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Total Factor Productivity Growth and the Sources of Growth in Korean Manufacturing Industries, 1971-1993*

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A growth accounting framework is used to measure total factor productivity (TFP) in Korean manufacturing industries at a disaggregated level for 1971-93. The contributions of capital, labor manhours, labor education, and productivity growth to the growth in output are presented. The average annual rate of increase in total factor productivity on a value added basis in the total, heavy, and light manufacturing industries are about 3, 4.5, and 1.1 percent, respectively. The contribution by capital input is the largest and comprised about 54 percent of the output growth in the total manufacturing sector. Labor man-hours and labor-education inputs contributed about 21 percent and 4 percent, respectively. The growth in TFP accounted for about 22 percent of the growth of value added. In the period 1989-93, the growth rate of TFP in the manufacturing sector fell to 0.6 percent, and its contribution declined to about 9.4 percent. For manufacturing industry, the average rate of increase in the unit labor cost, about 13 percent, is higher than average inflation rate, about 11 percent. The estimates of TFP growth by other studies for the Korean manufacturing based on net value added range from 1 percent to 7 percent. The selected estimates of TFP growth based on gross output are from -2.5 percent to +8.8 percent. Despite a wide difference, TFP estimates all indicate that productivity growth has been slowing in recent years. The empirical results support Krugman's view that the East Asia economies would not sustain high growth unless a low growth in TFP reverses. Future rapid growth thus depends on accepting decentralized institutions and the dispersion of decision making. It is an unescapable arrangement to achieve productivity growth and an increasing-return-to-scale economy.

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1. INTRODUCTION

Total factor productivity (TFP) measures the productive efficiency of an economy. The growth of total factor productivity shifts the capacity to produce with the proportionate increases in each of the factors of production. This shift, in turn, augments the competitiveness of the economy in the world economy and the real incomes of the average providers of inputs. Growth in total factor productivity is thus vital to the economic welfare of a nation.

The importance of productivity growth has been recognized by both economics profession and policy makers. A substantial amount of research has been done over the years on the theoretical and empirical measurement of total factor productivity. Empirical research has been performed to estimate the growth of total factor productivity and the contributions to growth in output in many different countries, including Korea.[1)]

In this study we aim at systematically measuring total factor productivity at the total and its heavy and light components in Korean manufacturing industries. Then, using the "accounting for the growth of output" methodology, we measure the contributions of capital, labor and productivity growth to the growth in output.

This paper is divided into five parts. Following the introduction, part 2 outlines the framework for the measurement of total factor productivity. Part 3 describes the data needed for the measurement and how we obtain them in details. Part 4 measures total factor productivity in the case of net value added at the manufacturing industries and discusses the contributions of productivity and factor input growth on output growth. It presents the measurement of total factor productivity in the case of gross output and discusses the contributions of productivity and factor input growth to output growth. Part 5 summarizes the main findings and concludes policy implications.

2. FRAMEWORK FOR THE MEASUREMENT OF TOTAL

1) For a clear description on growth accounting, see Barro (1998), and a survey and discussion on total factor productivity in East Asian economies, see Dowling and Summers (1998).

FACTOR PRODUCTIVITY

The framework for measuring total factor productivity (TFP) is extensively discussed in the literature on productivity and growth.[2)] We briefly review the derivation of two well-known approaches to measure total factor productivity.

To derive a total factor productivity equation, let us assume a single output to be produced with several inputs. Further, we assume that the production technology is described by a twice-differentiable homogenous production function as follows:

$$Y = F(X_1, X_2, \ ..., X_n, t) \tag{1}$$

where Y is the output, X_i is ith input, and t is time. Total differentiation of (1) with respect to time t and the division of the resulting equation by Y yield: after rearrangement of terms,

$$\frac{1}{y}\frac{dY}{dt} = \sum_i \frac{1}{Y}\frac{\partial F}{\partial X_i}\frac{dX_i}{dt} + \frac{1}{y}\frac{\partial F}{\partial t} \tag{2}$$

Rearranging (2) we derive the framework for total factor productivity:

$$\dot{A} = \dot{Y} - \sum_i \frac{X_i}{Y}\frac{\partial F}{\partial X_i}\dot{X}_i \tag{3}$$

$$where \ \ \dot{A} = \frac{1}{Y}\frac{\partial F}{\partial t}, \dot{Y} = \frac{1}{Y}\frac{dY}{dt}, \ and \ \ \dot{X}_i = \frac{1}{X_i}\frac{dX_i}{dt}$$

Dot(.) notation refers to the rate of change with respect to time.

Let us hypothesize that a firm determines the amount of input X_i in order to attain a minimum cost, with the given production function and the price of input P_i. The first-order necessary condition for the cost minimization is:

2) See Abramovitz (1993), Hall (1989), Jorgenson (1995), Jorgenson, Gallop, and Fraument (1997), Kim and Lau (1994), and Nadiri (1972).

$$\frac{\partial F}{\partial X_i} = \frac{P_i}{(\partial C / \partial Y)} \tag{4}$$

where C is total cost $\Sigma P_i X_i$, and $\partial C/\partial Y$ is marginal cost.

The marginal cost is the cost-output elasticity, E_{cy}, times the average cost:

$$\frac{\partial C}{\partial Y} = E_{cy} \left(\frac{C}{Y}\right) \tag{5}$$

Combining (3)-(5) and using the fact that the reciprocal of the cost-output elasticity indicates returns to scale of production, μ , (3) may be expressed by:

$$A = Y - m \sum_i \frac{P_i X_i}{C} X_i \tag{6}$$

Equation (6) describes the growth of total factor productivity (TFP) which can be calculated using data on output growth, input growth, prices and amounts of inputs, and the return to scale parameter.

To specify (6) in an explicit form, we assume that the output under discussion is value added and is produced with two inputs, namely labor (L) and capital (K). If the production function is a transcendental logarithmic function, equation (1) becomes

$$\begin{aligned} \ln Y = {} & \alpha_0 + \alpha_1 \ln L + \alpha_2 \ln K + \alpha_3 t + \beta_{11} \tfrac{1}{2}(\ln L)^2 + \beta_{22} \tfrac{1}{2}(\ln K)^2 + \beta_{33} \tfrac{1}{2} t^2 \\ & + \beta_{12}(\ln L \times \ln K) + \beta_{13}(t \times \ln L) + \beta_{23}(t \times \ln K) \end{aligned} \tag{7}$$

Under competitive output and input markets, the assumption of cost minimization with respect to labor, which is a necessary condition for overall cost minimization, implies that the share of labor cost to the value(cost) of output is equal to the elasticity of output with respect to labor; w being the wage rate:

$$wL/C = \alpha_1 + \beta_{12} \ln K + \beta_{11} \ln L + \beta_{13} t. \tag{8}$$

The share of capital cost is equal to the elasticity of output with respect to capital; q being the price of capital service:

$$qK/C = á_2 + â_{12} \ln L + â_{22} \ln K + â_{23}\, t. \qquad (9)$$

Since the share of capital cost is (1 – the share of labor cost), the joint estimation of (7) and (8) identifies all the parameters. Given the estimated parameters, the rate of change in the total factor productivity is measured by:

$$ÄA/A = á_3 + â_{13} \ln L + â_{23} \ln K + â_{33}\, t. \qquad (10)$$

Equation (10) is the empirical framework for a trans-log production function approach to compute TFP growth. If we substitute the cost share of labor and capital in (6) by (8) and (9), respectively, and substitute $ÄA/A$ in (6) by (10), we may obtain the measure on the return to scale of production from equation (6).

