Sources of Aggregate Economic Growth in Japan During the Period 1960-1985[1]

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Abstract

The purpose of this paper is to give the overview of the aggregate economic growth in Japan during the period 1960-1985. Sources of growth in output for the economy as a whole can be divided between the rate of aggregate technical change and the contributions of aggregate capital and labor inputs. We construct measures of growth in output, the rate of technical change, and the contributions of capital and labor inputs for the economy as a whole. Our objective is to measure value added for the economy as a whole. Our measurements of the sectoral gross output are based upon the input-output accounting framework. The sectoral models of production are specified in terms of the price function in which prices of output are a function of capital service prices, labor input prices, energy input price, intermediate input price and time. Our input-output accounting framework and the sectoral price functions give aggreagte measures of value-added prices and factor-input prices. These prices generate the quantity of aggregate value-added and factor inputs as the dual index in which nominal accounting balances in each sector and in the economy as a whole are maintained.

1. Introduction

The purpose of this paper is to give the overview of the aggregate economic growth in Japan during the period 1960-1985. Sources of growth in output for the economy as a whole can be divided between the rate of aggregate technical change and the contributions of aggregate capital and labor inputs. We construct measures of growth in output, the rate of technical change, and the contributions of capital and labor inputs for the economy as a whole.

As is well known, Japanese economy accomplished a rapid economic growth at more than 10 percent per year until the beginning of 1970's. According to the statistics of the System of National Accounts, the growth rate of the nominal gross national products was 15.90 percent year during the period 1960-1970, and 11.63 percent per year during the period 1970-1980. The growth rate of the real gross national product were 10.23 percent and 4.75 percent per year respectively, during these periods. The rates of economic growth such as those of Japan during the postwar period might be rare cases in the world economic history. Indeed, Japan's growth rates exceeded the average estimated by Simon Kuznets (1971) for the industrialized countries since the Industrial Revolution. In contrast, the postwar U.S. economy grew at about 3 percent per year in terms of the real gross national product. After 1974 both economies experienced a dramatic deterioration, inter alia by the impact of the increasing oil prices.

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[1]This project has been continued in Keio Economic Observatory in collaboration with Harvard University since 1981. Authors greatly appreciate valuable comments from Dale W. Jorgenson, Harvard University. Of course, any remaining faults are solely our own.

Our first objective is to measure value added for the economy as a whole. Our measurements of the sectoral output are based upon the input-output accounting framework. The sectoral models of production are specified in terms of the price function in which prices of otuput is a function of capital service prices, labor input prices, energy input prices, intermediate input prices and time. Our input-output accounting framework and the sectoral price functions give aggregate measures of value added prices and factor input prices. These prices generate the quantity of aggregate value added and factor inputs as the dual index in which nominal accounting balances in each sector and economy as a whole are maintained.

It should be emphasized that we do not necessarily assume the existence of an aggregate production function or an aggregate price function. The existence of such aggregate functions imply stringent restrictions on sectoral models of production and technical changes utilized: All sectoral price functions must be identical to the aggregate price function and all sectoral value added prices, capital service prices and labor service prices must be equal to each aggregate prices respectively. Unless these assumptions of the aggregate production model are met, the analysis of sources of the economic growth generates differences between sectoral and aggregate models of production and technical change. The differences can be identified with the contributions of reallocations of value added and primary factor inputs among sectors to the rate of aggregate technical change.

In Section 2 we present estimates of aggregate value added based upon our input-output accounting framework. In Section 3 we allocate the growth of value added among its components — the contributions of capital and labor inputs in economy as a whole and the rate of aggregate technical change. We further decompose the contribution of capital and labor input into the contributions of the quantity of inputs — the contributions of capital stock and hours worked — and the contributions of the quality of capital and labor inputs. In Section 4 we present the methodological framework in order to allocate the rate of aggregate technical change among a weighted sum of rates of sectoral technical change and reallocations of value added and the primary factor inputs among sectors. Finally, we conclude by presenting the results of the decompositions of the rate of aggregate technical change in the Japanese economy and comparing the features of the Japanese economic growth to those of the U.S. estimated in the same methodological framework. Although we can summarize our results in Table 1 and 2, reader can find our detailed measures of our methodologies in Appendix.

2. Aggregate Output

Our measurement of the sectoral gross output is based on the input-output accounting framework. The quantity of aggregate output, that is aggregate value added, is defined as the sum of quantities of value added over all sectors. We begin with the explanation of our input-output accounting framework in order to confirm the definition of the quantity and the price of the aggregate output.

Our input-output accounting framework is based on the System of National Accounts. Sectoral accounting balance is composed of two concepts of classification — commodity and industry. Relationships between commodity and industry is represented by two tables — Make matrix, so called V table and Absorption matrix, so called U table. V table provides the information of commodity product-mix within each industry. U table provides the composition of the intermediate inputs by commodities in each industrial sector. Commodities and industries are classified into thirty-one commodities and industries respectively. Each industry generates value added, composed of factor compensation imputed to labor and capital inputs, business consumption expenditure and indirect taxes less subsidies.

Imports are divided into two categories — competitive (transferred) imports and noncompetitive (directly allocated) imports. The competitive imports are included in each transaction of intermediate and final demand. The noncompetitive imports are allocated into each industry as an imported intermediate input or into each final use as an imported final demand.

