GROWTH ACCOUNTING OF POSTWAR JAPAN:
THE INPUT SIDE*

By MITSUO EZAKI

1. Introduction

National income statistics (NIS) and input-output table (IO table) constitute a basic part of
the system of national accounts in the broad sense (SNA). They are closely related with each
other in that net outputs or values added in NIS must be equal to primary inputs in IO table.
As a result, they must be mutually dependent also in terms of growth rates, on which growth
accounting is based. Growth accounting from the input side is a method of analysis to account
for growth of output(s) in terms of growth of various inputs, so that it is often called analysis of
sources of growth from the input side.1) In almost all cases, output growth cannot be explained
completely by input growth, and so-called "residuals" appear which mean the unexplained por-
tion of output growth. The "residuals" can be identified with productivity increase or estimated
rate of disembodied technical progress. Measurement of productivity change, therefore, may be
used synonymously with the growth accounting or the analysis of sources of growth (from the
input side).

In his previous study (Ezaki [8, Ch. 2]), the author has discussed the methodology of growth
accounting under the framework of IO tables from the point of view of measuring productivity
change or technical progress. There he has presented a view that, not only in the individual
industry level but also in the aggregate national level, the productivity measure which introduces
intermediate inputs explicitly (i.e., growth accounting of the IO basis) is theoretically better than
the conventional one which uses value added as output neglecting in a sense intermediate inputs
as production factors (i.e., growth accounting of the NIS basis).2) He has also derived there the
relationship or linkage between IO and NIS measures as a by-product.

The main purpose of this paper is to provide the growth accounting of postwar Japanese eco-

omy by applying the above method to two pairs of input-output tables (the 1955 and 1959 tables
and the 1960 and 1970 tables), and to analyze the growth performance of individual industries

* The first half (Section 2) of this paper was presented at the Annual Meeting of the Japan Associa-
tion of Economics and Econometrics held at Seikei University in October 1977. The author
expresses his appreciation to Professors Yoko Sazanami and Yasukichi Yasuba, and also to an
anonymous referee, for their helpful comments. The author, however, is solely responsible for any
remaining errors. This study was financially supported by Mombusho (Kagaku Kenkyuhi Hojo-
kin, D).

1) For the growth accounting from the input side in general, see the two surveys on methodology and
measurement made by Nadiri [17, 18]. For the growth accounting from the demand side, see Section
4 (Concluding Remarks) of this paper.

2) This view was expressed originally in Ezaki [6]. The same view is proposed also by Star [23].

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as well as of aggregate national economy in the 1955–59 and 1960–70 periods. The growth accounting from the input side, which is synonymous with the measurement of productivity change, can be expressed also in terms of the changes in input coefficients of IO tables. The second purpose of this paper is to analyze, theoretically and empirically, sources of the change in input coefficient, decomposing it into substitution effect due to changes in input prices, specific effect caused by biased technical progress and common effect due to neutral technical progress. The methodological outcome here is closely related to the RAS method developed by Stone and Brown [24].

In Section 2, we will briefly review method on the growth accounting of the IO basis and provide corresponding measurement. In Section 3, we will discuss theory and measurement on the decomposition of change in input coefficient. Section 4 will be used for concluding remarks.

2. Growth Accounting of the IO Basis

Methodology: A Brief Review

Here we will briefly review the methodology of growth accounting based on the IO framework from the point of view of productivity measurement. Detailed explanations and proofs are given in Ezaki [8, Ch. 2].

Let us first consider the case of industry productivity change. Under the framework of input-output table, the following accounting identity must hold for the i-th industry:

\[ q_i y_i = \sum_{k=1}^{n} q_k y_{ki} + \sum_{j=1}^{m} p_j x_{ji} \quad (i = 1, \ldots, n) \]

where \( y_i \) is quantity of total output, \( y_{ki} \)'s are quantities of intermediate inputs, \( x_{ji} \)'s are quantities of primary factor inputs (services), and \( q_k \)'s and \( p_j \)'s are corresponding prices. The Divisia productivity index for the i-th industry (\( T^i \)) can be derived from this identity, i.e.,

\[ T^i = \frac{\dot{y}_i}{\dot{y}_i} - \sum_{k=1}^{n} \frac{q_k y_{ki}}{y_i} \frac{\dot{y}_{ki}}{y_{ki}} - \sum_{j=1}^{m} \frac{p_j x_{ji}}{y_i} \frac{\dot{x}_{ji}}{x_{ji}} \]

where dot (\( \cdot \)) means total differentiation with respect to time (\( t \)). Equation (2.2) gives the growth accounting formula for the i-th industry when written as output growth (\( \dot{y}_i/y_i \)) being equal to input growth plus productivity increase (\( \dot{T}^i/T^i \)) (See Tables 1-4).

We can justify \( \dot{T}^i/T^i \) as an appropriate measure of productivity change theoretically in the following way. Write the production function of the i-th industry as

\[ y_i = f^i(y_{1i}, \ldots, y_{ki}, y_{ni}, x_{1i}, \ldots, x_{ji}, \ldots, x_{mi}; t) \]

and assume constant returns to scale. Then the time shifts of this function are expressed as

\[ \frac{f^i}{f^i} = \frac{\dot{y}_i}{y_i} - \sum_{k=1}^{n} \frac{f_k^i y_{ki}}{y_i} \frac{\dot{y}_{ki}}{y_{ki}} - \sum_{j=1}^{m} \frac{f_j^i x_{ji}}{y_i} \frac{\dot{x}_{ji}}{x_{ji}} \]

where \( f^i = \partial f^i/\partial t, f_k^i = \partial f^i/\partial y_{ki} \) and \( f_j^i = \partial f^i/\partial x_{ji} \). Under the marginal conditions of producer equilibrium, the shifts in production function reduce to the Divisia index for productivity change defined above, i.e.,

\[ \dot{y}_i/y_i = \frac{\dot{T}^i}{T^i} \text{ if } f_k^i = q_k/q_i \text{ and } f_j^i = p_j/q_i. \]

There is another justification for \( \dot{T}^i/T^i \). By using input coefficients (i.e., \( a_{ki} \equiv y_{ki}/y_i \) and \( b_{ji} \equiv x_{ji}/y_i \)), equation (2.2) can be written as

\[ \dot{T}^i/T^i = f^i \]

3) For the Divisia index, see Jorgenson [12], Jorgenson and Griliches [13], Richter [20], etc.
which means the weighted average of the rates of decrease in input coefficients. This is the continuous version of Leontief’s definition on the rate of technical progress in the \(i\)-th industry.\(^4\)

It should be noted here that the above measure of industry productivity change, which we call of the IO basis, allows explicitly for intermediate inputs as production factors. In many cases, however, the industry productivity change or industry technical progress is measured by using real value added and primary factor inputs only. It is obvious that this conventional measure, which we call of the NIS basis, is not an appropriate one, since real value added does not represent quantity of output correctly and the role of intermediate goods is not clear in this measure.\(^5\)

Let us next consider the aggregate productivity change for the national economy as a whole. For the purpose of aggregation, we employ the following definitions of aggregate variables:

\[
(2.7) \quad U_k = \sum_{i=1}^{n} y_{ki} \quad \text{(total intermediate input of good \(k\))}
\]

\[
(2.8) \quad X_j = \sum_{i=1}^{n} x_{jt} \quad \text{(total primary input of factor \(j\))}
\]

\[
(2.9) \quad Y_t = y_t - U_t \quad \text{(output \(i\) delivered to final demands)}.
\]

Then, using equation (2.1), we get

\[
(2.10) \quad \sum_{i=1}^{n} q_i y_i = \sum_{i=1}^{n} q_i U_t + \sum_{j=1}^{m} p_j X_j
\]

\[
(2.11) \quad \sum_{i=1}^{n} q_i Y_t = \sum_{j=1}^{m} p_j X_j
\]

which are the aggregate identities for total economy.