Alternatively, we assume a Cobb-Douglas production function with constant return to scale, $ì = 1$. In this specific case, $â\_ = 0$ for all i and j. If we introduce this information into (6), the rate of growth in total factor productivity is simplified to:

$$ÄA/A = ÄY/Y - á_1\, ÄL/L - á_2\, ÄK/K. \qquad (11)$$

Equation (11) is the growth accounting approach of measuring total factor productivity growth. Total factor productivity growth is a residual which is left over output growth after input growth has been accounted for. This study uses (11) to measure total factor productivity. This specific growth accounting approach enables us to reduce the degree of complexity expected to occur if the production function approach was utilized.[3)]

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3) Hong and Kim (1996) show that the estimates of TFP growth by the growth accounting approach are similar to the estimates by the translog production approach in Korean manufacturing industries during 1967-1993. In Park (1993) the cost-output elasticity estimates do not substantially differ from one. We also regressed the specification, $\ln Y_i = c_{1i} + c_{2i}\,\text{TIME} + c_{3i} \ln YC_i$, to data on value added and gross output at the nine sectoral level of manufacturing industries. Y_i is output, and TIME is a time trend variable. YC_i is the aggregate total cost index for the ith sector, which is the weigthed average of the index of each factor input by its relative cost share. The majority of the estimated results does not reject the assumption of constant return to scale. The production function with constant retuern to scale is regarded as a good first approximation. (See Mankiew, Ramoer and Wel

We aim to measure TFP growth in each of two different measures of output, namely, value added output and gross output. The measurement of TFP changes are performed using the following equations:

$$\Delta A/A = \Delta Y/Y - \alpha_1 \Delta L/L - (1-\alpha_1)\Delta K/K \qquad (12)$$

$$\Delta A_g/A_g = \Delta Y_g/Y_g - \gamma \Delta R/R - (1-\gamma)[\alpha_1 \Delta L/L + (1-\alpha_1)\Delta K/K] \qquad (13)$$

$$\Delta Y_g/Y_g = (1-\gamma)\Delta Y/Y + \gamma \Delta R/R \qquad (14)$$

where $\Delta A/A$ and $\Delta A_g/A_g$ are TFP growth rates in the case of value added output (Y) and gross output, (Y_g). R is the amount of raw materials and intermediate materials. γ is the value share of intermediate material cost to the value of gross output.

From (12)-(14), two interesting propositions can be observed. First, the relationship between the growth in productivity measured on net value added and gross output, $\Delta A/A$ and $\Delta A_g/A_g$, is as follows:

$$\Delta A_g/A_g = (1-\gamma)\Delta A/A. \qquad (15)$$

Since the share of the cost of materials is positive and less than one, (15) implies that growth in the total factor productivity in gross output is a fraction of the growth in the total factor productivity in net value added.

Secondly, the rate of change in the productivity of labor is derived from (12)-(13):

$$\Delta Y/Y - \Delta L/L = \Delta A/A + (1-\alpha_1)\Delta(K/L)/(K/L) \qquad (16)$$

$$\Delta Y_g/Y_g - \Delta L/L = \Delta A_g/A_g + \gamma \Delta(R/L)/(R/L) + (1-\gamma)(1-\alpha_1)\Delta(K/L)/(K/L) \qquad (17)$$

These two equations show that the labor productivity growth is positively affected by the growth in total factor productivity and the the rate of growth in the ratio of capital to labor input. Let $\Delta A_g/A_g$ in equation (17) be substituted with

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(1992)).

the relation in total factor productivity between gross output and net value added output, as given by (15). Substituting $\Delta A/A$ by (12) and rearranging the terms, we obtain the relation in labor productivity between gross output and net value added output:

$$\Delta Y_g/Y_g - \Delta L/L = (1-\gamma)\,(\Delta Y/Y - \Delta L/L) + \gamma\, \Delta(R/L)/(R/L) \qquad (18)$$

Equation (18) shows that if the elasticity of materials demanded with respect to output is one or close to one, the labor productivity measured in gross output is identical or close to the labor productivity measured in net value added output.

3. DESCRIPTION AND SOURCES OF DATA

We intend to measure the total factor productivity of Korean manufacturing industries at the aggregated level (total, heavy, and light industries), and at the two-digit Standard Industrial Classification of the nine industries. The aggregation method utlized in this paper is the Divisia method.[4)] Two measures of output are of interest: value added output, and gross output. The primary source of data we want to use in the calculation of TFP in manufacturing industries is *National Accounts* published by the Bank of Korea. The data on gross output, value added output, and factor incomes are those in the sections "Gross Domestic Product and Factor Income by Kind of Economic Activity" in *National Accounts*. We do not make use of census data published in *Report on Mining and Manufacturing Survey* by the National Statistical Office in

4) Two methods are frequently used in deriving aggregates: the arithmeticsum method, and the Divisia method. The arithmetic method regards an aggregate output (capital, labor, etc) as the relative shares in quantity-weighted average of outputs at a sectoral level. It means that aggregate output is the arithmetic sum of sectoral outputs, $Y=\Sigma_{i=1} Y_i$. This follows that the rate of change in aggregate output is the average of sectoral output growth rates weighted by the relative quantity shares: $\Delta Y/Y = \Sigma(Y_i/Y)\ \Delta Y_i/Y$. The aggregate output by the Divisia index method starts from the fact that the value of aggregate output is the arithmetic sum of the value of sectoral output, $PY = \Sigma\ (P_iY_i)$. It follows that the growth rate of aggregate output is the average of sectoral output growth rates weighted by the value shares: $\Delta Y/Y = \Sigma(P_iY_i/PY)\ \Delta Y_i/Y_i$. For the Divisia index, see Divisia (1939).

calculating TFP measures. The census data and other sources of statistics are utilized to construct data on labor input in man-hours, net fixed capital stock, and other data for the nine sectoral industries in such a way that they are consistent as much as possible with the available statistics in *National Accounts*.

3.1. Gross Output, Net Value Added Output (GDP) and Implicit Price Deflators

The annual data on the nominal value of gross output and net value added are available from 1970 to 1993 for total manufacturing and nine sectoral manufacturing industries. Implicit price deflators in 1990 as the base year for net value added of total manufacturing are published in *National Accounts*. Implicit price deflators for value added GDP originating from the nine sectoral industries were provided unofficially by the Bank of Korea. The implicit price deflators for the individual industries follow more or less movements in the prices of producer goods in the corresponding industries. The data on real value added output in 1990 constant prices at the disaggregated level (except for the 9th industry, miscellaneous manufacturing) were constructed by dividing nominal values of GDP by implicit price deflators. The real value added output for the 9th industry is real value added for total manufacturing minus the sum of real value added output from the first to eightth industry. The implicit deflator for the 9th industry is the nominal value added divided by the real value added. When we have data on total manufacturing and the nine industries, data for the 9th industry is residually derived. By doing this we can force the data consistency within the manufacturing sector.

The data on real gross output, value in 1990 based constant prices, are constructed by adding up real output and real intermediate products and material inputs. While annual data on the nominal values of intermediate inputs are available at the aggregate and disaggregate levels, data on real intermediate inputs are not published by the Bank of Korea. Consequently, real intermediate inputs are constructed by dividing the nominal values of intermediate inputs by prices of intermediate inputs. It is assumed that prices of intermediate inputs are identical to the individual industries. Further, prices of intermediate inputs are assumed to be the weighted average of producer price index of raw materials and producer price index of intermediate materials. The weights are 0.14 and 0.86, respectively, and these weights are derived from the weights given in the construction of producer price index. The producer prices are obtained from *Yearbook of Economic Statistics* by the Bank of Korea.

A Divisia measure of the nominal (quantity) index for each of the total manufacturing, heavy manufacturing, and light manufacturing industries is obtained by the following two steps. First, the rate of change in an aggregate index is the average of the rate of change in industrial outputs (prices), weighted by average shares of individual industries in the value of outputs in the current and preceding years. Second, the index of aggregate quantity (price) measured in 1990 = 100 basis is obtained from the data on the rate of changes in a constructed aggregate quantity (price) index.

