THE SOURCES OF JAPANESE ECONOMIC GROWTH: 1955-71

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The rapid growth of the Japanese economy has been one of the most remarkable economic phenomena of the postwar period. Between 1953 and 1971, real gross national product increased at an average annual rate of 10%, and Japan is now the world's third largest economy (behind the U.S.A. and the U.S.S.R.). By contrast, the U.S. economy grew at an average rate of 4%, the U.K. at 3%, and West Germany at 6% over the same period.[2/]

This paper studies the sources of Japan's postwar economic growth. The Japanese private domestic economy is broken down into ten sectors, and for each sector the growth rate of real gross output is allocated between the growth rates of (a) real intermediate input, (b) real capital services, (c) the quantity and quality of real labour services, and (d) a residual, which is conventionally associated with the growth of total factor productivity. We then aggregate across sectors to obtain an estimate of the sources of growth for the private domestic economy as a whole. The growth rate of aggregate real product is allocated between (a) the growth in aggregate labour services, and (c) the weighted sum of the sectoral productivity residuals, where the weights sum to a quantity greater than one to allow for the effect of intermediate input.

Our principal conclusion is that produced factors of production--capital and intermediate goods--were the predominant source of sectoral economic growth in Japan for the period 1955-71. At the aggregate level, capital accumulation accounted between 52% and 58% of the growth in gross private domestic product, labour for 17%, and productivity change for between 32% and 25%. This is in sharp contrast to the findings of most of the other studies of aggregate Japanese growth. Denison and Chung (1976), for a recent example, find that for the period 1953-71, capital accounted for only 22% of the growth in real product (they use national income originating in the non-residential business sector), that labour accounted for 20%, and that the change in total factor productivity accounted for 58%. The Denison-Chung results thus assign to productivity change the dominant role in Japanese economic growth, while our findings suggest that this position should be assigned to capital and intermediate input.[3/]

The paper is organized into four sections. In Section I, the theoretical framework underlying our estimation is described. In Section II, we outline the methods and data sources used in estimating the growth rates and shares of real product and real factor input. Our results are set out in Section III and compared to the results of other studies in Section IV.

I. THE THEORETICAL FRAMEWORK

Productivity change is conventionally defined as the shift in an aggregate (or sectoral) production function, and factor accumulation is associated with movements along this function.[4/] The magnitude of the shift is measured by the residual growth rate of output not explained by the weighted growth rates of the real factor inputs. The weights are the factors' shares in total income, and are equivalent to output elasticities under the assumption of competitive equilibrium.

Part A of this section considers the problem of measuring total factor productivity at the sectoral level of aggregation. Both primary and intermediate inputs are included in the derivation of the sectoral residuals. In Part B, the aggregate rate of productivity change is derived. Since factor intensities differ between sectors, the aggregate rate is based on the net social production possibility frontier rather than on the aggregate production function. The aggregate rate is then shown to be the weighted sum of the sectoral rates, with the sum of the weights exceeding one to allow for the expansion in intermediate input induced by the shifting sectoral technologies.

A. The Sectoral Rate of Productivity Change

We assume that the technology of each sector can be characterized by a Hicks-neutral constant returns production function[5/]

$$Q_i = A_i F^i(L_i, K_i, X_i) \tag{1}$$

where L_i, K_i, and X_i denote vectors of labour, capital, and intermediate input, respectively, Q_i is sectoral gross output, and A_i is the Hicksian efficiency index. We assume also that each factor is paid the value of its marginal product in each sector:

$$\frac{\partial Q_i}{\partial L_{\ell i}} = \frac{w_\ell}{p_i} \quad , \quad \frac{\partial Q_i}{\partial K_{ki}} = \frac{c_k}{p_i} \quad , \quad \frac{\partial Q_i}{\partial X_{ji}} = \frac{p_j}{p_i} \tag{2}$$

where p_i, w_ℓ, and c_k denote the prices of real product, labour, and capital services. Equations (1) and (2) imply, by Euler's Theorem, the accounting identity between value of product and value of input

$$p_i Q_i = \sum_{\ell} w_{\ell} L_{\ell i} + \sum_{k} c_k K_{ki} + \sum_{j} p_j X_{ji} \quad . \tag{3}$$

Also, since output is allocated between deliveries to intermediate demand (X_{ij}) and deliveries to final demany (Y_i),

$$p_i Q_i = \sum_{j} p_i X_{ij} + p_i Y_i \tag{4}$$

Combining (3) and (4) and summing over sectors, we obtain the aggregate accounting identity

$$\sum_i \sum_{\ell} w_{\ell} L_{\ell i} + \sum_i \sum_k c_k K_{ki} = \sum_i p_i Y_i \tag{5}$$

which relates total value added to total value of final demand. Equations (3), (4) and (5) provide the link between national accounting data and the underlying technology.

The conventional productivity residual is derived by logarithmic differentiation of the technologies (1) and from (2):

$$\frac{\dot{A}_i}{A_i} = \frac{\dot{Q}_i}{Q_i} - \sum_{\ell} \frac{w_{\ell} L_{\ell i}}{p_i Q_i} \frac{\dot{L}_{\ell i}}{L_{\ell i}} - \sum_k \frac{c_k K_{ki}}{p_i Q_i} \frac{\dot{K}_{ki}}{K_{ki}} - \sum_j \frac{p_j X_{ji}}{p_i Q_i} \frac{\dot{X}_{ji}}{X_{ji}} \quad . \tag{6}$$

Dots over variables denote derivatives with respect to time;[6/] terms such as $\dot{Q}_i/Q_i$ are thus rates of growth. The left hand side of (6) is the residual growth rate of output not accounted for by the weighted growth rates of the real factor inputs. It can be calculated using price and quantity data from national income and wealth accounts. The equality in (6) inplies that this observable residual is equivalent to the growth rate of the Hicksian efficiency parameter, $\dot{A}_i/A_i$, which can be interpreted as the rate at which the technologies (1) shift over time. Equation (6) is the fundamental relationship underlying much of the empirical work of the suceeding sections.[7/]

B. The Aggregate Rate of Productivity Change

It is useful to have a summary measure of productivity change for the entire economy. One possibility is to assume the existence of an aggregate production function

$$Q = A_0 F^0(L,\ K) \tag{7}$$

where $Q = \sum_i Q_i$, $L = \sum_i L_i$, and $K = \sum_i K_i$. The aggregate rate of productivity change would then be $\dot{A}_0/A_0$. Unfortunately, the existence of (7) is consistent with the existence of the sectoral technologies (1) <u>if, and only if</u>, the F^i exhibit equal factor intensities.[8/] Since this is an overly restrictive assumption, we assume instead the existence of a convex net social production possibility frontier

$$F(Y,\ L,\ K,\ t) = 0 \tag{8}$$

where Y is the vector of sectoral final demand and L and K are assumed to be allocated efficiently between sectors. The aggregate rate of productivity change, A, is then defined as the rate of change of (8) with respect to time (holding L and K constant), measured along the economy's equilibrium growth path.

