Capacity Utilization, Economies of Scale and Technical Change in the Growth of Total Factor Productivity: An Explanation of South Korean Manufacturing Growth*

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I. Introduction

Recent advances in the productivity measurement enable us to overcome deficiencies inherent in the conventional Divisia index of total factor productivity (TFP). The new approach involves explicit specification of a production function and the direct linkage of productivity growth to key parameters of this function.[1] Furthermore, the econometric implementation of the new approach yields parametric estimates of the production technology as a by-product in the process of measuring the productivity growth.

While the present study encompasses such recent advances in the productivity measurement, its main novelty lies in the inclusion of capacity utilization in the analysis of the sources of growth. To date, very little systematic effort has been devoted to exploring the role of capacity utilization as a possible source of the productivity growth. The omission entails an especially serious drawback when dealing with the productivity growth of the developing economies that have experienced significant changes in the capacity utilization. That the capacity utilization may have played a

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1) For recent development in the productivity measurement, see Solow (1957), Kendrick (1961, 1973), Denison (1962, 1967), Star (1974), Jorgenson and Griliches (1977), and Hulten (1975, 1978). Also, see Diewert (1981), Gollop and Roberts (1981), Dunny, Fuss and Waverman (1981), Nadiri and Schankerman (1981), and Cowing, Small and Stevenson (1981) for more recent development. Another important development that has both theoretical and econometric implications for the measurement of productivity is the cost function model based upon the duality theory and the work of Shephard (1953, 1970), Uzawa (1964) and McFadden (1978).

significant role in the productivity growth for the developing economies has been suggested by Bruton (1967), Kim and Kwon (1977), and Williamson (1969). For the U.S. economy, Christensen and Jorgenson (1970) and Jorgenson and Griliches (1967) have demonstrated the sensitivity of the magnitude of the "unexplained residual" to the rate of capacity utilization.

The dual objectives of this study are (a) to develop a method of decomposing the measured growth in total factor productivity into technology, returns to scale and capacity utilization and (b) to use the decomposition method to identify the sources of the productivity growth of the South Korean manufacturing. The decomposition method developed in this study is linked to the theory of cost function by the cost/output elasticity and by the cost/capacity-utilization elasticity.

Apart from its general interest, the present study is of special importance in that it investigates the economy, South Korea, which has achieved a record of remarkable growth in the last two decades.

The paper proceeds as follows: Section 2 develops a method of decomposing the measured growth in total factor productivity (TFP) into three parts. In Section 3, a translog cost function is used to derive the cost/output and the cost/capacity-utilization elasticity functions. The empirical results are presented in Section 4 and summary and conclusions are given in the last section.

II. Total Factor Productivity and Cost Function

We propose a method of decomposing the measured growth in total factor productivity into parts related to changes in technology, economies of scale and capacity utilization.

The rate of growth of TFP is defined as

$$\dot{TFP} = \dot{Q} - \dot{F} \tag{1}$$

where Q is output, F denotes total factor input and a dot represents a rate of growth $\frac{dX}{dt}\cdot\frac{1}{X}$. At the aggregate level there is only one output, so that Q is defined unambiguously. For measuring F, the following Divisia index is used:

$$\dot{F} = \sum_i \frac{P_i X_i}{C} \dot{X}_i \tag{2}$$

where P_i is the price of input i; X_i, the quantity of input i; $\dot{X}_i$, the proportionate rate of growth of input i; and $C \equiv \sum_i P_i X_i$, the total cost. Under the assumption of cost-minimizing behavior, the duality theory implies that, for any production function, there exists a cost function that provides an equivalent description of the technology.

Suppose we represent the cost function by

$$C = g(P, Q, T, \lambda) \tag{3}$$

where P is the vector of input prices, T denotes time and λ denotes the capacity-utilization rate.