3.2. Labor

Data on labor consists of the number of persons employed, man-hours worked per person employed, education level, and wage compensation. Labor employment includes both employees and self-employed workers. The data on labor employment which are relevant in the computation of TFP are the data published in the *Input-Output Tables* that underlie the national income accounts.[5)]

The *Input-Output Tables* contain the data on the number of employees and the numbers of self-employed and unpaid family members working for the total and sectoral manufacturing industries. Unfortunately, the annual data are only available for 1970, 1973, 1975, 1980, 1985, and 1990. Neverthless, we made an attempt to calculate the number of employment, employees, and self-employed for the years that are not available from the *Input-Output Tables*. The calculated labor figures should be consistent with labor figures in the *Input-Output Tables*. We utilize two sources of data: *Annual Report on the Economically Active Population Survey*, and *Report on Mining and Manufacturing Survey*. *Annual*

5) Employment figures published in the *Input-Output Tables* are substantially smaller than employment figures in *Annual Report on the Economically Active Population Survey* published annually by the National Statistical Office. For example, a 4.359 million employment for 1990 in the *Input-Output Tables* is about 88 percent of the 4.911 million employment in *Annual Report on* the Economically Active Population Survey. The figures in the *Input-Output Tables* are lower because they are based on the numbers of hours worked during a year.

Report provides annual data on employment, employees, and self-employed workers for the total manufacturing industry; *Report on Mining and Manufacturing Survey* supplies the number of employees and self-employed for the total manufacturing sector and the nine individual industries.

We took the following three steps to caculate labor figures. First, the number of employees and self-employed in the total manufacturing published by the *Annual Report on the Economically Active Population Survey* are distributed to the nine industries according to the relative shares of each industry in the total numbers of employees and self-employed workers in the total manufacturing sector published by the *Report on Mining and Manufacturing Survey*. Secondly, the numbers of employees and self-employed in the total manufacturing for the years for which data are not available in the *Inputs-Output Tables* are generated in such a way that the rate of change in the labor figures is the same as the growth rate in the employees and self-employed workers reported in the *Economically Active Population Survey*. Third, the data on employees and self-employed workers of an individual sector for the years that are not given in the *Input-Output Tables* are constructed such that they follow the movements of the employees and self-employed workers of each sector obtained by the first step. Moreover the sum of employees and self-employed workers of the nine sectors is equal to the data of the total manufacturing industry published in the *Input-Output Tables* and constructed in the second step.

Hours worked during a year per person in each industry are the same as those per employee. Implicitly we assume that hours worked per the self-employed workers are identical to those per employee. The data on hours worked are obtained from "Average Monthly Wage, Days and Hours Worked by Year and Industry" in *Yearbook of Labor Statistics* by the Ministry of Labor. Man-hours worked for indivudal industries are the man-hours worked per employed times the number of the labor employed and worked in the industries.

Wage compensation for each individual industry is defined as the sum of wage compensation for employees and wage compensation for the self employed and unpaid family workers. Wage compensation reported in the *National Accounts* is the wage compensation of employees. Hence, we must estimate wage compensation for the self-employed and unpaid family workers. To compute wage compensation for the self-employed workers, the wage compensation per unit of the man-hour of the workers is assumed to be equal to the wage compensation per unit of the man-hour of employees.[6)]

As Jorgenson, Gallop, and Fraumeni (1997) demonstrate, it is desirable to capture a change in labor quality by distinguish the workers in terms of age, sex, years of schooling completed, and number of years working. Time series data which classify labor by age, years of education, years of working, and sex are not available for the nine individual industries. Distinguishing laborers in the manufacturing industry by years of schooling completed captures a substantial portion of the difference in the quality of the labor (see Lee Jong Wha and Sun-Bin Kim (1995)). Hence, we attempt to construct data on the number of schooling years completed for the labor force in the total manufacturing sector. The data source is the *Report on Wage Survey by Occupational Category* published by the Ministry of Labor. Annual data series are available from 1980 on wage earnings, employees, and hours worked. The work forces are classified over four educational categories: elementary or lower school graduates, middle school graduates, two year college graduates, and college or higher graduates. The data for 1970 and 1975 on the composition of the labor force by similar educational categories are available in *the Report on Population and Housing Census in Korea* (Economic Planning Board, National Statistical Office). This information and the data published in *the Report on Wage Survey by Occupational Category* are utilized to construct an index of the labor in the manufacturing sector at each level of education. The Divisia index of the labor's schooling for the total manufacturing industry is constructed from the average of the rate of growth of each education category of laborers, weighted by its relative shares in the salaries and bonus of the total manufacturing sector. The index is assumed to represent the index of the laborer's education level in each of the manufacturing industries. The use of this manufacturing industry wide index

6) The distribution of the self-employed in the manufacturing industry by the level of education is as follows: 40% are middle-school graduates or lower, 45% are high school graduates, and 15% are college graduates or post-graduater. The distribution by level of education of employees is as follows: 33% are middle school graduates or lower, 51% are high school graduates, and 15% are college graduates or post-graduate. It appears that the self-employed and unpaid family workers are somewhat less educated than employees in Korea. Other things being equal, it seems likely that hourly compensation of the self-employed workers is somewhat lower than that of employees. To avoid complications, however, we assume that the hourly wage compensation for the self employed worker is the same as the hourly wage compensation for the employee.

permits to capture the spillover of knowledge of workers across individual industries. (see Lucas (1988)).

3.3. Capital Stock

Capital stock used is net fixed capital stock in real terms and does not include land, inventories, and intangible assets. For an individual industry in the manufacturing sector, two types of capital stock were computed: a) building & structures and b) machinery equipments. Capital stock of an individual industry is defined as the sum of two constructed capital stocks. Thus, the capital stock of an individual industry is not aggregated by the use of the Divisia method, which requires the user cost of capital for the two types of capital stocks. However, aggregate capital stocks of the total manufacturing industry, the heavy manufacturing industry, and the light manufacturing industry were computed by the Divisia method.

For a specific type of capital asset, the capital stock at the end of year is the sum of the capital stock at the end of the preceding year and gross investment, less depreciation during the year. Depreciation is a constant depreciation rate times the stock at the end of the preceding year. This is written:

$$K_t = I_t + (1 - ä)K_{t-1} \tag{19}$$

where K_t is the capital stock at the end of year t. I_t is real gross investment flows, and *ä* is the constant depreciation rate. A polynomial equation is obtained by successive replacement of *K*:

$$K_t = S(1 - ä)^s I_{t-s} + (1 - ä)^{s+1} K_{t-s-1}. \tag{20}$$

Given data series on gross investment, a capital stock series can be constructed by making use of (19) and (20) if we have either the measure of capital stock in two benchmark years or the measure of capital stock in one benchmark year and the estimate of the constant rate of depreciation. We decided to make use of the double benchmark method to generate the capital stock series. This decision is based on the assumption that the two benchmark capital stock figures are available and that the depreciation rate is computed to establish the consistency of data between gross investment and capital stock.

The double benchmark method requires data on gross investment and the capital stock in two benchmark years. Statistics on the nominal and real values of gross fixed investment for the total manufacturing industry by types of capital goods are available, but statistics on the nominal and real values of gross fixed investment for the nine industries are not reported in the *National Accounts*. Yet the *Report on the Mining and Manufacturing Industry Survey* publishes census data on the values of gross investments by the types of capital goods of the nine manufacturing industries. By using the following procedures, we construct the values (and quantity) of gross investments of the nine industries in such a way that the sum of the value (and quantity) of their gross investment is identical to the value (and quantity) of gross investment for the manufacturing sector reported in the *National Accounts*.

