Title	SOURCES OF QUALITY CHANGE IN LABOR INPUT AND ECONOMIC GROWTH IN JAPAN 1960-1979
Sub Title	
Author	IMAMURA, Hajime
Publisher	Keio Economic Society, Keio University
Publication year	1982
Jtitle	Keio economic studies Vol.19, No.2 (1982.) ,p.71- 93
JaLC DOI	
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Notes	
Genre	Journal Article
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=AA00260492-19820002-0071

SOURCES OF QUALITY CHANGE IN LABOR INPUT AND ECONOMIC GROWTH IN JAPAN 1960–1979

Hajime IMAMURA

ABSTRACT: This paper analyzes the sources of quality change in labor inputs in Japan for the period of 1960–1979. Decomposition of quality change was made using the Divisia indices of labor input, which are consistent with transcendental logarithmic aggregator functions. A comparison between Japan and the U.S. was made citing some U.S. results in a comparable framework.

The empirical results show that quality changes in labor inputs in Japan were positive through 1960–1979, and that the sources of these quality changes were mainly an age effect, an education effect and the interactive effects of education-age and education-occupation. During this time, the Japanese economy was catching up with the technology of the U.S. and Western Europe. The results of this paper, concerning quality changes in labor inputs, are consistent with this catch-up process. That is, the more the technology level is enhanced through the development of technology, the more is the quality change in labor input required. This coincidence of quality change in labor with technological development has been one of causes of rapid productivity change in the Japanese economy.

On the other hand, the comparison between the U.S. and Japan shows that quality change in labor input in the U.S. was apparently small compared to that of Japan, especially in terms of the sex and age effects. Only the education effect turned out to be significantly positive, though its impact was reduced when an adjustment for occupation was made. This result shows that quality changes in labor input have not been a major factor for the productivity change in the U.S., while they contributed significantly to Japanese productivity changes.

INTRODUCTION

The purpose of this paper is to analyze the sources of quality change in labor input in Japan for the period 1960–1979, and consequently, to give insights into understanding the causes for high productivity performance of the Japanese economy. We also look for the difference in quality change in labor input between the U.S. and Japan, in order to understand the characteristics of economic growth in both countries.

Under the assumption of weak separability of labor inputs with other factor inputs, we can assume the existence of aggregator functions for heterogeneous labor inputs. This enables us to analyze the sources of quality change in labor inputs independently from other factor inputs. In aggregating labor inputs, we utilize Divisia indices which are consistent with transcendental logarithmic aggregator functions. That is to say, our analysis is based on the neoclassical theory of production, and we measure labor quality under the premise of equality between wage rates and the value of marginal productivity.

Although our framework in this paper is limited to labor input, this is the first step to investigate the interdependent relationships among input structure, technological change and economic growth. The result of this paper must be interpreted in recognition of such interdependence.

Now, let us briefly review previous reserch work on quality change in labor inputs in Japan.

The standard research works in the measurement of quality change in labor input in Japan are Watanabe–Egaizu [13], Denison–Chung [3] and Tachibanaki [12].

Watanabe–Egaizu measured quality changes in labor inputs for 1951–1964, and compared these with results for other developed countries. Quality changes in labor inputs in Japan were relatively low, which they explained was the consequence of an imitation-lag in technical progress. That is to say, they considered that technical change at that time was embodied in imported capital goods. Hence, there was little need for highly qualified workers to be employed in original technological developments. This resulted in a low level of quality changes in labor inputs. Finally, they forecasted the characteristics of quality change in labor inputs which would occur after the end of the 1960's. Their prediction was that there would be high quality changes in labor inputs in the process of technological catch-up with the U.S. and Western Europe. The reason for these was that high quality change in labor input is necessary for original technological development.

On the other hand, the assertion made by Denison–Chung about quality changes in labor inputs especially for the effect of education was opposite to the results of Watanabe–Egaizu. According to the estimation made by Denison for the period of 1953–1971, the contribution of the education effect to economic growth (10.4 percent per annum) was 0.41 percent per annum, while in Watanabe–Egaizu it was 0.06–0.18 percent.

Denison–Chung have some problem in their framework. They used data cross-classified only by age and sex. Education was not cross-classified. This imposes the strong restriction that the education effect was almost the same in all of the age-sex categories.

We should draw on Tachibanaki [12], who measured quality changes in labor inputs for 1956–1970. He found that the major source of quality change was education and especially experience. However, we have to point out that his framework of analysis treats the number of employees of a company as one of the measures of the quality of labor, and that he measured labor input only by the numbers of persons, assuming hours were constant throughout the observation period.

The contribution of this paper to research in quality change in labor inputs is, first, that we measured quality changes in labor inputs in 29 industries using Divisia indices which are consistent with the neoclassical theory of production under some necessary assumptions. Not only single dimensional effects, but all orders of multi dimensional effects were analyzed which enables us to understand quality changes in labor inputs more systematically than any other previous research. Secondly, we compiled a huge amount of data for labor inputs cross-classified into age, sex, education, occupation and industry. Such kinds of data have not yet been developed consistently over time. Thirdly we compared quality changes in labor inputs between the U.S. and Japan in a more decomposed manner than any other previous researches. Also we examine the causes of differences in productivity change between the U.S. and Japan precisely.

However, further analysis is needed for a more exact understanding of the input structure. Subsequent analysis will use the results of this paper as a clue for constructing the framework of analysis.

2. THEORETICAL FRAMEWORK FOR MEASURING LABOR INPUT

2.1 *Measurement of Total Factor Productivity and the Divisia Index*

Let us consider the i-th industrial sector, where the social accounting identity exists as follows.

$$q_i Z_i = p_X^i X_i + p_K^i K_i + p_L^i L_i \tag{1}$$

where Z_i represents gross output of the i-th industry, X_i intermediate input, K_i capital input, L_i labor input, and q_i, p_X^i, p_K^i, p_L^i represent their respective prices.

Defining total factor productivity P_i as

$$P_i = Z_i / I_i \tag{2}$$

where Z_i represents gross output, I_i total factor input, then differentiating (1) logarithmically with respect to time, we get the growth rate of total factor productivity.

$$\frac{\dot{P}_i}{P_i} = \frac{\dot{Z}_i}{Z_i} - V_X^i \frac{\dot{X}_i}{X_i} - V_K^i \frac{\dot{K}_i}{K_i} - V_L^i \frac{\dot{L}_i}{L_i} \tag{3}$$

where V_X^i, V_K^i, V_L^i, are the value shares of intermediate, capital and labor inputs in the total factor input respectively.

Equation (3) was derived from the social accounting identity. On the other hand, the same equation can be derived from the production function. Let us assume perfect competition in the market, and that producers behave under the profit maximization principle.