Totally differentiate Eq. (3) with respect to time, T,

$$\frac{dc}{dT} = \sum_i \frac{\partial g}{\partial p_i} \cdot \frac{dp_i}{dT} + \frac{\partial g}{\partial Q} \cdot \frac{dQ}{dT} + \frac{\partial g}{\partial T} + \frac{\partial g}{\partial \lambda} \cdot \frac{d\lambda}{dT} \tag{4}$$

Rearranging Eq.(4) and dividing through C and setting $\frac{\partial g}{\partial P_i} = X_i$ (by Shephard's lemma),

$$\frac{1}{C}\frac{dC}{dT} = \sum_i \frac{P_i X_i}{C} \dot{P}_i + \frac{\partial g}{\partial Q} \cdot \frac{Q}{C} \cdot \dot{Q} + \frac{1}{C} \frac{\partial g}{\partial T} + \frac{\partial g}{\partial \lambda} \cdot \frac{\lambda}{C} \dot{\lambda} \tag{5}$$

If the proportionate shift in the cost function due to technology is defined as $\dot{\beta} \equiv (1/C)\partial g/\partial T$, then Eq. (5) after rearrangement becomes

$$\dot{\beta} = \dot{C} - \sum_i \frac{P_i X_i}{C} \dot{P}_i - E_{CQ} \cdot \dot{Q} - E_{C\lambda} \cdot \dot{\lambda} \tag{6}$$

where $E_{CQ} \equiv (\partial g/\partial Q)\cdot(Q/C) \equiv$ the cost/output elasticity and $E_{C\lambda} \equiv (\partial g/\partial \lambda)(\lambda/C) \equiv$ the cost/capacity-utilization elasticity. Eq. (6) shows that the proportionate shift in the cost function, ($\dot{\beta}$), equals the proportionate change in costs minus the proportionate change in aggregate inputs, the scale economies ($E_{CQ}.\dot{Q}$) and the capacity utilization ($E_{C\lambda} \cdot \dot{\lambda}$).

Totally differentiating $C = \sum_i P_i X_i$ with respect to time and rearranging,

$$\sum_i \frac{P_i X_i}{C} \dot{P}_i = \dot{C} - \sum_i \frac{P_i X_i}{C} \dot{X}_i \tag{7}$$

Substituting (7) into (6) we obtain

$$-\dot{\beta} = E_{CQ} \cdot \dot{Q} + E_{C\lambda} \cdot \dot{\lambda} - \sum_i \frac{P_i X_i}{C} \dot{X}_i \tag{8}$$

or

$$-\dot{\beta} = E_{CQ} \cdot \dot{Q} + E_{C\lambda} \cdot \dot{\lambda} - \dot{F} \tag{9}$$

Given $\dot{TFP} = \dot{Q} - \dot{F}$ and $\dot{F} = E_{CQ} \cdot \dot{Q} + E_{C\lambda} \cdot \dot{\lambda} + \dot{\beta}$,

$$\dot{TFP} = \dot{Q} - E_{CQ} \cdot \dot{Q} - E_{C\lambda} \cdot \dot{\lambda} + \dot{\beta} \tag{10}$$

or

$$\dot{TFP} = -\dot{\beta} + (1 - E_{CQ})\dot{Q} - E_{C\lambda} \cdot \dot{\lambda} \tag{11}$$

If constant returns to scale exist and the cost/capacity-utilization elasticity is zero, then $\dot{TFP} = -\beta$. In this case, the change in total factor productivity reflect the shifts both in the production and cost functions due to technology. An implication of the above analysis is that, when the scale and the capacity utilization effects are present, the conventional total productivity index measures neither the shifts in the production function nor the shifts in the cost function. However, when the cost elasticities are known, the intertemporal shifts in the cost function and scale effect as well as the capacity utilization effect can be separated.