Accounting balance in the j-th industrial sector is represented as follows:

$$(\frac{1}{1+t^j})p^j_I Z^j_I = \sum_{i=1}^{n} p_{oi}X^j_i + p_d d^j + p_{bc}b^j + L^j p^j_L + K^j p^j_K, \tag{1}$$

where

t^j: the effective rate of net indirect tax which is defined by

$$t^j = \frac{Indirect\ Tax\ -\ Subsidies}{\sum_{i=1}^{n} p_{oi}X^j_i + p_d d^j + p_{bc}b^j + L^j p^j_L + K^j p^j_K}, \tag{2}$$

p^j_I, Z^j_I: output price and quantity in the j-th industry which are defined as commodity aggregates produced within the j-th industry.

p_{oi}: over-all price of the i-th commodity which is composed of domestically produced goods and transferred imports.

X^j_i: quantity of the i-th intermediate good including domestic goods and transferred imports used in the j-th industry.

p_d, d^j: price and quantity of directly allocated import of the j-th sector.

p_{bc}, b^j: price and quantity of business consumption of the j-th sector.

p^j_L, L^j: price and quantity of labor service input of the j-th sector.

p^j_K, K^j: price and quantity of capital service input of the j-th sector.

Rearranging (1), we can deduce the value-added of the j-th sector.

$$\begin{aligned} p^j_v V^j &= L^j p^j_L + K^j p^j_K \\ &= (\frac{1}{1+t^j})p^j_I Z^j_I - \sum_{i=1}^{n} p_{oi}X^j_i - p_d d^j - p_{bc}b^j, \\ &= p^{j*}_I Z^j_I - \sum_{i=1}^{n+2} p_i X^j_i, \end{aligned} \tag{3}$$

where p^j_v and V_i are respectively the value-added deflator and real value-added of the j-th sector. To simplify, we replace $(\frac{1}{1+t^j})$ p^j_I to p^{j*}_I, p_{oi} $(i=1,...n)$ to p_i $(i=1,...n)$, p_d to p_i $(i=n+1)$, p_{bc} to p_i $(i=n+2)$, d^j $(j=1,...n)$ to X^j_i $(i=n+1,\ j=1,...n)$ and b^j $(j=1,...n)$ to X^j_i $(i=n+2, j=1,...n)$ in the last equation.

Differentiating (3) logarithmically with respect to time, we have

$$\begin{aligned} \frac{\dot{p}^j_v}{p^j_v} + \frac{\dot{V}^j}{V^j} = &\left[\frac{p^{j*}_I Z^j}{p^j_v V^j}\cdot\frac{\dot{p}^{j*}_I}{p^{j*}_I} - \sum_{i=1}^{n+2}(\frac{p_i X^j_i}{p^j_v V^j})\cdot(\frac{\dot{p}_i}{p_i})\right] \\ &+ \left[\frac{p^{j*}_I Z^j}{p^j_v V^j}\cdot\frac{\dot{Z}^j_I}{Z^j_I} - \sum_{i=1}^{n+2}(\frac{p_i X^j_I}{p^j_v V^j})(\frac{\dot{X}^j_i}{X^j_i})\right]. \end{aligned} \tag{4}$$

The growth rate of the Divisia price index of value-added is then subtracted from the rate of growth of net output values in current prices in order to obtain a measure of the growth rate of real value added. The discrete approximation for this deflation procedure for the value added is as follows:

$$\begin{aligned}\ln V^j(T) - \ln V^j(T-1) = & [\ln p_v^j(T)\, V^j(T) - \ln p_v^j(T-1)\, V^j(T-1)] \\ & - [\frac{1}{2}[v^j(T) + v^j(T-1)]\,[\ln p_I^{j*}(T) - \ln p_I^{j*}(T-1)] \\ & - \sum_{i=1}^{n+2} \frac{1}{2}[v_i^j(T) + v_i^j(T-1)]\,[\ln p_i(T) - \ln p_i(T-1)],\end{aligned} \tag{5}$$

where

$$v^j(T) = p_I^{j*} Z^j(T) / p_v^j V^j(T),$$

and

$$v_i^j(T) = p_i X_i^j(T) / p_v^j V^j(T).$$

Our concept of the sectoral value added is evaluated in terms of the factor cost. Each sectoral value added defined in (3) includes the following items:

Sectoral value added in current prices
= Gross domestic output at the factor cost
  − Intermediate input at the over-all price
  − Direct allocated import in current prices
  − Business consumption expenditure in current prices
= Labor compensation
(= Compensation for the full-time employee
  + Compensation for the day laborer
  + Compensation for the day laborer
  + Compensation for self-employed
  + Compensation for unpaid family worker)
  + Capital compensation
(= Business surplus
  − Compensation for self-employed
  − Compensation for unpaid family worker
  + Capital consumption allowance
  + Taxes on capital).

Next, we define gross domestic products (*GDP*) — the economic-wide aggregate measure of net output — as the sum of sectoral value added as follows:

$$\begin{aligned}p_v V &= \sum_{j=1}^{n} p_v^j V^j \\ &= \sum_{j=1}^{n} (L^j p_L^j + K^j p_K^j),\end{aligned} \tag{6}$$

where p_v and V are *GDP* deflator and real *GDP* respectively.

Differentiating (6) logarithmically with respect to time, we have,

$$\frac{\dot{p}_v}{p_v} + \frac{\dot{V}}{V} = \sum_{j=1}^{n} \frac{p_v^j V^j}{p_v V} \cdot \frac{\dot{p}_v^j}{p_v^j} + \sum_{j=1}^{n} \frac{p_v^j V^j}{p_v V} \cdot \frac{\dot{V}^j}{V^j} \tag{7}$$