The best way to define the aggregate productivity change \(\dot{T}/\bar{T}\) is to take weighted average of the industry productivity changes \(\dot{T}_i/\bar{T}_i\) with output share of each industry as weight:

\[
(2.12) \quad \overline{\dot{T}} = \sum_{i=1}^{n} \frac{q_i y_i}{q_i y_i} \cdot \dot{T}_i/\bar{T}_i.
\]

We can justify this measure theoretically based on the aggregate production function:

\[
(2.13) \quad F(Y_1 \ldots Y_n, X_1 \ldots X_m; t) = 0.
\]

It is natural to interpret equation (2.13) as the production possibility frontier derived from individual industry production functions (equation (2.3)) allowing for accounting constraints (equations (2.7)–(2.9)). Then, we can prove\(^6\)

\[^4\] Leontief et al. [15], pp. 31–35.

\[^5\] As the referee points out, the net production function will be an appropriate analytical basis for the measurement of productivity change if the gross production function (2.3) is Hicks-neutral and, at the same time, separable between intermediate inputs and primary factors. The real world, however, is not always the world of Hicks-neutral technological change (See Section 3), and the separability restrictions are not always satisfied.

\[^6\] Consider the following mathematical problem of sectoral aggregation:

Maximize \(Y_t\)

with respect to \(Y_t, y_{ki}, x_{jt}, y_t, y_t, y_t\) and \(U_k\)

subject to the constraints

\[
y_i = f(y_{1i} \ldots y_{ni}, x_{1i} \ldots x_{mi}, t) \quad (i = 1 \ldots n)
\]

\[
U_k = \sum_{i=1}^{n} y_{ki} \quad (k = 1 \ldots n)
\]

\[
Y_t = y_t - U_t \quad (i = 1 \ldots n)
\]

and

\[
X_j = \sum_{i=1}^{m} x_{jt} \quad (j = 1 \ldots m)
\]

under the given parameters \(Y_2 \ldots Y_n, X_1 \ldots X_m\) and \(t\).
The Economic Studies Quarterly  Vol. XXIX, No. 3

(2.14) \[ F_t = - \sum_{i=1}^{n} F_i y_i \cdot (f'/f') \] where \( F_t = \partial F/\partial t \) and \( F_i = \partial F/\partial Y_i \), so that the best way to define the shifts in aggregate production function (2.13) is to take weighted average of the shifts in individual industry production functions (2.3):

(2.15) \[ HF_t \equiv \sum_{i=1}^{n} \frac{F_i y_i}{F_i y_i} \cdot \frac{f'_t}{f'_t} \] where \( 1/H = -\Sigma F_i y_i \).

When all of the marginal conditions hold, the shifts in aggregate production function reduce to the aggregate productivity change defined above7):

(2.16) \[ \dot{T}/T = HF_t \quad \text{if} \quad F_i/F_k = q_i/q_k, \text{etc.} \]

The aggregate productivity change defined in (2.12) can be transformed into another useful expression:

(2.17) \[ \dot{T}/T = \dot{y}/y - (1 - \theta) \cdot \frac{\dot{U}}{U} - \theta \cdot \frac{\dot{X}}{X} \]

where

\[ \theta = \Sigma p_j X_j/\Sigma q_i Y_i = \Sigma q_i Y_i/\Sigma q_i Y_i \] (value added ratio)

\[ (1 - \theta) = \Sigma q_i U_i/\Sigma q_i U_i \] (intermediate input ratio)

\[ \dot{y}/y = \Sigma (q_i y_i/\Sigma q_i y_i) \cdot (\dot{y}/y) \] (Divisia quantity)

\[ \dot{U}/U = \Sigma (q_i U_i/\Sigma q_i U_i) \cdot (\dot{U}/U) \] (Divisia quantity)

\[ \dot{X}/X = \Sigma (p_j X_j/\Sigma p_j X_j) \cdot (\dot{X}/X) \] (Divisia quantity)

This indicates that \( \dot{T}/T \) is identical with the Divisia index for productivity change derived from identity (2.10). It should again be noted that, as in the case of industry productivity change, the aggregate productivity change is defined in such a way as to allow explicitly for intermediate inputs as production factors. We call \( \dot{T}/T \) as the measure of the IO basis.

The conventional way of measuring the aggregate productivity change (\( \dot{P}/P \)), which we call

In this problem of constrained maximization, the Lagrangean function is

\[ L = Y_1 + \sum_{i=1}^{n} \xi_i (y_i - f'(y_1t \ldots y_{kt} \ldots y_{mt}, x_{1t} \ldots x_{jt} \ldots x_{mt}, t)) \]

\[ + \sum_{k=1}^{m} \eta_k (U_k - \sum x_{kt}) + \sum_{i=1}^{n} \lambda_i (y_i - U_i - Y_i) + \sum_{j=1}^{m} \mu_j (X_j - \sum x_{jt}) \]

and the first order conditions for maximization become

\[ 1 - \lambda_1 = 0 \]

\[ \xi_i \partial f'/\partial y_{kt} - \eta_k = 0 \quad (i = 1 \ldots n, k = 1 \ldots m) \]

\[ \zeta_i + \lambda_i = 0 \quad (i = 1 \ldots n) \]

\[ \eta_k - \lambda_k = 0 \quad (k = 1 \ldots n). \]

These first order conditions, together with the constraints of the present maximization problem, determine the maximized value of \( Y_1 \) in terms of the given parameters:

\[ Y_1 = f(Y_2 \ldots Y_n, X_1 \ldots X_m, t) \]

which, when written in the form of implicit function, gives the economy's net production frontier (2.13). Furthermore, from the properties of Lagrangean multipliers, we get

\[ \partial Y_1/\partial Y_i = -\lambda_i \quad (i = 2 \ldots n) \] and \[ \partial Y_1/\partial t = -\sum_{i=1}^{n} \xi_i f'_i \]

so that, using the first order conditions, we can derive

\[ F_t = -F_1 \cdot (\partial Y_1/\partial t) = +F_1 \cdot \sum_{i=1}^{n} \xi_i f'_i = -F_1 \cdot \sum_{i=1}^{n} \lambda_i f'_i \]

\[ = -F_1 \cdot \lambda_i f'_i + \sum_{i=1}^{n} F_1 \cdot (\partial Y_1/\partial Y_i)f'_i = -F_1 \cdot f'_i + \sum_{i=1}^{n} (-F_i f'_i) \]

\[ = -\sum F_i y_i \cdot (f'/f'_i) \quad \text{where} \quad F_i = \partial F/\partial Y_i \quad (i = 1 \ldots n). \]

7) Compare our justification of \( \dot{T}/T \) with the justification of \( \dot{P}/P \) by Jorgenson and Griliches [13].
as the measure of the NIS basis, is based on the Divisia index derived from the accounting identity (2.11):

\[
\frac{\dot{P}}{\dot{P}} = \frac{\dot{Y}}{\dot{Y}} - \frac{\dot{X}}{\dot{X}} = \sum \frac{q_i Y_i}{\sum q_i Y_i} \cdot \frac{\dot{Y}_i}{\dot{Y}_i} - \sum \frac{p_i X_i}{\sum p_i X_i} \cdot \frac{\dot{X}_i}{\dot{X}_i}.
\]

The relationship between our measure of the IO basis and the conventional measure of the NIS basis can easily be proved to be

\[
\frac{\dot{P}}{\dot{P}} = \frac{1}{\theta} \cdot \frac{\dot{T}}{\dot{T}} = \sum \frac{q_i Y_i}{\sum q_i Y_i} \cdot \frac{\dot{T}_i}{\dot{T}_i}
\]

which is simple but quite interesting since it reveals that \(\dot{P}/\dot{P}\) is a weighted sum but not a weighted average of the components industry productivity changes (\(\dot{T}/\dot{T}\)).

It must be noted that the industry productivity change (\(\dot{P}/\dot{P}\)) which corresponds directly to the aggregate one (\(\dot{P}/\dot{P}\)) is

\[
\frac{\dot{P}}{\dot{P}} = \frac{(y_t - y_{n})}{(y_t - y_{n})} \left( \sum_{k=1}^{n} \frac{q_k y_{k} y_k}{q_k (y_t - y_{n})} \cdot \frac{\dot{y}_k}{\dot{y}_k} + \sum_{j=1}^{n} \frac{p_j x_{j} x_{j}}{p_j (y_t - y_{n})} \cdot \frac{\dot{x}_j}{\dot{x}_j} \right),
\]

but not the conventional measure of the NIS basis mentioned before. Both measures (\(P\) and \(P\)) are derived from a common principle in defining sectoral output in the net sense:

- "net" output of a sector
  - total output (gross output) of the sector
  - output of the sector used as input of the sector.

This principle can be applied consistently to any level of sectoral aggregation, i.e., whether the sector in question is an individual industry or the aggregate national economy taken as a whole. In this situation, an appropriate "net" production function is assumed independently in each level of sectoral aggregation so that, except for the above principle, there exist no definite relations between industry production functions (or productivity changes) and aggregate ones such as equation (2.15) or (2.12). It is the view of the author that the output of a sector used as input in that sector, which is nothing but the intermediate input in the case of aggregate national economy, should be treated as a production factor in the measurement of productivity change.

**Measurement: 1955–59 and 1960–70.**

Let us apply our theoretical framework briefly outlined above to the actual Japanese data. We employ two sets of input-output tables for which the data at both current and constant prices are available: the 1955 and 1959 tables of Ministry of International Trade and Industry [16] and the 1969 and 1970 tables of Administrative Management Agency et al. [2]. The 1965 table, which is also available at both current and constant prices, is not used since the year 1965 belongs to a recession period. The four years under present consideration are all in boom periods.

