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Abstract:
This paper proposes a framework for the cross-country comparison of labor input and measures the relative price, quality, and the purchasing power parity for labor input between the U.S. and Japan during 1960-2000, based on detailed labor data cross-classified by sex, age, education, class of worker, and industry in both countries.

Keywords:
Purchasing Power Parity for Labor Input, Relative Price, Relative Quality

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1 Introduction

Across economies, the purchasing power parity (PPP) is required in order to translate data measured in nominal values in different currencies into a common unit. Using the U.S. dollar as the numeraire, the PPP between the U.S. and Japan is defined by the number of yen required in Japan to buy the same quantity of goods or services that one dollar can buy in the U.S. The PPP translates units not only to a common currency, the U.S. dollar, but converts values such that the converted units are expressed as one dollar's worth of each goods and service. The exchange rate is not sufficient for the translation since it fails to account for different price levels, it converts only to a common currency. The relationship between the PPP and the exchange rate in a cross-country comparison is similar to that between the unit price and denomination in time-series.

The concept of the purchasing power parity for labor input can be defined analogously with purchasing power parities for commodities, which are familiar. As the PPP for commodities is the ratio of own-country prices at the most detailed level of commodity, the PPP for labor input is simply the ratio of per hour labor compensation for each type of worker by country. We classify workers in the US and Japan into homogenous types and compute the PPP for each type and for larger groups. Labor input purchasing power parities allow for supply-side comparisons of labor, and are necessary for comparing labor productivity and total factor productivity across countries.

In this paper, we measure the purchasing power parity for labor input between the U.S. and Japan during 1960-2000. Our measurement is based on detailed cross-classified labor data; Jorgenson data at Harvard University covers the U.S. and Keio Economic Observatory Database (KDB) at Keio University covers Japan. Data used in our study is an updated version of the data desribed in Ho-Jorgenson(1999) and Kuroda-Shimpo-Nomura-Kobayashi(1997). Each data set has labor input cross-classified by sex, age, education, class of worker, and industry. From these detailed categories, we can construct indices of constant quality labor input and measures of the purchasing power parity for labor input.

In section 2, after we describe briefly the framework for labor input in the time-series comparison, we propose the framework for the cross-country comparison and constructing the purchasing power parity for labor input in each category and aggregating to the economy as a whole. In this section we define the relative price of labor taking into account the impact of the exchange rate on relative price levels in the U.S. and Japan, and introduce a measure of quality differences between the work forces in both countries. We introduce our labor data, homogenize the datasets of both countries over a group of common categories in section 3. We discuss the estimated results of the purchasing power parity for aggregate level labor input in section 4. In addition, we decompose the contributions to the growth of the relative price for labor input, discuss the relative per worker price, and compare the relative prices for different groups of workers. In section 5, we present industry level detail and describe how variation in relative prices by industy has changed over time. Section 6 concludes the paper.

2 Framework

2.1 Time-Series Comparison

We begin with the following notation. Let

E^x_{saecjt}	=number of workers by sex s, age a, education e, class of worker c, industry j, year t, and country x;
h^x_{saecjt}	=average annual working hours by $saecjtx$;
H^x_{saecjt}	$=E^x_{saecjt}h^x_{saecjt}$, hours worked by $saecjtx$;
c^x_{saecjt}	=average hourly labor compensation by $saecjtx$;
C^x_{saecjt}	=annual labor compensation by $saecjtx$;
L^x_{saecjt}	=quantity of labor input by $saecjtx$;
p^x_{saecjt}	=price index of labor input by $saecjtx$; and,
Q^x_{saecj}	=quality of labor input by $saecjx$.

This notation is based on Jorgenson-Gollop-Fraumeni (1987) and Ho-Jorgenson (1999), both of which measure the labor input in the U.S. For our cross-country comparison of quantity, price, and quality of labor input, we expand these variables conceptually and add some notation later. At first, for each country, we describe briefly the framework for labor input in each country, in order to clarify the relationship between the time-series comparison in each coutry and the cross-country comparison in each year. First, the quantity of labor input is assumed to be propotional to hours worked in each category ,

$$L^x_{saecjt} = Q^x_{saecj}H^x_{saecjt}, \tag{1}$$

where quality of labor input, Q^x_{saecj}, is constant for all year t. We assume that labor quality for detailed categories of workers does not change over time. That is, an hour worked by category $saecj$ in year t equals an hour worked in year $t + s$. By definition, annual labor compensation is described in two ways; hours worked and labor input,

$$C^x_{saecjt} = H^x_{saecjt}c^x_{saecjt} = p^x_{saecjt}L^x_{saecjt}. \tag{2}$$

We should make clear the unit of measurement of each variable. Labor compensation per year, C^x_{saecjt}, and per hour, c^x_{saecjt}, are measured in own-country currency units. Constant quality of labor input Q^x_{saecj} is measured in own-country constant currency units per hour.