Further, suppose that there exists a production function with constant returns to scale.

$$(4) \qquad Z_i = F_i(X_i, K_i, L_i, t)$$

Differenciating (4) logarithmically with respect to time we obtain

$$(5) \qquad \frac{d \ln Z_i}{dt} = \frac{\partial \ln Z_i}{\partial \ln X_i} \frac{d \ln X_i}{dt} + \frac{\partial \ln Z_i}{\partial \ln K_i} \frac{d \ln K_i}{dt} + \frac{\partial \ln Z_i}{\partial \ln L_i} \frac{d \ln L_i}{dt} + \frac{\partial \ln Z_i}{\partial t}$$

Under perfect competition, output elasticity is equal to the value share of each factor.

$$(6) \qquad \frac{d \ln Z_i}{dt} = V_X^i \frac{d \ln X_i}{dt} + V_K^i \frac{d \ln K_i}{dt} + V_L^i \frac{d \ln L_i}{dt} + V_t^i$$

where $V_t^i = \partial \ln Z_i(X_i, K_i, L_i, t)/\partial t$ (we do not assume any specific neutrality of technical change in this framework).

Each factor inputs appearing on the right hand side of Eqa. (5) and (6) can also be disaggregated into more decomposed elements, when we define the constant returns to scale aggregator function under the assumption of separability of each factor input.

$$(7) \qquad \begin{aligned} X_i &= X_i(X_{1i}, X_{2i}, \cdots, X_{ni}) \\ K_i &= K_i(K_{1i}, K_{2i} \cdots, K_{pi}) \\ L_i &= L_i(L_{1i}, L_{2i}, \cdots, L_{qi}) \end{aligned}$$

Under the assumption of perfect competition in factor markets, differentiating (7) logarithmically with respect to time we obtain

$$(8) \qquad \begin{aligned} \frac{d \ln X_i}{dt} &= \sum_{j=1}^{n} \frac{\partial \ln X_i(X_{1i}, \cdots, X_{ni})}{\partial \ln X_{ji}} \cdot \frac{d \ln X_{ji}}{dt} = \sum_{j=1}^{n} V_{Xj}^i \frac{d \ln X_{ji}}{dt} \\ \frac{d \ln K_i}{dt} &= \sum_{k=1}^{p} \frac{\partial \ln K_i(K_{1i}, \cdots, K_{pi})}{\partial \ln K_{ki}} \cdot \frac{d \ln K_{ki}}{dt} = \sum_{k=1}^{p} V_{Kk}^i \frac{d \ln K_{ki}}{dt} \\ \frac{d \ln L_i}{dt} &= \sum_{l=1}^{q} \frac{\partial \ln L_i(L_{1i}, \cdots, L_{qi})}{\partial \ln L_{1i}} \cdot \frac{d \ln L_{li}}{dt} = \sum_{l=1}^{q} V_{Ll}^i \frac{d \ln L_{li}}{dt} \end{aligned}$$

These are the growth rates of Divisia indices of intermediate, capital and labor inputs respectively.

Here, we should comment on the data. The discussion above was made in the world of continuous data, but data in the real world can only be obtained as discrete form. To cope with a discrete data system, discrete approximation is needed. Equation (6) and (8) can be rewritten as follows.

$$(9) \qquad \begin{aligned} \ln Z_i(t) - \ln Z_i(t-1) = \bar{V}_X^i(&\ln X_i(t) - \ln X_i(t-1)) \\ &+ \bar{V}_K^i(\ln K_i(t) - \ln K_i(t-1)) \\ &+ \bar{V}_L^i(\ln L_i(t) - \ln L_i(t-1)) + \bar{V}_t^i \end{aligned}$$

where

$$\bar{V}^i_X=\frac{1}{2}(V^i_X(t)+V^i_X(t-1)), \qquad \bar{V}^i_K=\frac{1}{2}(V^i_K(t)+V^i_K(t-1))$$

$$\bar{V}^i_L=\frac{1}{2}(V^i_L(t)+V^i_L(t-1)), \qquad \bar{V}^i_t=\frac{1}{2}(V^i_t(t)+V^i_t(t-1))$$

(10)
$$\ln X_i(t)-\ln X_i(t-1)=\sum_{j=1}^{n}\bar{V}^i_{Xj}(\ln X_{ji}(t)-\ln X_{ji}(t-1))$$

where
$$V^i_{Xj}=\frac{1}{2}(V^i_{Xj}(t)+V^i_{Xj}(t-1))$$

$$\ln K_i(t)-\ln K_i(t-1)=\sum_{k=1}^{p}\bar{V}^i_{Kk}(\ln K_{ki}(t)-\ln K_{ki}(t-1))$$

where
$$\bar{V}^i_{Kk}=\frac{1}{2}(V^i_{Kk}(t)+V^i_{Kk}(t-1))$$

$$\ln L_i(t)-\ln L_i(t-1)=\sum_{l=1}^{q}\bar{V}^i_{Ll}(\ln L_{1i}(t)-\ln L_{1i}(t-1))$$

where
$$\bar{V}^i_{Ll}=\frac{1}{2}(V^i_{Ll}(t)-V^i_{Ll}(t-1)).$$

These discrete type Divisia indices are in fact exact and superative index numbers of a translog aggregator function. Proof for this approximation was given by Diewert [5].

2.2. *Measurement of the Quality Change in Labor Input*

To calculate an aggregate index taking into account the heterogeneity of labor inputs, we use Eqs. (8) or (10) (discrete approximation of (8)). Then, we divide the index into a man-hour index and a quality index. Further we can decompose the quality index with respect to quality factors.

Let us assume there are only four quality factors of labor input, sex (*s*), occupation (*o*), education (*e*), and age (*a*). We can define the growth rate of the Divisia index of labor input employed in the *i*-th industry as follows.

(11)
$$\frac{\dot{L}_{it}}{L_{it}}=\sum_s\sum_o\sum_e\sum_a V_{soea,it}\frac{\dot{L}_{soea,it}}{L_{soea,it}}$$

where
$$V_{soea,it}=\frac{W_{soea,it}L_{soea,it}}{\sum_s\sum_o\sum_e\sum_a W_{soea,it}L_{soea,it}}$$

W_{soea},it; hourly wage rates of the soea-th labor input of the i-th industry

L_{soea},it; quantity of labor input in terms of man-hours of the i-th industry

The quantity of labor input ($L_{soea,it}$) can be rewritten as the product of total man-hours worked in the i-th industry ($M_{it}H_{it}$) and the proportion of man-hours worked by the soea-th type of labor input in the i-th industry ($d_{soea,it}$).

$$L_{soea,it} = d_{soea,it} M_{it} H_{it} \tag{12}$$

Differentiating (12) logarithmically with respect to time and substituting into (11) yields

$$\begin{aligned} \frac{\dot{L}_{it}}{L_{it}} &= \sum_s \sum_o \sum_e \sum_a V_{soea,it} \left(\frac{\dot{d}_{soea,it}}{d_{soea,it}} + \frac{\dot{M}_{it}}{M_{it}} + \frac{\dot{H}_{it}}{H_{it}} \right) \\ &= \sum_s \sum_o \sum_e \sum_a V_{soea,it} \frac{\dot{d}_{soea,it}}{d_{soea,it}} + \left(\frac{\dot{M}_{it}}{M_{it}} + \frac{\dot{H}_{it}}{H_{it}} \right) \end{aligned} \tag{13}$$

The growth rates of the Divisia index are now expressed as the sum of quality change and the growth rate in hours of work. The first term of the right hand side of (13) accounts for the quality change in labor input, and the second term accounts for the growth rate in hours of work of labor.