It must be noted that the 1955 and 1959 tables distinguish between competitive and non-competitive...
tive imports while the 1960 and 1970 tables regard all imports as competitive, so that comparisons between the 1955–59 and the 1960–70 periods are not always direct. The results of measurement are presented in Tables 1 and 2 for industries of major division and total economy, and in Tables 3 and 4 for components industries of manufacturing sector (See Appendix for the data sources of primary factor inputs). We can find from these four tables several interesting facts on the growth performance of postwar Japanese economy, which are summarized and discussed one by one below.

(i) For total economy (Tables 1 and 2), contributions to output growth of each production factor and productivity are calculated as:

<table>
<thead>
<tr>
<th>Productivity growth</th>
<th>Intermediate inputs</th>
<th>Labor inputs</th>
<th>Capital inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955–59: 1.9%</td>
<td>62%</td>
<td>4%</td>
<td>19%</td>
</tr>
<tr>
<td>1960–70: 1.7%</td>
<td>58%</td>
<td>5%</td>
<td>22%</td>
</tr>
</tbody>
</table>

A remarkable fact found in this calculation is that a considerable portion (85%) of output growth can be explained by the growth of various inputs making small the role of productivity increase or so-called “residuals.”

According to the results transformed into the NIS basis, on the other hand, the portion of output growth (i.e., growth of real GNP) explained by input growth (i.e., growth of labor and capital inputs) becomes 62% or 65% which is in a comparable level with other studies.

(ii) The rate of productivity increase equals the weighted average of the rates of decrease in input coefficients with value share of each input as weight (See equation (2.6)). For total economy, we can rewrite the results of Tables 1 and 2 as follows on the basis of this relationship:

<table>
<thead>
<tr>
<th>Productivity growth</th>
<th>Intermediate inputs</th>
<th>Labor inputs</th>
<th>Capital inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955–59: 1.9%</td>
<td>$-.555 \times (14.1 - 12.7)$</td>
<td>$-.231 \times (2.4 - 12.7)$</td>
<td>$-.214 \times (11.7 - 12.7)$</td>
</tr>
<tr>
<td></td>
<td>$[-0.8%]$</td>
<td>$[+2.4%]$</td>
<td>$[-0.2%]$</td>
</tr>
<tr>
<td>1960–70: 1.7%</td>
<td>$-.543 \times (12.0 - 11.2)$</td>
<td>$-.242 \times (2.4 - 11.2)$</td>
<td>$-.214 \times (11.7 - 11.2)$</td>
</tr>
<tr>
<td></td>
<td>$[-0.4%]$</td>
<td>$[+2.1%]$</td>
<td>$[-0.1%]$</td>
</tr>
</tbody>
</table>

This decomposition indicates that the productivity increase in total economy is exclusively dependent on the decrease in labor coefficient which probably can be identified with the labor-saving technical progress.

(iii) Comparison between the latter half of 1950's (Table 1) and the 1960's (Table 2) indicates a uniform productivity growth or technical progress for the aggregate national economy.

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11) Similar results are obtained for most of the aggregate industries with primary (agriculture, forestry and fisheries) and mining industries as the exceptions. A large productivity decrease (−6.6%) in construction for the 1955–59 period is caused by an abnormally rapid increase in inventory stocks (50% annually!) in that sector.

12) The result is consistent with those derived directly from national income statistics (Ezaki [8], Table 2.16).

13) See the analyses of Section 3 (though the measurement there is provided for the manufacturing industries only).
Table 1  Growth Accounting from the Input Side: 1955–59*

<table>
<thead>
<tr>
<th>Industries</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
<th>( \hat{y}_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Agriculture, forestry &amp; fishery</td>
<td>2.1 = .369 x 13.2</td>
<td>+ .375 x (-3.4)</td>
<td>+ .038 x 8.1</td>
<td>+ .011 x 12.3</td>
<td>+ .207 x 0.5</td>
<td>+ [-2.0]</td>
<td></td>
</tr>
<tr>
<td>2. Mining</td>
<td>5.5 = .342 x (-2.7)</td>
<td>+ .423 x 4.9</td>
<td>+ .201 x 8.1</td>
<td>+ .043 x 7.3</td>
<td>+ [2.5]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Manufacturing</td>
<td>13.6 = .723 x 13.3</td>
<td>+ .119 x 3.0</td>
<td>+ .100 x 17.4</td>
<td>+ .059 x 18.9</td>
<td>+ [0.8]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Construction</td>
<td>14.8 = .659 x 20.6</td>
<td>+ .194 x 6.7</td>
<td>+ .031 x 20.6</td>
<td>+ .116 x 50.7</td>
<td>+ [-6.6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Others</td>
<td>15.5 = .434 x 15.1</td>
<td>+ .314 x 3.9</td>
<td>+ .168 x 8.3</td>
<td>+ .033 x 9.7</td>
<td>+ .052 x 8.6</td>
<td>+ [5.6]</td>
<td></td>
</tr>
</tbody>
</table>

Total economy (Divisia aggregation)

<table>
<thead>
<tr>
<th>( \hat{y} )</th>
<th>( \hat{y} )</th>
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<th>( \hat{y} )</th>
<th>( \hat{y} )</th>
<th>( \hat{y} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7 = .555 x 14.1</td>
<td>+ .231 x 2.4</td>
<td>+ .122 x 11.1</td>
<td>+ .054 x 17.1</td>
<td>+ .019 x 8.6</td>
<td>+ .019 x 0.5</td>
<td>+ [1.9]</td>
</tr>
</tbody>
</table>

Total economy (NIS base) (Divisia aggregation)

<table>
<thead>
<tr>
<th>( \hat{y} )</th>
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<th>( \hat{y} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.0 = .520 x 2.4</td>
<td>+ .275 x 11.1</td>
<td>+ .121 x 17.1</td>
<td>+ .042 x 8.6</td>
<td>+ .042 x 8.6</td>
<td>+ .042 x 0.5</td>
<td>+ [4.2]</td>
</tr>
</tbody>
</table>

* Based on real IO tables at constant 1955 prices. Note that growth rates of capital stocks here are average annual compound rates for 1955–60. See text for notations other than the following:

- \( U_i \) = Divisia aggregation of intermediate inputs; \( L_i \) = labor inputs adjusted by working hours; \( K_{Di} \) = stocks of producers’ durables (reproducible tangible fixed assets); \( K_{Hi} \) = inventory stocks; \( K_{Ri} \) = residential stocks; \( K_{Si} \) = agricultural land area; \( \omega_{Li} \), \( \omega_{KD} \), \( \omega_{KJ} \), \( \omega_{KR} \), \( \omega_{KS} \) = shares in value added; \( \theta_i \) = value added ratio; Variable without subscript \( i \) = quantity (Divisia aggregation) or share for total economy.

(N.B. \( \hat{y}_i \) = \( \sum (q_k y_{ki} / \Sigma q_k y_{ki}) \cdot (\hat{y}_{ki} / y_{ki}) \) and \( \omega_{Di} + \omega_{KD} + \omega_{KJ} + \omega_{KR} + \omega_{KSi} = 1 \)).
### Table 2: Growth Accounting from the Input Side: 1960-70

<table>
<thead>
<tr>
<th>Industries</th>
<th>( \Delta y_i = (1 - \theta) \Delta y_i )</th>
<th>( \omega x_i \cdot \Delta y_i )</th>
<th>( \omega x_i \cdot \Delta y_i - \delta x_i \cdot \Delta y_i )</th>
<th>( \omega x_i \cdot \Delta y_i - \delta x_i \cdot \Delta y_i + \omega x_i \cdot \Delta y_i )</th>
<th>( \Delta y_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Agriculture, forestry &amp; fishing</td>
<td>1.7 = 348 × 5.3 + 439 × 9.1 + 215 × 2.0 + 509 × 8.9 + 164 × 0.9</td>
<td>-0.1</td>
<td>-1.2</td>
<td>-0.9</td>
<td>-0.1</td>
</tr>
<tr>
<td>2. Mining</td>
<td>8.2 = 339 × 6.5 + 387 × 2.9 + 107 × 13.5 + 508 × 9.3</td>
<td>1.5</td>
<td>1.8</td>
<td>[0.1]</td>
<td>[1.2]</td>
</tr>
<tr>
<td>3. Manufacturing</td>
<td>12.8 = 653 × 13.5 + 207 × 3.4 + 501 × 26.8 + 809 × 9.3</td>
<td>0.4</td>
<td>0.6</td>
<td>[0.4]</td>
<td>[1.2]</td>
</tr>
<tr>
<td>4. Construction</td>
<td>10.6 = 34 × 12.0 + 187 × 3.1</td>
<td>0.7</td>
<td>0.8</td>
<td>[0.8]</td>
<td>[2.9]</td>
</tr>
<tr>
<td>5. Electricity, gas &amp; water</td>
<td>11.9 = 231 × 14.8 + 388 × 3.6</td>
<td>1.4</td>
<td>2.9</td>
<td>[1.3]</td>
<td>[3.1]</td>
</tr>
<tr>
<td>6. Commerce, finance, real estate &amp; communication</td>
<td>11.1 = 312 × 9.0 + 283 × 13.2</td>
<td>1.5</td>
<td>0.8</td>
<td>[1.3]</td>
<td>[3.1]</td>
</tr>
<tr>
<td>7. Transportation &amp; communication</td>
<td>7.9 = 378 × 11.0 + 403 × 3.5</td>
<td>0.4</td>
<td>0.2</td>
<td>[0.2]</td>
<td>[0.4]</td>
</tr>
<tr>
<td>8. Services &amp; other</td>
<td>Total economy (NIS base)</td>
<td>( \Delta y = (1 - \theta) \Delta y_i )</td>
<td>( \omega x_i \cdot \Delta y_i )</td>
<td>( \omega x_i \cdot \Delta y_i - \delta x_i \cdot \Delta y_i )</td>
<td>( \Delta y_i )</td>
</tr>
<tr>
<td></td>
<td>10.2 = 348 × 12.0 + 242 × 2.4</td>
<td>0.6</td>
<td>0.4</td>
<td>[0.2]</td>
<td>[0.4]</td>
</tr>
</tbody>
</table>