First, we obtain the values of gross investment series by building and structures, plants and equipment, and transportation equipment of the nine industries. We then add plant and equipment to transportation equipment. The added series are called gross investment in machinery equipment. The relative value shares of gross investments of individual industries to the gross investments of total manufacturing are computed for each type of capital good, namely building and structures, and machinery equipment. The values of gross investments of individual industries by individual types of capital goods are obtained by multiplying the relative value shares of gross investments of individual industries to the value of gross investment for the manufacturing industry reported in the *National Accounts*.

Secondly, price deflators are needed for gross investments of each of the nine industries by the two types of capital good. Price deflators for plants and equipment, and transportation equipment for the total manufacturing industries are obtained from the *National Accounts.* These price deflators are assumed to be the price deflators for each of the capital goods in each industry sector. Price deflators for the building and structures of each of the nine industries are assumed to be the weighted averages of price deflators for gross investment in residential structures, non-residential structures, and other constructions for the total manufacturing industry. Weights for each individual industries are the relative shares of the value of the residential buildings, non-residential buildings, and structures in the value of buildings and structures. The weigths are computed from the data available for 1967, 1977, and 1987, from *Survey of National Wealth* by National Statistical Office. To take care of the data in missing years, it is assumed that the weights during 1970-1976 are the average of the shares in 1967 and 1977, the weights during 1978-86 are the average of the shares in 1977 and 1987, and the weights from 1987 to 1993 are the shares in 1987.

Third, real gross investments are obtained by dividing the values of gross investment by the price deflators. Real gross investments in machinery equipment are the sum of real gross investment in plants and equipment and real gross investment in transportation equipment. In order to hold the constraint that the sum of gross investment in building and structures (machinery equipment) of the nine sectors is equal to the gross investments in building & structures (machinery equipment) for the total manufacturing sector, the nominal and real gross investments for each type of the capital goods in the 9th industry are residually computed. Then the price deflators for the 9th industry are computed by dividing its nominal gross investment by its real gross investment.

Estimates of net fixed capital stock for 1977 and 1987 come from the *Survey of National Wealth* for 1977 and 1987. The benchmark figures of real net capital stock, measured in 1990 prices by the two types of capital goods for individual industry are based upon the benchmark figures of nominal net capital stock and implicit price deflators constructed above. Benchmark figures for 1970 are not available. Thus, the 1970 benchmark capital stock figures of individual industries by the two types of capital goods are assumed to be equal to the figures obtained by multiplying the benchmark figures for 1977 by the two types of capital goods times the ratios of the estimates of capital stock for 1970 to the estimates for 1977 of capital stock given by Pyo (1988).

The benchmark figures of capital stock and the depreciation rates computed by the double benchmark polynomial method are summarized in Table 1. During the period 1977-1987, most of the calculated depreciation rates are sensible, judging from the depreciation rates computed by a straight declining depreciation method (the depreciation rate for a capital stock is one divided by the years of duration of capital goods reported in the *Survey of National Wealth*).

Table 1 Capital Stocks in the Benchmark Year and Depreciation Rate Estimates

	Industry	Assets	Capital Stock (90 billion won)	Depreciati on Rate	1969-77	1978-87	1988-93
M31	Building	615.3	1385.7	3173.3	-2.3	0.7	0.7
	Machinery	179.0	622.4	2277.5	16.4	16.7	16.7
	Total	794.2	2008.1	5450.9	3.9	6.6	6.8
M32	Building	789.9	2967.4	5363.7	-9.4	0.0	2.0
	Machinery	495.0	1653.4	4586.5	23.2	12.1	12.1
	Total	1284.9	4620.8	9950.2	-2.9	4.8	6.7
M33	Building	120.2	262.2	384.0	-2.2	4.4	4.4
	Machinery	116.6	152.8	244.1	13.6	21.2	21.2
	Total	236.8	415.0	628.2	0.0	10.8	15.2
M34	Building	147.4	432.0	988.9	-5.4	5.0	5.0
	Machinery	171.0	374.2	1228.8	4.1	14.5	14.5
	Total	318.5	806.2	2217.8	13.2	9.7	8.8
M35	Building	593.6	1488.1	4096.3	1.1	1.2	1.2
	Machinery	625.2	1362.6	3895.1	17.3	27.0	5.0
	Total	1218.8	2850.7	7991.5	9.2	12.1	3.6
M36	Building	968.1	2266.4	3285.6	-8.5	0.0	2.0
	Machinery	258.4	587.9	2450.5	21.3	7.7	15.0
	Total	1226.5	2854.2	5736.1	-7.5	2.5	7.5
M37	Building	188.8	1785.0	2764.2	-17.2	8.4	8.4
	Machinery	155.4	1449.4	4491.0	1.7	26.3	15.0
	Total	344.2	3234.5	7255.3	-9.5	17.8	12.8
M38	Building	669.1	3930.5	10915.2	-12.6	0.0	2.0
	Machinery	223.8	1923.6	11385.6	4.8	12.3	12.3
	Total	892.9	5864.2	22300.8	-10.1	5.1	7.3
M39	Building	55.2	210.9	509.7	-9.1	0.0	2.0
	Machinery	17.9	85.9	284.9	0.6	17.0	17.0
	Total	73.2	296.9	794.7	-5.3	5.0	7.2
M3	Building	4147.8	14738.6	31481.2	-8.3	1.2	2.0
	Machinery	2242.5	8212.4	30844.4	13.0	16.2	14.3
	Total	6390.4	22951.0	62325.7	-1.9	7.4	7.3
M3H	Building	2419.7	9480.2	21061.4	-9.5	1.4	2.1
	Machinery	1262.9	5323.6	22222.3	10.8	17.2	10.2
	Total	3265.1	14803.8	43283.7	-2.6	8.1	7.1
M3L	Building	1728.1	5258.4	10419.8	-6.4	0.8	1.7
	Machinery	979.6	2888.8	8622.1	16.9	14.1	13.0
	Total	2267.3	8147.2	19041.9	-4.8	6.0	7.9

Note: 1) Depreciation rates during 1969-77 and 1988-93 for total capital stocks are approximated figures.
2) Building refers to building and structures, and machinery refers to machines, plants, and equipment.
3) M3 and M3H cover M31-M39 and M35-M38. M3L covers M31-M34 and M39.

As expected, the depreciation rates on machinery equipment are higher than the depreciation rates on buildings and structures. The calculated depreciation rates are generally lower than the estimates of depreciation rates reported by other studies, such as Park (1993), and Pyo (1988). Four calculated depreciation rates on the building and structures are zero, which seems to be lower than what would be expected. For the capital stock in building and structures where depreciation rates are zero, the depreciation rates used for the calculation of capital stock from 1988 to 1993 are assumed to be 2.0 percent per year. The estimated depreciation rates during 1970-1977 in building and structures are negative. This result seems to indicate that the benchmark figures and gross investment figures are not comparable to yield positive depreciation rates. The role of the estimated capital stocks with negative depreciation rates from 1970 to 1976 are expected to be small, since the period for most of our analysis covers 1976 to 1993. Using the estimated capital stocks and depreciation rates by the two types of goods for individual industries, we calculate the total capital stock and the implied depreciation rate for individual industries. The capital stock and depreciation rates for the three aggregate industries are calculated.

3.4. Factor Cost Shares

The total factor cost is the sum of capital consumption allowance, wage compensation of employees, and operational surplus reported in the national income at factor cost. In the case of net value added income at factor cost, the nominal value of income paid to capital services is obtained by subtracting wage compensation paid to labor services from the total factor cost. The shares of labor cost in the total factor cost are the wage compensation divided by the total cost, and the shares of capital cost is (one minus the shares of labor cost). As discussed above, the value of wage compensation paid to the labor employed - employees, self-employed and unpaid family workers- is larger than the value of wage compensation to employees. The shares of labor cost computed in this study are larger than the shares of wage compensations to employees that are reported in the *National Accounts*.