By using discrete approximation, equation (13) can be rewritten as follows.

$$\begin{aligned} \ln L_i(t) - \ln L_i(t-1) &= (\ln M_i(t) - \ln M_i(t-1)) + (\ln H_i(t) - \ln H_i(t-1)) \\ &\quad + \sum_s \sum_o \sum_e \sum_a \frac{1}{2} (V_{soea,it}(t) + V_{soea,i}(t-1)) \\ &\quad \times (\ln d_{soea,i}(t) - \ln d_{soea,i}(t-1)) \end{aligned} \tag{14}$$

2.3. *Decomposition of Quality Change in Labor Input*

The Divisia index of labor input increases through upward movement of quality change even though there is no increase in total hours worked. In reality, heterogeneity of labor input should be expressed not by one dimension, for example, education, but by multiple dimensions, education, sex, age and occupation, because individuals with given educational attainment must be either male or female and of a certain age. We cannot treat those measures of quality independently.

We show a simple model in Fig. 1 to explain this mutiplicity in the quality of labor. Here, we assume that there are only two measures of quality we can identify, education and age. Moreover, we assume that there ate two categories for each: only highly educated and less well educated, and young and old workers.

In Fig. 1 L represents the quantity of labor input in terms of man-hours, W

		Age		Total
		Old	Young	
Education	High	L_{HO} W_{HO}	L_{HY} W_{HY}	L_H W_H
	Low	L_{LO} W_{LO}	L_{LY} W_{LY}	L_L W_L
	Total	L_O W_O	L_Y W_Y	L W

Fig. 1. Classification of Quality of Labor Input in 2 Dimensions.

represents hourly wage rates, and suffixes correspond to each category of classification.

Let us assume three different types of labor aggregator functions.

$$X_1 = F_1(L_{HY}, L_{HO}, L_{LY}, L_{LO}) \tag{15}$$

$$X_2 = F_2(L_H, L_L) \tag{16}$$

$$X_3 = F_3(L_O, L_Y) \tag{17}$$

(15) is a multi-dimensional aggregator function, while (16) and (17) are single-dimensional aggregator functions. Differentiating these equations logarithmically with respect to time yields

$$\frac{d\ln X_1}{dt} = \frac{\partial \ln X_1}{\partial \ln L_{HY}}\frac{d\ln L_{HY}}{dt} + \frac{\partial \ln X_1}{\partial \ln L_{HO}}\frac{d\ln L_{HO}}{dt} + \frac{\partial \ln X_1}{\partial \ln L_{LY}}\frac{d\ln L_{LY}}{dt} + \frac{\partial \ln X_1}{\partial \ln L_{LO}}\frac{d\ln L_{LO}}{dt} \tag{18}$$

$$\frac{d\ln X_2}{dt} = \frac{\partial \ln X_2}{\partial \ln L_H}\frac{d\ln L_H}{dt} + \frac{\partial \ln X_2}{\partial \ln L_L}\frac{d\ln L_L}{dt} \tag{19}$$

$$\frac{d\ln X_3}{dt} = \frac{\partial \ln X_3}{\partial \ln L_Y}\frac{d\ln L_Y}{dt} + \frac{\partial \ln X_3}{\partial \ln L_O}\frac{d\ln L_O}{dt} \tag{20}$$

Assuming a linear homogeneous aggregator function and perfect competition, the output elasticity of a individual factors in each equation equals the value share of the same factor. We can rewrite the above equations as follows.

$$\frac{\dot{X}_1}{X_1} = \frac{W_{HY}L_{HY}}{WL}\frac{\dot{L}_{HY}}{L_{HY}} + \frac{W_{HO}L_{HO}}{WL}\frac{\dot{L}_{HO}}{L_{HO}} + \frac{W_{LY}L_{LY}}{WL}\frac{\dot{L}_{LY}}{L_{LY}} + \frac{W_{LO}L_{LO}}{WL}\frac{\dot{L}_{LO}}{L_{LO}} \tag{21}$$

(22) $$\frac{\dot{X}_2}{X_2}=\frac{W_H L_H}{WL}\frac{\dot{L}_H}{L_H}+\frac{W_L L_L}{WL}\frac{\dot{L}_L}{L_L}$$

(23) $$\frac{\dot{X}_3}{X_3}=\frac{W_Y L_Y}{WL}\frac{\dot{L}_Y}{L_Y}+\frac{W_O L_O}{WL}\frac{\dot{L}_O}{L_O}$$

Equation (21) is the only multi-dimensional specification reflecting all of the quality change in labor input. The other two assume equality of wage rates in either the education or age classification.

If the value share of each input is constant at time, t, the quality change in labor input will take place through the change of man-hour proportions in each category. That is, there would be no quality change if the growth rates of man-hour in each decomposed category is exactly the same, namely,

(24) $$\frac{\dot{L}}{L}=\frac{\dot{L}_{HY}}{L_{HY}}=\frac{\dot{L}_{HO}}{L_{HO}}=\frac{\dot{L}_{LY}}{L_{LY}}=\frac{\dot{L}_{LO}}{L_{LO}}$$

in this case (21) becomes

$$\frac{\dot{X}_1}{X_1}=\frac{\dot{L}}{L}$$

But, if only one of them is not equal to the other three, then a quality change in the labor input appears.

Next, we consider the case under the existence of the below equality.

(25) $$\frac{\dot{L}_H}{L_H}=\frac{\dot{L}_{HY}+\dot{L}_{HO}}{L_{HY}+L_{HO}}=\frac{\dot{L}_L}{L_L}=\frac{\dot{L}_{LY}+\dot{L}_{LO}}{L_{LY}+L_{LO}}$$

In this case, Eq. (22) gives us zero quality change in the labor input, but as (25) is not a sufficient condition for the existence of (24), we do not necessarily obtain zero quality change in Eq. (21). The single-dimensional aggregator function (16) and (17) have biases with respect to the multi-dimensional function (15). These biases are the result of calculating quality change in a single dimensional framework.

Let us call the quality change calculated from the single dimension aggregator function as the main effect, and the difference between the multi-dimensional and single-dimensional quality change as the interactive effect.

To explain these two effects more precisely, we use a four dimensional classification of labor, sex (s), occupation (o), education (e) and age (a). We define the following five types of growth rates of Divisia indices.