- Based on real IO tables at constant 1970 prices. See text and footnote to Table 1 for notations.
The accelerated growth of productivity in agriculture, mining, manufacturing and construction industries seems to be cancelled out by the decelerated growth of productivity in other industries, resulting in the uniform productivity growth for total economy (though the measurement on "other" industries may not be reliable since measurement errors are liable to concentrate on the industries classified as others). Furthermore, the result of the NIS basis is far from the trend acceleration showing even a trend deceleration for the aggregate economy. It is almost certain that, as far as the growth accounting is made on the basis of the GNP or national income statistics data averaging individual industries in the national economy, we cannot observe an explicit tendency of acceleration in productivity growth between the 1950's and the 1960's.\(^{14}\)

Whether productivity growth (i.e., technical progress) accelerated or not is closely related to whether the catching-up process based on imported technology began at the end of the 1950's (Sato [21]) or before than that (e.g., Ohkawa and Rosovsky [19]), so that observations on the manufacturing industries may be more relevant than those on total economy (or non-primary sector). Our observations on the manufacturing sector in Tables 1 and 2 clearly show the acceleration tendency in productivity growth around the end of the 1950's.

(iv) For the manufacturing sector as a whole (Tables 1 and 2 or Tables 3 and 4), we get almost the same observations as those for total economy discussed in (i) and (ii) above, except for the fact that capital coefficients show slight increases. It can be said that technical progress in the manufacturing sector, on the average, was of intermediate-goods-neutral, labor-saving and capital-using nature during the two periods (See Section 3 for detailed analyses).

(v) For components industries of the manufacturing sector (Tables 3 and 4), we observe high rates of productivity growth in rapidly growing industries (many of which belong to the heavy industry) while low rates of productivity growth in stagnant industries (many of which are in the light industry). A considerable positive correlation can be found between output growth and productivity growth from Figure 1 where each industry is plotted along the two axes denoting growth rates of output and productivity (i.e., \(\dot{y}_i/y_i\) and \(\dot{T}_i/T_i\)) respectively. Furthermore, the higher the rate of productivity growth, the greater its contribution to output growth, because \((\dot{T}_i/T_i)/(\dot{y}_i/y_i)\) is measured by the slope of the line connecting between origin and each plotted point in Figure 1. It should be noted that the regression line cuts off the horizontal axis at around 6–9% of output growth.\(^{15}\) This level may be considered to be a break-even point for output growth (i.e., demand growth) below which productivity growth cannot be sustained, resulting in the relative decrease in average input price \((p_i)\) compared to output price \((q_i)\), because productivity

---

\(^{14}\) Check the results obtained in Ezaki [8, Table 2.16] and Denison and Chung [4, Table 4-6], both of which deal with the highly aggregated national economy based on the national income statistics data.

\(^{15}\) The OLS method applied to Figure 1 gives:

\[
\begin{align*}
1955-59: & \quad \frac{T_i}{T_i} = -2.109 + .228\frac{y_i}{y_i}, \quad R^2 = .685 \\
 & \quad (1.304) \quad (.076) \\
1960-70: & \quad \frac{T_i}{T_i} = -2.041 + .317\frac{y_i}{y_i}, \quad R^2 = .754 \\
 & \quad (1.112) \quad (.080)
\end{align*}
\]

where standard errors are shown in parentheses.
### Table 3  Growth Accounting from the Input Side
(Manufacturing Industries): 1955–59*

(% at annual compound rate)

<table>
<thead>
<tr>
<th>Industries</th>
<th>( \frac{\dot{y}<em>i}{y_i} = (1 - \theta_i) \cdot \frac{\dot{U}<em>i}{U_i} + \theta_i \omega</em>{Li} \cdot \frac{L_i}{L_i} + \theta_i \omega</em>{KDi} \cdot \frac{K_{Di}}{K_{Di}} + \theta_i \omega_{KII} \cdot \frac{K_{II}}{K_{II}} + \frac{\dot{P}_i}{P_i} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Food manufacturing</td>
<td>6.3 = .612 \times 4.7 [2.9] + .099 \times (-0.3) [-0.0] + .176 \times 11.1 [2.0] + .113 \times 12.0 [1.4] + [0.1]</td>
</tr>
<tr>
<td>2. Spinning (yarns)</td>
<td>9.2 = .769 \times 8.1 [6.2] + .112 \times (-3.9) [-0.4] + .072 \times 4.0 [0.3] + .046 \times 8.4 [0.4] + [2.8]</td>
</tr>
<tr>
<td>3. Weaving &amp; others</td>
<td>7.8 = .839 \times 8.3 [6.9] + .131 \times (-1.9) [-0.3] + .015 \times 21.5 [0.3] + .016 \times 29.2 [0.5] + [0.3]</td>
</tr>
<tr>
<td>4. Wood products&lt;sup&gt;a)&lt;/sup&gt;</td>
<td>4.0 = .748 \times 4.9 [3.7] + .175 \times 1.0 [0.2] + .048 \times 4.5 [0.2] + .029 \times 4.9 [0.1] + [0.2]</td>
</tr>
<tr>
<td>5. Pulp &amp; paper</td>
<td>13.5 = .748 \times 13.3 [9.9] + .135 \times 2.5 [0.3] + .092 \times 26.4 [2.4] + .025 \times 16.9 [0.4] + [0.4]</td>
</tr>
<tr>
<td>6. Miscellaneous&lt;sup&gt;b)&lt;/sup&gt;</td>
<td>14.0 = .645 \times 14.5 [9.4] + .220 \times 3.5 [0.8] + .070 \times 16.1 [1.1] + .065 \times 17.8 [1.2] + [1.6]</td>
</tr>
<tr>
<td>7. Chemicals</td>
<td>14.6 = .760 \times 11.9 [9.1] + .085 \times (-1.8) [-0.2] + .111 \times 20.9 [2.3] + .044 \times 18.3 [0.8] + [2.5]</td>
</tr>
<tr>
<td>8. Petroleum &amp; coal products</td>
<td>19.8 = .720 \times 16.0 [11.5] + .019 \times (-6.2) [-0.1] + .196 \times 12.9 [2.5] + .065 \times 23.3 [1.5] + [4.4]</td>
</tr>
<tr>
<td>9. Non-metallic minerals</td>
<td>15.0 = .593 \times 13.5 [8.0] + .207 \times 2.3 [0.5] + .169 \times 29.3 [5.0] + .031 \times 22.6 [0.7] + [0.9]</td>
</tr>
<tr>
<td>10. Basic metals</td>
<td>16.6 = .838 \times 17.8 [14.9] + .059 \times 3.8 [0.2] + .072 \times 22.4 [1.6] + .032 \times 27.3 [0.9] + [-1.0]</td>
</tr>
<tr>
<td>11. Metal products</td>
<td>13.3 = .620 \times 16.0 [9.9] + .255 \times 8.4 [2.1] + .076 \times 25.0 [1.9] + .049 \times 22.5 [1.1] + [0.2]</td>
</tr>
<tr>
<td>13. Electric machinery</td>
<td>35.3 = .628 \times 38.0 [23.9] + .176 \times 18.2 [3.2] + .098 \times 24.2 [2.4] + .098 \times 29.4 [2.9] + [3.0]</td>
</tr>
<tr>
<td>14. Transp. equipments</td>
<td>23.7 = .695 \times 21.6 [15.0] + .172 \times 3.8 [0.7] + .068 \times 19.7 [1.3] + .066 \times 19.5 [1.3] + [5.5]</td>
</tr>
<tr>
<td>15. Precision machin.</td>
<td>16.0 = .566 \times 12.5 [7.0] + .239 \times 8.8 [2.1] + .122 \times 22.8 [2.8] + .037 \times 17.0 [1.2] + [2.8]</td>
</tr>
</tbody>
</table>

| Total manufacturing<sup>c)</sup>    | 13.0 = .723 \times 12.6 [9.1] + .119 \times 2.6 [0.3] + .100 \times 15.8 [1.6] + .059 \times 17.3 [1.0] + [1.0] |

* Based on real IO tables at constant 1955 prices. See text and footnote to Table 1 for notations.