In order to derive an explicit expression for this measure of aggregate technical change, we differentiate (8) logarithmically with respect to time, and evaluate the derivative along the equilibrium path; this yields

$$\sum_i \frac{p_i Y_i}{\sum_i p_i Y_i} \frac{\dot{Y}_i}{Y_i} = A + \sum_i \sum_\ell \frac{w_\ell L_{\ell i}}{\sum_i p_i Y_i} \frac{\dot{L}_{\ell i}}{L_{\ell i}} + \sum_i \sum_k \frac{c_k K_{ki}}{\sum_i p_i Y_i} \frac{\dot{K}_{ki}}{K_{ki}} \quad . \tag{9}$$

This is the basic sources of growth equation for the economy as a whole. It can be used to calculate the aggregate rate, A, directly. However, it is useful to relate A to the sectoral rates of productivity change. This is done by differentiating (4) logarithmically, and substituting into (9), then substituting for $\dot{Q}_i/Q_i$ using (6), and observing that terms involving intermediate goods cancel. The result is

$$A = \sum_i \frac{p_i Q_i}{\sum_i p_i Y_i} \frac{\dot{A}_i}{A_i} \quad . \tag{10}$$

This states that the aggregate rate of productivity change is the weighted <u>sum</u> of the sectoral rates. The weights sum to a variable quantity exceeding one, since $\sum_i p_i Q_i$ is greater than $\sum_i p_i Y_i$ by (4). This reflects the presence of intermediate goods: as sectoral technologies shift outward ($\dot{A}_i/A_i > 0$), additional output is generated and this output is used in part to increase intermediate input. The effect of sectoral productivity change is thus magnified, and the degree of magnification is reflected in the weights.[9/]

Alternative definitions of aggregate productivity change have been proposed. Domar (1961) was the first to note the importance of the variable weighting scheme in the presence of intermediate goods, but uses <u>final</u> output rather than <u>gross</u> output in weighting the individual sectoral rates of productivity change. The difference is the quantity of a sector's own output which it uses in production, X_{ii}. If the X_{ii} are always zero, or productivity change augments all inputs except X_{ii}, Domar's procedure is valid.[10/] However, the former is not empirically justified, and the latter does not seem theoretically appealing. Watanabe (1971) uses gross output weights, $p_i Q_i/\sum_i p_i Q_i$, in aggregating the $\dot{A}_i/A_i$. This corresponds to defining aggregate productivity change as the shift in the gross production possibility frontier. It is, however, the net frontier (8) which is the effective constraint in the problem of maximizing social welfare, and (10) would seem preferable on this account.[11/]

II. REAL PRODUCT AND REAL FACTOR INPUT

In order to estimate the Japanese productivity residuals for each sector, data on gross output, intermediate input, and capital and labour services are needed in both current and constant prices. The Japanese economy is broken down into ten sectors, which are listed in Table 1, along with the sectoral shares in gross enterprise domestic product (GEDP).[12/]

Table 1

Sectoral Shares in Gross Enterprise Domestic Product
1955 and 1971
Japan

(in percent)

Sector	1955 Share	1971 Share
1. Agriculture, Forestry and Fishery	21.4	6.2
2. Mining	2.2	0.8
3. Manufacturing	25.3	32.6
4. Construction	4.5	7.4
5. Electricity, Gas and Water	2.0	1.8
6. Transportation and Communication	9.0	7.7
7. Wholesale and Retail Trade	17.0	18.5
8. Finance and Insurance	4.2	5.2
9. Real Estate	3.9	6.3
10. Services	10.5	13.5

Source: Authors' estimates from data published in Annual Reports on National Income Statistics, Economic Planning Agency, Government of Japan, and from unpublished worksheets provided by the Economic Planning Agency.

It is evident from Table 1 that the Japanese economy experienced substantial shifts in economic activity over the period of this study. Manufacturing, construction, and services all show substantial increases in their shares of total product, while agriculture-forestry-fishery and mining experience a significant decline.

The following subsections outline the procedures used in measuring sectoral input and output in current and constant prices. Part A discusses the estimates of gross output and intermediate input, Part B discusses the measurement of labour input corrected for compositional change, and Part C develops the estimates of capital services and imputed services prices.[13/]

A. Real Product and Real Intermediate Input

Gross output at factor cost is the measure of real product implied by (1) and (6). Gross product in current prices is the sum of value added and current value of intermediate input (equation (3)). The value added measure used in this study is gross enterprise domestic product at factor cost. GEDP is defined as the sum of compensation of employees less domestic product by public administration, income of unincorporated enterprises, rental income, net interest corporate income before tax, corporate transfer payments, income from government enterprises, indirect business taxes less sales and excise taxes, current subsidies, capital consumption allowance, and inventory valuation adjustment less net factor income from abroad and interest on consumer's debt. Sales and excise taxes are excluded, for they are not costs of production from the producer's point of view, whereas other indirect taxes on ownership or utilization of factors of production are costs of production and are included. Subsidies are included since they are part of producer's income. The general government sector (public administration) is also excluded. On the other hand, government enterprises are included for they are considered as profit-maximizing organizations, and comprise a significant portion of some sectors. The value of intermediate goods is added to this total to arrive at sectoral gross output in current prices. Data for these calculations is derived from the Annual Report on National Income Statistics (NIS) of the Economic Planning Agency (EPA), and unpublished worksheet provided by the EPA.