III. Modelling the Cost Structure and Derivation of Cost/Output and Cost/Capacity-Utilization Elasticities

As mentioned in Sections 1 and 2, the present approach directly links the productivity growth to key parameters of the specific production (and cost) function. The main points of linkage are the cost/output and cost/capacity-utilization elasticities that can be obtained in the process of estimating the cost structure.

The theory of duality[2] between the cost and production functions permits us to obtain the structural information about the production process by estimating the firm's cost function. The duality theory posits that, under rather weak regularity conditions, there is a unique correspondence between the production and cost functions. Furthermore, the duality theory can be exploited without imposing a restriction on the returns to scale in the underlying technology.

The generalized cost function for the firm minimizing costs allowing for variations in technology and capacity utilization would be

$$C = g(P, Q, T, \lambda) \tag{3a}$$

where C, P, and Q are total costs, a vector of factor prices, and the level of output, respectively; and T is the index of the level of technology and λ denotes the level of capacity utilization.[3] the translog specification of this generalized cost function is given by:

$$\ln C = \alpha_O + \alpha_Q \ln Q + \tfrac{1}{2}\alpha_{QQ} (\ln Q)^2 + \sum_i \alpha_i \ln P_i +$$
$$\tfrac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \gamma_{Qi} \ln Q \ln P_i + \sum_i \theta_i \ln P_i \ln T$$

2) See Shephard (1970).

3) A full discussion of the translog cost functional form is given in Christensen, Jorgenson and Lau (1973) and in Hans Binswinger (1974).

$$+\theta_Q \ln Q \ln T + \beta_t \ln T + ½ \beta_{tt} (\ln T)^2 + \sum_i \delta_i \ln P_i \ln \lambda + \delta_Q \ln Q \ln \lambda$$
$$+\delta_t \ln T \ln\lambda + \rho_\lambda \ln\lambda + ½ \rho_{\lambda\lambda} (\ln\lambda)^2 \qquad (12)$$

where i, j = L(labor), E(energy), K(capital) and M(material). The cost-share equations can be obtained from Shephard's lemma as

$$S_i = \alpha_i + ½ \sum_j \gamma_{ij} \ln P_j + \gamma_{Qi} \ln Q + \theta_i \ln T + \delta_i \ln\lambda$$

for i, j = L, E, K, M, (13)

where $S_i = \frac{\partial \ln C}{\partial \ln P_i} P_i X_i / C$ is the cost share.

There are several parametric restrictions on the translog cost function. First, the cost function must be linearly homogeneous in factor prices. This implies that

$$\sum_i \alpha_i = 1,\ \sum_i \sum_j \gamma_{ij} = \sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0, \text{ and } \sum \gamma_{\theta i} = \sum \theta_i = \sum \delta_i = 0. \qquad (14)$$

Second, since the translog is viewed as a quadratic (logarithmic) approximation, the cross partial derivatives of the cost function must be equal. This implies the symmetry condition

$$\gamma_{ij} = \gamma_{ji}. \qquad (15)$$

The system of equations consisting of the cost function (12) and three of the four cost-share equations (13) were estimated as simultaneous systems.[4] In fact, exploiting the duality theory and estimating the cost share equations jointly with the cost function increases the statistical degree of freedom, since the cost share parameters are a subset of the cost-function parameters. The limited time series (1960-1978) make this procedure imperative. The cost/output and the cost/capacity-utilization elasticity estimates can be obtained once the parameters of the model are estimated; these elasticities are given by

$$E_{CQ} = \alpha_Q + \alpha_{QQ} \ln Q + \sum_i \gamma_{Qi} \ln P_i + \theta_Q \ln T + \delta_Q \ln \lambda \qquad (16)$$

$$E_{C\lambda} = \sum_i \delta_i \ln P_i + \delta_Q \ln Q + \delta_t \ln T + \rho_\lambda + \rho_{\lambda\lambda} \ln\lambda. \qquad (17)$$

The cost/output elasticities as well as the cost/capacity-utilization elasticities vary with factor prices, level of output, technology and capacity utilization rate.