<sup>a)</sup> Including furniture.

<sup>b)</sup> Consisting of printing & publishing, leather & leather products, rubber products, and other manufacturing industries.

<sup>c)</sup> Divisia aggregation.
<table>
<thead>
<tr>
<th>Industries</th>
<th>( \frac{\dot{y}<em>I}{y_I} = (1 - \theta_I) \cdot \frac{U</em>{Li}^*}{U_{Li}} + \theta_I \omega_{LI} \cdot \frac{L_{ki}}{L_{ki}} + \theta_I \omega_{KD_i} \cdot \frac{\dot{K}<em>{DI}}{K</em>{DI}} + \theta_I \omega_{KJ_i} \cdot \frac{\dot{K}<em>{IJ_i}}{K</em>{IJ_i}} + \frac{T_I}{T_I} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Food manufacturing</td>
<td>5.5 = .732 × 5.2 [3.8] + .078 × 0.2 [0.0] + .112 × 13.5 [1.5] + .078 × 13.8 [1.1] + [-0.9]</td>
</tr>
<tr>
<td>2. Spinning (yarns)</td>
<td>3.5 = .744 × 4.4 [3.3] + .139 × (-3.9) [-0.5] + .073 × 6.8 [0.5] + .045 × 5.0 [0.2] + [0.1]</td>
</tr>
<tr>
<td>3. Weaving &amp; others</td>
<td>7.8 = .757 × 8.1 [6.1] + .199 × 2.0 [0.4] + .021 × 18.3 [0.4] + .023 × 15.5 [0.4] + [0.5]</td>
</tr>
<tr>
<td>4. Wood products</td>
<td>8.5 = .771 × 7.3 [5.7] + .154 × 1.3 [0.2] + .043 × 6.9 [0.3] + .032 × 7.6 [0.2] + [2.1]</td>
</tr>
<tr>
<td>5. Furniture</td>
<td>14.1 = .650 × 17.9 [11.7] + .273 × 3.4 [0.9] + .052 × 20.7 [1.1] + .025 × 24.9 [0.6] + [-0.2]</td>
</tr>
<tr>
<td>6. Pulp and paper</td>
<td>12.2 = .744 × 11.4 [8.5] + .129 × 2.5 [0.3] + .101 × 9.2 [0.9] + .026 × 6.7 [0.2] + [2.3]</td>
</tr>
<tr>
<td>7. Printing &amp; publishing</td>
<td>15.6 = .535 × 13.5 [7.2] + .290 × 3.9 [1.1] + .116 × 13.4 [1.6] + .059 × 0.7 [0.0] + [5.6]</td>
</tr>
<tr>
<td>8. Leather &amp; its products</td>
<td>7.8 = .764 × 10.1 [7.7] + .193 × 2.1 [0.4] + .021 × 15.1 [0.3] + .023 × 12.9 [0.3] + [-1.0]</td>
</tr>
<tr>
<td>9. Rubber products</td>
<td>11.6 = .673 × 10.9 [7.3] + .203 × 2.7 [0.6] + .085 × 15.0 [1.3] + .040 × 8.6 [0.3] + [2.1]</td>
</tr>
<tr>
<td>10. Chemical products</td>
<td>15.9 = .680 × 12.5 [8.5] + .103 × 1.7 [0.2] + .159 × 12.8 [2.0] + .058 × 9.8 [0.6] + [4.7]</td>
</tr>
<tr>
<td>12. Non-metallic mineral products</td>
<td>15.0 = .591 × 15.0 [8.9] + .205 × 3.1 [0.6] + .166 × 10.2 [1.7] + .038 × 13.1 [0.5] + [3.3]</td>
</tr>
<tr>
<td>13. Basic metals</td>
<td>14.8 = .803 × 14.3 [11.5] + .067 × 2.1 [0.1] + .093 × 12.6 [1.2] + .036 × 8.8 [0.3] + [1.7]</td>
</tr>
<tr>
<td>14. Metal products</td>
<td>18.5 = .579 × 18.2 [10.6] + .275 × 5.7 [1.6] + .095 × 23.6 [2.3] + .051 × 17.3 [0.9] + [3.2]</td>
</tr>
<tr>
<td>16. Electric machinery</td>
<td>17.6 = .667 × 15.0 [10.0] + .152 × 5.6 [0.9] + .092 × 14.4 [1.3] + .090 × 12.6 [1.1] + [4.3]</td>
</tr>
<tr>
<td>17. Transp. equipments</td>
<td>16.6 = .676 × 16.7 [11.3] + .177 × 5.9 [1.0] + .087 × 17.3 [1.5] + .060 × 8.7 [0.5] + [2.3]</td>
</tr>
<tr>
<td>18. Precision machinery</td>
<td>14.3 = .586 × 14.0 [8.2] + .240 × 4.8 [1.1] + .103 × 10.3 [1.1] + .072 × 12.7 [0.9] + [2.9]</td>
</tr>
<tr>
<td>19. Others</td>
<td>19.9 = .669 × 18.4 [12.3] + .220 × 3.2 [0.7] + .059 × 18.8 [1.1] + .053 × 0.3 [0.0] + [5.8]</td>
</tr>
<tr>
<td><strong>Total manufacturing</strong></td>
<td><strong>13.2 = .700 × 12.3 [8.6] + .139 × 3.1 [0.4] + .104 × 14.5 [1.5] + .057 × 11.9 [0.7] + [2.0]</strong></td>
</tr>
</tbody>
</table>

* Based on real IO tables at constant 1970 prices. See text and footnote to Table 1 for notations.

a) Divisia aggregation.
Fig. 1 Productivity growth versus output growth

Fig. 2 Productivity growth versus price changes
growth can be defined also as $\dot{q}_i/T_i = p_i/q_i - \dot{q}_i$ from the point of view of the dual.\footnote{Note that $p_i$ here is the Divisia price index for input, the growth rate of which is defined as the weighted average of the growth rates of all input prices (i.e., prices of intermediate goods and primary factors) with their input shares as weights.}

(vi) From Figure 2 where each industry is plotted along the two axes denoting growth rates of output price and productivity (i.e., $q_i/T_i$ and $\dot{q}_i/T_i$) respectively, we can find a negative correlation between the two rates especially for the 1960–70 period.\footnote{A similar negative correlation is observed also on the NIS base in Shinohara and Asakawa [22, pp. 41–42].} The OLS method applied to Figure 2 gives the following regression estimates (with standard errors in parentheses):

\[
\begin{align*}
1955–59: \quad & \dot{q}_i/q_i = 1.093 - 0.295\dot{q}_i/T_i, \quad R^2 = 0.124 \\
& (0.804) \quad (0.333) \\
1960–70: \quad & \dot{q}_i/q_i = 3.231 - 0.559\dot{q}_i/T_i, \quad R^2 = 0.713. \\
& (0.520) \quad (0.175)
\end{align*}
\]

If the latter relation, which is significant in both $t$-ratios and $R^2$, is interpreted as showing the average performance of the manufacturing sector in the 1960’s, the coefficient estimate (0.559) roughly indicates that about one half (55.9%) of productivity increase was directed toward pushing down the increase in output prices while the remaining half (44.1%) was used to absorb the increase in input prices (of intermediate goods, labor and capital) during the 1960–70 period.\footnote{This kind of interpretation would be more meaningful when it is applied to each industry based on the time-series data. In any case, it must be noted that the regression relationship shown above cannot be a precise one in general, since it imposes certain restriction(s) on production function when it holds rigorously.}

(vii) Comparisons between the latter half of 1950’s (Table 3) and the 1960’s (Table 4) make it possible to point out two groups of different nature from the point of view of productivity growth. One is a group of light industries such as food, textiles, etc., in which productivity growth is either quite low or in the deceleration tendency. The other is a group of heavy industries such as chemicals, metals, machineries, etc., in which the acceleration in productivity growth is explicit.\footnote{This group, however, has an important exception: the industry of transport equipments, in which motor vehicle industry is dominant in terms of output share (35% in 1960 and 58% in 1970) and followed by steel ship industry (14% in 1960 and 12% in 1970). Reasons are not clear for the deceleration in productivity growth in this sector of transport equipments.}

It may be said, therefore, that the technological catching-up process became more conspicuous in relation to those heavy industries in the 1960’s than in the 1950’s.\footnote{The appropriate analysis of Japanese catching-up process must be made on the basis of the international comparison of productivity between Japan and the United States (i.e., the leader country), as can be seen from the comprehensive work of Abramovitz [1] on the growth potential and its realization for postwar capitalist economies. This important topic is left to the author’s future researches. In this field of study, productivity comparison at the industry level, in particular, seems to be an effective approach and the carefully executed work of Yukizawa [27] will be an indispensable starting point.}

3. Sources of the Changes in Input Coefficients

In the previous section, we have derived a definite relationship between productivity growth and changes in input coefficients (equation (2.6)) and utilized it in interpreting empirical results.
The change in input coefficient is, however, caused by various factors not only of the input side but also of the demand side. Here it is decomposed into three effects only of the input side:

\[
\text{Change in input coefficient} = \text{substitution effect due to changes in input prices (S-effect)} + \text{specific effect due to biased technical progress (B-effect)} - \text{common effect due to neutral technical progress (T-effect)}
\]

Note that the Hicks-neutrality is employed here as the criterion to distinguish between neutral and biased technical inventions. In this section, we will derive the above formula of decomposition under the framework of neoclassical production theory, and apply it to the manufacturing industries to supplement the empirical findings of the previous section.