In the case of gross output, total factor cost is the sum of the factor cost as defined in the case of net value added and the value of intermediate materials. The shares of intermediate materials are the nominal values of intermediate materials divided by the total cost in the case of gross output. The shares of labor (and capital) cost are (1 – the shares of intermediate materials) times the shares of labor (and capital) cost calculated in the case of net value added.

4. MEASURING TFP AND THE SOURCES OF OUTPUT GROWTH

4.1. Measuring TFP and the Sources of Output Growth in Value Added Output

The specification to calculate the growth in total factor productivity for an aggregate manufacturing group g is:

$$\text{Äln}\, AD_g = \text{Äln}\, YD_g - s_{1g}(\text{Äln}\, LD_g + \text{Äln}\, E_m) - (1 - s_{lg})\text{Äln}\, KD_g \tag{21}$$

$$\text{Äln}\, YD_g = Ssy_{gj}\, \text{Äln}\, Y^{gj},\ \text{Äln}\, LD_g = Ssw_{gj}\, \text{Äln}\, L_{gj},\ \text{Äln}\, KD_g = Ssu_{gj}\, \text{Äln}\, K_{gj} \tag{22}$$

where subsription g refers to the aggregate manufacturing group, g=3 (total manufacturing), 3H (heavy manufacturing), and 3L (light manufacturing), namely g =3, 3H, 3L.

Equations (21) and (22) are applied when the aggregation is made by the use of the Divisia method. AD_g, YD_g, LD_g, and KD_g are the indices of productivity, output, labor manhours, and capital in the aggregate manufacturing group g, measured by the Divisia index method. A_{gj}, Y_{gj}, L_{gj}, and K_{gj} are the levels of productivity, output, labor manhours, and capital in sector j which belongs to the aggregate group g. E_m refers to the average of the years of education by labor employed in the manufacturing sector as a whole, measured by the Divisia method. It is assumed to represent the years of education by workers employed in industry i. s_{1i} is the arthemetic average of the ratios of wage compensation paid to labor to total cost (net value added) in industry i during the current and preceeding periods. s_{lg} is the arithmetic average of the relative value share of wage compensation to the value of net value added output of aggrgate group g in the current and preceeding periods. sy_{gj}, sw_{gj}, and sr_{gj} are the arithmetic averages of the relative value shares of output, the relative wage shares of labor manhours, and the relative user cost shares of capital of industry *j* (which belongs to aggregate group *g*) in the value of output, value of wage compensation, and the user cost of aggregate group *g* in the current and preceeding years.

4.1.1. TFP Measurement

Since we deal with annual data, gross investments made during a year do not influence the production in that year. It seems reasonable to expect that the addition of the capital stock made in early parts of the year has an effect on production. In order to introduce this effect, the capital stock actually used in the computation of total factor productivity is the average of the capital stock at the end of current and preceding years. Tornqvist (1936) provides an approximation for discrete points of time to the continuous Divisia indexes. As Tornqvist approximation, the relative shares of labor income, capital cost, and intermediate material cost are the arithmetic averages of the relative shares in the current and preceding periods.

Table 2 presents the growth in total factor productivity at the aggregate level over the business cycle period. As the average annual rates of growth in output show, the periods 1971-79 and 1979-85 are the periods of high and low growth, respectively. The low growth partially resulted from the second oil shock. The period of low growth is followed by the period of high growth in the years 1985-90, attributable to the international circumstance of low oil prices, low interest rates, and low yen-dollar exchange rates. Since 1990, the economy has entered the period of growth slowdown. The growth rates are higher compared to economic growth in the industrial countries. It is important to note that heavy manufacturing industry grew at higher rates than light manufacturing. The heavy industries tend to lead the manufacturing industry in recent years; in contrast, the growth of the light industries slowed significantly.

The growth rate in total factor productivity of the total manufacturing industry during the period 1971 to 1993 is 3 percent.[7)] This is lower than the 4.5 percent

7) The calculation of total factor productivity at the aggregate level is made with aggregate output, labor, and capital computed by the Divisia method and arithmetic sum method. The rate of productivity growth in the manufacturing industry aggregated by the Divisia method, 3 percent, is slightly higher than 2.9 percent growth obtained when aggregated by arithmetic sum method.

Table 2 Divisia Aggregates in Korean Manufacturing Industry, Value Added, with Labor Education Input, 1971-1993

Output (average annual rates of growth)

	71-79	79-85	85-89	89-93	71-93
Total Manufacturing	0.196	0.095	0.130	0.068	0.139
Heavy Manufacturing	0.250	0.118	0.162	0.097	0.178
Light Manufacturing	0.148	0.067	0.077	0.004	0.090
TFP					
Total Manufacturing	0.038 (19.5)	0.024 (25.3)	0.010 (7.6)	0.006 (9.4)	0.030 (21.6)
Heavy Manufacturing	0.060 (24.0)	0.032 (27.5)	0.010 (6.3)	0.014 (14.7)	0.045 (25.5)
Light Manufacturing	0.018 (12.0)	0.016 (24.3)	0.011 (14.7)	-0.013 (-331.7)	0.011 (12.0)

Note: 1) Figures in parentheses are TFP's contribution to output growth in percent.
2) Labor education refers to the labor's education level in total manufacturing, represented by the mean aducation years in total manufacturing.

rate of growth in productivity of heavy manufacturing, but higher than the 1.1 percent rate of growth in light manufacturing. This phenomenon is clear in the period 1989 to 1993 in which the compositions of output shifted toward heavy manufacturing, away from light manufacturing. The growth in productivity of the total manufacturing sector is 0.6 percent, whereas the growth in productivity of heavy and light manufacturing is 1.4 and negative 1.3 percent, respectively. The growth in total factor productivity exhibits a downward trend.

4.1.2. Contribution of Capital, Labor, and TFP Growth

Manufacturing

The rate of growth in output in the manufacturing sector lies in the contributions made by the growth in capital, labor manhours, labor education, and total factor productivity. As Table 3 shows, the most important source of output growth in the manufacturing sector is the contribution of capital input.

Table 3 Contributions to Growth in Value Added Output in Korean Manufacturing Industry, (Divisia)

Growth (average annual rates of growth)

	71-79	79-85	85-89	89-93	71-93
Output	0.196	0.095	0.130	0.068	0.139
Capital	0.193	0.095	0.140	0.124	0.142
Labor Manhours	0.109	0.035	0.089	-0.005	0.065
Labor Education	0.006	0.012	0.013	0.013	0.010
TFP	0.038	0.024	0.010	0.006	0.030
Contribution of Growth in Factor Inputs and TFP					
Capital	0.107 (54.9)	0.047 (49.7)	0.069 (53.6)	0.058 (85.0)	0.075 (53.5)
Labor Manhours	0.047 (24.1)	0.018 (18.7)	0.044 (33.9)	-0.003 (-4.4)	0.030 (21.2)
Labor Education	0.003 (1.5)	0.006 (6.4)	0.006 (4.9)	0.007 (10.0)	0.005 (3.7)
TFP	0.038 (19.5)	0.024 (25.3)	0.010 (7.6)	0.006 (9.4)	0.030 (21.6)

Note: 1) Labor Manhours refer to the man-hours worked without adjusting the education level of labors in total manufacturing.
2) Labor Education refers to the labor's education level in total manufacturing, represented by the mean aducation years in total manufacturing.
3) Figures in parentheses are contribution to output growth in percent.