From equations (1) and (2), labor quality index can be also described as follows,

$$c_{saecjt}^{x} = Q_{saecj}^{x} p_{saecjt}^{x}. \tag{3}$$

Quality for labor input is defined from the quantity-side in the Equation (1) and from the price-side in equation (3). In the base year T, quality of labor, Q_{saecj}^{x}, equals per hour labor compensation, c_{saecjT}^{x}, and quantity of labor input, L_{saecjT}^{x}, equals per year labor compensation, C_{saecjT}^{x}, since $p_{saecjT}^{x} = 1.0$ for each country.

Next, we describe briefly the framework for the aggregate measure of labor input in each country. Total labor compensation in each year and in each country, C_t^x, is defined as follows,

$$C_t^x = p_t^x L_t^x = \sum_{saecj} p_{saecjt}^{x} L_{saecjt}^{x} = \sum_{saecj} C_{saecjt}^{x}, \tag{4}$$

where L_t^x and p_t^x represents quantity and price of the aggregate labor input, respectively. We define the aggregate measure of quantity of labor input as a Divisia index,

$$L_t^x = L_T^x exp\left[\int_T^t \sum_{saecj} v_{saecjt}^{x} \left(\frac{\dot{L}_{saecjt}^{x}}{L_{saecjt}^{x}}\right) d\tau\right], \tag{5}$$

$$v_{saecjt}^{x} = \frac{C_{saecjt}^{x}}{C_t^x}, \tag{6}$$

where $L_T^x = C_T^x$ at the base year T.

The corresponding price of aggregate labor input can be derived by equation (4) as the ratio of total labor compensation to the aggregate quantity of labor. Alternatively, the aggregate price can be derived by equation (5) and the differencial of equation (4), as the aggregate measure of price of labor input as a Divisia index,

$$p_t^x = \frac{C_t^x}{L_t^x} = exp\left[\int_T^t \sum_{saecj} v_{saecjt}^{x} \left(\frac{\dot{p}_{saecjt}^{x}}{p_{saecjt}^{x}}\right) d\tau\right]. \tag{7}$$

Additionally, we define total hours worked and simple average hourly labor compensation in each year and in each country as,

$$H_t^x = \sum_{saecj} H_{saecjt}^{x}, \tag{8}$$

$$c_t^x = \frac{C_t^x}{H_t^x}. \tag{9}$$

We can define the aggregate measure of quality of labor input in two ways; from the quantity-side in equations (5) and (8) and the price-side in equations (7) and (9),

$$L_t^x = Q_t^x H_t^x, \tag{10}$$

$$c_t^x = Q_t^x p_t^x. \tag{11}$$

It is important that the aggregate measure of quality, Q_t^x, depends on year t, though quality of labor in each category, Q_{saecj}^x, does not. In each detailed category, because of the assumption of constant labor quality in equations (1) and (3), the growth rates of labor input and hours worked coincide and the growth rates of average hourly labor compensation and price of labor input also coinside. However, the growth rate of the aggregate measure of quality of labor input, $(\dot{Q}_t^x/Q_t^x)$, is non-zero and measured from the quantity-side and the price-side as, differenciating equations (10) and (11) respectively, [*1]

$$\frac{\dot{Q}_t^x}{Q_t^x} = \frac{\dot{L}_t^x}{L_t^x} - \frac{\dot{H}_t^x}{H_t^x} = \frac{\dot{c}_t^x}{c_t^x} - \frac{\dot{p}_t^x}{p_t^x}. \tag{12}$$

The change of aggregate quality of labor depends on the change of price in each labor input. The labor inputs in each category are assumed to be homogeneous over time, however, the price of the labor, which represents the marginal product of labor, can be different. Also, the change of the aggregate quality of labor depends on the change of allocation among labor inputs. In the special case of constant prices of each labor input over time, or equal price changes across all categories, the movement of workers across categories drives the aggregate quality of labor.