**Theory: Decomposition of Change in Input Coefficient**

Let us consider again the industry production function of neoclassical type which is used in the previous section (i.e., equation (2.3)). To simplify the notation, however, we drop the subscript \( i \) (to denote industry \( i \)) and do not distinguish notationally between intermediate inputs and primary factor inputs. Then, the first order conditions for cost minimization in the case of producing one unit of output are:

\[
\begin{align*}
(3.1) \quad & f(a_1, \ldots, a_j, \ldots, a_N; t) = 1 \\
(3.2) \quad & \lambda(\partial f/\partial a_j) = p_j \quad (j = 1, \ldots, N)
\end{align*}
\]

where \( a_j \)'s are input coefficients of intermediate goods or primary factors, \( p_j \)'s are corresponding input prices and \( \lambda \) is the Lagrange multiplier. Using these necessary conditions, we can write the optimal input coefficients and the minimized cost (i.e., cost function) as:

\[
\begin{align*}
(3.3) \quad & a_j = a_j(p_1, \ldots, p_N; t) \quad (j = 1, \ldots, N) \\
(3.4) \quad & \lambda = \sum p_j \cdot a_j(p_1, \ldots, p_N; t) = \text{minimized cost}
\end{align*}
\]

From equation (3.3), we get equation (3.5) and then equation (3.6) below:

\[
\begin{align*}
(3.5) \quad & \sum_{k=1}^{N} (\partial a_j/\partial p_k) \cdot dp_k + (\partial a_j/\partial t) \cdot dt \\
(3.6) \quad & \frac{\partial a_j}{a_j} = \sum_{k} (\partial \ln a_j/\partial \ln p_k) \cdot (\hat{p}_k/p_k) + (\partial a_j/\partial t)/a_j
\end{align*}
\]

Introducing Allen’s partial elasticities of substitution (\( \sigma_{jk} \)'s; Allen [3, pp. 502–505]), we can rewrite equation (3.6) as

\[
(3.7) \quad \frac{\partial a_j}{a_j} = \sum_{k} \omega_k \sigma_{jk} \cdot (\hat{p}_k/p_k) + (\partial a_j/\partial t)/a_j
\]

since \( \partial \ln a_j/\partial \ln p_k = \omega_k \sigma_{jk} \) (Allen [3, p. 508]) where \( \omega_k \)'s are input shares.

Equation (3.6) or equation (3.7) indicates that change in input coefficient can be decomposed into the substitution effect (S-effect) and the effect due to technical progress. The latter, however, is further decomposable based on the criterion for the classification of technological inventions proposed by Uzawa and Watanabe [26]:

---

21) Note that \( N \) (number of inputs) = \( n \) (number of intermediate inputs) + \( m \) (number of primary factors).

22) Set \( \phi(p) = 1 \) in the proof given in Allen [3, pp. 506–508]. This means that the effects from the demand side are not allowed for here because of the cost function approach.
(3.8) \( \frac{\partial a_i}{\partial t} / a_j = B_j - f_i / f \) where \( B_j \equiv \frac{\partial a_j}{\partial t} / a_j + f_i / f \)

Note that the technological innovations can be called, from the point of view of the Hicks-neutrality, as:

- \( j \)-saving if \( B_j < 0 \),
- \( j \)-neutral if \( B_j = 0 \),
- \( j \)-using if \( B_j > 0 \).

\( B_j \) represents the effect of biased technical progress specific to input \( j \) (\( B \)-effect) while \( f_i / f \), which reduces to the rate of productivity change in each industry (i.e., \( \dot{T} / T' \) of the previous section), represents the effect (in the negative direction) of neutral technical progress common to every input (\( T \)-effect).

As a result of these decompositions, we get the final formula for the change in input coefficient expressed in terms of the \( S \), \( B \) and \( T \)-effects mentioned above:

\[
\frac{a_j}{a_i} = \sum_k \omega_k \sigma_{jk} \cdot (\hat{p}_{ki} / p_k) + B_j - f_i / f \quad (j = 1 \ldots N).
\]

In this formula, there seems to exist \( N^2 \) partial elasticities of substitution (\( \sigma_{jk} \)'s) and \( N \) coefficients of biased technical progress (\( B_j \)'s). All of the \( \sigma_{jk} \)'s and \( B_j \)'s, however, are not independent because we must allow for \( N(N + 1)/2 \) constraints for \( \sigma_{jk} \)'s and one constraint for \( B_j \)'s:

\[
\begin{align*}
\sigma_{jk} &= \sigma_{kj} \quad (j, k = 1 \ldots N; j \neq k) \\
\sum_j \omega_j \sigma_{jk} &= 0 \quad (k = 1 \ldots N) \\
\sum_j \omega_j B_j &= 0
\end{align*}
\]

When the subscript \( i \) is introduced explicitly to denote industry \( i \), the above formula and constraints will be written as:

\[
\begin{align*}
\frac{a_j}{a_i} &= \sum_{k=1}^{N} \omega_k \sigma_{jk} \cdot (\hat{p}_{ki} / p_k) + B_j - f_i / f \\
\sum_j \omega_j \sigma_{jk} &= 0 \quad (k = 1 \ldots N) \\
\sum_j \omega_j B_j &= 0
\end{align*}
\]


So far has been concerned with the theoretical aspect of decomposition. Our next problem is how to estimate the \( S \) and \( B \)-effects separately (and also the \( T \)-effect if necessary). There are at least three alternatives. The first is to assume a very specific production function of Cobb-Douglas type for each industry. In this case, the \( B \)-effect can be identified with the rate of decrease in input share. The second is to employ a translog production (or cost) function for each industry, provided that the sufficient time-series data are available to estimate it. In this case, the partial elasticities of substitution are directly estimable, making it possible to calculate

23) Note that, though \( f \equiv 1 \) in the present case, \( f \) is introduced explicitly here to indicate the shifts in production function (\( f_i / f \)) clearly (where \( f_i \equiv \theta f / \partial t \) as in the previous section). Formula (3.8) is, of course, valid for the general case where \( f \) takes any positive value.

24) See Allen [3, p. 504] for the constraints (3.10) and (3.11). See equation (15) of Uzawa and Watanabe [26] for the constraint (3.12), which can be proved also by using equations (2.5), (2.6) and (3.11) in this paper.

25) Note that, in equation (3.13), prices of input \( k \) (i.e., \( p_{ki} \)'s) are considered to be different among industries. This is because each input, whether it is a primary factor or an intermediate good, is more or less an aggregation of components inputs. Note also that \( f_i / f \) is replaced by \( \dot{T} / T' \) in equation (3.13).

26) In general, the \( T \)-effect (i.e., \( \dot{T} / T' \)) can be measured independently of the \( S \) and \( B \)-effects as in the previous section.

27) See equation (23) of Uzawa and Watanabe [26].
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the S-effect.28) The third is an extension or a modification of the RAS method, which is employed in the measurement of this section.

The RAS method, developed by Stone and Brown [24] and applied by University of Cambridge [25], assumes a simple relationship (at constant prices) between input coefficient of the base period \((a_{ij}^0)\) and that of the succeeding period \((a_{ij}^1)\):

\[
3.15 \quad a_{ij}^1 = r_j a_{ij}^0 s_i
\]

where \(r_j\) represents row (substitution) effect while \(s_i\) column (fabrication) effect, both of which are considered to be caused by technological changes. When two input-output tables are available (though this is not the case of the original RAS method), \(r_j\) and \(s_i\) will be determined in such a way as to minimize the sum of squared deviations (Johansen [11, p. 80]):

\[
\sum_{ij} (a_{ij}^1 - r_j a_{ij}^0 s_i)^2 \quad \text{or} \quad \sum_{ij} (\ln a_{ij}^1 - \ln a_{ij}^0 - \ln r_j - \ln s_i)^2.
\]

It seems clear that the RAS method has several analytical limitations when we compare equation (3.15) with equation (3.13). First, \(r_j\) is a mixture of the substitution effect due to price changes (our S-effect) and the (substitution) effect due to biased technical progress (our B-effect). Second, \(r_j\) is assumed to be common to every industry. Third, the RAS method is concerned about intermediate inputs only without proper allowance for primary factor inputs,29) resulting in, on the one hand, the neglection of required constraints on parameters (equation (3.14)) and, on the other, the use of insufficient informations to estimate \(s_i\) which can be interpreted as the effect of neutral technical progress in each industry (our T-effect).