4) We follow the literature in specifying additive disturbances in each share equation and the cost function. The system can be estimated by Zellner's (1962) seemingly unrelated regression technique.

IV. Data and Empirical Results

1. Data

Data consists of annual time-series for the Korean manufacturing, 1960-1978. They are measures of aggregate output and the quantities and prices of labor, capital, energy and materials. The index of manufacturing production is used as a measure of aggregate output while the quantity of labor input is represented by the total man-hour worked.

The data for employee renumeration, the number of manhours worked and expenditures on energy and materials are available from the Report on Mining and Manufacturing Survey, and the price indices for the energy and materials as well as the index of manufacturing production are available from the Economic Statistics Yearbook. Total costs are defined as the sum of four elements: nominal expenditures on labor, energy material and the value of flow services of capital.

The computation of the service price of capital is based on the abbreviated version of Christensen and Jorgenson (1969). It is the sum of an expected real rate of interest plus the rate of depreciation of 7%, multiplied by the price index of the net capital stock.[5] The quantity as well as the price indices of the net capital stock is available from the *Estimates of the Value of Capital in Korean Manufacturing* by Choo et al. (1981).

The capacity utilization measure is the electricity measure devised by Foss (1963) and later used by Jorgenson and Griliches (1967), Christensen and Jorgenson (1970), Heathfield (1972) and Kim and Kwon (1977). Input and output price indices, input cost and capacity utilization data are given in Table A2 of the Appendix.

2. Results

(a) Cost/Output Elasticities (E_{CQ}) and Cost/Capacity-utilization Elasticities ($E_{C\lambda}$).

Empirical estimates of E_{CQ} and $E_{C\lambda}$ based on Eqs. (16) and (17) are presented in Table 1.[6] In order to reflect the changing phase of the South Korean development, the period in the study is divided into two subperiods: 1960-1972 and 1973-1978, the former was the period of self-sustaining growth economy while the latter was the period of transition

5) The depreciation data are available after 1971. The average rate of depreciation during the 1971-80 period is 6.97 percent. See Financial Statement Analysis for 1980 (1981).

6) To conserve space, the parametric estimates of the four factor unconstrained translog cost function are presented in Table A1 of the Appendix. The estimated coefficients represent a well-behaved cost function at each observation.

[Table 1] Estimates of Cost/Output and Cost/Capacity-Utilization Elasticities and Returns to Scale*

Period	Cost/Output Elasticities (E_{CQ})	Returns to Scale ($1-E_{CQ}$)	Cost/Utilization Elasticities ($E_{C\lambda}$)
1960-72	0.321	0.679	−0.705
1973-78	0.433	0.567	−0.565
1960-78	0.357	0.643	−0.661

*Estimates at the sample means.

toward the heavy/chemical intensive manufacturing.[7]

The rate of returns to scale defined as $1-E_{CQ}$ is 0.643 for the 1960-78 period, suggesting that the underlying technology exhibits substantial increasing returns to scale in South Korean manufacturing.[8] For the entire period, the E_{CQ} of 0.357 means that, on the average, a 1% increase in output results in 0.357% increase in total cost. The gradual reduction of $1-E_{CQ}$ from one period to another period also suggests that the Korean manufacturing has been exploiting the scale economies through expansion of the size of its operation.

At the same time, the production efficiency has been also achieved through the cost reduction accompanied by the increase in capacity utilization rate. The importance of the capacity utilization factor, especially during the first phase of the industrialization, is seen by $E_{C\lambda} = -0.705$, which means that 1% increase in the rate of capacity utilization results in the 0.705% reduction in the total cost.

