(.881)	(-.032)	(1.187)	(1.367)	(.297)	(.468)	(-.137)	(3.074)
38. Transp. Eq.	-.109	.174	-.004	1.151	.047	-.010	-.043	.207
	(-.341)	(2.373)	(-.016)	(4.142)	(.823)	(-.169)	(-.431)	(1.926)

[1] (3.8) $\frac{\ln V}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 \frac{\ln K}{\ln L} + a_2 + a_3 \frac{(\ln K)^2}{\ln L} + a_4 \ln L + a_5 \ln K.$

Table B.3 Estimates of the Generalized AMCS (Equation 3.9)[1] for Individual Industries

	$\hat{a}_o$ (t-value)	$\hat{d}$ (t-value)	$\hat{a}_1$ (t-value)	$\hat{a}_2$ (t-value)	R^2 (SSR)
20.Food	1.166	-.215	.150	.084*	.649
	(9.792)	(-.185)	(16.458)	(3.112)	(2.130)
21.Beverage	1.720	-.201	1.388	.177*	.541
	(9.093)	(-1.909)	(9.432)	(4.093)	(2.686)
23.Textile	.191	.136	.477	.111*	.371
	(1.526)	(.147)	(7.286)	(4.482)	(2.456)
24.Footwear & Apparel	1.267	-.048	1.059	-.075*	.687
	(10.016)	(-.632)	(10.340)	(-2.614)	(1.053)
25.Wood	1.014	.261	.407	-.042	.434
	(6.091)	(.239)	(3.198)	(-.825)	(2.324)
26.Furniture	.861	.081	1.017	.009	1.017
	(6.408)	(1.246)	(10.829)	(.244)	(10.829)
27.Paper	.494	-.036	1.050	.182*	.601
	(3.195)	(-.412)	(10.883)	(4.564)	(2.919)
28.Printing	.756	.047	.683	.008	.229
	(3.226)	(.379)	(4.560)	(-.123)	(3.523)
29.Leather	1.130	-.106	.820	.000	.820
	(3.338)	(-.533)	(3.224)	(.000)	(3.224)
30.Rubber	.931	.061	1.159	.041	.438
	(3.964)	(.469)	(6.570)	(.811)	(1.964)
31.Chemicals	1.380	-.080	.983	-.014	.569
	(10.487)	(-1.059)	(11.517)	(-.448)	(1.998)
32.Petro. & Coal	1.005	.023	1.121	.074	.501
	(4.680)	(.240)	(6.849)	(1.500)	(1.436)
33.Clay	.656	-.015	.787	.044	.490
	(9.229)	(-.201)	(9.526)	(1.611)	(3.235)
34.Basic Metal	.979	-.015	1.032	.046	.402
	(5.275)	(-.150)	(7.866)	(1.012)	(2.035)
35.Metal Prod.	.887	-.006	.908	.013	.392
	(5.808)	(-.084)	(7.040)	(.390)	(1.600)
36.Machine	.024	.105	.280	.180*	.528
	(.297)	(1.268)	(5.468)	(6.194)	(2.311)
37.Elec. Mach.	1.316	-.235	1.383	-.019	.602
	(8.257)	(-2.628)	(11.482)	(-.484)	(1.512)
38.Transp. Eq.	.949	-.071	1.008	.013	.489
	(7.493)	(-1.089)	(9.585)	(.448)	(1.271)

[1](3.9) $\frac{\ln(V/L)}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} + a_1 \frac{\ln(W/L)}{\ln L} + a_2$.

*$\hat{a}_2$ is significantly different from zero at the 5 percent level.