In estimating constant price gross output by sector, sectoral price indexes from the Bank of Japan's Price Indexes Annual were used to deflate NIS gross output in current prices. The deflation procedure used is based on the Divisia index, rather than on the double deflation procedure of the National Accounts. Specifically, a discrete approximation to the Divisia index is used which takes the form

$$\ln Q_{it} - \ln Q_{it-1} = [\ln (p_i Q_i)_t - \ln (p_i Q_i)_{t-1}] - [\ln p_{it} - \ln p_{it-1}] .$$

This approximates the continuous Divisia index $\dot{Q}_i/Q_i$ of (6).

The current value of intermediate input is not available by sector of delivery. The NIS reports only the current value of total intermediate deliveries to each sector. To allocate this total between sectors of origin (i.e., to estimate the $p_j X_{ji}$), input-output data from the Interindustry Relationship Tables of the Administrative Management Agency, et al., are used. This data includes the 1955 54 x 54 sector table, the 1960 and 1965 56 x 56 sector tables, and the 1970 59 x 59 sector table. The first task is to aggregate those sectors up to 10 x 10 in such a way that the resulting tables' industry classification scheme corresponds exactly to our sectoral classification. Then, having completed this aggregation for the four benchmark tables, the next step is to estimate the interbenchmark years' input-output relationship for the ten sectors. This is done in two stages. First, the value term input-output coefficients for the 10 x 10 tables, $p_j X_{ji} / \Sigma_j p_j X_{ji}$, are computed for the benchmark years. Second, those coefficients for 1956-1959, 1961-1964, and 1966-1969 and 1971 are estimated by means of linear interpolation. Thus, a new set of annual interindustry input-output relationships is generated by multiplying the NIS total intermediate input valued for each sector with the respective column of coefficients obtained from the second stage. This yields an estimate $p_j X_{ji}$ for each year which sums to the NIS control total for each sector. Real intermediate input is then computed using the discrete Divisia deflation procedure. This, in turn, is used to calculate the sectoral Divisia index of total real intermediate input

$$\sum_j \frac{p_j X_{ji}}{p_i Q_i} \frac{\dot{X}_{ji}}{X_{ji}} \quad .$$

A discrete approximation is again used; the discrete weights are calculated as the simple average between years t-1 and t.

The average annual growth rates of real gross output and real intermediate input by sector are given in rows 1 and 2 of Table 3. When sectoral output prices, based on Bank of Japan estimates, are aggregated across sectors using a discrete approximation to

$$\sum_i \frac{p_i Y_i}{\sum_i p_i Y_i} \frac{\dot{p}_i}{p_i}$$

the result is an average annual growth rate of 3.1% per year. The NIS implicit deflator for gross national expenditure at market prices grows at 4.5% per year (for the period 1955-1971). Although they are not strictly comparable, the divergence between these two aggregate deflators is of potential importance, since any error made in deflating the nominal growth rates of output and intermediate input directly affects the estimated residual. This can be illustrated most simply by assuming that the error is distributed proportionately across sectors (in any year): $\lambda p_i = p_i^*$, where p_i^* is the correct deflator. The relationship between the incorrectly measured residual, $\dot{A}_i'/A_i'$, and the true residual, $\dot{A}_i^*/A_i^*$, is then given by

$$\frac{\dot{A}_i^*}{A_i^*} = \frac{\dot{A}_i'}{A_i'} + (1 - \sum_j \frac{p_j^* X_{ji}}{p_i^* Q_i}) \frac{\dot{\lambda}}{\lambda}$$

If the true deflator is growing more rapidly than the observed deflator, $\dot{\lambda}/\lambda < 0$, and the estimated residual overstates the true residual. While proportionality of errors is unlikely, this analysis suggests that if the NIS deflator is more accurate than the Bank of Japan deflator, then our estimate residuals will on average overstate the true residudal. We note, however, that we have no basis in fact for assuming that the NIS deflator is more accurate than the weighted average of the Bank of Japan sectoral deflators.

B. Real Labour Input

In estimating the labour component of (6), a Divisia index of real labour input is constructed which distinguishes between workers with different characteristics. The five characteristics considered in this study are occupation, sex, size of firm, age and education. Unfortunately, age and education are not easily cross-classified, and it is necessary to estimate quality change separately for age-occupation-sex-size of firm and education-occupation-sex size of firm (for which cross classifications are readily available). Table 2 describes the level of detail with each classification.

The Divisia index of real labour input is the weighted average of the annual growth rate of manhours worked by each type of labour. For each sector, this index is

$$\frac{\dot{L}_i}{L_i} = \sum\sum\sum\sum_{k\ell mn} \frac{W_{k\ell mn,i}\, L_{k\ell mn,i}}{\sum\sum\sum\sum_{k\ell mn} W_{k\ell mn,i}\, L_{k\ell mn,i}} \frac{\dot{L}_{k\ell mn,i}}{L_{k\ell mn,i}} \qquad (12)$$

where k, ℓ, m, n refer to the characteristics listed in Table 2. When multiplied by the ratio of total sectoral labour income to total sectoral income, equation (12) becomes the labour component of (6).

In analyzing the contribution of labour to economic growth, the usual procedure is to allocate $\dot{L}_i/L_i$ between the growth of employment, the growth in average hours worked, and the change in composition of the labour force. This is done by claculating the proportion of total sectoral manhours worked by each type of worker.

$$e_{k\ell mn,i} = \frac{L_{k\ell mn,i}}{M_i H_i} \qquad (13)$$

Table 2

The Disaggregation of Real Labour Input

1.	Sex	1.	Male
		2.	Female
2.	Occupation	1.	Blue-collar Workers
		2.	White-collar Workers
3.	Size of Firm	1.	1000 - Employees
		2.	100 - 999 Employees
		3.	10 - 99 Employees
4.	Age*	1.	- 17 Years
		2.	18 - 19 Years
		3.	20 - 24 Years
		4.	25 - 29 Years
		5.	30 - 34 Years
		6.	35 - 39 Years
		7.	40 - 49 Years
		8.	50 - Years
5.	Education**	1.	9 years or less (Elementary and Junior High School)
		2.	12 years or less (High School)
		3.	14 years or less (Junior College, Technical School)
		4.	16 years or less (College or University)

* For female labour service, the age categories 5 and 6 as well as 7 and 8 are classified together.