(26) Divisia growth rate of man-hour labor input

$$\Delta \ln MH=\Delta \ln \sum_s \sum_o \sum_e \sum_a (MH)_{soea}$$

where s: sex classification (male & female)
o: occupation (blue & white collar)

e: education (junior high school, senior high school, junior college and university graduates)

a: age (less than 17, 18–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and more than 65 years old)

(27) First order Divisia growth rate of labor input

$$\Delta \ln L_i = \sum_i \bar{V}_i \Delta \ln \sum_j \sum_k \sum_l (MH)_{ijkl}$$

$$i = s,\ o,\ e,\ a$$

$$j,k,l = s,\ o,\ e,\ a \quad (j,k,l \neq i)$$

(28) Second order Divisia growth rate of labor input

$$\Delta \ln L_{ij} = \sum_i \sum_j \bar{V}_{ij} \Delta \ln \sum_k \sum_l (MH)_{ijkl}$$

$$i,j = s,\ o,\ e,\ a \quad (i \neq j)$$

$$k,l = s,\ o,\ e,\ a \quad (k,l \neq i,j)$$

(29) Third order divisia growth rate of labor input

$$\Delta \ln L_{ijk} = \sum_i \sum_j \sum_k \bar{V}_{ijk} \Delta \ln \sum_l (MH)_{ijkl}$$

(30) Forth order Divisia growth rate of labor input

$$\Delta \ln L_{ijkl} = \sum_i \sum_j \sum_k \sum_l \bar{V}_{ijkl} \Delta \ln (MH)_{ijkl}$$

where $\bar{V}$ represents the value share of the period, and Δ denotes the first difference operator.

Using these growth rates of Divisia indices, we define the main effects and interactive effects for the quality change in labor inputs.

(31) Main effects for sex, occupation, education and age

$$q_i = \Delta \ln L_i - \Delta \ln MH \quad (i = s,\ o,\ e \text{ and } a)$$

(32) First order interactive effects for quality change

$$q_{ij} = \Delta \ln L_{ij} - \Delta \ln MH - q_i - q_j \quad (i,j = s,\ o,\ e \text{ and } a)\ (i \neq j)$$

(33) Second order interactive effects for quality change

$$q_{ijk} = \Delta \ln L_{ijk} - \Delta \ln MH - q_i - q_j - q_k - q_{ij} - q_{ik} - q_{jk}$$

$$(i,j,k = s, o, e \text{ and } a)$$

(34) Third order interactive effects for quality change

$$q_{ijkl}=\Delta \ln L_{ijkl}-\Delta \ln MH-q_i-q_j-q_k-q_l-q_{ij}-q_{ik}-q_{il}$$
$$-q_{jk}-q_{jl}-q_{kl}-q_{ijk}-q_{jkl}-q_{ijl}$$
$$(i,j,k,l=s,o,e \text{ and } a)$$

(35) Total quality change in labor input

$$\Delta \ln L_{ijkl}-\Delta \ln MH=\text{Main effects } (q_i+q_j+q_k+q_l)$$
$$+\text{First order interactive effects } (q_{ij}+q_{ik}+q_{il}+q_{jk}+q_{jl}+q_{kl})$$
$$+\text{Second order interactive effects } (q_{ijk}+q_{ikl}+q_{jkl}+q_{ijl})$$
$$+\text{Third order interactive effect } (q_{ijkl})$$

Also we can define the marginal effects for each category as the effect of the n-th factor added to (n-1) factors of labor quality.

(36) Marginal effects for labor quality change

Sex:	$q_i+q_{ij}+q_{ik}+q_{il}+q_{ijk}+q_{ijl}+q_{ikl}+q_{ijkl}$
Occupation:	$q_j+q_{ij}+q_{jl}+q_{jk}+q_{ijk}+q_{ijl}+q_{jkl}+q_{ijkl}$
Education:	$q_k+q_{ik}+q_{jk}+q_{kl}+q_{ijk}+q_{jkl}+q_{ikl}+q_{ijkl}$
Age:	$q_l+q_{il}+q_{jl}+q_{kl}+q_{ijl}+q_{jkl}+q_{ikl}+q_{ijkl}$

3. DATA COMPILATION

The data source for full-time employed workers in nonagricultural industries was primarily the *Basic Wage Structure Survey* (BWSS). We obtained data for the numbers of employees, average hours worked, wages and bonuses cross classified by sex, occupation, education and age. Industries for which data were available were Mining, Construction, 20 two-digit level Manufacturing industries and 6 two-digit level service industries. Also, we obtained sub-aggregated BWSS data for motor vehicles, so the total number of industries available was 29 (see Table 4). Data for Agriculture, forestry and fishery are available from another source, *Labor Force Survey* (LFS), which was only classified by sex. The time period for index construction was 1960–1979.

We should make a note here about the definition of a full-time employee in BWSS. First, we begin with the definition of an employee in BWSS.

(i) workers employed with no particular contract with respect to period of employment

(ii) workers employed with contracts for more than three months.

(iii) temporary and daily workers employed in the same enterprise for more than 18 days in the preceding 2 months respectively. This category of employee is divided into full-time employees and part-time employees. Full-time employees are defined as those employees whose hours of work are the usual daily contractual hours, while part-time employees work less than that. As part-time employees are not cross classified by sex, occupation, education, age and industry, our analysis focuses on full-time employees.

According to the classification described in Eq. (26), we basically obtained data for $2\times2\times4\times12=192$ categories of heterogeneous labor for each of the 29 industries. However, in the process of data construction, BWSS did not give us full information about all of the categories, we made a few estimates using LFS and *Manufacturing Census*.

4. EMPIRICAL RESULTS

In what follows, the magnitude of the contribution of quality change in labor inputs to economic growth is discussed, and the results of the decomposition of quality change is examined, especially for the contribution of each quality factor. On the basis of these results, we will be able examine whether a linear logarithmic specification of the labor aggregator function, represented by the main effect, is plausible as the measure of quality change.

We will also discuss the results of analysis with special reference to technological development in the postwar Japanese economy. Finally, our results will be compared with the results of Chinloy [2] and Gollop–Jorgenson [6].

4.1. *Sources of Economic Growth in Japan*

Figure 2 and Table 1 show the time-series trend of economic growth and its sources during the period 1960–1979 in Japan. V stands for the aggregate index of real domestic product. K^s and L^s represent the Divisia index of capital and labor service inputs. L^{mh} denotes the Divisia index of man-hour labor input. The difference between L^s and L^{mh} represents quality changes in labor input. T.F.P. is an aggregate index of total factor productivity.

The contribution of the labor input remained stable compared to the capital input, but the proportion of quality change in the labor input (L^s-L^{mh}) to the Divisia index of labor input (L^s) has increased remarkably.

4.2. *Trends of Quality Change of Labor Input in Manufacturing and Service Industries*

Quality change in labor input became dominant after 1965. Figures 3a and b show quality change in labor inputs in manufacturing and services. $\bar{L}$ represents man-hour quantity change and $\bar{Q}$ represents quality change. In terms of man-hour quantity change, the growth rate in manufacturing slowed down at the end of the 1960's and decreased remarkably after the Oil Crisis in 1974. On the other hand, in services, growth of man-hour labor inputs continued to increase until the first oil crisis. Although it experienced a slight decrease after the oil crisis, man-hour growth recovered to the trend level in 1979.