The growth rate of the Divisia price index, which is represented by the first term of the right-hand side of the equation (7), is then subtracted from the rate of growth of the nominal gross domestic products in order to obtain a measure of the growth rate of the real GDP. The discrete approximation for the growth rate of the real GDP is as follows:

$$\begin{aligned} &\ln V(T) - \ln V(T-1) \\ &= [\ln p_v(T)\, V(T) - \ln p_v(T-1)\, V(T-1)] \\ &\quad - \sum_{j=1}^{n} \frac{1}{2} [w^j(T) + w^j(T-1)][\ln p_v^j(T) - \ln p_v^j(T-1)], \end{aligned} \tag{8}$$

where

$$w^j(T) = p_v^j(T)\, V^j(T) / p_v(T)\, V(T).$$

The sum of value added in all sectors $p_{vi}V^j$ is equal to the sum of capital compensation and labor compensation for the economy as a whole. Value added for the economy as a whole is equal to the sum of the value added at current price over all sectors.

$$p_v V = \sum_{j=1}^{n} p_v^j V^j = \tilde{p}_v \sum_{j=1}^{n} V^j, \tag{9}$$

where p_v is the translog price index derived from the discrete approximation for the growth rate of the sectoral value- added price, and $\tilde{p}_v$ is the aggregate price index which is defined corresponding to the sum of the quantities of real value added in all sectors. The translog price index, p_v is not necessarily equal to the aggregate price index, $\tilde{p}_v$. They are equal if and only if prices of value added in all sectors are identically equal to p_v and value shares w^j in all sectors are constant.

Labor and capital compensation of different types are equal to the sectoral sum of compensations paid for the each type of labor and capital.

$$p_{Ll} L_l = \sum_{j=1}^{n} p_{Ll}^j L_l^j = \tilde{p}_{Ll} \sum_{j=1}^{j} L_l^j, \tag{10}$$

$$p_{Kk} K_k = \sum_{j=1}^{n} p_{Kk}^j K_k^j = \tilde{p}_{Kk} \sum_{j=1}^{n} K_k^j, \tag{11}$$

where subscripts l and k denote l-th and k-th type of labor and capital input. $\tilde{p}_{Ll}$ and $\tilde{p}_{Kk}$ are the aggregate price index defined corresponding to the sum of the quantities of real labor and capital inputs of different types over all sectors.

Similar to the aggregate value-added price index, $\tilde{p}_{Ll}$ and $\tilde{p}_{Kk}$ are not necessarily equal to the translog price index p_{Ll} and p_{Kk}. Labor and capital compensation for the economy as a whole are equal to the sum of each input compensation at current price over all input types.

$$p_L L = \sum^{l} p_{Ll} L_l = \tilde{p}_L \sum^{l} L_l, \tag{12}$$

$$p_K K = \sum^{k} p_{Kk} K_k = \tilde{p}_K \sum^{k} K_k, \tag{13}$$

where p_L and p_K are the translog price index of labor and capital input for the economy as a whole and $\tilde{p}_L$ and $\tilde{p}_K$ are the aggregate price index defined corresponding to the sum of quantities of real labor and capital inputs over all input types. If and only if prices of labor and capital inputs in various types are identical to the aggregate translog price index p_L and p_K respectively, then $\tilde{p}_L$ and

$\tilde{p}_K$ are equal to p_L and p_K.

3. Aggregate Labor and Capital Input

Rearranging (10) – (13),

$$p_L L = \sum^{j} \sum^{l} p^j_{Ll} L^j_l, \tag{14}$$

$$p_k K = \sum^{j} \sum^{k} p^j_{Kk} L^j_k, \tag{15}$$

where subscript j stands for the j-th sector.

Considering labor and capital inputs data for the economy as a whole at any two discrete points of time, the discrete approximations for the changes of their translog index can be written as the weighted average of the growth rates of hours worked and capital service input by different types of labor and capital, $\{L^j_l\}$ and $\{K^j_k\}$, over all sectors.

$$\begin{aligned}\Delta \ln L &= \ln L(T) - \ln L(T-1) \\ &= \sum^{j} \sum^{l} \bar{v}^j_{Ll} \, [\ln L^j_l \, (T) - \ln L^j_l \, (T-1)],\end{aligned} \tag{16}$$

and

$$\begin{aligned}\Delta \ln K &= \ln K(T) - \ln K(T-1) \\ &= \sum^{j} \sum^{K} \bar{v}^j_{Kk} \, [\ln K^j_k \, (T) - \ln K^j_k \, (T-1)],\end{aligned} \tag{17}$$

where the weights are given by the average value share of the l-th labor or the k-th capital compensation in the j-th sector accruing to respective total compensation for the economy as a whole.

$$\bar{v}^j_{Ll} = \frac{1}{2} \, [v^j_{Ll} \, (T) + v^j_{Ll} \, (T-1)], \tag{18}$$

$$v^j_{Ll} = \frac{p^j_{Ll} L^j_l}{\sum^j \sum^l p^j_{Ll} L^j_l} .$$

$$\bar{v}^j_{Kl} = \frac{1}{2} \, [v^j_{Kk} \, (T) + v^j_{Kk} \, (t-1)], \tag{19}$$

$$v^j_{Kk} = \frac{p^j_{Kk} K^j_k}{\sum^j \sum^k p^j_{Kk} K^j_k} .$$

Note that hours worked, L^j_l, and capital service input, K^j_k, can be expressed as the product of the following two terms respectively.