** For male workers, the education categories 2 through 4 are aggregated.

where M_i is total employment, H_i average hours worked, and $e_{k\ell mn,i}$ the relevant proportion. When (13) is differentiated logarithmically and substituted into (12), the rate of change of the sectoral labour index becomes

$$\frac{\dot{L}_i}{L_i} = \frac{\dot{M}_i}{M_i} + \frac{\dot{H}_i}{H_i} + \sum_{k\ell mn}\sum\sum\sum \frac{W_{k\ell mn,i}\, L_{k\ell mn,i}}{\sum_{k\ell mn}\sum\sum\sum W_{k\ell mn,i}\, L_{k\ell mn,i}} \frac{\dot{e}_{k\ell mn,i}}{e_{k\ell mn,i}} \qquad (14)$$

The last term on the right hand side of (14) is the weighted change in the composition of the labour force. Under the assumption that prices reflect marginal products, it measures the change in productivity associated with the change in composition.[14/]

Equation (14) is estimated using data from the Report on the Basic Wage Structure Survey, the Total Report on Monthly Employment Survey, and the Annual Report on National Income Statistics. These results are reported in rows 4 through 8 of Table 3. It may be noted that most of the growth rate of the labour input is due to the growth in employment. Due to data restrictions, the quality adjustment is made only for the period 1958-1971, and for all sectors except agriculture-forestry-fisheries and services.

C. Real Capital Input

A Divisia index of real capital services is needed for the capital component of (6). This is constructed, ideally, by weighting the growth rates of the different types of capital services (structures, producers' durables, etc.) by their respective shares in total capital income in each sector. The resulting index is

$$\frac{\dot{K}_i}{K_i} = \sum_k \frac{c_{ki}K_{ki}}{\sum_k c_{ki}K_{ki}} \frac{\dot{K}_{ki}}{K_{ki}} \qquad (15)$$

Capital's contribution to sectoral growth is obtained by multiplying (15) by the ratio of total capital income to total income in each sector.

If capital services were purchased in the same way as labour services, i.e., on current account, then the calculation of (15) would be straightforward. Unfortunately, most business assets are owner utilized, and the rental price c_{ki} and service flow K_{ki} must be inferred by an indirect process. The imputation process is carried out using the dual relationship between (a) the stock of capital at time t ($K_{ki,t}$) and the flow of past investment ($I_{ki,s}$):

$$K_{ki,t} = \sum_{s=1}^{t} (1 - \mu_{ki})^{t-s} I_{ki,s} + (1 - \mu_{ki})^{t} K_{ki,0} \qquad (16)$$

and (b) the asset price at time t ($q_{ki,t}$) and the flow of future rental income ($c_{ki,s}$):

$$q_{ki,t} = \sum_{\tau=t}^{\infty} [\prod_{s=t+1}^{\tau+1} \frac{1}{1 + r_{i,s}}] c_{ki,\tau+1} (1 - \mu_{ki})^{\tau-t} \qquad (17)$$

where $r_{i,s}$ is the rate of discount in year s. A constant rate of replacement, μ_{ki}, is assumed; equation (17) also assumes equilibrium with perfect foresight in the asset market, and that the rate of discount is the same for all assets in a given sector. Furthermore, we have omitted the tax structure for simplicity. In the actual application of (17), the tax code pertaining to each asset, sector, and form of organization is taken into account. The form of organization refers to corporate and non-corporate parts of each sector, which are treated differently under Japanese business tax code. This distinction also requires that we measure asset stocks separately for corporations and non-corporations.

For non-depreciable assets--land and inventories--asset stocks are directly available. The imputed rental price for these assets is calculated by setting $\mu_{ki} = 0$ in (17). For the seven types of depreciable assets considered in this study--residential buildings, non-residential building, other structures, machinery, water transport vessels, land and air transport vessels, and tools and fixtures--the stocks are estimated by a perpetual inventory method based on (16), and the corresponding rate of replacement is used in the rental price imputation.

The perpetual inventory estimates of the stocks of depreciable assets require data on nominal investment, an investment deflator, a capital benchmark, and an estimate of the rate of replacement. The investment series and deflators, by asset, sector, and form of organization, were obtained from the Annual Report on National Income Statistics, the Report on the Corporate Industry Investment Survey, the Quarterly Report on the Non-corporate Enterprise Survey, and the Bank of Japan Price Indexes Annual. The National Wealth Survey (NWS) provides net asset stock levels for the years 1955, 1960, 1965, and 1970. These provide net benchmarks for each type of capital asset. The NWS also provides average asset lifetimes. Under the assumption of geometric depreciation at a double declining balance rate, the rate of replacement is $2/N_{ki}$, where N_{ki} is the average life. This method is used to compute rates of replacement for non-corporate assets and selected corporate assets.

Where data permitted, endogenous rates of replacement were calculated using the NWS benchmarks. Given benchmarks $K_{ki,0}$ and $K_{ki,t}$ and an investment series for the intervening years, $I_{ki,s}$, equation (16) is a polynominal in μ_{ki} which can be solved for an implicit estimate.[15/] Since the method of solution is sensitive to variations in the data, only benchmark years 1955 and 1960 were used, and only corporate μ_{ki} were calculated. Even with this restriction, some estimates were implausibly large or small, and double declining balance rates were used in their place.

Given the estimates of real investment, the benchmarks, and the estimated rates of replacement, the stocks of depreciable assets were calculated using the perpetual inventory equation

$$K_{ki,t} = I_{ki,t} + (1 - \mu_{ki})K_{ki,t-1}$$

Since every μ_{ki} is not reconciled to each of the NWS benchmark years, not all the estimated $K_{ki,t}$ will duplicate all the NWS benchmarks. The estimated growth rates of capital stock are given in row 9 of Table 3. Subsequent to these calculations, EPA sectoral investment deflators (unpublished) and NWS investment deflators by asset became available, as did additional information about the 1970 net benchmarks. This permitted us to recalculate a capital stock series which uses the EPA sectoral deflators and the NWS aggregate deflator, and which reconciled to the NWS net benchmarks. These alternative estimates are given in rows 10, 11 and 12 of Table 3. The new estimates show lower growth rates than the original estimates in all sectors except construction, and the new aggregate rate of growth is 13.10% as opposed to the original rate of 14.86%.