(b) The Contribution of Changes in Scale Economies, Technology and Capacity Utilization to Total Factor Productivity Growth

In order to characterize the growth of South Korean manufacturing over the 1960-1978 period, the rates of growth of real inputs ($\dot{F}$), real outputs ($\dot{Q}$) and the capacity utilization ($\dot{\lambda}$) have been calculated for the two subperiods (Table 2). As mentioned in Section 2, The Divisia Index is used to measure $\dot{F}$, as in Eq. (2), where $\dot{X}_i = \dot{L}, \dot{K}, \dot{E}, \dot{M}$, the rate of growth of labor, capital stock, energy and materials, respectively. For the 1960-72 period, the cost shares (i.e., $S_i = \frac{P_i X_i}{C}$) are 10.0%, 30.0% 5.0% and 56.0%, for labor, capital, energy and materials, respectively.

7) See *National Income in Korea* (1982, pp. 11-30).

8) The magnitude of the returns to scale reported in this paper is somewhat larger than the result ($1-E_{CQ} = 0.35$) reported by Kwon and Williams (1982) based on the cross-section analysis of the Korean manufacturing in 1973. It is also larger than the 0.20 for the U.S. manufacturing in 1971, reported by Berndt and Khaled (1979).

[Table 2] Average Annual Percentage Rates of Growth of Real Inputs, Outputs, and Capacity Utilization

	Total Factor Input	Factor Inputs				Total Output	Capacity Utilization
		Labor	Capital	Energy	Material		
	$\dot{F}$	$\dot{L}$	$\dot{K}$	$\dot{E}$	$\dot{M}$	$\dot{Q}$	$\dot{\lambda}$
1960-72	14.58	11.15	13.90	15.53	19.05	17.90	9.40
1972-78	18.47	13.77	19.41	15.86	25.05	26.70	1.69
1960-78	15.82	11.98	15.64	15.63	20.94	20.67	6.96

The following points are worth mentioning. First, both the total factor input and the total output grew quite rapidly throughout the entire period. Second, the rates of growth of both the total input and total output were even higher in the second period. Third, the rate of capacity utilization grew rather rapidly at an average annual rate of 9.40% during the first phase of the industrialization. The rate grew from 12.53% in 1960 to the peak of 33.25% in 1973 and then gradually tapered off thereafter. Fourth, the capital stock, energy and material inputs grew much faster than the labor input, suggesting the labor-saving nature of the technology. A further support for the capital-using and labor-saving nature of the technology is evidenced in Table Al in Appendix which shows $\theta_k = .158$ with the t-statistic of 9.74 and $\theta_L = -.032$ with the t-statistic of 3.48.

Given this information, we now attempt to determine for South Korean manufacturing the relative importance of scale economies, changes in technology and capacity utilization in the measured total factor productivity growth. To allocate the relative contributions, we used the equation developed in Section 2.

$$T\dot{F}P = -\dot{\beta} + (1-E_{CQ})\,\dot{Q} - E_{C\lambda}\ \dot{\lambda}\,. \tag{11a}$$

The required cost/output (E_{CQ}) and cost/capacity-utilization ($E_{C\lambda}$) weights are taken from Table 1, and the proportionate shift in the cost function, $\dot{\beta}$, is calculated as a residual from Eq. (9):

$$-\dot{\beta} = E_{CQ}\cdot\dot{Q} + E_{C\lambda}\cdot\dot{\lambda} - \dot{F}\,. \tag{9a}$$

Table 3 presents the results of this allocation exercise. These results show the decomposition of $T\dot{F}P$ (which appears in Column 1) and enables us to make the following observations:

1. The scale economies have become increasingly important over time in the development of South Korean manufacturing. It accounted for over

[Table 3] Decomposition of TFP Growth, 1960-1978

Period	Total Factor Productivity	Percentage Contributions to $\dot{TFP}$ due to		
		Shifts of Cost Function	Non-Consant Returns to Scale	Capacity Utilization
	$\dot{TFP}$	$-\dot{\beta}$	$(1-E_{CQ})\dot{Q}$	$-E_{C\lambda}\dot{\lambda}$
1960-72	3.32	45.19	35.57	19.24
1972-78	8.23	32.82	63.22	3.97
1960-78	4.85	42.16	42.94	14.89

35% of the growth in $\dot{TFP}$ in the 1960-72 period and 63% of $\dot{TFP}$ in the 1972-78 period.[9]

2. By contrast, the technical change represented by the proportionate shift in the cost function has become less important over time, declining from 45% to 33%.