Table B.4 Nonlinear Estimates of the CES Function (Equation 3.10)[1] for Individual Industries

	$\hat{a}_o$ (1)	$\hat{d}$ (2)	$\hat{\theta}$ (3)	$-\hat{\delta}$ (4)	$\hat{\lambda}$ (5)	R^2 (6)
20.Food	-1.185	.000	.498	.063	1.276	.426
	(-1.505, -.865)[2]	(.000, .000)	(.329, .666)	(.487, .614)	(1.203, 1.350)	
21.Beverage	-.488	.335	.677	-1.554*	1.404	.432
	(-.920, -.056)	(.152, .517)	(.370, .984)	(-3.062, -.046)	(1.305, 1.502)	
23.Textile	.461	.212	.415	-.852	1.125	.399
	(.299, .623)	(.082, .342)	(.298, .533)	(-1.726, .023)	(1.077, 1.172)	
24.Footwear &	.246	.334	.241	.421	.974	.429
Apparel	(.012, .480)	(.166, .502)	(.105, .377)	(-.614, 1.457)	(.895, 1.052*)	
25.Wood &	-.005	.247	.354	-.265	1.105	.524
Cork	(-.381, .371)	(.075, .419)	(.216, .493)	(-.825, .294)	(1.004, 1.206)	
26.Furniture	-.476	.408	.251	-.008	1.189	.346
	(-.848, -.104)	(.229, .587)	(-.042, .544)	(-2.575, 2.599)	(1.069, 1.309)	
27.Paper	.192	.023	.445	.215	1.088*	.503
	(-.457, .074)	(-.173, .219)	(.303, .586)	(-.341, .772)	(.983, 1.193)	
28.Printing	-.335	.242	.252	.016	1.133	.121
	(-.823, .154)	(.007, .478)	(-.118, .621)	(-1.800, 1.831)	(1.004, 1.262)	
29.Leather	.387	.157	.185	.395	1.001*	.156
	(-.365, 1.139)	(-.226, .540)	(-.229, .599)	(-.776, 2.551)	(.776, 1.226)	
30.Rubber	-.776	.244	.664	-1.454	1.187	.392
	(-1.154, -.398)	(-.025, .513)	(.307, 1.020)	(-3.491, .584)	(1.084, 1.289)	
31.Chemicals	-.652	.155	.785	-1.685*	1.212	.388
	(-1.046, -.257)	(-.016, .326)	(.509, 1.062)	(-3.282, -.088)	(1.137, 1.287)	
32.Petro. &	-.656	.179	.437	-.032	1.288	.534
Coal	(-.947, -.365)	(.025, .334)	(.257, .616)	(-.649, .584)	(1.208, 1.369)	

Table B.4 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)
33.Clay	.110	-.045	.318	1.014	1.005*	.519
	(-.101, .321)	(-.191, .100)	(.081, .555)	(-.198, 2.225)	(.946, 1.064)	
34.Basic Metal	-.204	-.020	.170	.907	1.174	.252
	(-.519, .112)	(-.263, .224)	(-.012, .352)	(1.211, 2.026)	(1.081, 1.266)	
35.Metal Prod.	-.178	.199	.315	1.428	1.091	.197
	(-.443, .087)	(.026, .371)	(.064, .565)	(-2.200, 1.343)	(1.016, 1.165)	
36.Machine	.099	.303	.335	-5.280	1.076	.464
	(-.352, .552)	(.144, .463)	(-.224, .895)	(-16.110, 5.544)	(1.030, 1.112)	
37.Elec. Mach.	-.149	.007	.327	.066	1.085*	.163
	(-.529, .232)	(-.243, .258)	(.159, .495)	(-.759, .891)	(.972, 1.198)	
38.Transp. Eq.	-.252	.170	.198	.148	1.159	.214
	(-.523, .019)	(.025, .315)	(-.004, .400)	(-.834, 1.129)	(1.095, 1.222)	

[1] (3.10) $$\frac{\ln V}{\ln L} = a_o \frac{1}{\ln L} + d\frac{D}{\ln L} - \frac{\lambda}{\delta}\,\frac{\ln[\theta K^{-\delta} + (1-\theta)L^{-\delta}]}{\ln L}$$

[2] The numbers in parentheses indicate the approximate lower and upper bounds of the 95 percent confidence interval.

*$\hat{\lambda}$ is not significantly different from unity at the 5 percent level.

REFERENCES

1. Arrow, K., Chenery, H., Minhas, B., and Solow, R. "Capital-Labor Substitution and Economic Efficiency," Review of Economics and Statistics, August 1961.