The land series are compiled from the National Wealth Survey, the Report on Corporate Industry Investment Survey, and agricultural and urban land price indices made available by the Japan Real Estate Research Institute. Stock levels for inventory are computed from the Annual Report on National Income Stastics, the National Wealth Survey, and the Report on the Corporate Industry Investment Survey.

Equation (17) provides the basis for imputing the rental price by type of asset. (17) can be solved to yield

$$c_{ki,t} = r_{i,t}\, q_{ki,t-1} + \mu_{ki}\, q_{ki,t} + (q_{ki,t} - q_{ki,t-1}) \qquad (18)$$

Letting $\pi_{i,t}$ denote income accruing to capital in sector i on year t,

$$\pi_{i,t} = \sum_k c_{ki,t}\, K_{ki,t} \qquad (19a)$$

$$= r_{i,t} \sum_k q_{ki,t-1}\, K_{ki,t} + \sum_k \mu_{ki,t}\, q_{ki,t}\, K_{ki,t} - \sum_k \Delta q_{ki,t}\, K_{ki,t} \qquad (19b)$$

All variables in (19b) are observable except the rate of return, $r_{i,t}$, so that (19b) can be used to impute this variable. The resulting estimate of $r_{i,t}$ can then be put into (18) to estimate $c_{ki,t}$.16/ This, in turn, can be used to calculate $c_{ki,t}K_{ki,t}$, and thus the weights $c_{ki,t}K_{ki,t}/\pi_{i,t}$, which leads directly to the Divisia index of capital (15).

As indicated above, the tax structure applicable to each asset, sector, and form or organization must be taken into account in order to correctly impute the true rental price. A model of asset pricing which captures the Japanese business tax structure is given by the following analogue to (17):

$$q_t = \sum_{\tau=t}^{\infty} \left[\prod_{s=t+1}^{\tau+1} \frac{1}{1+(1-u_s)(1-v_s)r_s} \right] \left[(1-\mu)^{\tau-t}(1-u_{\tau+1})(1-v_{\tau+1})(c_{\tau+1}-k_{\tau+1}q_{\tau+1}) + [u_{\tau+1} + v_{\tau+1}(1-u_{\tau+1})]q_t(1+w_t)D_{\tau-t} \right] - w_t q_t \quad ,$$

where

u_t: corporate income tax rate

v_τ: business establishment income tax rate

k_τ: business property tax rate

w_t: real property acquisition tax rate

$D_{\tau-t}$: capital consumption allowance for tax purposes for the (τ-t)-th year.

(The sector and asset subscripts are temporarily suppressed for clarity here.)

Solving for the rental price as before

$$c_t = \psi_t[r_t q_{t-1} + \mu q_t - (q_t - q_{t-1})] + k_t q_t, \tag{20}$$

where

$$\psi_t = \frac{(1 + w_t)\{1 - [u_t + v_t(1 - u_t)]\ z\}}{(1 - u_t)\ (1 - v_t)} \tag{21}$$

and z is the present value of capital consumption allowances (per unit service price) for tax purposes,

$$z = \sum_{\tau=t}^{\infty} \prod_{s=t+1}^{\tau+1} \frac{1}{1 + (1 - u_s)(1 - v_s)r_s}\ D_{\tau-t} \tag{22}$$

Equations (20), (21) and (22) are general expressions for the rental prices used in this study.[17/] The rental prices for different assets and sectors are special cases of (20). Substitution of the various forms of (20) into (19a) yields an equation analogous to (19b) in which all variables have been measured except the rate of return. The construction of the Divisia index of capital, (15), follows immediately.

It should be noted that we have not allowed for changes in the utilization of the capital stock. In principle, the flow of capital services is not a constant proportion of the stock. Since we in fact are measuring the growth rate of the stock, an utililization adjustment is called for. Unfortunately, this is not possible because of data limitations. The effect is to overstate (understate) the productivity residual when the utilization of capital is increasing (decreasing).

III. THE SOURCES OF JAPANESE GROWTH

Table 3 summarizes the estimates of real product and real factor input developed in the preceding section. Row 1 gives the average annual growth rate of real gross product by sector, and rows 2 through 10 correspond to the growth rates of the various input indexes (i.e., equations (11), (12), (14) and (15)).

It is evident from Table 3 that the first two sectors--agriculture-forestry-fishery and mining--behave differently from the remaining eight. These two sectors have the smallest rates of growth of real gross product, real intermediate input, and NWS net capital stock, and experienced a large decline in employment over the period of this study. The remaining sectors experienced a rapid growth of real gross product and double digit growth rates of capital stock and intermediate input. By contrast, the labour indexes grow more slowly, and this growth is due largely to the growth of employment. Only manufacturing and trade experience a growth rate of labour quality (using age) which exceeded 0.5% per year. With education as a quality characteristic, transportation and finance experienced negative quality change of approximately 0.5% a year, and the manufacutring and trade rates fall to 0.63% and 0.35% respectively. The use of age rather than education has the effect of increasing observed labour quality in all sectors except public utilities, where the difference is negligible.

Table 4 presents the sources of growth decomposition for each of the ten sectors included in this study. Three variants of the productivity residual (TFP) are included; these correspond to equation (6) with different measures of labour and capital. By comparing these residuals with the growth rate of output, it can be seen that productivity change was the dominant factor in the growth of only two sectors: agriculture-forestry-fishery and mining. In four other sectors, productivity change explains approximately 10% to 25% of the growth in real product, in three sectors it explains almost nothing. In the real estate sector, the residual is strongly negative; this is almost certainly the result of measurement error, most likely in the estimate of real product. This sector is, however, relatively small (see Table 1), and is thus not a large source of bias in the aggregate estimates of growth.