The exact treatment based on equation (3.13), however, requires to estimate a huge number of parameters, while the amount of informations contained in an input-output table is limited and only a few input-output tables are available in general. Our proposal, here, is to use the rigorous relationship (3.13), by which the first and third limitations above are cleared, and to regress it on the cross-section data (of input-output tables) assuming the parameter values to be common to each industry under consideration (without allowing for the second limitation above). Then, the equation to be used in regression and the corresponding constraints on parameters can be summarized as

\[
\begin{align*}
3.16 & \quad \left( \frac{d a_{i}}{d a_{i}} + \frac{T'}{T} \right) = \sum_{k=1}^{N} \bar{\sigma}_{jk} \left( \omega_{ki} \cdot \tilde{P}_{ki} \right) + \tilde{B}_j \quad (j = 1 \ldots N) \\
3.17 & \quad \bar{\sigma}_{jk} = \bar{\sigma}_{kj} \quad (j, k = 1 \ldots N; j \neq k), \quad \sum_{j} \tilde{\sigma}_j \bar{\sigma}_{jk} = 0 \quad (k = 1 \ldots N),
\end{align*}
\]

where \(\bar{\sigma}_{jk}\)'s, \(\tilde{B}_j\)'s and \(\tilde{\sigma}_j\)'s are average partial elasticities of substitution, average coefficients of biased technical progress and average input shares, respectively, of the \(M\) industries taken as a whole. Note that the T-effect (i.e., \(T'/T\)) is independently measurable as in the previous section, so that it can be treated as the given data. It is needless to say that \(\tilde{B}_j\) is estimated as the co-

28) An example is the analysis of Japanese rice production by Kako [14], which applies a translog cost function to the time-series data (supplemented by the cross-section ones), trying to find the relative importance of S and B-effects in the changes in factor combination ratio (under a theoretical framework different from the present one).

29) Note that the RAS method was originally developed to estimate the coefficients of intermediate inputs in a succeeding year utilizing the informations on total intermediate outputs (i.e., outputs minus final demands) and total intermediate inputs (i.e., outputs minus values added) for that year.

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efficient of a dummy variable which takes one for input $j$ and zero otherwise.

In this formulation, we still have a considerable number of parameters ($\phi_{jk}$'s and $\beta_j$'s) to be estimated, especially when the number of inputs ($N$) is not small (i.e., $N(N-1)/2$ $\phi_{jk}$'s and $(N-1)\beta_j$'s). Therefore, we deal with here the simplest case of $N = 3$ allowing for three aggregate inputs only: intermediate input, labor input and capital input. Furthermore, we apply equation (3.15) to all or part of the manufacturing industries only, neglecting other industries of the economy, because of the validity in assuming common parameter values throughout industries under consideration. The regression here is based on the weighted least squares method with the product of input share in each industry ($\omega_{ji}$) and output share of each industry ($\omega_i$) as weight.30)

The results of estimation are presented in Tables 5 and 6 for the two periods of 1955–59 and 1960–70 respectively. The data sources are completely the same as in Tables 3 and 4. However, it should be noted that the data on the service prices of labor and capital for the 1955–59 period are estimated indirectly,31) resulting perhaps in less reliable measurement for that period (Table 5) than for the 1960–70 (Table 6). In Tables 5 and 6, regression estimates are shown for three sets of manufacturing industries: total manufacturing industry, heavy industry (chemicals, metals and machineries), and other manufacturing industry.32) There also are shown average price elasticities ($\bar{E}_{jk}$'s) and average substitution effects ($\bar{S}_j$'s) which are computed by

$$\bar{E}_{jk} = \bar{c}_k \phi_{jk} \quad \text{and} \quad \bar{S}_j = \sum_k \bar{E}_{jk} \cdot \bar{p}_k / \bar{p}_k$$

where $E_{jk}$ is defined as $\ln a_{ij} / \ln p_{ki}$ and $\bar{p}_k$ is the average price of input $k$ in each of the three sets of manufacturing industries.

From the two tables, we can derive several interesting facts on the sources and natures of the changes in input coefficients for the manufacturing industries (in the average sense). First, technological innovations in both periods were intermediate-goods-neutral, labor-saving and capital-using in nature. (Check signs and standard errors of $\beta_j$'s.) Second, the substitution effects due to price changes were as important as the effects due to biased technical progress especially for the 1960's. (Compare levels of $\bar{S}_j$'s with those of $\beta_j$'s.) Third, the biased technical progress leveled down while the substitution effects increased between the two periods. (Compare levels of $\beta_j$'s and $\bar{S}_j$'s between Tables 5 and 6.) Fourth, intermediate inputs were competitive with primary factors while primary factors (capital and labor) were complementary with each other in both periods, though the latter complementary relationship cannot be stressed too much.33) (Check signs of $\phi_{jk}$'s or $\bar{E}_{jk}$'s.) These fact findings are based mainly on the observations on total manufacturing industry. They are, however, still valid with only a few exceptions on the more

30) The OLS method is applied to the following linear stochastic model:

$$\delta \omega_{ji} = \delta \omega_i F_i + \gamma_i + \frac{1}{T} \sum_{i=1}^N \phi_{jk} \delta \omega_{jki} \cdot \frac{\bar{p}_{ki}}{p_{ki}} + \delta \omega_j \beta_j$$

where certain proper parameters are substituted by the solutions of the linear constraints (3.17) in the actual regression.

31) See Appendix of this paper.

32) The heavy industry here consists of eight components industries (10), (11), (13), (14), (15), (16), (17) and (18) in Table 4.

33) See Table 7 which shows a negative but a small and insignificant estimate of $\phi_{LK}$ or $\bar{E}_{LK}$ for the 1960–70 period.
## Table 5  Regression Estimates (Manufacturing Industries): 1955–59*

<table>
<thead>
<tr>
<th>Total manufacturing</th>
<th>Heavy manufacturing</th>
<th>Other manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>(15 industries)</td>
<td>(8 industries)</td>
<td>(7 industries)</td>
</tr>
<tr>
<td>( \sigma_{jk} )</td>
<td>( \bar{B}_j )</td>
<td>( \sigma_{jk} )</td>
</tr>
<tr>
<td>( U ) .181</td>
<td>.417</td>
<td>( U ) .220</td>
</tr>
<tr>
<td>( L ) -.309</td>
<td>-.1664</td>
<td>( L ) .231</td>
</tr>
<tr>
<td>( K ) .491</td>
<td>-.904</td>
<td>( K ) .747</td>
</tr>
<tr>
<td>( \bar{E}_{jk} )</td>
<td>( \bar{S}_j )</td>
<td>( \bar{E}_{jk} )</td>
</tr>
<tr>
<td>( U ) -.130</td>
<td>.535</td>
<td>( U ) -.153</td>
</tr>
<tr>
<td>( L ) .299</td>
<td>-.039</td>
<td>( L ) .161</td>
</tr>
<tr>
<td>( K ) .352</td>
<td>-.211</td>
<td>( K ) .521</td>
</tr>
</tbody>
</table>

\[ R^2 = .775 \quad S.S. = 45 \quad D.F.M. = 40 \]

\[ R^2 = .763 \quad S.S. = 24 \quad D.F.M. = 19 \]

\[ R^2 = .852 \quad S.S. = 21 \quad D.F.M. = 16 \]

* Based on equation (3.16). See text for notations other than the following subscripts: \( U \) (intermediate input), \( L \) (labor input) and \( K \) (capital input).