2. Baer, W., and Herve, M. E. A. "Employment and Industrialization in Developing Countries," Quarterly Journal of Economics, Vol. 80, No. 1, 1966.

3. Balassa, B. The Structure of Protection in Developing Countries, Johns Hopkins Press, 1971.

4. Balassa, B. "Industrial Policies in Taiwan and Korea," Weltwirtschaftliches Archiv, Vol. 106, 1971, pp. 55-77.

5. Baldwin, R. E. "The Case Against Infant-Industry Tariff Protection," Journal of Political Economy, Vol. 41, 1969, pp. 295-305.

6. Bank of Korea: Financial Statement Analysis, 1968.

7. Bank of Korea: Economic Statistics Yearbook, various issues.

8. Bank of Korea: National Income Statistic Yearbook, various issues.

9. Berndt, E. R., and Christenson, L. R. "The Translog Function and the Substitution of Equipment, Structure, and Labor in U. S. Manufacturing 1929-1968," Journal of Econometrics, March 1973, pp. 81-113.

10. Bhagwati, J. The Theory and Practice of Commercial Policy: Departure from Unified Exchange Rates, Princeton University Press, 1968.

11. Bhagwati, J. and Krueger, A. O. "Exchange Control, Liberalization, and Economic Development," American Economic Review, May 1973.

12. Bronfenbrenner, M. and Douglas, P. H. "Cross-section Studies in the Cobb-Douglas Function," Journal of Political Economy, December 1939.

13. Brown, G. "The Impact of Korea's 1965 Interest Rate Reform on Savings, Investment, and the Balance of Payments," a paper presented at the CENTO symposium on Central Banking Monetary Policy in Economic Development, Izmir, Turkey, April 1971.

14. Christenson, L. R., Jorgenson, D. W., and Lau, L. J. "Transcendental Logarithmic Production Frontier," Review of Economics and Statistics, February 1973.

15. Clague, C. K. "Alternative Estimates of Capital-Labor Substitution in Manufacturing in Developing Countries, Econometrica, July 1969, pp. 528-537.

16. Cobb, C. W. and Douglas, P. H. "A Theory of Production," American Economic Review, Vol. 18, 1928, pp. 139-165.

17. Corden, W. M. "Monopoly, Tariffs and Subsidies," Economica, February 1967, pp. 50-58.

18. Dhrymes, P. J. "Some Extensions and Tests for the CES Class of Production Functions," Review of Economics and Statistics, November 1965.

19. Diewert, W. E. "Functional Forms for Profit and Transformation Function," Journal of Economic Theory, June 1973.

20. Douglas, P. H. and Gunn, G. T. "The Production Functio for American Manufacturing for 1914," Journal of Political Economy, August, 1942.

21. Eckaus, R. S. "The Factor Proportions Problem in Underdeveloped Areas," American Economic Review, September, 1955.

22. Economic Planning Board, Korea, Major Economic Indicator, various issues.

23. Eisner, R. "Capital and Labor in Production: Some Direct Estimates," in M. Brown (ed.), The Theory and Empirical Analysis of Production, Studies in Income and Wealth, Vol. 31, NBER, New York, 1967.

24. Frank, C., Kim, K. S., and Westphal, L. Foreign Trade Regimes and Economic Development: South Korea, NBER, New York, (mimeographed).

25. Goldberger, A. S. Econometric Theory, John Wiley and Sons, Inc., New York, 1964, p. 125.

26. Goldfeld, S., and Quandt, R. "Some Tests for Homoscedasticity," Journal of the American Statistical Association, June 1965.

27. Griliches, Z. "Specification Bias in Estimates of Production Functions," Journal of Political Economy, Vol. 39, 1957, pp. 8-20.

28. Griliches, Z. "Production Function in Manufacturing: Some Preliminary Results," in M. Brown (ed.), The Theory and Empirical Analysis of Production, Studies in Income and Wealth, Vol. 31, NBER, New York, 1967.