During the period 1971-1993, capital input accounts for about 54 percent of the output growth. The second important source is the contribution of total factor productivity, which takes care of 22 percent of the output growth. The third and fourth sources are the contributions of labor man-hours and labor education (measured by mean schooling years of labors in the manufacturing industry), which account for 21 and 4 percent, respectively. In the period 1989-93, the contribution of capital is about 85 percent of the output growth. This large contribution is made possible by the increased capital stocks in machinery equipments and structures. The contribution of labor man-hours is negative as a result of the decrease in the man-hours worked. Although the contributions of labor education are about 4 percent of output growth over the entire period, its

Table 4 Contributions to Growth in Value Added Output in Korean Heavy Manufacturing Industry, (Divisia)

Growth (average annual rates of growth)

	71-79	79-85	85-89	89-93	71-93
Output	0.250	0.118	0.162	0.097	0.178
Capital	0.219	0.099	0.158	0.140	0.160
Labor Manhours	0.143	0.058	0.132	0.012	0.090
Labor Education	0.006	0.012	0.013	0.013	0.010
TFP	0.060	0.032	0.010	0.014	0.045
Contribution of Growth in Factor Inputs and TFP					
Capital	0.131 (52.2)	0.054 (45.5)	0.088 (54.2)	0.071 (73.2)	0.091 (50.9)
Labor Manhours	0.057 (22.8)	0.026 (22.3)	0.058 (36.0)	0.006 (5.7)	0.037 (20.9)
Labor Education	0.003 (1.1)	0.006 (4.7)	0.006 (3.5)	0.007 (6.4)	0.005 (2.6)
TFP	0.060 (24.0)	0.032 (27.5)	0.010 (6.3)	0.014 (14.7)	0.045 (25.5)

Note: see Table 3.

contributions have been rising over time as the mean schooling level of labor has been rising, for example 10 percent in the period 1989-93.

Heavy Manufacturing

Table 4 gives the sources of growth in the heavy manufacturing industry. The contributions of each factor input and total factor productivity to the growth of output are similar to the contributions described for the manufacturing industry. The ordering of the contributions by inputs are capital, total factor productivity, labor man-hours, and labor education. In the period 1989-93, the contribution of labor manhours is 6 percent of output growth, which differs substantially from the contribution to output growth in the manufacturing sector. In addition, the contribution of total factor productivity accounts for 26 percent of the output growth, which is higher than the contribution of productivity in the

Table 5 Contributions to Growth in Value Added Output in Korean Light Manufacturing Industry, (Divisia)

Growth (average annual rates of growth)

	71-79	79-85	85-89	89-93	71-93
Output	0.148	0.067	0.077	0.004	0.090
Capital	0.170	0.091	0.103	0.087	0.119
Labor Manhours	0.085	0.007	0.030	-0.036	0.039
Labor Education	0.006	0.012	0.013	0.013	0.010
TFP	0.018	0.016	0.011	-0.013	0.011
Contribution of Growth in Factor Inputs and TFP					
Capital	0.089 (59.7)	0.039 (59.0)	0.040 (52.3)	0.032 (826.4)	0.055 (61.1)
Labor Manhours	0.039 (26.2)	0.004 (6.3)	0.018 (23.0)	-0.023 (-607.3)	0.018 (20.3)
Labor Education	0.003 (2.1)	0.007 (10.4)	0.008 (10.1)	0.008 (212.6)	0.006 (6.6)
TFP	0.018 (12.0)	0.016 (24.3)	0.011 (14.7)	-0.013 (-331.7)	0.011 (12.0)

Note: see Table 3.

manufacturing sector.

Light Manufacturing

Over the period 1971 to 1993, the contribution of capital is the largest and amounts to about 61 percent in the growth of output in light manufacturing industries, as observed from Table 5. The labor man-hours become the second rank by contributing to the output growth by 21 percent. This is a direct result of the fact that light manufacuring contains relatively high labor-intensive industries. The contribution of productivity growth is the third rank and is about 12 percent of the growth of output. During the period 1989-93, the growth of output is on average 0.4 percent. This low growth is attributed largely to the negative rates of growth in the labor manhours and total factor productivity, negative 3.6 and 1.3 precent, respectively. Consequently, their contributions are negative. Capital is the most important factor for the output growth. The capital input contribution is about 826 percent, obtained by dividing the 0.4 rate of growth in output by 3.2 percent capital contribution. The labor education is the second important factor for the output growth, 212 percent rate of contribution during the period 1989-93.

4.1.3. Labor Productivity and Unit Labor Cost

The productivity per labor man-hours adjusted for variations in education years is the ratio of output to the labor man-hours adjusted for variations in education years. Labor productivity is positively related to total factor productivity and to the ration of capital to labor. Further, the unit labor cost is the ratio of wage payments to output, and, thus, it is negatively related to labor productivity. For an aggregate manufacturing group, the labor productivity and unit labor cost in the growth rate term are as follows: for aggregate manufacturing group g,

$$\text{Äln}\, YD_g - \text{Äln}\, LD_g - \text{Äln}\, E_m = \text{Äln}\, AD_g + (1 - s_{lg})(\text{Äln}\, KD_g - \text{Äln}\, LD_g - \text{Äln}\, E_m) \qquad (23)$$

$$\text{Äln}\, ULC_g = \text{Äln}\, WR_g - (\text{Äln}\, YD_g - \text{Äln}\, LD_g - \text{Äln}\, E_m) \qquad (24)$$

where ULC_g and WR_g are the unit labor cost and the wage compensation per unit of labor man-hours adjusted for variations in education years.

Labor Productivity

We calculate the labor productivity and unit labor cost of total manufacturing, heavy manufactruing, and light manufacturing industries. Table 6 contains the growth rate in the labor productivity and unit labor cost. During the period 1971 to 1993, the growth rate in the labor productivity in the total manufacturing industry is 6.4 percent. The growth rate tends to decline until 1989 and to rise again during the period 1989-93. A rise in the labor productivity in the 1989-93 period is related to a 12 percent rise in capital intensity.

Table 6 Labor Productivity, Wages, and Inflation (Value Added, Divisia)

Total Manufacturing Industry

	71-79	79-85	85-89	89-93	71-93
Labor Hour Productivity	0.080	0.048	0.028	0.061	0.064
TFP	0.038	0.024	0.010	0.006	0.030
Capital-Labor Ratio	0.077	0.048	0.038	0.117	0.067
Hourly Compensation Rate	0.265	0.184	0.084	0.139	0.195
Unit Labor Cost	0.185	0.136	0.056	0.078	0.132
CPI	0.151	0.120	0.042	0.069	0.108

Heavy Manufacturing Industry

Labor Hour Productivity	0.101	0.048	0.017	0.072	0.078
TFP	0.060	0.032	0.010	0.014	0.045
Capital-Labor Ratio	0.070	0.029	0.013	0.114	0.060
Hourly Compensation Rate	0.278	0.170	0.067	0.136	0.197
Unit Labor Cost	0.177	0.122	0.050	0.063	0.119
CPI	0.151	0.120	0.042	0.069	0.108

Light Manufacturing Industry

Labor Hour Productivity	0.057	0.048	0.034	0.027	0.041
TFP	0.018	0.016	0.011	-0.013	0.011
Capital-Labor Ratio	0.079	0.072	0.060	0.111	0.069
Hourly Compensation Rate	0.231	0.202	0.115	0.113	0.180
Unit Labor Cost	0.174	0.154	0.080	0.085	0.140
CPI	0.151	0.120	0.042	0.069	0.108

The growth in the capital intensity explains about 53 percent of the growth of the labor productivity in the total manufacturing industry. The growth in the total factor productivity explains 48 percent of the growth in the labor productivity. The labor productivity growth in the heavy manufacturing industries is 7.8 percent during 1971 to 1993, which is higher than the growth in the total manufacturing sector. But, the trend in the TFP growth follows the trend in the TFP growth in the manufacturing industry. The labor productivity growth in the light manufacturing industry is 4.1 percent in the period 1971-93. Unlike the heavy industries, the labor productivity growth in the period 1989-93 is lower than the productivity growth in the period 1985-89. This is a reflection of the sharp decrease in the total factor productivity growth in the light manufacturing industries.