Since the estimates of efficiency gains due to technical change are residually determined, an interpretation of the estimated results is in order. First, the estimated change in technology includes any errors resulting from the estimation of both the cost/output and cost/capacity-utilization elasticities. Second, as with any residual, it represents a quantitative expression of our ignorance.

3. The increase in capacity utilization played a significant role in the productivity growth. Its contribution which accounted for 19 percent of the growth of total factor productivity in the 1960-72 period was accomplished through the steady growth of the utilization rate throughout the first phase of the industrialization. However, the capacity utilization appears to have become a less important source of TFP growth since 1973 when the utilization rate reached its peak.

4. For the entire period, 1960-1978, the growth of capacity utilization contributed 15% of the $\dot{TFP}$ while the technology and scale economies have contributed 42% and 43% of the $\dot{TFP}$, respectively.

(c) Sources of the Real Output Growth

To understand the importance of total factor productivity in accounting for the growth of output, we follow the standard growth accounting approach. Table 4 shows the relative importance of growth in total factor

9) However, it is possible that a portion of the contribution of scale in Table 3 may be due to scale-augmenting technical change. It is included as an economies of scale contributing since larger scale is necessary to realize this additional cost savings from innovation. See Denny, Fuss and Waverman (1981).

[Table 4] Accounting for the Growth of Aggregate Output

Period	Total Factor Productivity	Total Output	Relative Importance of Various Contributors to the Growth of Output (%)*				
	$\dot{TEP}$	$\dot{Q}$	$\dot{TFP}$	$\dot{L}$	$\dot{K}$	$\dot{E}$	$\dot{M}$
1960-72	3.32	17.90	18.55	18.77	15.98	21.79	24.92
1972-78	8.23	26.70	30.82	14.75	14.31	15.27	24.85
1960-78	4.85	20.67	23.46	17.17	15.43	19.11	24.82

*Cost shares were used as weights (see Table 2).

productivity, labor, capital, energy and materials in the growth of real output. During the 1960-72 period, while the output growth was high, total factor productivity grew at a moderate pace and contributed only 18.6% of the growth of output. The largest proportion of the growth of output was explained by the growth of the material inputs. Then the picture changed considerably in the 1972-78 period. First, during this period, the output grew even faster and so did the total factor productivity. Second, the contribution of the growth of total factor productivity to the output growth rose to 30.8% which is considerably higher than that for the 1960-72 period. Third, the $\dot{TFP}$ emerged as the single largest contributor to the output growth. Fourth, the relative importance of the growth of labor and energy declined while that of the capital and material inputs remained unchanged.

Although a precise intercountry comparison of the productivity growth is not possible, a review of findings is nevertheless of some interest. According to the study of Japanese manufacturing by Nishimizu and Hulten (1978), during the 1955-71 period, the change of total factor productivity accounted for approximately 14.4% of the growth of real output which is somewhat lower than the 18.6% for the Korean manufacturing for the 1960-72 period. During the same period in Japan capital and intermediate inputs accounted for approximately 80% of the growth of real output, leaving only 20% for the growth of TFP and labor. This is in contrast with the Korean experience where the growth of TFP and labor together accounted for 37%, leaving 63% for capital, energy and materials.

According to another study by Norsworthy and Malmquist (1983) for the 1965-73 period, the characteristics of the growth of Japanese manufacturing were those of rapid growth of capital (16.5%), energy (11.0%), materials (11.4%) in contrast with the virtual constancy of the labor force (1.4%). To the extent that capital, energy and material grew faster than the labor, the Japanese pattern of the growth of its manufacturing is similar to the Korean experience of the 1960-78 period. However, the two part company when the growth rate of the labor is compared. In Korean manufacturing the labor grew at the rate of 11% as compared with 1.4% for Japan.