$$L^j_l = d^j_l \, (\sum^{j} \sum^{l} L^j_l), \; (l = 1, \ldots, l; \; j = 1, \ldots, \; n), \tag{20}$$

$$K^j_k = h^j_k \, (\sum^{j} \sum^{k} K^j_k), \; (k = 1, \ldots, k; \; j = 1, \ldots, \; n), \tag{21}$$

where d^j_l and h^j_k denote the proportion of hours worked by the l-th type in the j-th sector to the total hour worked for the economy as a whole and the proportion of capital service input by the

k-th type in the j-th sector to the total capital service input for the economy as a whole respectively. Changes of the translog quantity index for labor and capital inputs for the economy as a whole can be expressed alternatively as follows:

$$\Delta \ln L = [\ln \sum^{j} \sum^{l} L_l^j (T) - \ln \sum^{j} \sum^{l} L_l^j (T-1)] + \sum^{j} \sum^{l} \bar{v}_{Ll}^j [\ln d_l^j (T) - \ln d_l^j (T-1)], \tag{22}$$

$$\Delta \ln K = [\ln \sum^{j} \sum^{l} K_k^j (T) - \ln \sum^{j} \sum^{l} K_k^j (T-1)] + \sum^{j} \sum^{k} \bar{v}_{Kl}^j [\ln h_k^j (T) - \ln h_k^j (T-1)]. \tag{23}$$

The first terms of the right-hand side in (22) and (23) account for the changes in the quantity of total labor and capital inputs. The second terms, the weighted average of the change in the hours worked proportions and capital service input proportion by different type and different sector of labor and capital, can be interpreted to account for change in the quality of labor and capital input for the economy as a whole.

$$\begin{aligned} \Delta \ln Q_L &= \ln Q_L (T) - \ln Q_L (T-1) \\ &= \sum^{j} \sum^{l} \bar{v}_{Ll}^j [\ln d_l^j (T) - \ln d_l^j (T-1)], \\ &= \Delta \ln L - [\ln \sum^{j} \sum^{l} L_l^j (T) - \ln \sum^{j} \sum^{l} L_l^j (T-1)], \end{aligned} \tag{24}$$

$$\begin{aligned} \Delta \ln Q_K &= \ln Q_K (T) - \ln Q_K (T-1) \\ &= \sum^{j} \sum^{k} \bar{v}_{Kk}^j [\ln h_k^j (T) - \ln h_k^j (T-1)], \\ &= \Delta \ln K - [\ln \sum^{j} \sum^{l} K_k^j (T) - \ln \sum^{j} \sum^{l} K_k^j (T-1)]. \end{aligned} \tag{25}$$

The evaluation of changes in the quality of labor and capital input for the economy as a whole is presented in the following section.

4. Aggregate Productivity Index

We have presented indices of output and input for the economy as a whole. Our next objective is to formulate an index of Total Factor Productivity (TFP) change for the economy as a whole. We can define an index of productivity at the sectoral level as follows:

$$v_T^j = \frac{\dot{Z}_l^j}{Z_l^j} - \sum^{i} \frac{p_i X_i^j}{p_l^j * Z_l^j} (\frac{\dot{X}_i^j}{X_i^j}) - \sum^{l} \frac{p_{Ll}^j L_l^j}{p_l^j * Z_l^j} (\frac{\dot{L}_l^j}{L_l^j}) - \sum^{k} \frac{p_{Kk}^j K_k^j}{p_l^j * Z_l^j} (\frac{\dot{K}_k^j}{K_k^j}) \tag{26}$$

Alternatively, using the definitions of the value added in the j-th sector, we can write the index of the rate of TFP change v_T^j,

$$v_T^j = \left(\frac{p_{vi}V^j}{p_I^j * Z^j}\right)\left(\frac{\dot{V}^j}{V^j}\right)$$

$$- \sum \frac{p_{LI}^j L_l^j}{p_I^j * Z_l^j}\left(\frac{\dot{L}_l^j}{L_l^j}\right) - \sum^k \frac{p_{Kk}^j K_k^j}{p_I^j * Z^j}\left(\frac{\dot{K}_k^j}{K_k^j}\right). \tag{27}$$

The discrete approximation for the growth rate of the sectoral TFP change is as follows:

$$\begin{aligned}\hat{v}_T^j &= [\ln v_T^j(T) - \ln v_T^j(T-1)] \\ &= \frac{1}{2}[v^j(T) + v^j(T-1)][\ln V^j(T) - \ln V^j(T-1)] \\ &\quad -\sum \frac{1}{2}[v_{LI}^j(T) + v_{LI}^j(T-1)][\ln L_l^j(T) - \ln L_l^j(T-1)] \\ &\quad -\sum \frac{1}{2}[v_{Kk}^j(T) + v_{Kk}^j(T-1)][\ln K_k^j(T) - \ln K_k^j(T-1)],\end{aligned} \tag{28}$$

where

$$v^j(T) = \frac{p_v^j V^j(T)}{p_I^j * Z^j(T)},\quad v_{LI}^j(T) = \frac{p_{Kk}^j K_l^j(T)}{p_I^j * Z^j(T)},\quad v_{Kk}^j(T) = \frac{p_{LI}^j K_k^j(T)}{p_I^j * Z^j(T)}.$$

We can aggregate the above sectoral accounts into the nation-wide account as follows:

$$\begin{aligned}\sum^j \frac{p_I^{j*} Z^j}{p_v V} &= \sum^j \frac{p_v^j V^j}{p_v V} \cdot \frac{\dot{V}^j}{V^j} \\ &\quad - s_L \cdot \sum^j \sum^l \frac{p_{LI}^j L_l^j}{\Sigma^j \Sigma^l p_{LI}^j L_l^j} \cdot \frac{\dot{L}_l^j}{L_l^j} \\ &\quad - s_K \cdot \sum^j \sum^k \frac{p_{Kk}^j K_k^j}{\Sigma^j \Sigma^k p_{KI}^j K_k^j} \cdot \frac{\dot{K}_k^j}{K_k^j},\end{aligned} \tag{29}$$

where

$$s_L = \frac{\Sigma^j \Sigma^l p_{LI}^j L_l^j}{p_v V},\quad s_K = \frac{\Sigma^j \Sigma^k p_{Kk}^j K_k^j}{p_v V}.$$