Quality changes both in manufacturing and services continued positively during

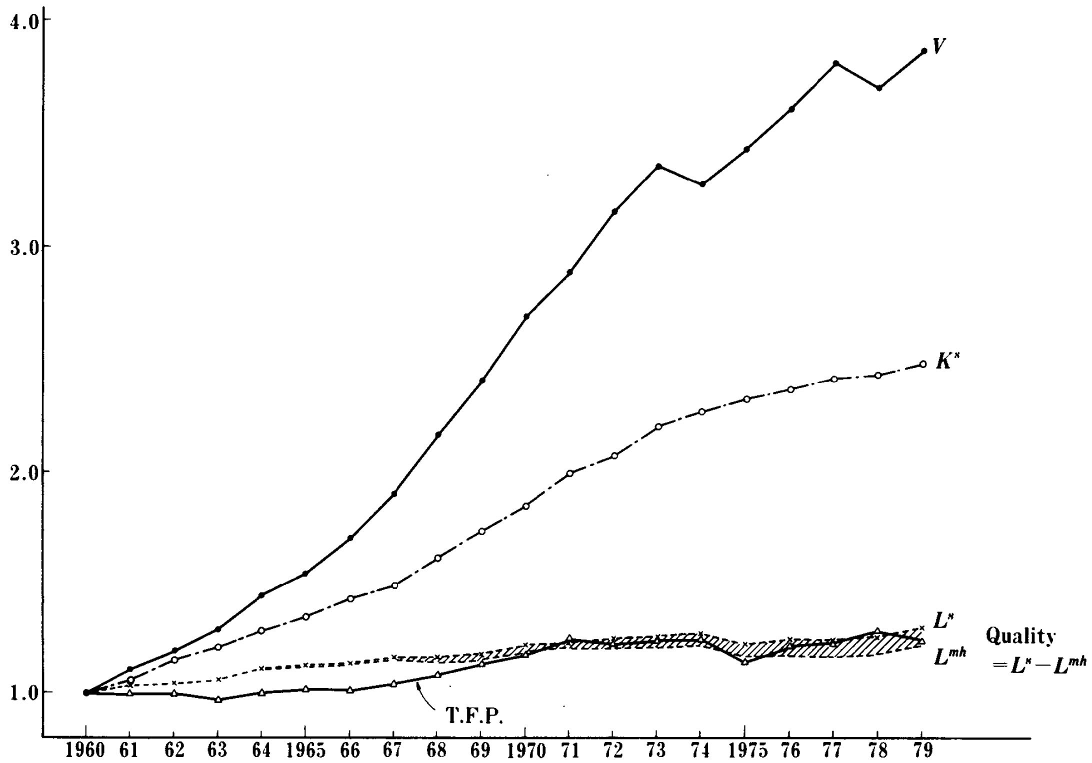

Fig. 2. Source of Economic Growth in Japan.

TABLE 1. AGGREGATED DIVISIA INDEXES

	Val. add	Labor	Capital	L. quality	L. manhour	Technology
1960	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
1961	1.109946	1.049951	1.059911	0.999306	1.051238	1.000084
1962	1.190533	1.051994	1.156123	0.997537	1.055248	0.979968
1963	1.296742	1.065752	1.219799	0.999993	1.066544	1.000601
1964	1.453947	1.102960	1.289688	1.001762	1.102139	1.029642
1965	1.550432	1.134796	1.355829	1.006756	1.128777	1.015445
1966	1.706101	1.148762	1.433682	1.009607	1.139476	1.046596
1967	1.900526	1.172713	1.499796	1.011800	1.160829	1.095778
1968	2.174340	1.162880	1.624192	1.015507	1.146564	1.171953
1969	2.417864	1.187755	1.742841	1.017751	1.168846	1.192528
1970	2.690737	1.221420	1.854811	1.027068	1.191491	1.216698
1971	2.886212	1.236750	1.986354	1.032274	1.200398	1.203530
1972	3.152347	1.251941	2.079793	1.037019	1.209766	1.243109
1973	3.357734	1.266745	2.204737	1.042780	1.217265	1.234722
1974	3.276709	1.285245	2.263719	1.048981	1.227772	1.153863
1975	3.437368	1.238671	2.320924	1.054136	1.176536	1.223092
1976	3.617861	1.259067	2.364419	1.059737	1.189802	1.244255
1977	3.822124	1.252460	2.407564	1.063774	1.178950	1.298330
1978	3.706379	1.269048	2.438205	1.069050	1.188866	1.225293
1979	3.873339	1.312111	2.485820	1.073623	1.224380	1.214982

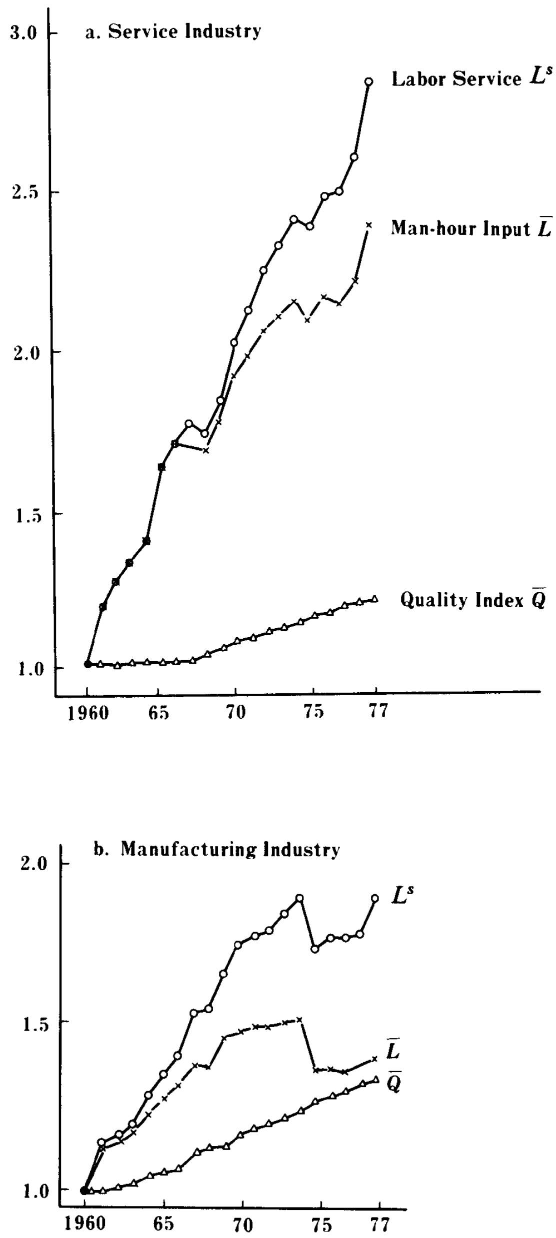

Fig. 3a and b. Labor Input Index in Japan.

the whole period. It is apparent from Figs. 3a and b that quality change in manufacturing was larger than that in services. In manufacturing, the average annual growth rate of quality change was 1.65 percent. In services quality change started at the end of the 1960's at an annual rate of 0.95 percent.

4.3. *Decomposition of Quality Change in Labor Input in Manufacturing*

A summary of quality decompositon is shown in Table 2

(i) *Sex effect*

During 1966–1969 the main effect of sex was Δ 0.14 percent per annum, while it was more than 0.20 percent for 1969–1973 and 1973–1979. The main effect of sex explains more than 10 percent of all quality change in manufacturing, which reflects the increasing proportion of male workers.