2.2 Cross-Country Comparison

Now, we describe the cross-country comparison of quantity, price, and quality of labor in each category and at the aggregate level. At first, we introduce the quantity and price of labor, each of which is comparable with that in the base country y,in the reference country x. Quantity of labor input, L_{saecjt}^x, in equation (1) or price index of labor, p_{saecjt}^x, in equation (3) is sufficient for a time-series comparison in each country. However, they are not sufficient for a cross-country comparison. Adjusting by the quality of labor input in base country, we define the quality-adjusted quantity and price of labor input in the reference country, as $L_{saecjt}^{x|y}$ and $p_{saecjt}^{x|y}$ respectively. For the cross-country comparison, the equations of quantity and price in (1) and (3) and the balance equation on nominal labor compensation in (2) should be redefined as,

$$L_{saecjt}^{x|y} = Q_{saecj}^y H_{saecjt}^x, \tag{1$'$}$$

$$c_{saecjt}^{x|y} = Q_{saecj}^y p_{saecjt}^{x|y}, \tag{3$'$}$$

$$C_{saecjt}^{x|y} = H_{saecjt}^x c_{saecjt}^{x|y} = p_{saecjt}^{x|y} L_{saecjt}^{x|y}, \tag{2$'$}$$

[*1] In measurement of equations (5) and (7), we use the discrete approximation by Theil-Törnqvist indices of aggregate quantity and price of labor input. It is important to note that Theil-Törnqvist index numbers are not transitive. Then, equation (12) is satisfied approximately.

where the labor compensations, per year $C^{x|y}_{saecjt}$ and per hour $c^{x|y}_{saecjt}$, in the reference country are defined by the base country's currency; $C^{x|y}_{saecjt}$=$C^{x}_{saecjt}/e^{x|y}_{t}$ and $c^{x|y}_{saecjt}$=$c^{x}_{saecjt}/e^{x|y}_{t}$, using annual average exchange rate, $e^{x|y}_{t}$. Quantity and price of labor input in the reference country are evaluated by the quality of labor in the base country in (1)′ and (3)′.

Assuming that the quality-adjusted labor inputs in each category are homogeneous, it is convenient to define the relative quantity and price of labor input, $RL^{x|y}_{saecjt}$ and $Rp^{x|y}_{saecjt}$, the relative values of hours worked and per hour labor compensation, $RH^{x|y}_{saecjt}$ and $Rc^{x|y}_{saecjt}$, and the relative values of per year labor compensation, $RC^{x|y}_{saecjt}$, based on equations (1)′, (3)′, and (2)′. Each relative variable in the reference country to the base country can be described as follows,

$$RL^{x|y}_{saecjt} = RH^{x|y}_{saecjt}, \tag{13}$$

$$Rc^{x|y}_{saecjt} = Rp^{x|y}_{saecjt}, \tag{14}$$

$$RC^{x|y}_{saecjt} = RH^{x|y}_{saecjt}Rc^{x|y}_{saecjt} = Rp^{x|y}_{saecjt}RL^{x|y}_{saecjt}, \tag{15}$$

where

$$RC^{x|y}_{saecjt} = \frac{C^{x|y}_{saecjt}}{C^{y}_{saecjt}}, RL^{x|y}_{saecjt} = \frac{L^{x|y}_{saecjt}}{L^{y}_{saecjt}}, RH^{x|y}_{saecjt} = \frac{H^{x}_{saecjt}}{H^{y}_{saecjt}}, Rc^{x|y}_{saecjt} = \frac{c^{x|y}_{saecjt}}{c^{y}_{saecjt}}, Rp^{x|y}_{saecjt} = \frac{p^{x|y}_{saecjt}}{p^{y}_{saecjt}}. \tag{16}$$

By the quality adjusting of the quantity and price of labor input in the reference country, the relative labor quantity coincides with the relative hours worked and the relative per hour compensation coincides with the relative price of labor input in each labor category. The relative price of labor, $Rp^{x|y}_{saecjt}$ in equation (16), defines an index such that the price of labor input in the base country is set as unity every year. So, $Rp^{x|y}_{saecjt}$ represents the price-gap index of labor input in both countries and is not unity even in the base year. Similarly, we can define the purchasing power parity for labor input in each category as follows,

$$PPP^{x|y}_{saecjt} = e^{x|y}_{t} Rp^{x|y}_{saecjt}. \tag{17}$$

If $PPP^{x|y}_{saecjt}$ for a particular labor input is smaller than the exchange rate $e^{x|y}_{t}$, that is $Rp^{x|y}_{saecjt} < 1$, it implies that the cost of labor services for worker category *saecjt* in the reference country is lower than that in the base country. Comparing Japan and the U.S., the purchasing power parity for labor input, $PPP^{J|U}_{saecjt}$, is the number of yen required in Japan to purchase the homogeneous labor input costing one dollar in the U.S., and its units are yen/dollar. [*2]

[*2] From the viewpoint of measurement, it is easy to uderstand $PPP^{x|y}_{saecjt}$ is defined by the relative value of per hour labor compensation; $c^{x}_{saecjt}/c^{y}_{saecjt}$, in equation (17), because per hour labor compensations in each category and in each country are directly observed and the PPP can be measured indepent of the exchange rate.