On the other hand, let us assume *a priori* the aggregate production function is based upon the aggregate net output and aggregatte labor and capital input, hypothetically, in order to clarify the relationship between the aggregate productivity growth and the sectoral productivity growth. We can define the aggregate rate of TFP change for the economy as a whole from the accounting identity,

$$p_v V = p_L L + p_K K. \tag{30}$$

The aggregate rate of TFP change can be written as follows:

$$v_T = \frac{\dot{V}}{V} - s_L \frac{\dot{L}}{L} - s_K \frac{\dot{K}}{K}, \tag{31}$$

where

$$\frac{\dot{V}}{V} = \sum^{j} \frac{p_v^j V^j}{p_v V} \cdot \frac{\dot{V}^j}{V^j}$$

$$= \sum^{j} \frac{\tilde{p}_v V^j}{p_v V} \cdot \frac{\dot{V}^j}{V^j},$$

$$s_L = \frac{p_L L}{p_v V},$$

$$\frac{\dot{L}}{L} = \sum^{l} \frac{p_{Ll} L_l}{p_L L} \cdot \frac{\dot{L}_l}{L^l}$$

$$= \sum^{l} \frac{\tilde{p}_{Ll} L_l}{p_L L} \cdot \frac{\dot{L}_l}{L^l},$$

$$s_K = \frac{p_K K}{p_v V},$$

$$\frac{\dot{K}}{K} = \sum^{k} \frac{p_{Kk} K_k}{p_K K} \cdot \frac{\dot{K}_k}{K^k}$$

$$= \sum^{k} \frac{\tilde{p}_{Kk} k_k}{p_K K} \cdot \frac{\dot{K}_k}{K^k}.$$

In the aggregate production function, we assume that sectoral net output is homogeneous among sectors and the value-added price is identical among sectors. Then the growth rate of aggregate net output represented in the first item of the right-hand side in (31) is equal to the growth rate of the simple sum of the sectoral value added, $\sum^j \frac{V^j}{\sum^j V^j}$. On the other hand, as concerns labor and capital input, it is assumed that each l-th type labor input price and each k-th type capital input price are identical among sectors, while input prices of the different types might not be identical among types, that is, $p_{Ll}^j = \tilde{p}_{Ll}$ *and* $p_{Kk}^j = \tilde{p}_{Kk}$. This also implies that the l-th type aggregate labor input and the k-th type aggregate capital input are equal to the simple sum of the l-th and k-th type labor and capital over sectors respectively, that is, $L_l = \sum^j L_l^j$ and $K_k = \sum^j K_k^j$. Then the aggregate labor and capital index are aggregated over the different types of labor and capital inputs by the Divisia index as shown in (31).

Rearranging (31) with (27), we obtain the following relationship between the sectoral productivity and the aggregate productivity.

$$v_T \cdot p_v V = \sum^{j} \tilde{p}_v^j \dot{V}_j - \sum^{l} \tilde{p}_{Ll} \dot{L}_l - \sum^{k} \tilde{p}_{Kk} \dot{K}_k$$

$$= \sum^{j} \tilde{p}_v^j \dot{V}_j - \sum^{j} p_v^j \dot{V}^j + \sum^{j} p_v^j \dot{V}^j - \sum^{l} \tilde{p}_{Ll} \dot{L}_l - \sum^{k} \tilde{p}_{Kk} \dot{K}_k$$

$$= \sum^{j} [v_T^j p_I^{j*} Z^j + \sum^{l} p_{Ll}^j \dot{L}_l^j + \sum^{k} p_{Kk}^j \dot{K}_k^j]$$

$$+ (\sum^{j} \tilde{p}_v \dot{V}^j - \sum p_v^j \dot{V}^j) - \sum^{l} \tilde{p}_{Ll} \dot{L}_l - \sum^{k} \tilde{p}_{Kk} \dot{K}_k$$

$$= \sum^{j} v_T^j p_I^{j*} Z^j + \sum^{j} (\tilde{p}_v - p_v^j)\, \dot{V}^j$$

$$+ \sum^{j} \sum^{l} (p_{Ll}^{j} - \tilde{p}_{Ll}) \dot{L}_l^j + \sum \sum (p_{Kk}^{j} - \tilde{p}_{Kk}) \dot{K}_k^j. \tag{32}$$

This formulation implies that we can understand the aggregate rate of TFP change for the economy as a whole as a compound of three components as follows. Rearranging equation (32), we obtain

$$v_T = \sum^{j} (\frac{p_I^{j*} Z^j}{p_v V}) v_T^j + \sum^{j} (\frac{\tilde{p}_v - p_v^j}{p_v V}) \dot{V}^j$$
$$+ \sum^{j} \sum^{l} (\frac{p_{Ll}^{j} - \tilde{p}_{Ll}}{p_v V}) \dot{L}^j + \sum^{j} \sum^{l} (\frac{p_{Kk}^{j} - \tilde{p}_{Kk}}{p_v V}) \dot{K}^j. \tag{33}$$

The first term of the right-hand side of the equation represents the weighted average of the rates of sectoral TFP change, in which the weight is defined by the proportion of the nominal gross product of the j-th sector to the total nominal value added. The sum of the weight among sectors is necessarily more than unity. Consequently, the aggregate rate of TFP change is necessarily more than the simple average of the rate of sectoral technical change. This implies that the aggregate rate of TFP change should be evaluated with respect to both direct and indirect effects of the increasing efficiency, because the TFP change in certain sectors might have contributions not only on the production efficiency in their own sector, but also on that in other related sectors. It is plausible that such interdependence of technologies among sectors can create the aggregate rate of technical change greater than the average of the sectoral technical change.