The sum of interactive effects in terms of sex was Δ 0.16–Δ 0.33 percent per annum. The minus sign persisted during the whole period especially for sex and age (*SA*), which indicates an expanding proportion of female and young workers, both in low wage levels.

(ii) *Education effect*

The main effect of education was quite high. It explains more than 25 percent of total quality change in labor inputs.

Disaggregated figures of the interactive effect between education and age (*EA*) and education and occupation (*EO*) are shown in Table 4. The interactive effect between education and age increased gradually, while the interactive effect between education and occupation decreased.

The increase in the *EA* effect reflects the increasing proportion of older and highly educated workers in the labor force, while the decrease of the *EO* effect represents an increase of the proportion of highly educated blue collar workers.

In postwar Japan, the proportion of highly educated workers has been increased as the result of reform in the education system and changes in human capital investment behavior by workers themselves. This movement caused an increase in highly educated older workers, while the over-supply of highly educated younger workers resulted in the increase of highly educated blue collar workers.

Relative prices between heterogeneous labor have a great influence on the Divisia index of labor input. Shimada [10] pointed out that wage differentials in Japan were largely affected by years of experience (or age as a proxy) and years of education, and that interactive effects of education and age to the wage differentials were quite high. Our observation of the high main effect of education and the movement of interactive effects of *EA* and *EO* must inevitably be affected by the characteristics of wage profiles in Japan.

Our analysis started with the assumption of perfect competition in the labor market without any analysis of the mechanism behind the emergence of such wage profiles. Therefore, we should further investigate these problems in the future.

(iii) *Age effect*

The main effect of age explains more than 70 percent of quality change in labor input in Japan. This is extremely high compared to other main effects.

Interactive effects in terms of age were fairly small during the whole period, which means that the effect of age influenced globally all categories of labor as a demographic factor. The main cause of this strong age effect in all categories of labor inputs is the demographic trend of aging from a young generation to an experienced middle age generation in Japanese society.

Under the assumption of perfect competition the observed upward sloping of

TABLE 2. SUMMARY TABLE OF QUALITY CHANGES IN LABOR INPUT
—MANUFACTURING INDUSTRY— (Unit = 1/100%)

	1960–1966	1966–1969	1969–1973	1973–1979	1960–1973	1960–1979
interactive effects						
SE	−0.0007585	−0.0011481	−0.0006500	−0.0008448	−0.0008032	−0.0008142
SA	−0.0034451	−0.0019709	−0.0027907	−0.0011032	−0.0028957	−0.0024243
SO	−0.0004251	−0.0006961	0.0001469	−0.0002599	−0.0002791	−0.0002741
EA	−0.0001637	−0.0015920	0.0020466	0.0018282	0.0003185	0.0007162
EO	0.0000401	0.0026989	−0.0028279	−0.0022479	−0.0004165	−0.0008988
AO	−0.0027440	−0.0003876	−0.0004185	−0.0007677	−0.0014092	−0.0012404
SEA	0.0009279	0.0008135	0.0001230	−0.0002301	0.0006161	0.0003929
SEO	0.0005751	0.0005503	0.0003405	0.0004559	0.0004864	0.0004787
SAO	0.0010481	0.0010681	−0.0003505	0.0003319	0.0005531	0.0004950
EAO	0.0012617	−0.0000306	−0.0004169	0.0003090	0.0003853	0.0003653
SEAO	−0.0004863	−0.0003507	−0.0001021	0.0000887	−0.0003200	−0.0002124
Sex (*S*)						
Interactive effect	−0.0025558	−0.0017263	−0.0032777	−0.0015583	−0.0026361	−0.0023525
Main effect	0.0004740	−0.0014408	0.0021324	0.0022879	0.0006552	0.0010843
Marginal effect	−0.0020790	−0.0031729	−0.0011451	0.0007315	−0.0019801	−0.0012673
Education (*E*)						
Interactive effect	0.0013857	0.0009718	−0.0014800	−0.0006374	0.0002728	0.0000334
Main effect	0.0037251	0.0051727	0.0035524	0.0035343	0.0039740	0.0038576
Marginal effect	0.0051327	0.0061388	0.0020761	0.0028992	0.0042553	0.0038986
Age (*A*)						
Interactive effect	−0.0035833	−0.0024350	−0.0018952	0.0004587	−0.0027346	−0.0018952
Main effect	0.0079880	0.0094042	0.0123177	0.0112162	0.0098362	0.0101995
Marginal effect	0.0044050	0.0069866	0.0104313	0.0116787	0.0071068	0.0083084
Occupation (*O*)						
Interactive effect	−0.0007256	0.0028868	−0.0036227	−0.0020869	−0.0009891	−0.0012782
Main effect	0.0043392	0.0096312	0.0054502	0.0013933	0.0058680	0.0046883
Marginal effect	0.0036287	0.0125237	0.0018406	−0.0006895	0.0048876	0.0034170
Total quality change	0.0124083	0.0218086	0.0185595	0.0160027	0.0166121	0.0164518
Manhour quantity change	0.0503902	0.0360832	0.0093336	−0.0176437	0.0325003	0.0190611
Divisia growth rate	0.0628729	0.0578604	0.0277519	−0.0013447	0.0491304	0.0356054

TABLE 3. Summary Table of Quality Changes in Labor Input —Service Industry— (Unit = 1/100%)

	1960–1966	1966–1969	1969–1973	1973–1979	1960–1973	1960–1979
Interactive effects						
SE	0.0000734	0.0003853	0.0006800	0.0002308	0.0003567	0.0003242
SA	0.0003252	0.0002966	−0.0016302	−0.0002276	−0.0003797	−0.0003397
SO	0.0	0.0	0.0	0.0	0.0	0.0
EA	−0.0002860	0.0013342	0.0016642	0.0022058	0.0007572	0.0011387
EO	0.0	0.0	0.0	0.0	0.0	0.0
AO	0.0	0.0	0.0	0.0	0.0	0.0
SEA	0.0002594	−0.0001657	−0.0001378	−0.0001493	0.0000267	−0.0000197
SEO	0.0	0.0	0.0	0.0	0.0	0.0
SAO	0.0	0.0	0.0	0.0	0.0	0.0
EAO	0.0	0.0	0.0	0.0	0.0	0.0
SEAO	0.0	0.0	0.0	0.0	0.0	0.0
Sex (*S*)						
Interactive effect	0.0006609	0.0005169	−0.0010864	−0.0001446	0.0000057	−0.0000338
Main effect	−0.0033318	−0.0019360	0.0027399	−0.0002860	−0.0008680	−0.0007149
Marginal effect	−0.0026553	−0.0014167	0.0016613	−0.0004303	−0.0008501	−0.0007397
Education (*E*)						
Interactive effect	0.0000486	0.0015543	0.0022078	0.0022898	0.0011415	0.0014439
Main effect	0.0010138	0.0039139	0.0018454	0.0018759	0.0019312	0.0019169
Marginal effect	0.0010653	0.0054636	0.0040512	0.0041656	0.0030727	0.0033598
Age (*A*)						
Interactive effect	0.0002956	0.0014648	−0.0001030	0.0018291	0.0004034	0.0007792
Main effect	0.0030518	0.0075750	0.0107908	0.0084810	0.0067787	0.0072269
Marginal effect	0.0033274	0.0090313	0.0107031	0.0103130	0.0071783	0.0080023
Occupation (*O*)						
Interactive effect	0.0	0.0	0.0	0.0	0.0	0.0
Main effect	0.0	0.0	0.0	0.0	0.0	0.0
Marginal effect	0.0	0.0	0.0	0.0	0.0	0.0
Total quality change	0.0011587	0.0113840	0.0159492	0.0121317	0.0086098	0.0095358
Manhour quantity change	0.0930510	0.0139723	0.0405788	0.0221920	0.0568695	0.0476313
Divisia growth rate	0.0942278	0.0256805	0.0563440	0.0344839	0.0656691	0.0573721