One of the main conclusions which emerges from Table 4 is that capital and intermediate input account for the largest portion of the growth of real product. These inputs account for three-fourths or more of the growth rate of output in nine of the ten sectors (using our original definition of capital stock). In the tenth sector, the combined contribution is 58%. When the NWS capital stocks are used, capital and intermediate input account for over 50% of the growth of real product in all sectors, and over 73% in eight of the ten sectors. Thus while total factor productivity and labour input are important in absolute terms in some sectors, their contribution was small relative to growth of the produced factors of production.

The aggregate sources of Japanese growth are set out in Table 5. The average annual growth rate of aggregate real product is 11.45%, and this is allocated between capital, labour, and productivity change according to the following percentages: 58%, 17% and 25%. When NWS net capital stock is used, these percentages are 52%, 17% and 32%. The contribution of labour and TFP are thus relatively small under either definition of capital stock; the contribution of labour quality (based on age) is minimal in relative terms: 1.92% of the growth in GEDP. Furthermore, in assessing the contribution of productivity change--which is between one quarter and one third the change in output--it must be recalled that the aggregate residual is the weighted <u>sum</u> of the sectoral residual and not the weighted <u>average</u>. This implies that, at the aggregate level, productivity change exerts an influence via an expansion in intermediate input.

These results should not be interpreted as an argument that productivity change and the growth in the quantity and quality of labour has a negligible influence on the growth of the Japanese economy. These factors were of absolute importance in both sectoral and aggregate growth. What our results do suggest is that these factors are not sufficient to explain the remarkably high growth rate observed for the Japanese economy. The main emphasis must be placed on capital formation and on the ability of the Japanese economy to "supply" the intermediate inputs needed to sustain the high rate of growth. However, this conclusion must itself be modified by the recognition that the high growth rate of produced input is partly attributable to changes in productivity. Part of the growth rate of produced input must be reassigned to productivity change before a final assessment on the importance of productivity change is made.[18/]

Table 3

Growth Rates (Unwieghted) of Real Gross Output and Real Inputs

Japan, 1955-1971

(in percent per year)

	(1) Agr.For. & Fish.	(2) Mining	(3) Mfg.	(4) Constr.	(5) Elec.Gas & Water	(6) Trans. & Com.	(7) Trade	(8) Fin. & Ins.	(9) Real Estate	(10) Services	(11) Aggregate
1. Real Gross Product	3.42	5.82	14.13	14.32	11.43	9.22	13.43	10.20	7.69	11.07	11.45
2. Real Intermediate Input	5.86	4.12	12.84	15.09	12.55	12.06	15.13	10.78	19.13	15.11	13.10
3. Real Labour Input(Age)	- 4.75	- 4.63	5.14	6.21	2.13	3.72	7.03	4.74	10.16	4.09	3.38
4. Employment	- 4.45	- 5.20	4.32	5.69	2.45	3.24	6.02	4.78	10.27	4.39	2.99
5. Hours	- 0.03	0.60	0.09	0.56	- 0.40	0.32	0.37	0.06	0.16	- 0.30	0.06
6. Quality(Age)[a]	---	- 0.02	0.91	- 0.01	0.10	0.19	0.78	- 0.11	- 0.32	---	0.41
7. Real Labour Input(Ed.)	---	- 4.87	4.92	6.06	2.13	3.22	6.67	4.40	10.14	---	3.18
8. Quality(Ed.)[a]	---	- 0.33	0.63	- 0.15	0.11	- 0.47	0.35	- 0.53	- 0.34	---	0.16
9. Real Capital Input	14.67	9.11	15.81	21.89	12.15	13.35	11.81	11.37	20.65	14.33	14.86
10. Real Capital Inputs(NWS)	8.29	5.93	15.45	24.53	11.80	11.60	10.99	12.74	12.09	13.80	13.10
11. Nominal Capital(NWS)[b]	12.20	7.60	17.10	26.10	13.90	14.30	13.50	15.40		16.27	15.40
12. EPA Deflator[c]	3.91	1.67	1.65	1.57	2.10	2.70	2.51	2.66	3.31	2.47	2.30[d]

(a) 1958-1971
(b) 1970 National Wealth Survey of Japan, Vol. 1, Table 8-3, p.63. (1955-1970).
(c) Economic Planning Agency, Japan, Gross Fixed Nonresidential Business Capital in Japan (1954-1972), unpublished worksheets, Table 7, p. 30-33. Note that EPA excludes residential buildings from their estimates.
(d) Computed from 1970 National Wealth Survey of Japan, Vol. 1, Tables 1 and 2, p. 358-369.

Note: Average factor shares in gross output for 1955-1971 can be computed using the unweighted growth rates of this Table and the weighted growth rates of Table 4 and Table 5.

Table 4

Sources of Growth by Sector

Japan, 1955-1971

(in percent per year)

	(1) Agr.For. & Fish.	(2) Mining	(3) Mfg.	(4) Constr.	(5) Elec.Gas & Water	(6) Trans. & Com.	(7) Trade	(8) Fin. & Ins.	(9) Real Estate	(10) Services
1. Real Gross Product	3.42	5.82	14.13	14.32	11.43	9.22	13.43	10.20	7.69	11.07
2. Real Intermediate Input	1.50	1.47	8.93	10.63	5.70	4.28	3.66	2.68	3.55	5.10
3. Real Capital Input	1.67	2.84	2.44	2.45	3.02	3.85	4.17	6.64	13.31	3.03
4. Real Labour Input(Age)	- 3.03	- 1.31	0.78	1.15	0.65	1.32	2.81	0.82	1.91	1.89
5. Employment	- 2.84	- 1.47	0.65	1.05	0.74	1.14	2.40	0.82	1.93	2.02
6. Hours	- 0.19	0.16	0.01	0.10	- 0.12	0.13	0.14	0.01	0.03	- 0.13
7. Quality(Age)[(a)]	---	- 0.01	0.13	- 0.00	0.03	0.06	0.31	- 0.01	- 0.05	---
8. TFP(Age)	3.28	2.82	1.98	0.09	2.06	- 0.23	2.79	0.06	-11.08	1.05
9. Real Labour Input(Ed.)	---	- 1.40	0.75	1.13	0.65	1.16	2.69	0.76	1.90	---
10. Quality(Ed.)[(a)]	---	- 0.09	0.09	- 0.02	0.03	- 0.16	0.14	- 0.09	- 0.06	---
11. TFP(Ed.)	---	2.91	2.01	0.11	2.06	- 0.07	2.91	0.12	-11.07	---
12. Real Capital Input(NWS)[(b)]	0.94	1.85	2.38	2.74	2.93	3.35	3.88	7.44	7.79	2.92
13. TFP(Age & NWS)	4.01	3.81	2.04	- 0.20	2.15	0.27	3.08	- 0.74	- 5.56	1.16