Unit Labor Cost

For manufacturing industry as a whole, the average rate of increase in the unit labor cost, about 13 percent during 1971-93, is higher than average inflation rate measured by the consumer price index, which is about 11 percent. We observe that the rates of increase in the unit labor cost are higher than inflation in the four sub-periods, 1971-79. 1979-85, 1985-89, 1989-93. The average rate of increase in the unit labor cost for heavy manufacturing is 11.9 percent. The rate of increase in the unit labor cost is higher in the period 1971-79 and 1985-89 and is lower in the period 1989-93 than the inflation rate. The average rate of the unit labor cost for light manufacturing, 14 percent during 1971-93 period, is higher than the inflation rate by 3 percent. Over all the four sub-periods, the changes in the unit labor cost are higher than inflation. This is the result of the hourly compensation rates in the light manufacturing which are similar to the hourly compensation rate in the heavy manufacturing, despite the fact that the growth in the labor productivity in the light manufacturing industry is lower than the growth in the labor productivity in the heavy manufacturing industry.

4.1.4. Selected TFP Estimates

Table 7 summarizes the estimates of total factor productivity by selected authors for the Korean manufacturing industry. The estimates differ significantly; they range from 1 percent to 7 percent. The sources of these differences are many fold: different periods of measurement, differences in data used and differences in aggregation methods. One of the sources is the difference in the estimation of capital stock figures. The capital stock figures calculated directly for the total manufacturing industry are susceptiable to errors because of ignoring different depreciation rates applicable to different fixed assets and industries. The comparison of the growth in productivity in terms of the contribution to the growth of output is more meaningful than the comparison of the productivity growth by itself. The range of contribution is also wide, from 9 percent to 36 percent. The estimate of the total factor productivity by this study, 3.2 percent, is similar to the estimate by Young (1995), 3 percent, and by Moon, *et al.* (1991), 3.7 percent. It is worth noting that a substntial differnece exists clearly between a measure of TFP growth at the economy wide level and a meassure of TFP growth at the manufacturing industry level. TFP growth at the manufacuring industry is higher than TFP growth at the economy level, because manufacturing sector is a leading tradable goods sector. For example, economy wide TFP estimate by Young (1995) is 1.7 percent and manufacturing industry TFP estimate is 3.0 percent.

Table 7 Selected Estimates of Total Factor Productivity Growth in Korean Manufacturing Industry Based on Net Value Added

(in percent)

Authors	Periods	TFP	Value Added	TFP/ Value Added	Sources
C. Kim and Shon (1979, p.56)	1966-75	2.6	25.5	10.20	MMS
Kim C. K. (1979, p.97)	1966-75	2.6	25.5	10.19	MMS
Kim, Yoo and Hwang (1984, p.50)	1967-79	5.5	23.6	23.3	MMS
Kim and Park (1988, p.91)	1966-83	7.03	19.51	36.0	MMS
S. S. Lee (1988, p.32)	1966-83 1973-83	6.15 2.0	18.97 13.58	32.4 15.2	MMS
Cho(1991)	1971-90	2.1	13.6	15.4	NIA
Moon, Cho, Whang, and Kim(1991, p.87)	1971-89	3.66	13.24	27.64	NIA
Pyo, Kong, Kown, and Kim(1993, p.62)	1970-90	1.07	12.77	8.37	NIA
Pilat(1995, p.141)	1967-87	4.3			MMS
Young(1995, p.660)	1966-90	3.00	14.1	21.28	NIA
Pyo, H(1995, pp.45-47)	1970-92	1.09	12.23	8.95	NIA
This Study(1999)	1971-93	3.2	14.2	22.7	NIA

Note: 1) MMS indicates that primary data source is *Report on Mining and Manufacturing Survey*.
2) NIA indicates that primary data source is *National Accounts*.

4.2. Measuring TFP and the Sources of Output Growth in Gross Output

This section analyzes the total factor productivity in the case of gross output, as measured by the Divisia.The methods to calculate the growth in total factor productivity are as follows:

$$\text{Äln}\ AGD_g = \text{Äln}\ YGD_g - s_{rg}\ \text{Äln}\ MD_g - (1 - s_{rg})(s_{lg}(\text{Äln}\ LD_g + \text{Äln}\ E_m) - (1 - s_{lg})\text{Äln}\ KD_g) \qquad (25)$$

where $\text{Äln}\ YGD_g = Ssy_{gj}\ \text{Äln}\ Y^{gj}$, $\text{Äln}\ MD_g = Ssr_{gj}\ \text{Äln}\ M_{gj}$, $\text{Äln}\ LD_g = Ssw_{gj}\ \text{Äln}\ L_{gj}$, $\text{Äln}\ KD_g = Ssu_{gj}\ \text{Äln}\ K_{gj}$. Subscription g refers to aggregate manufacturing group, $g = 3, 3H, 3L$. AGD_g, YGD_g, MGD_g, LGD_g, and KD_g are the index of total factor productivity, gross output, intermediate goods and raw materials, labor manhours, and capital in an aggregate manufacturing group g, aggregated by the Divisia index method. s_{rg} is the arithmetic average of the relative shares of raw materials to the total cost (value of gross output) in an aggregate group g in the current and proceeding periods. s_{lg} is the arithmetic average of the relative shares of labor cost to the value of net value added for group g in the current and proceeding periods in group g.

4.2.1. TFP Measurement

In the Korean manufacturing industries, the shares of material cost remains around 75 percent, and thus TFP growth measured on the basis of gross output is about 25 percent of TFP growth measured on the basis of value added output, according to equation (15). Over the entire period 1971-1993, the average annual rate of growth of the total factor productivity in the total manufacturing industry is 0.7 percent. The average rate of growth in the heavy manufacturing industry, 1.2 percent, is higher than that in the light manufacturing industry, 0.2 persent. In the three aggregate manufacturing industries, the growth in total factor productivity tended to slow down, although the growth in the productivity of the heavy manufacturing was up in the period 1989-93.

4.2.2. Contribution of Intermdiate Materials, Capital Stock, Labor, and TFP Growth

Manufacturing

The growth of intermediate materials is the most important contributing factor for the growth of gross output, and the rate of contribution is about 73 percent of the growth of gross output during the period 1973-93. The remaining 26 percent of the output growth is realized by the contribution of the growth in capital, labor, and productivity. The contriution by capital is the second largest amount at 14.6 percent, followed by the contribution of labor man-hours and education at, 6.7

percent, and by total factor productivity at 5.5 percent of the growth of gross output.

Heavy Manufacturing

The contributions of factor inputs and TFP in the heavy manufacturing industry are similar to those discussed in the case of the total manufacturing industry with one exception. The contribution of the growth in total factor productivity is greater than the contribution of the growth in labor man-hours and education. In the period 1989-93, the contribution of the labor input is very small, 3.1 percent. The decreasing trend of the contribution of the labor input is a result of the decreasing growth in labor man-hours, about a 1.2 percent rate. The contribution of labor's education shows a rising trend. The same phenomenon also occur in the light manufacturing industry.

Light Manufacturing

Almost 90 percent of the growth in gross output is explained by the growth in intermediate materials and capital during the period 1971 to 1993. The labor input explains about 6.6 percent of output growth, and the growth in the productivity explains about 2.7 percent of output growth in the light manufacturing industry. The low contribution by productivity growth is not surprising due to the fact that Korea has concentrated its effort to advance technological innovation in the heavy industry. During the period 1989-93, the growth in the labor man-hours and the total factor productivity was negative. Consequently, the contribution of these factors to the output growth was negative.