TABLE 4. FIRST ORDER INTERACTIVE EFFECTS OF QUALITY CHANGE BETWEEN EDUCATION-AGE (*EA*) AND EDUCATION-OCCUPATION (*EO*)

	EA				*EO*			
	1960–1966	1966–1969	1969–1973	1973–1979	1960–1966	1966–1969	1969–1973	1973–1979
1. Agriculture, forestry								
2. Mining	0.090	0.020	0.183	0.180	−0.088	0.034	−0.090	−0.127
3. Construction	0.008	−0.193	0.134	0.246	−0.385	1.180	−0.300	−0.101
4. Food, kindred product	0.143	−0.030	0.436	0.175	0.530	0.593	−0.193	−0.139
5. Textile mill	−0.252	−0.291	0.020	−0.159	0.012	0.083	−0.450	−0.269
6. Apparel, other fabric	0.018	−0.583	−0.085	0.086	−0.059	−0.585	−0.283	−0.512
7. Lumber, wood except F.	0.042	0.093	0.371	0.280	0.337	0.346	−0.005	−0.150
8. Furniture, fixtures	0.095	−0.066	0.257	0.247	0.097	−0.009	−0.137	−0.195
9. Paper, allied product	0.170	0.153	0.344	0.253	0.256	0.256	−0.155	−0.121
10. Print, publish allied	0.213	−0.197	0.282	0.115	0.188	−0.076	−0.379	−0.238
11. Chemical	0.336	0.265	0.372	0.505	0.291	0.265	−0.258	−0.206
12. Petroleum refinery	0.751	0.821	0.157	1.038	0.526	1.693	−0.289	−0.023
13. Rubber, miscellaneous	−0.127	−0.262	0.055	0.259	0.025	−0.006	−0.224	−0.164
14. Leather	0.068	−0.087	0.211	0.449	0.008	0.012	−0.168	−0.132
15. Stone, clay, glass	0.170	0.071	0.428	0.227	0.360	0.314	−0.124	−0.067
16. Iron & steel	0.439	0.247	2.032	0.415	0.724	1.337	−0.188	−0.044
17. Non-ferrous metals	0.282	0.028	0.353	0.444	0.291	0.432	−0.072	−0.143
18. Fabricated metal	0.035	−0.199	0.236	0.143	0.224	0.316	−0.199	−0.075
19. Machinery	0.135	−0.057	0.332	0.239	0.096	0.272	−0.175	−0.139
20. El. machinery	−0.028	−0.382	−0.030	0.350	0.157	0.017	−0.365	−0.393
21. Motor vehicles	0.016	0.066	0.443	0.229	0.290	0.339	−0.203	−0.149
22. Transportation	0.181	0.366	0.356	0.228	0.009	0.226	−0.102	−0.147
23. Precision	0.009	−0.252	0.084	0.182	0.132	−0.264	−0.073	−0.283
24. Miscellaneous MFG	−0.020	−0.313	0.221	0.169	0.202	−0.158	−0.375	−0.193
25. Trans. communication	0.128	0.166	0.278	0.299				
26. Electric, gas water	0.267	0.216	0.463	0.286				
27. Wholesale, retail	0.113	−0.043	0.308	0.175				
28. Finance insurance	0.113	0.276	0.471	0.259				
29. Real estate	−0.222	−0.018	0.416	0.209				
30. Other service	−0.217	−0.072	−0.186	0.032				

the age-wage profile is interpreted to reflect the marginal differential of productivity of labor inputs for different age classes, which is equivalent to assuming that older people always are more productive than younger people since wage increases according to age. This may appear a peculiar assumption, but if we regard age as the proxy of experience or accumulation of some other relevant know-how in a company under the life-time employment system, we cannot refute a priori the existence of such an equality between wage and marginal productivity. As far as our time period of analysis is concerned, the age effect was a large contributing factor to quality change.

(iv) *Occupation effect*

The main effect of occupation was almost the same magnitude as the main effect of education. It explained more than 40 percent of quality change from 1966–1969, while it explained less than 10 percent of quality change from 1973–1979. This means that the proportion of white collar workers increased in the period 1966–1969, but not so much as in other subsequent periods.

4.4. *Decomposition of Quality Change of Labor Input in Services*

Table 3 shows the summary of quality changes in services. In spite of a higher growth rate in man-hour labor inputs compared with that in manufacturing, the growth rate of quality changes was smaller than in the manufacturing.

Since the service sector in BWSS data is not classified by occupation category, we cannot observe quality change in terms of occupation. Among the remaining three categories, the age effect was the dominant factor in quality change. Also the interactive effect by education and age (*EA*) increased during the observation period.

4.5. *Bias of Aggregation Resulting from Linear Logarithmic Index*

Table 5 shows the bias of aggregation if we aggregate labor inputs by linear logarithmic aggregator functions (represented by the main effect). The bias is calculated by subtracting the total quality change in labor inputs from the simple sum of main effects.

In manufacturing, the linear logarithmic index tends to have an upward bias

TABLE 5. BIAS OF AGGREGATION BY LINEAR LOGARITHMIC SPECIFICATION

		(1) Sum of main effects	(2) Quality change	(3) [(2) − (1)/(1)] × 100
1960–1973	Manufacturing	2.033	1.661	22.4
	Service	0.784	0.861	−8.9
1960–1979	Manufacturing	1.983	1.645	20.5
	Service	0.843	0.954	−11.6

compared with the transcendental logarithmic index, while in the service sector it tends to have a downward bias. The bias amounts to more than 20 percent in manufacturing and around -10 percent in services. This means a linear logarithmic aggregator function, say the Cobb = Douglas function, is less effective than a transcendental logarithmic aggregator function for the measurement of quality change in labor inputs.