The other three terms of (33) represent the contributions of the reallocational changes of value-added, labor and capital inputs among sectors on the aggregate rate of TFP change. In the second term, if prices of the net output in all sectors, p_{vi} are equal to $\tilde{p}_v$, this term becomes zero. In these situations the aggregate translog price index p_v is equal to $\tilde{p}_v$. This means that the second term can be thought to represent the allocational bias which stems from the differences of the prices of net output among sectors. If this second term is positive, the aggregate rate of technical change, v_T might be under-evaluated compared to the weighed average of the rate of sectoral technical change defined by the first term. If the second term is negative, v_T might be over-evaluated.

Similarly, the third and the fourth terms of (33) represent the contributions of the allocational biases of labor and capital among sectors. If p_{Ll}^j and p_{Kk}^j are all equal to $\tilde{p}_{Ll}$ and $\tilde{p}_{Kk}$ respectively, these two terms must be zero. If they are not equal to zero, p_{Ll}^j $(j=1,\ldots n)$ and p_{Kk}^j $(j=1,\ldots n)$ are different among sectors. Therefore certain allocational biases of factor input among sectors have some impact on the aggregate rate of TFP change for the economy as a whole. We call these three terms allocational biases of net output, labor and capital inputs among sectors contributing to the aggregate rate of technical change.

Finally, the discrete approximation of the aggregate rate of TFP change, $\hat{v}_T$ is formulated as follows:

$$\hat{v}_T = \sum^{j} \bar{w}^j \hat{v}_T^j + [\sum^{j} (\bar{w}_v - \bar{w}_v^j) (\ln V^j (T) - \ln V^j (T)]$$
$$+ [\sum^{j} \sum^{l} (\bar{w}_{Ll}^j - \bar{w}_L) (\ln L_l^j (T) - \ln L_l^j (T-1)]$$
$$+ [\sum^{j} \sum^{k} (\bar{w}_{Kk}^j - \bar{w}_k) (\ln K_k^j (T) - \ln K_l^j (T-1)], \tag{34}$$

where

$$\bar{w}^j = \frac{1}{2}\left[\frac{p_I^{j*}(T)\, Z^j(T)}{p_v(T)\, V(T)} + \frac{p_I^{j*}(T-1)\, Z^j(T-1)}{p_v(T-1)\, V(T-1)}\right],$$

$$\bar{w}_v = \frac{1}{2}\left[\frac{\tilde{p}_V(T)\, V^j(T)}{p_v V(T)} + \frac{\tilde{p}_V(T-1)\, V^j(T-1)}{p_v V(T-1)}\right],$$

$$\bar{w}_v^j = \frac{1}{2}\left[\frac{p_v^j(T)\, V^j(T)}{p_v(T)\, V(T)} + \frac{p_v^j(T-1)\, V^j(T-1)}{p_v(T-1)\, V(T-1)}\right],$$

$$\bar{w}_{Ll}^j = \frac{1}{2}\left[\frac{p_{Ll}^j(T)\, V_l^j(T)}{p_v(T)\, V(T)} + \frac{p_{Ll}^j(T-1)\, L_l^j(T-1)}{p_v(T-1)\, V(T-1)}\right],$$

$$\bar{w}_L = \frac{1}{2}\left[\frac{\tilde{p}_{Ll}(T)\, L_l^j(T)}{p_v(T)\, V(T)} + \frac{\tilde{p}_{Ll}(T-1)\, L_l^j(T-1)}{p_v(T-1)\, V(T-1)}\right],$$

$$\bar{w}_{Kk}^j = \frac{1}{2}\left[\frac{p_{Kk}^j(T)\, K_k^j(T)}{p_v(T)\, V(T)} + \frac{p_{Kk}^j(T-1)\, K_k^j(T-1)}{p_v(T-1)\, V(T-1)}\right],$$

and

$$\bar{w}_K = \frac{1}{2}\left[\frac{\tilde{p}_{Kk}(T)\, K_k^j(T)}{p_v(T)\, V(T)} + \frac{\tilde{p}_{Kk}(T-1)\, K_k^j(T-1)}{p_v(T-1)\, V(T-1)}\right].$$

Thus, we can divide the aggregate rate of TFP change into four parts: the weighed average of the rate of sectoral TFP change, allocational biases by the structural changes of net output, labor and capital inputs.

5. Sources of the Economic Growth: Aggregate

The purpose of this section is to decompose sources of the economic growth for the economy as a whole in Japan during the period 1960-1985. Drawing on the U.S. estimates of Jorgenson-Gollop-Fraumeni (1987), we can compare the sources of the economic growth between U.S. and Japan and depict specific features of the economic growth in the two economies respectively.

Table 1 presents decompositions of the sources of Japanese economic growth during the period 1960-1985. Each item in the rows of the Table shows the average annual rate of growth of each item in the decomposition of the sources of the economic growth for the economy as a whole. Items in each row are broadly divided into three parts: One is the decomposition of the source of the economic growth based upon the Divisia aggregate framework, which is shown in (29); second is the decomposition of the source of the economic growth based upon the aggregate accounts in turn based upon the formulation of (31); and third is the reallocational biases which are shown in the second to the fourth items of the right-hand side of (33). At first we will focus on the decomposition based upon the Divisia aggregate. The first row represents the average annual rate of net aggregate output. It should be noted that while the average rate per year over the whole period 1960-1985 reaches more than 6.7 percent, it was remarkably higher (11.8 percent) during the high economic growth period in Japan, 1965-1970 compared to 3.78 percent per year after the period of the first oil crisis, 1975-1980. Column (7) and (8) represent the average annual growth rate of the net output during the periods 1960-1972 and 1972-1980. The growth of the Japanese economy is clearly kinked by almost more than half of the growth in the high economic growth

Table 1 Decomposition of Sources in Economic Growth During the Period 1960-1985 in Japan