This difference in the growth rates of labor can be explained by the difference in the degree of substitutability between capital and labor. The estimated Allen partial elasticity of substitution between capital and labor was approximately 0.6 to 0.7 for Korea while it was 1.7 for Japan.[10] This low degree of substitutability seems to be the key to the explanation of the rapid growth of labor force in the face of the rapidly rising wages in Korea throughout the entire 1960-78 period.

V. Summary and Conclusions

In this paper we have presented a method of interpreting the growth of total factor productivity, directly linking the productivity growth to key parameters of a specific cost function. We have shown that the productivity index can be decomposed into effects due to (a) technical change, (b) nonconstant returns to scale, and (c) change in capacity utilization. The decomposition framework was applied to data on South Korean manufacturing during 1960 and 1978, when the manufacturing achieved a most remarkable success.

Total factor productivity was found to have grown at 4.9% per annum. Scale economies contributed about 43% of the growth of TFP; the technical change, 42%; and the changes in capacity utilization rate about 15%.

These are some of the elements of the rapid growth of Korean manufacturing: all four factor inputs (labor, capital, energy and materials) grew quite rapidly throughout the 1960-78 period. The three factors (capital, energy and materials) grew considerably faster than the labor. This rapid growth of capital made it possible for labor to process increasing amounts of materials. This, in conjunction with the increasing rate of growth of TFP, seems to have been the major source of growth of Korean manufacturing. The role of the change in capacity utilization in the productivity growth which accounted for roughly 19% in the first phase (1960-72) of the industrialization, although diminished to a little more than 4% in the

10) See Kang (1983) whose results are based on the aggregate economy of Japan and Korea including the manufacturing sector. Kang's results for Korea concurs with the results reported by Kwon and Williams (1982) for the Korean manufacturing based on the 1973 cross-section data.

second phase 1972-80) cannot be overlooked. This is attributable to the fact that the capacity utilization rate grew at an average annual rate of 9.4% in the first phase.

The results of this study support the view that for growing less-developed economies the growth in capital utilization rate is a source of growth in total productivity that is too significant to be ignored.

At the same time, the virtual standstill of the capacity utilization rate in Korean manufacturing since 1973 raises an interesting question regarding the optimum rate of utilization. Is the utilization rate of 33% (which is equivalent to the 8-hour operation of plants and equipments) optimal? This is an important question that needs to be explored in the future research.

The results of the study also imply that, for South Korean manufacturing, further gains in efficiency can be achieved by further exploitation of the scale economies and technical change.

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Appendix

[Table A1] Parameter Estimates of the Unconstrained Translog Cost Function—Korean Manufacturing, 1960-1978.[a]

Parameter[b]	Estimates (t-ratio)	Parameter	Estimates (t-ratio)
α_Q	−.553 (.430)	γ_{EQ}	.047 (4.502)
α_{QQ}	−.470 (2.688)	γ_{KQ}	−.029 (2.583)
α_L	.393 (6.581)	γ_{MQ}	−.074 (4.263)
α_E	.551 (6.602)	θ_L	−.032 (3.476)
α_K	−.671 (6.885)	θ_E	−.049 (3.500)
α_M	.727 (6.648)	θ_K	.158 (9.747)
γ_{LL}	.152 (4.461)	θ_M	−.077 (2.142)
γ_{LE}	−.060 (4.640)	θ_Q	.246 (.944)
γ_{LK}	−.004 (.453)	β_t	2.401 (1.840)
γ_{LM}	−.088 (7.627)	β_{tt}	.375 (1.330)
γ_{EE}	.131 (4.153)	δ_L	.001 (.066)
γ_{EK}	−.022 (1.723)	δ_E	.092 (3.307)
γ_{EM}	−.049 (6.020)	δ_K	−.131 (4.152)
γ_{KK}	.051 (2.163)	δ_M	−.815 (2.583)
γ_{KM}	−.024 (4.422)	δ_Q	1.793 (3.584)
γ_{MM}	.161 (5.427)	δ_t	−1.462 (2.248)
γ_{LQ}	.056 (6.301)	ρ_λ	6.691 (2.167)
		$\rho_{\lambda\lambda}$	2.170 (1.858)