29. Griliches, Z. and Ringstad, V. Economies of Scale and the Form of the Production Function, North-Holland, Amsterdam, 1971.

30. Harris, J. R., and Todaro, M. P. "Migration, Unemployment and Development: A Two Sector Analysis," American Economic Review, March 1970.

31. Hildebrand, G. H. and Liu, T. C. Manufacturing Production Functions in the United States 1957, Cornell University Press, 1965.

32. Hodgins, C. Economies of Scale in Canadian Manufacturing, unpublished Ph.D. dissertation, University of Chicago, 1968.

33. Johnston, J. Econometric Methods, McGraw-Hill, New York, 1972, p. 281.

34. Katz, J. M. Production Function, Foreign Investment and Growth, North-Holland, Amsterdam, 1969.

35. Keesing, D. B. "Outward-looking Policies and Economic Development," Economic Journal, June 1967.

36. Kindleberger, C. P. Economic Development, McGraw-Hill, New York, 1958, Chapter 6.

37. Klein, L. R. "Macroeconomics and the Theory of Rational Behavior," Econometrica, April 1946.

38. Kmenta, J. "On the Estimates of the CES Production Functions," International Economic Review, June 1967.

39. Krueger, A. O. "Some Economic Costs of Exchange Control: The Turkish Case," Journal of Political Economy, October 1966.

40. Lewis, W. A. "A Review of Economic Development," American Economic Review, May 1965, p. 12.

41. Little, I. M., Scitovsky, T., and Scott, M. Industry and Trade in Some Developing Countries: A Comparative Study, Oxford University Press, published for the O.E.C.D., London, 1970.

42. Malinvaud, E. Statistical Methods of Econometrics, North-Holland, Amsterdam, 1970.

43. McKinnon, R. I. Money and Capital in Economic Development, The Brookings Institution, Washington, D. C., 1973.

44. Moore, F. T. "Economies of Scale: Some Statistical Evidence," Quarterly Journal of Economics, Vol. 73, 1959, pp. 232-245.

45. Mukerji, V. "Generalized SMAC Function with Constant Ratios of Elasticities of Substitution," Review of Economic Studies, Vol. 30, 1963, pp. 233-236.

46. Nataf, A. "Sur la Possibilité de Construction de Certains Macromodels," Econometrica, October 1950.

47. Nelson, R. R. "A Diffusion Model of International Productivity Differences in Manufacturing Industries," American Economic Review, December 1968.

48. Nerlove, M. "Recent Empirical Studies of the CES and Related Production Functions," in M. Brown (ed.), The Theory and Empirical Analysis of Production, Studies in Income and Wealth, Vol. 31, NBER, New York, 1967.

49. Parks, R. W. "Price Responsiveness of Factor Utilization in Swedish Manufacturing, 1870-1950," Review of Economics and Statistics, May 1971.

50. Patinkin, D. Money, Interest and Prices, Harper and Row, New York, 1965.

51. Pursell, G. and Snape, R. H. "Economies of Scale, Price Discrimination and Exporting," Journal of International Economics, August 1973, pp. 85-91.

52. Reynolds, L. G. "Wages and Employment in a Labor Surplus Economy," American Economic Review, March 1965.

53. Shim, B. K., Suh, S. Y., Chee, Y. H. and Lee, D. H. A Study of Preferential Interest Rate Structure, the Korean Experience 1963-1971, October 1972, (mimeographed).

54. Stalely, E. and Morse, R. Modern Small Industries for Developing Countries, McGraw-Hill, New York, 1965.

55. Theil, H. Principles of Econometrics, John Wiley and Sons, Inc., New York, 1971, p. 551.

56. Walters, A. A. "Production and Cost Functions: A Econometric Survey," Econometrica, January - April, 1963.

57. Witte, A. D. "Alternative Estimates of Capital-Labor Substitutions in Manufacturing in Developing Economies: Comment on Professor Clague," Econometrica, November 1971.

58. Witte, A. D. "Employment in the Manufacturing Sector of Developing Economies: A Study of Mexico and Peru," Journal of Development Studies, October 1973.