Standard errors are shown in parentheses. \( R^2 \) = coefficient of determination. \( S.S. \) = sample size. \( D.F.M. \) = degree of freedom.
<table>
<thead>
<tr>
<th></th>
<th>Total manufacturing (19 industries)</th>
<th>Heavy manufacturing (8 industries)</th>
<th>Other manufacturing (11 industries)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_{jk}$</td>
<td>$\hat{B}_j$</td>
<td>$\sigma_{jk}$</td>
</tr>
<tr>
<td>$U$</td>
<td>$-.335$</td>
<td>$.510$</td>
<td>$1.021$</td>
</tr>
<tr>
<td>$(.026)$</td>
<td></td>
<td>$(.093)$</td>
<td>$(.081)$</td>
</tr>
<tr>
<td>$L$</td>
<td>$.510$</td>
<td>$-1.458$</td>
<td>$-.960$</td>
</tr>
<tr>
<td>$(.093)$</td>
<td></td>
<td>$(.462)$</td>
<td>$(.380)$</td>
</tr>
<tr>
<td>$K$</td>
<td>$1.021$</td>
<td>$-.960$</td>
<td>$-3.616$</td>
</tr>
<tr>
<td>$(.081)$</td>
<td></td>
<td>$(.380)$</td>
<td>$(.428)$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>$.897$</td>
<td></td>
<td>$S.S.$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>$.908$</td>
<td></td>
<td>$S.S.$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\bar{E}_{jk}$</th>
<th>$\bar{S}_j$</th>
<th>$\bar{E}_{jk}$</th>
<th>$\bar{S}_j$</th>
<th>$\bar{E}_{jk}$</th>
<th>$\bar{S}_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U$</td>
<td>$-.235$</td>
<td>$.071$</td>
<td>$1.64$</td>
<td>$.011$</td>
<td>$U$</td>
<td>$.081$</td>
</tr>
<tr>
<td>$L$</td>
<td>$.357$</td>
<td>$-.203$</td>
<td>$-.154$</td>
<td>$-.026$</td>
<td>$L$</td>
<td>$.124$</td>
</tr>
<tr>
<td>$K$</td>
<td>$-.715$</td>
<td>$-.133$</td>
<td>$-.581$</td>
<td>$-.024$</td>
<td>$K$</td>
<td>$.224$</td>
</tr>
</tbody>
</table>

* See footnote to Table 5.
disaggregate basis since coefficient estimates are not very much different between the heavy and
the other industries.

In the above regression, productivity growth in each industry ($\dot{T}_i/T_i$) presented in Tables 3
and 4 is used as the data for the common effect of neutral technical progress in each industry
(our $T$-effect). The $T$-effect, however, can be estimated also under the present regression framework by the following modified regression equation (to be compared with (3.16)):

$$\frac{\tilde{a}_{ij}}{a_{ij}} = \sum_{k=1}^{N} \tilde{a}_{jk} (\omega_{ki} \cdot \tilde{p}_{ki} p_{ki}) + \tilde{B}_j - \tilde{T}_i$$

where $\tilde{T}_i$ is the coefficient of a dummy variable which takes minus one for industry $i$ and zero
otherwise, and corresponds to the $T$-effect of the $i$-th industry. For reference purposes, regression results based on equation (3.18) are summarized in Table 7 only for total manufacturing

<table>
<thead>
<tr>
<th>$\hat{a}_{jk}$</th>
<th>$\tilde{B}_j$</th>
<th>$\tilde{T}_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U$</td>
<td>$-0.232$</td>
<td>$0.006$</td>
</tr>
<tr>
<td>$L$</td>
<td>$0.203$</td>
<td>$-0.102$</td>
</tr>
<tr>
<td>$K$</td>
<td>$0.843$</td>
<td>$-3.578$</td>
</tr>
<tr>
<td>$R^2 = .795$</td>
<td>$S.S. = 57$</td>
<td>$D.F.M. = 33$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\tilde{E}_{jk}$</th>
<th>$\tilde{B}_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U$</td>
<td>$-0.162$</td>
</tr>
<tr>
<td>$L$</td>
<td>$0.142$</td>
</tr>
<tr>
<td>$K$</td>
<td>$0.591$</td>
</tr>
</tbody>
</table>

* Based on equation (3.18). The industry number here is the same as in Table 4. Standard errors are shown in parentheses. See text and footnote to Table 5 for notations.

industry of the 1960–70 period. We can see from Table 7 that most of the coefficient estimates
($\tilde{a}_{jk}$'s, $\tilde{B}_j$'s and $\tilde{T}_i$'s) under this alternative method are in a comparable level with those in Table 6 and Table 4, though standard errors are not small in many cases especially for $\tilde{T}_i$'s. It is needless to say that this alternative method is closer to the RAS method as far as the estimation procedure is concerned.
4. Concluding Remarks

In this paper, we have provided a growth accounting of postwar Japanese economy on the basis of the IO framework using four input-output tables of 1955, 1959, 1960 and 1970, and investigated in detail the growth performance of individual industries as well as of aggregate national economy for the two periods 1955–59 and 1960–70. The growth accounting presented here is the one from the input side in the sense that growth of output(s) is accounted for in terms of growth of various inputs. There exists, however, another important aspect of growth accounting. It is the growth accounting from the demand side where growth of output(s) is accounted for in terms of growth of various demands.34) A more complete analysis of growth performance can be made by the synthesis of both input and demand sides, which will be a major task of the author's subsequent researches.

In this paper, we have also presented a methodological framework for the decomposition of change in input coefficient, and applied it to the same input-output tables in order to provide supplementary evidences with the growth accounting mentioned above. The method developed here has been closely related with the RAS method. On the one hand, our method is an extension of the RAS method in that it makes it possible to distinguish between substitution effect due to price changes and that of biased technical progress. On the other, our method has a limitation in measurement since its exact treatment requires to estimate a huge number of parameters by regression, while only a few input-output tables are available both at current and constant prices. In this paper, utilizing only two such input-output tables (which are in number the necessary minimum) for each of the 1955–59 and 1960–70 periods, we have applied the method to the simplest case of only three aggregate inputs (i.e., intermediate input, labor input and capital input) in the manufacturing industries. The applicational validity of the present method, therefore, must be checked and tested further for more general situations.35) 36)

35) For the 1960–70 period, the method was applied also to the case of ten inputs allowing for intermediate inputs from eight aggregate sectors in addition to labor and capital inputs. In this case, however, many of the coefficient estimates were insignificant, suggesting the need for more informations to get better estimates. It seems certain that the results for the same case will be improved by introducing the 1965 input-output table (if possible), which not only doubles the sample size in regression but also makes it possible to utilize two different kinds of informations contained in the two different periods 1960–65 and 1965–70. Furthermore, if a series of consistent IO tables will become available for, say, 1955, 1960, 1965, 1970 and 1975 (i.e., if consistent informations will become available for, say, 1955–60, 1960–65, 1965–70 and 1970–75 periods), it will be possible to deal with far more general situations, increasing the number of inputs in each industry, on the one hand, and reducing the number of industries for which common parameter values are assumed, on the other.
36) If we are interested only in the average (total) substitution effect without requiring detailed informations on its components, then we can apply regression method to the following simplified equation:

$$\frac{\hat{a}_{iL}}{a_{ji}} + \frac{\hat{p}_i}{p_i} = \hat{S}_j . \hat{P}_i + \hat{B}_j$$

(under the constraints: \(\sum_j \omega_{ji}S_j = 0\) and \(\sum_j \omega_{ji}B_j = 0\))

where \(\frac{p_i}{p_i} \equiv \sum_k \omega_{ki} (p_{ki}/p_{ki}) = \text{Divisia price index for input in industry } i,\)
Appendix. Data Sources for Primary Factor Inputs in Tables 1-4.

Labor Inputs. Quantity of labor input ($L_i$) is the number of workers in each industry available in “Koyo-hyo (Table on Employee)” attached to each input-output table. It is adjusted by average working hours using Chingin Kozo Kihon Tokei Chosa (Basic Statistical Survey of Wage Structure) for non-primary industries and Nohka Keizai Chosa Hokoku (Survey Report on Farm Household Economy) for agriculture, forestry and fisheries. Labor share in value added ($\omega_{Li}$) is the share of labor income which consists not only of wage income available in “Table on Employee” but also of imputed income accruing to self-employed persons and unpaid family workers. In case of the 1960-70 period (i.e., for 1960 and 1970), the latter imputed labor income is estimated by using average daily wages of non-regular employees and average working hours of family workers in Survey Report on Farm Household Economy for agriculture (c.f., Hayami [10, Appendix B]), average estimated family wages in Gyoka Keizai Chosa Hokoku (Survey Report on Fishermen’s Household Economy) for fisheries, and average wages per employee in “Table on Employee” for other industries including forestry. In case of the 1955-59 period, the labor share is assumed to be equal to that of 1960.

Capital Inputs. Quantity of capital service input ($K_i$), which is assumed to be proportional to the level of real capital stocks, is the net assets in each industry available in Kokufu Chosa (National Wealth Surveys) of 1955, 1960 and 1970, deflated by corresponding implicit deflators in Kokumin Shotoku Tokei Nenpo (Annual Report on National Income Statistics). Land as a capital input is explicitly allowed for only in the agricultural sector, while it is assumed to be proportional to the real net assets mentioned above in other sectors. Capital share in value added of each type of assets ($\omega_{Ki},$ etc.) is estimated by prorating total capital income including indirect taxes (i.e., value added other than labor income) to each type of assets on the basis of the nominal values of net assets. That is to say, in each industry, the nominal rate of return is assumed to be common among various types of capital assets. The asset value of agricultural land is the product of land area (i.e., quantity data) in Nogyo Census (Agricultural Census) and average price of ordinary paddy and other fields in “Survey of Real Farm Rent and Price of Farm Land” by Japan Real Estate Institute.

(Kyoto University)

REFERENCES


Mitsuo Ezaki: Growth Accounting of Postwar Japan