4.6. *Quality Change in Labor Inputs and Economic Growth*

Watanabe–Egaizu [13] estimate quality change in labor inputs in Japan for 1951–1964. They concluded that quality change in labor inputs in Japan was lower than that in other developped countries. One reason given for this was the existence of an "imitation-lag" in technology with the U.S. and Western European countries. At that time, Japan depended on imported technology in which technical progress was embodied in capital inputs. Therefore, the amount of demand for high quality labor was limited, which resulted in a low level of quality change. Watanabe–Egaizu indicated that there would be a high level of quality change in labor inputs as the technological level of Japan caught up with those of the U.S. and Western Europe.

The time period for our analysis is 1960–1979. During this time, the Japanese economy was catching up with the technology of the U.S. and Western Europe. Looking at Figs. 3a and b, quality change of labor inputs occurred continuously after the 1960's. And, as stated previously, the main sources of quality change are the main effects of age and education, and the interactive effect of education and age. All of those effects are contributing factors for the technological development because a high level of technological development requires positive quality change in labor inputs especially in education and age. The former represents for the amount of general training, and the latter represents experience and company specific skills. We can conclude that this coincidence of quality change in labor inputs with technological development has been one of the causes for rapid economic growth and the strong upward trend of productivity in the Japanese economy.

However, further analysis with a framework which treats technological change as an endogenous factor is necessary to analyze this coincidence more accurately.

4.7 *Comparison of Quality Change in Labor Inputs between Japan and the U.S.*

We can draw on Gollop–Jorgenson[6] and Chinloy [2] (see Table 6) for a similar analysis of the United States. They reported some specific features of quality change in labor input in the U.S. We compared them with those for Japan as follows:

(i) In the United States the main effect in terms of sex was negative for the whole period of 1959–1974, which is the opposite of the result obtained for Japan. In Japan, the main effect in terms of sex was positive except for 1966–1969.

(ii) The main effect in terms of age was negative in the United States. On the other hand, it was positive in Japan, where this effect explained more than 50

TABLE 6. QUALITY CHANGE OF LABOR INPUT IN THE UNITED STATES

	1959–63	1963–67	1967–71	1971–74
Main effect				
Sex (*S*)	−.05	−.24	−.22	−.06
Class (*C*)	.14	.04	.05	.09
Age (*A*)	−.07	−.22	−.20	−.29
Education (*E*)	.72	.85	.81	.67
Occupation (*I*)	.37	.14	.40	−.11
	1.11	.57	.84	.30
Interactive effect				
First order				
SC	.14	.17	.00	.02
SA	.13	.12	.02	−.01
SE	.13	.13	.03	.02
SI	.17	.15	.07	−.03
CA	.12	.04	−.01	−.03
CE	.06	−.20	−.04	−.02
CI	.07	−.51	.03	−.05
AE	.12	.03	−.01	−.07
AI	.09	.00	.04	.06
EI	−.18	−.36	−.35	−.05
Total	.85	−.43	−.22	−.16
Second order				
SCA	−.09	−.07	−.00	−.01
SCE	−.10	−.11	−.00	−.01
SCI	−.15	−.20	.01	−.01
SAE	−.09	.00	.02	.01
SAI	−.09	−.07	.00	−.01
SEI	−.17	−.12	−.05	−.04
CAE	−.06	−.02	.02	.02
CAI	−.11	.00	−.01	.01
CEI	−.08	.04	−.01	−.02
AEI	−.12	−.05	−.01	.02
Total	−1.06	−.60	−.03	−.04
Third order				
SCAE	.11	.03	.00	.00
SCAI	.10	.04	.00	.01
SCEI	.10	.13	.00	.00
SAEI	.10	.03	−.01	.01
CAEI	−.02	.07	.03	.00
Total	.48	.26	−.01	.02
Fourth order				
SCAEI	−.11	−.03	.00	.00
Quality change	1.27	−.23	.58	.12
Total hours	−.03	2.54	.26	2.55
Labor input	1.24	2.31	.84	2.67

Note: Chinloy (1980): "Source of Quality Change in Labor Input," *American Economic Review*, Vol. 70, No. 1, March.

percent of all quality change.

(iii) The main effect in terms of education was positive both in the U.S. and Japan. The main effect was 0.67–0.85 percent in the U.S. which was somewhat higher than that in Japan.

(iv) The interactive effect between education and occupation was negative in the U.S. Especially during the periods 1963–67 and 1967–71, its absolute value was greater than 40 percent of total quality change. On the other hand the interactive effect between education and age was negligibly small in the United States.

(v) In the United States such kinds of quality change resulted from increases in female and younger workers in the labor force. Such changes in the United States consequently worsened improvements in the quality of labor inputs. On the other hand, the effect of education contributed to the improvement of labor quality although a negative interactive effect between education and occupation which offset this improvement to some extent. Chinloy called this situation "over-education" in the United States.

(vi) Finally, quality changes in the United States on average were smaller than those in Japan. In the United States, quality change was 1.27 percent per year in 1959–63, 0.23 in 1963–67 and 0.58 in 1967–71, while in Japan quality changes were more than 1.0 percent per year during the whole period.

The characteristics of quality change are behind the difference of productivity performance between the U.S. and Japan. We may conclude that the high quality change of labor input in Japan affected favorably the development of technology, which resulted in high labor productivity, while the low quality change of labor input in U.S. downgraded the growth of labor productivity.

5. SUMMARY AND CONCLUSION

Quality change in labor inputs has been decomposed into effects in terms of sex, occupation, education and age, using Divisia index numbers. The transcendental logarithmic aggregator function underlying the Divisia index numbers is the exact and superlative. We assumed separability which permits us to construct Divisia index of labor input without any reference to other factors.

We compiled a data base for the analysis of quality change of labor input, the source of which was mainly the *Basic Wage Structure Survey*.

The upward trend of quality change of labor inputs began at the beginning of the 1960's for manufacturing, while it began at the end of the 1960's for services. The average growth rate in quality change of labor inputs was 1.65 percent per annum in manufacturing, and 0.95 percent in services.

The characteristic features of quality change in labor inputs in Japan were large age and education effects, and an increasing interactive effect of education and age. During our observation period from 1960–1979, the Japanese economy was catching up with the technology of the U.S. and Western Europe. The results of the analysis of quality change in labor inputs are consistent with this catch-up process. This is because, the more the technology level is enhanced through the development of technology, the greater is the quality change in labor input required. This coincidence of quality change in labor input with the technological development has been one of causes of rapid productivity change in the Japanese economy.

We can draw on Chinloy [2] for the same analysis of the United States. Comparison of results for the two countries indicated quality change in the U.S. and Japan has been dissimilar.

(i) Sex and age in the U.S. were negative factors while they were positive and strongly positive respectively in Japan.

(ii) The relatively higher effect of education in the U.S. was downgraded when an adjustment for occupation was made.

(iii) The total amount of quality change in labor inputs in the U.S. was smaller than that in Japan.

We may conclude from these facts that quality change in labor did not contribute much to the growth of labor productivity in the U.S. compared to the significant contribution in Japan.

Our analysis in this paper is part of research work to investigate the interdependent mechanism of the relationship between input structure and economic growth and technical progress. We must investigate further other factor inputs, such as capital and intermediate inputs, and also the interaction between labor, capital and intermediate inputs.

Keio University

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