(a) 1958-1971

(b) 1955-1970

Table 5

Aggregate Sources of Growth

Japan, 1955-1971

(in percent per year)

	(1) With original capital estimates		(2) With NWS capital estimates	
	Weighted growth rates	% of Output	Weighted growth rates	% of Output
1. Real Product	11.45		11.45	
2. Real Capital Input	6.68	58.34	5.90[a]	51.53
3. Real Labour Input	1.89	16.51	1.89	16.51
4. Employment	1.69	14.76	1.69	14.76
5. Hours	0.03	0.26	0.03	0.26
6. Quality (Age)[b]	0.22	1.92	0.22	1.92
7. TFP	2.88	25.15	3.66	31.96

(a) NWS nominal growth rate of capital is 15.40% per year (1970 National Wealth Survey of Japan, Vol. I. Table 8-2, rows 6 and 13, p. 63.) NWS deflator grows at 2.30% per year (computed from 1970 National Wealth Survey of Japan, Vol. I. Tables 1 and 2, pp. 358-369.) The NWS growth rate of real capital is thus estimated at 13.10% per year. The weighted growth rate of real capital is then estimated using our estimate of average capital share of 0.45.

(b) 1958-1971

IV. COMPARISON WITH OTHER STUDIES

The Brookings Institution has recently published the most detailed account of the Japanese economy available in the English language: Asia's New Giant, How the Japanese Economy Works. A chapter of this book by E. F. Denison and W. K. Chung is devoted to the sources of Japanese economic growth. Their results for the nonresidential business sector for 1953-1971 show that total factor input grew at an average annual rate of 4.18% and output per unit of input (total factor productivity) at 5.86%; 1.99% of the growth in total factor input is due to labor, and 2.19% is attributed to capital input. Their estimate of the growth of real national income is 10.04% per annum during this period, so that more than half (58.4%) of growth in output is explained by TFP. Labour input explains 19.8% and capital input 21.8% of the output growth rate.

Several earlier studies have also examined the source of Japanese economic growth. These studies cover different periods and employ different methods, and a complete account of their differences and a reconciliation of their results with ours is beyond the scope of this paper. Their results, however, are briefly summarized in Table 6. As Denison and Chung indicate, these earlier studies tend to confirm their finding that one half or more of the sources of Japanese growth is attributable to productivity change. A partial exception to this is the study of Ezaki and Jorgenson, who attribute approximately 38% of the growth in real product to change in total factor productivity.

It is clear from Table 4 that our results differ from those of the other studies cited. We assign far more importance to produced input and less

Table 6

Summary of Other Studies on Japanese Growth

(in percent per year)

	Denison Chung (1976)	Ekaizu Watamabe (1968)	Ezaki Jorgenson (1973)	Kanamori (1972)	Kosobud (1971)	Ohkawa (1968)	Ratcliffe Yoshihora (1972)	Watanabe (1972)
	1953-1971	1955-1964	1952-1971	1955-1968	1952-1968	1955-1961	1953-1965	1952-1964
1. Real Product	10.04	10.40	10.10	10.10	11.70	10.74	10.35	9.60
2. TFP	5.86	5.51	3.80	6.10	7.10	7.50	4.99	5.10
3. Percent of Output	58.37	52.98	37.62	60.40	60.68	69.83	48.21	53.13

importance to productivity change. A major source of the difference is associated with our use of gross domestic enterprise product rather than national income as our measure of real product, and our use of net rather than gross stocks of capital.

The major differences between GEDP and national income are capital consumption allowances and property taxes, both of which are component of property (capital) income. Capital's average share of GEDP is 45% for the period 1955-71. The corresponding share in national income is approximately 25%. Thus, when national income is used as the measure of real product, substantial components of property income are omitted, and the most rapidly growing real input--capital--is assigned a substantially smaller weight.

Our choice of GEDP rather than national income is dictated by the theoretical framework of Section I. One of the central propositions of productivity analysis is that factor shares are approximately equal to output elasticities. However, this is only true when (2) holds, i.e., when factors are paid the value of their marginal product. The existence of marginal products, in turn, implies the existence of an underlying technology which exhibits non-increasing returns to scale such as (1). But, as shown above, given constant returns to scale, (1) and (2) imply the accounting identity (3). Thus, if one imposes "adding-up", or constant returns, the choice of output measure is determined: for sectoral productivity analysis it is gross output; for aggregate analysis with intermediate input, it is the left-hand side of equation (9). Another way to make this point is to note that the price of capital services, c_k, in (2) is equivalent to what a capital asset would rent for in a competitive market. The competitive rental includes the cost of depreciation and property taxes, as shown in (18) and (20).

The EPA defines the gross stock of capital as the gross stock in the preceding year plus gross investment minus retirement. This is equivalent to assuming that all depreciable assets retain their full productive capacity until retirement (one-hoss-shay depreciation). NWS net stocks are calculated by depreciating gross investment at an exponential rate based on the relationship between initial value and scrap value (in constant prices).[19/] Both of the capital stock measures used in this study are net measures; our original estimate grows at an average annual rate of 14.9% and the NWS estimate at 13.1%. By contrast, the EPA gross estimate grows at an average annual rate of 10.1%.

The choice of net stocks rather than gross stocks is not a theoretical necessity, but a great practical convenience. As indicated in Section III.C, the same rate of replacement used in calculating the stock of capital must be used in imputing the price of capital services. When exponential depreciation is assumed, as in Section III.C, the rate of replacement is constant and the rental price imputation is straightforward. On the other hand, when one-hoss-shay depreciation is assumed, the rental price imputation becomes a rather complicated procedure.[20/] The use of gross stocks, with its implied assumption of one-hoss-shay, is thus an unattractive alternative from a computational standpoint. It is also unattractive from an intuitive point of view, since it is somewhat unrealistic to assume that all capital maintains its full productive efficiency until it is retired from use. This does not, of course, imply that exponential depreciation at a double declining balance rate is justified, although some support for the exponential form is provided by renewal theory.[21/]

Further research on this topic is needed to resolve this difficult, and important, issue.