[a]Log of likelihood function = 240.516; R^2 = 0.998.
[b]As defined in Eq. (12)

[Table A2] Input Prices Indices, Input Costs, Output Indices and Capacity Utilization Rate—Korean Manufacturing, 1960-1978.

	Price Indices				Input Costs (Billions of Current Won)				Output Qutntity Index	Capacity Util.Rate Index
	P_K	P_L	P_E	P_M	K	L	E	M	Q	λ^a
1960	.1570	.0531	.1000	.1230	4.1	6.8	3.9	45.2	.0680	.4203
1961	.2012	.0671	.1060	.1410	25.0	9.7	4.6	55.2	.0820	.3410
1962	.2088	.0786	.1160	.1550	35.9	12.9	5.7	76.9	.0920	.4710
1963	.1677	.0875	.1190	.1720	45.7	18.1	6.9	98.4	.1040	.4880
1964	.2501	.1116	.1330	.2290	76.3	23.2	10.0	137.4	.1120	.5690
1965	.3334	.1278	.1530	.2740	101.2	29.8	14.1	187.8	.1190	.6470
1966	.4631	.1456	.1650	.2940	118.8	37.8	17.6	243.6	.1490	.6320
1967	.7244	.1796	.1910	.3020	177.4	53.4	19.2	301.9	.1930	.7312
1968	.8241	.2244	.2080	.3150	224.2	77.1	30.4	437.2	.2620	.8960
1969	.8239	.2805	.2250	.3290	319.9	106.8	36.9	548.7	.3160	.9960
1970	.8696	.3486	.2420	.3610	412.6	137.8	48.2	736.5	.3550	1.0230
1971	.8114	.4151	.2720	.3870	529.9	161.5	53.2	928.9	.4110	1.0590
1972	.8360	.4735	.3280	.4400	688.6	211.5	74.7	1,267.2	.4760	1.0430
1973	.7622	.5849	.3560	.4970	937.6	310.6	105.2	2,116.5	.6480	1.0680
1974	.7740	.7577	.7630	.8070	1,419.5	451.3	217.3	3,619.3	.8370	.9690
1075	1.0000	1.0000	1.0000	1.0000	2,176.5	651.6	398.1	4,943.7	1.0000	1.0000
1976	1.5660	1.2809	1.0860	1.1010	3,066.6	1,009.1	478.6	7,124.9	1.3180	1.0490
1977	1.5680	1.6597	1.1860	1.1700	4,135.6	1,460.6	563.0	9,279.1	1.5870	1.0560
1978	1.4490	2.2942	1.3050	1.2280	5,970.9	2,222.0	677.6	12.289.1	1.9640	1.0560

[a] The utilization rate is defined as ratio of the actual consumption of electricity (KWH) to the maximum possible consumption by installed electric motors. Algebraically,

$\lambda_t\ [E_t^m\ /\ C_t^m \times 8.760 \div 0.9] \times 100$

λ_t : electric-motor utilization rate (%) in year t.

E_t^m : actual consumption of electricity (KWH) by motors in year t

C_t^m : "rated capacity" of installed electric motors (KW) in year t.

The number 8,760 is the number of hours in a year, and the fraction 0.9 is to allow for 10% dissipation of power input into motors in the form of heat. The maximum possible consumption is attainable if all installed electric motors are operated continuously without an interruption during a given calendar year.