(in percent)

	Item	60-65	65-70	70-75	75-80	80-85	60-72	72-85	60-85
				Divisia Aggregate					
(1)	Value-added	9.725	11.798	4.733	3.784	3.896	9.760	4.043	6.787
(2)	Labor Input	2.929	2.201	-.097	1.967	1.608	2.381	1.113	1.722
(3)	Capital Input	10.274	10.190	7.958	4.647	4.990	10.105	5.310	7.612
(4)	Labor Contribution	1.397	1.079	-.075	1.154	.953	1.156	.667	.902
(5)	Capital Contribution	5.349	5.237	3.792	1.925	2.047	5.190	2.267	3.670
(6)	Sectoral Productivity	2.979	5.482	1.016	.704	.895	3.415	1.108	2.215
				Aggregate Account					
(7)	Value-added	7.573	11.149	5.012	4.003	6.375	8.649	5.137	6.823
(8)	Labor Input	3.049	2.339	-.090	1.962	1.661	2.528	1.098	1.784
(9)	Man-hour	1.288	2.608	-.718	1.047	.735	1.667	.369	.992
(10)	Capital Input	10.817	11.210	8.517	5.055	5.189	10.829	5.692	8.158
(11)	Capital stock	5.578	7.689	6.973	4.484	3.648	6.829	4.608	5.674
(12)	Aggregate Productivity	.488	4.241	1.029	.757	3.261	1.860	2.043	1.955
				Contribution					
(13)	<Labor Input>	1.453	1.146	-.074	1.51	.985	1.227	.660	.933
(14)	Quality	.838	-.125	.332	.537	.549	.419	.433	.426
(15)	Man-hour	.616	1.272	-.406	.614	.436	.809	.227	.506
(16)	<Capital Input>	5.631	5.762	4.056	2.095	2.129	5.561	2.433	3.935
(17)	Quality	2.739	1.812	.742	.238	.632	2.069	.460	1.233
(18)	Capital stock	2.892	3.950	3.314	1.856	1.497	3.492	1.973	2.702
				Reallocation					
(19)	Value-added	-2.153	-.649	.279	.220	2.480	-1.111	1.094	.035
(20)	Labor Input	-.056	-.067	-.001	.003	-.032	-.072	.007	-.031
(21)	Capital Input	-.282	-.525	-.264	-.170	-.082	-.371	-.166	-.265

period affected by the shock of the oil crisis. The second and third rows represent the growth rate of the labor and capital input in the aggregate. The average annual growth rate of labor input and capital input are 1.72 and 7.61 percent during the period 1960-1985. As concerns labor input, the growth rate during the 1960s was more than 2 percent, while it slowed down after 1970. Especially, the growth rate during 1970-75 was negative, which was due to the labor input cut trend for the labor cost saving after the oil crisis. On the other hand, it is shown that capital input has grown remarkably in the Japanese economy. Especially, the average annual growth rate of the capital input during the 1960s was more than 10 percent. Although the growth rate after the oil crisis had deteriorated by almost half of the growth rate before that, it was still more than 5 percent on average. In comparison with the growth rate of output and inputs, we can point out that the average growth rate of capital input was clearly lower than that. It implies that the partial productivity of capital had gradually deteriorated, while the partial productivity of labor had remarkably increased during the period 1960-1985. The weighted average of the rates of sectoral TFP change is shown in the sixth row, which corresponds to the left-hand side in (29) or the first item of the right-hand side in (33). The average growth rate of sectoral productivity was 2.2 percent during the period 1960-1985, which is divided into 3.41 percent and 1.11 percent during the periods 1960-1972 and 1972-1985. It should be noted that the growth rate of sectoral productivity after the oil crisis also deteriorated remarkably by almost 30 percent of the level before the oil crisis. In the 1960s the rate of the sectoral productivity was more than 3 percent annually, while it was recorded at 5.48 percent during the period 1965-1970.

As concerns the three sources to the aggregate economic growth, the contributions of labor input, capital input and sectoral productivity to the aggregate economic growth of net output were 14 percent, 54 percent and 32 percent respectively on average during the period 1960-1985. Contribution of labor input were 14 percent, 9 percent, -1.5 percent, 30 percent and 24 percent in each sub-period of every five years since 1960 respectively. Contributions of capital input were 55 percent, 44 percent, 80 percent, 50 percent and 52 percent in the same sub-periods. On the other hand, contributions of sectoral productivity growth were 31 percent, 47 percent, 21 percent, 20 percent and 24 percent respectively. As we can expect, capital input greatly contributed to the economic growth in Japan. Also, we should note that during the high growth period in the 1960s, specially, during the period 1965-1970, increases in the sectoral productivity contributed to the economic growth by more than 40 percent, while contributions of labor input after the oil crisis increased remarkably in spite of the slowdown of the growth rate of labor input.