4.2.3. Labor Productivity and Unit Labor Cost

When output is represented by gross output, the labor productivity and unit labor cost are defined as below:

$$\Delta\ln YGD_g - \Delta\ln LD_g - \Delta\ln E_m = \Delta\ln AGD_g + s_{rg}(\Delta\ln MD_g - \Delta\ln LD_g - \Delta\ln E_m) + (1-s_{rg})(1-s_{lg})(\Delta\ln KD_g - \Delta\ln LD_g - \Delta\ln E_m) \quad (26)$$

$$\Delta\ln ULCG_g = \Delta\ln WR_g - (\Delta\ln YGD_g - \Delta\ln LD_g - \Delta\ln E_m) \quad (27)$$

where $ULCG_g$ is the unit labor cost.

We find that the labor productivity in gross output of the total manufacturing industry rises at an average annual rate of 5.8 percent during the period 1971-93. Average rates of increase in the labor productivity in the heavy manufacturing and the light manufacturing industries are 7.8 and 3.9 percent, respectively. The growth rate in the labor productivity in the heavy manufacturing industry is much higher during 1989-93 than that in the light manufacturing industry. The higher rates of increase in the capital-to-labor ratios are responsible for this upward movement in the labor productivity for the heavy manufacturing industry. The negative rates of growth in the total factor productivity are the main reason for the slowdown in the labor productivity for the light manufacturing industries.

The measures of the growth in labor productivity are similar to the measures of the growth in labor productivity based on the net value added measure of output. This reflects that output elasticity of intermediate materials demanded is close to one in Korean manufacturing industries. According to equaiton (18), two measures of the growth in labor productivity are closer. We also find that the growth rates in the unit labor cost are similar to the growth rates in the unit labor cost found in the case of net value added output.

4.2.4. Selected TFP Estimates

Table 8 includes the selected estimates of total factor productivity which were based on gross output in the manufacturing industry. An annual average growth rate are a wide range of estimates from negative 2.5 percent to 8.8 percent. The range of estimates of the contribution to output growth is also wide, from negative 85 percent to 5 percent. Two interesting observations can be made. First, comparing Tables 7 and 8, the estimates based on gross output are lower than the estimates based on net value added. This is expected from the analytical discussions made earlier. For example, the estimate based on gross output, 2.08 percent, by Kim and Park (1988) is 7 percent based on net value added, using the same set of data and sample period. The estimate based on gross output by this study, 0.8 percent, is about 25 percent of the estimate based on net value added. Secondly, the estimates by the studies which include data in more recent years are lower. This may indicate that a slowing down of productivity growth has been occuring in Korea.

Table 8 Selected Estimates of Total Factor Productivity Growth in

Korean Manufacturing Industry based on Gross Output

(in percent)

Authors	Periods	TFP	Output	TFP/ Output	Sources
Nishimizu and Robinson (1984)	1960-77	3.7	17.9	20.7	MMS
Kwon (1986, pp.81-83)	1961-80	2.95	19.45	15.17	MMS
Kim and Park (1988, p.75)	1966-83	2.08	19.14	10.9	MMS
Kwon and Yuhn (1990, p.156)	1961-71 1971-78 1978-81	1.90 1.08 -2.54	19.00 22.90 2.99	10.00 4.7 -85.3	MMS
S. S. Lee (1989, p.29)	1966-85	0.94	18.5	5.08	MMS
World Bank (1993, p.307)	1968-88	8.8			
Nadiri(1993)	1975-90	3.32			MMS
Kwon(1994)	1967-89	-1.6			MMS
Park and Kwon (1995, p.362)	1967-89	-1.6			MMS
Hong and Kim (1996, pp.51-72)	1967-93	1.71	15.80	10.82	MMS
Nadiri and Kim (1996)	1975-90	3.15			MMS
Yang (1996, p.362)	1976-91	0.64	12.91	4.94	MMS
This Study(1999)	1971-93	0.8	13.8	5.5	NIA

Note: 1) MMS indicates that primary data source is *Report on Mining and Manufacturing Survey*.
2) NIA indicates that primary data source is *National Accounts*.

5. SUMMARY AND IMPLICATIONS

Total factor productivity and its contribution to the growth in output were measured for Korean manufacturing industries for the period from 1971 to 1993. The main empirical findings are summarized as follows. First, the average annual rate of increase in total factor productivity on a value added basis in the total manufacturing and in the heavy, and light manufacturing industries are about 3, 4.5, and 1.1 percent, respectively. In the period 1989-93, the growth rate of productivity in the manufacturing sector fell to 0.6 percent. The decline was most severe in the light manufacturing industries in early 1990s.

Secondly, among the three inputs, namely capital stock, labor, and productivity for the pperiod from 1971 to 1993, the contribution by capital investment was the largest and about 54 percent of the output growth in the overall manufacuring sector, followewd by labor input. Labor man-hours and labor-education contributed by about 21 percent and 4 percent, respectively. The growth in total factor productivity accounted for about 22 percent of the growth of value added output during the period 1971-93. Its contribution declined greatly in the early 1990s averaging only about 9.4 percent over the period 1989-93.

Thirdly, across the period 1971-93, the average rates of increase in the productivity per unit of man-hours adjusted for the variations in the labor's mean education years are 6, 7.8, and 4 percent in the total, heavy, and light manufacturing industries, respectively. For manufacturing industry as a whole, the average rate of increase in the unit labor cost, about 13 percent, is higher than average inflation rate, about 11 percent. The average rates of increase in the unit labor cost for the heavy and light manufacturing are 11.9 percent and 14 percent, respectively, during 1971-93 period.

The growth in capital and labor inputs explains most of the growth in output. In contrast, the growth in total factor productivity contributed a smaller amount to the growth in output, and the contribution of productivity growth has been falling further in recent years. This seems to provide evidence for the position taken by Krugman (1994) that the East Asia economies would not be able to sustain high growth because their growth is extensive with a lower growth in TFP. However, past improvement in labor quality- i.e., its education level- suggest it can lead to high growth potential. Hence, the growth potential seems to be stronger than Krugman would allow.

The decline in productivity growth in the early 1990 leads to the rise in unit labor cost, thereby bringing about the decline in exports and the profit margin of exports. The decline in the profit margin increased corporate indebtedness and non-performing loans. This weakened corporate balance sheets even more and made financial institutions more fragile. Therefore, the productivity slowdown is one of the key causes of the financial crisis in Korea and lies on the supply side of the causes rather than on the financial side where most studies identified the causes.[8)]

8) For a detailed discussion, see Kwack (1998) and Mishkin (1996).

Declining productivity growth reflects inefficient use of usable resources and lags in knowledge. Industrial policy and credit allocation system did not raise productivity growth.[9] Rather, more often than not, centralized decision making tends to protect the forces opposing advancement in technological progress and oppose the forces for change.[10] Decentralized institutions with the dispersion of decision making enhances the social capability and economic ability of a nation to support technological progress and creativity. Improved adaptability is an unavoidable condition necessary for sustainable productivity growth and an increasing-return-to-scale economy. Fair competition in markets and foreign business operations in Korea would certainly be helpful for enhancing its economic adaptability. While improving the economy's adaptability, organizational reform should also be implemented to attain efficient utilization of resources. If total factor productivity continues to increase, living standards will rise as well.

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9) Lee Jong Wha (1995, p.403) concludes that "The empirical findings show no evidence to support any positive contributions made by government interventions to productivity growth."

10) See Parente, S. L. and E. C. Prescott (1994). John M. Keynes (1936) recognizes the reluctance of authority who hear voices of the air and concludes with the last sentence of his *The General Theory of Employment Interest and Money*, "But, soon or later, it is ideas, not vested interests, which are dangerous for good or evil."(p. 384)

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