To illustrate the effect of using national income and gross capital stock, we replace the average growth rate of NWS net stock by the average growth rate of EPA gross stock in Table 4, Column 2, and then switch from GEDP weights to national income weights (correspondingly, we replace GEDP with national income in calculating the average annual growth rate of real product). The results are given in Table 7. By reading along the bottom row, it can be seen that the effect of replacing net stocks with gross stocks is to increase the proposition of the growth of output explained by productivity change from 32% to 43%. The switch to national income further increases this ratio to almost 50%.[22/]

These results are indicative of the sensitivity of productivity analysis to changes in the definition of real product and real factor input. Finally, the reader must also keep in mind that the total factor productivity analysis is sensitive to the time period covered and the extent of total economic activity considered.

Table 7

Comparison of Alternative Assumptions

Japan, 1955-1971

(in percent per year)

	(1) GEDP and NWS Net Stock	(2) GEDP and EPA Gross Stock	(3) National Income and EPA Gross Stock
1. Real Product	11.45	11.45	10.15[a]
2. Real Capital Input (Weighted)	5.90	4.61[b]	2.56[b]
3. Average Share of Capital	45.00	45.00	25.00
4. Real Labour Input (Weighted)	1.89	1.89	2.54
5. Total Factor Input	7.79	6.50	5.10
6. TFP	3.66	4.95	5.05
7. Percent of Output	31.97	43.23	49.75

(a) National Income originating in nonresidential business sector. Computed from Table 2-3, column (7) (p.79) of Denison and Chung (1976).

(b) The unweighted average annual growth rate of Gross Capital Stock is 10.25%. This is computed from EPA's Gross Fixed Nonresidential Business Capital in Japan (1954-1972), unpublished worksheets, Table 3-3, pp.18-19.

Note that the EPA estimates for gross stock excludes government enterprises and residential buildings, whereas the NWS estimates include both.

NOTES

1/ We are greatly indebted to Professors C. F. Christ and D. W. Jorgenson for their advice. We acknowledge the financial support of U.S. Department of Labour, Manpower Administration, and the National Science Foundation.

2/ Computed from the U.N. Statistical Yearbook, Table 178 (1970) and Table 174 (1973). The figures are in terms of GDP at market prices for the U.S. and West Germany, GDP at factor cost for the U.K., and GNP at market prices for Japan.

3/ We do not take into account here the fact that part of the observed growth rate of produced input was the result of productivity change. As noted in Hulten (1975), this can result in a potentially large understatement of the importance of technical change.

4/ This interpretation is due to Solow (1957).

5/ We assume also that these functions are twice differentiable and strictly quasi-concave.

6/ We assume that each variable depends on time, e.g. $Q_i(t)$; this defines a path for each variable, which we assume to be differentiable.

7/ An alternative approach to measuring the productivity residual uses value added as the measure of real product. Letting p_i^v and v_i denote the price and quantity components of value added, this version of the residual is

$$\frac{\dot{B}_i}{B_i} = \frac{\dot{V}_i}{V_i} - \sum_{\ell} \frac{w_\ell L_{\ell i}}{p_i^v V_i} \frac{\dot{L}_{\ell i}}{L_{\ell i}} - \sum_{k} \frac{c_k K_{ki}}{p_i^v V_i} \frac{\dot{K}_{ki}}{K_{ki}} \qquad (6')$$

A necessary and sufficient condition for $\dot{B}_i/B_i$ to be a path independent measure of productivity change is that the sectoral technologies be of the form

$$Q_i = F^i[B_i g^i(L_i, K_i);\ h^i(X_i)] \qquad (7')$$

This function is weakly separable into a function of the primary inputs and a function of the intermediate inputs. If the technology is not of the form (1'), (6') will depend, in general, on the paths of the intermediate goods. For a discussion of path independence and separability, see Hulten (1973). For further discussion of the relationship between $\dot{B}_i/B_i$ and $\dot{A}_i/A_i$, see Nishimizu (1975).

8/ See Jones (1965), Green (1966), Chang (1970), and Hall (1973).

9/ This magnification effect is discussed in greater detail in Hulten (1974).

10/ When productivity change augments all input except X_{ii}, the productivity residual must be appropriately revised. See Nishimuzu (1975).

11/ If the value added approach to total factor productivity is taken (see footnote 7), the aggregate rate is defined by

$$B = \sum_i \frac{p_i^v V_i}{\sum_i p_i^v V_i} \frac{\dot{B}_i}{B_i} \qquad (10')$$

It can be shown that $B = A$, regardless of whether (1') holds.

12/ The terms gross enterprise domestic product (as distinguished from gross private domestic product) is used to emphasize the inclusion of government enterprises in the private business sector.

13/ For a more detailed description of data sources and computational methods, see Nishimizu (1975).

14/ See Jorgenson-Griliches (1967) and Griliches (1970).

15/ For a proof of the existence of an unique solution in the interval (0.1) and the discussion of an algorithum used to solve the polynomial, see Nishimuzu (1975).

16/ Our original capital stock estimates were used in the calculations. We are currently engaged in updating the service price imputations within the context of a more disaggregated study of the Japanese economy.

17/ See Nishimizu (1975) for a detailed discussion of the service price equations.

18/ See Hulten (1975).

19/ A detailed description of the NWS procedure is found in 1970 National Wealth Surveys of Japan.

20/ See Jorgenson (1973) for a further discussion of this point.

21/ Jorgenson (1973).

22/ Dension and Chung use national income as their measure of real product, but use a composite index for capital: three-fourth the growth rate of E.P.A. gross stock and one-fourth the growth rate of net stock. If the composite measure is used rather than gross stock in Column 3, row 2, the resulting T.F.P. estimate is 4.87. This explains 48% of the growth rate of national income.

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