Next, we will focus on the second part of the Table, the decomposition of the sources of the economic growth based upon the aggregate accounts formulated by (31). If we will assume the existence of the aggregate accounts, where it implies that the net output prices are identical among sectors and any l-th type labor input price and any k-th capital input price are also identical over sectors, we can decompose the 6.82 percent average annual growth rate of the net output during the period 1960-1985 into the contributions of the .93 percent average annual growth rate of the labor input, the 3.94 percent average annual growth rate of capital input and the 1.96 percent average annual growth rate of aggregate productivity, respectively. According to our formulation, the growth rate of net output based upon the Divisia aggregate in the first row is decomposed into the growth rate of net output in aggregate account and the contribution of reallocational biases of value added. As shown in the 19th row of the Table, the contribution of reallocational biases of value added is .035 on an average during the period 1960-1985. This implies that if we assume the existence of the aggregate production account, the growth rate of net output might be overestimated by .035 percent annually rather than that based upon the Divisia aggregate. During the 1960s the reallocational biases in value added were negative, where the growth rate of net output by the aggregate accounts might be underestimated rather than that based upon the Divisia aggregate. In other words, these values of reallocational biases represent the amount of the structural adjustments in terms of the sectoral value added, where the negative (positive) value of the real locational biases in value added implies rellocations of the sectoral value added are (not) contributed to the economic growth in the nation-wide aggregate. According to our observation, structural adjustments in terms of reallocations of the sectoral value added during the high economic period in Japan greatly contributed to the economic growth, while structural adjustments after the oil crisis did not necessarily contribute to the economic growth. By using the same methodology, we can decompose the growth rate of labor and capital inputs based upon the Divisia aggregate into the growth rate of those based upon the aggregate production account and the contributions of the reallocational biases. As shown in the formulation of (33), negative (positive) value of the reallocational biases in input implies that the efficiency of the input were increased (decreased) by the structural adjustment of the reallocation of the resources. According to our results, if we assume the existence of the aggregate production accounts, the growth rates of labor and capital inputs are overvalued by .204 percent and .612 percent annually rather than those based upon the Divisia aggregate on average during the period 1960-1985 respectively. In other wrods, efficiency of the inputs in the aggregate level was increased by the reallocation of the inputs among the sectors. Especially, in the 1960s structural adjustments of the allocation of resources among sectors were remarkably high both in labor and capital inputs in Japan. According to our formulation of (33), aggregate productivity is decomposed into sectoral productivity and the three

Table 2 Aggregate Output, Inputs, and Productivity in the U.S. Average Annual Rates of Growth 1947-1985

(in percent)

Variable	1947-1985	1960-1966	1966-1969	1969-1973	1973-1979	1979-1985
Value-added	3.28	4.72	3.60	3.06	2.12	2.22
Capital input	3.88	3.67	4.37	4.21	3.92	2.62
Labor input	1.81	2.48	2.26	1.28	2.19	1.46
Contribution of capital input	1.45	1.42	1.67	1.49	1.40	0.98
Contribution of labor input	1.12	1.51	1.40	0.82	1.39	0.89
Rate of productivity growth	0.71	1.79	0.53	0.74	-0.68	0.34
Contribution of capital quality	0.58	0.53	0.58	0.54	0.45	0.22
Contribution of capital stock	0.88	0.89	1.08	0.95	0.95	0.77
Contribution of labor quality	0.39	0.41	0.30	0.18	0.24	0.26
Contribution of hours worked	0.73	1.10	1.10	0.65	1.14	0.63
Rates of sectoral productivity growth	0.88	1.90	0.60	0.97	-0.12	0.29
Reallocation of value added	-0.19	-0.21	-0.07	-0.23	-0.53	0.06
Reallocation of capital input	0.05	0.09	0.01	0.06	-0.01	0.09
Reallocation of labor input	-0.03	0.01	-0.02	-0.05	-0.00	-0.10

Note: This stable is referenced from Jorgenson (1990).

components of the reallocational biases. If we assume the existence of the aggregate production accounts, the growth rate of productivity is underestimated by the contribution of the three reallocational biases rather than that based upon the weighted sum of the sectoral productivity, because we might ignore the increases of the efficiency in the aggregate level due to the structural adjustment in the reallocations among sectors of output and inputs.

The contributions of quantity and quality changes of labor and capital inputs are represented in rows 14 to 15 and rows 17 to 18 respectively. We should note that contributions of quality change of labor was around 0.5 percent. These contributions, however, gradually declined during the 1960s and were restored after the successive subperiods following the oil crisis. On the other hand, contributions of quality change of capital input also gradually declined, especially after 1973.

In Table 2 we summarized results along with the U.S. results by Gollop-Jorgenson (1985) for the international comparisons of sources of the economic growth. During the period 1960-1985, the average growth rate for the economy as a whole was 6.789 percent in Japan and 3.096 percent in the U.S. The sources of economic growth in terms of average growth rates of labor and capital input were 1.722 and 7.612 percent in Japan, and 1.947 and 3.368 percent in the U.S. respectively. Furthermore, the aggregate rate of technical change per year in Japan was 1.955 percent per year, which was more than double of that in the U.S. (0.53 percent per year).

When it comes to the decomposition of their contributions to the economic growth, sources of the economic growth in Japan are imputed to about 32 percent to technical change, 55 spercent to capital input and 13 percent to labor input, while they are 20 percent, 45 percent and 35 percent respectively in the U.S. As can easily be seen in Japan, we can conclude the rapid Japanese economic growth stems from the rapid growth of the technical change and the dramatic accumulation of capital input. Furthermore, the rapid increase of the aggregate rate of technical change in Japan was due to the dramatic capital accumulation with the allocational changes of capital resource among sectors.

On the other hand the average rate of aggregate technical change in the U.S., which reached 0.53 percent per year, is decomposed into the weighted average of the rate of sectoral technical change by 0.71 percent, the rate of allocational change of net output by -0.20 percent, and the rate of allocational changes of labor and capital inputs by -0.03 and 0.05 percent respectively. The average rate of sectoral technical change was the dominant factor in the U.S. and the allocational changes of outputs and inputs were less dominant in the U.S. in contrast to the allocational changes as a dominant factor in the Japanese economy. The features of contributions to the aggregate rate of technical changes, however, fluctuated during the successive subperiods in the U.S. Especially during the period 1973-1979 it shows -0.68 percent per year in which the weighted average rate of sectoral technical changes was not only -0.12 percent, but also allocational changes of net output and capital input was -0.53 percent and -0.01 percent respectively. After 1973, the rate of technical change declined both in the U.S. and Japan.

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