Under the assumption that prices of each category of labor input represent the marginal product of labor in each country, the PPP of each type of labor input represents the relative marginal product of labor. Labor services in each category in both countries are assumed to be homogeneous, however the marginal product of the labor can be different in each country.

Equation (17) can be also described as,

$$PPP^{x|y}_{saecjt} = \frac{Q^x_{saecj}}{Q^y_{saecj}} \left(\frac{p^x_{saecjt}}{p^y_{saecjt}} \right) = PPP^{x|y}_{saecjT} \left(\frac{p^x_{saecjt}}{p^y_{saecjt}} \right). \tag{17$'$}$$

The PPP in each labor input consists of constant relative labor quality and relative price index of labor input in each country. In the base year T, the PPP coincides with the relative labor quality in each category. In each labor category, the PPP and price indices in each country are transitive; $PPP^{x|y}_{saecjT} = Q^x_{saecj}/Q^y_{saecj}$. If we can observe the PPP only in the base year T, the PPP in any year t should be measured by multiplying the relative price index of labor input in each country.

Using the PPP for labor input, the quality-adjusted labor quantity is measured based on the equation,

$$L^{x|y}_{saecjt} = \frac{C^x_{saecjt}}{PPP^{x|y}_{saecjt} p^y_{saecjt}} = \frac{C^x_{saecjt}}{p^x_{saecjt} PPP^{x|y}_{saecjT}}. \tag{18}$$

An annual labor compensation in Japan, C^J_{saecjt}, can be transformed to the labor compensation, which is comparable with that in the U.S., dividing by the PPP. The transformed labor compensation in Japan can be realized to labor quantity, $L^{J|U}_{saecjt}$, which is comparable with that in the U.S., L^U_{saecjt}, dividing by the price of labor input in the U.S. Alternatively, C^J_{saecjt} can be transformed to the labor quantity, L^J_{saecjt}, dividing by the price of labor in Japan. The labor quantity in Japan can be realized to $L^{J|U}_{saecjt}$, dividing by the PPP in the base year. In each labor category, the relative labor quantity, which is cross-country comparable, coincides with the relative hours worked.

Next, we formulate an aggregate measure of quantity, price, and quality of labor input. Using the quality-adjusted quantity and price of each labor input, total labor compensation in equation (4) is redifined as,

$$C^{x|y}_t = p^{x|y}_t L^{x|y}_t = \sum_{saecj} p^{x|y}_{saecjt} L^{x|y}_{saecjt} = \sum_{saecj} C^{x|y}_{saecjt}, \tag{4$'$}$$

where $L^{x|y}_t$ and $p^{x|y}_t$ represents the quality-adjusted quantity and price of the aggregate labor input, respectively. We formulate the purchasing power parity for aggregate labor input as a Theil-Törnqvist index,

$$PPP^{x|y}_t = exp\left[\sum_{saecj} \frac{1}{2} (v^x_{saecjt} + v^y_{saecjt}) lnPPP^{x|y}_{saecjt} \right], \tag{19}$$

where v^{x}_{saecjt} is defined in equation (6). The rate of the PPP for aggregate labor input, $lnPPP^{x|y}_{t}$, is defined as the share weighted rate of the individual category PPPs where the shares are an average of each category's share of labor compensation in each country's aggregate labor compensation. Also, an aggregate measure of relative price for labor input is described as a Theil-Törnqvist index and simply described as,

$$Rp^{x|y}_{t} = \frac{PPP^{x|y}_{t}}{e^{x|y}_{t}}. \tag{20}$$

The aggregate PPP in equation (19) represents the relative marginal product of aggregate labor input in both countries, implicitly defined by a common translog labor aggregator function. Given the wage structure in the U.S. and Japan, the aggregate purchasing power parity, $PPP^{J|U}_{t}$, is affected by the allocation of workers across categories in each country since this allocation determines the weight entering the Divisia calculation. The smaller the PPP in each category, the lower the marginal product of labor in Japan, relatively. If workers in Japan shift to a category of labor, the PPP of which is smaller, the aggregate PPP will decrease since the marginal product of aggregate labor input in Japan will decrease. On the other hand, if workers in the U.S. shift to a category of labor, the PPP of which is smaller, the aggregate PPP will decrease since the marginal product of aggregate labor input in the U.S. will increase.

In each category, the quality-adjusted labor quantity is described as the labor quantity devided by the base-year PPP; $L^{x|y}_{saecjt} = L^{x}_{saecjt}/PPP^{x|y}_{saecjT}$ in equation (18). The aggregate measures of labor quantity, $L^{x|y}_{t}$ and L^{x}_{t}, are defined by equation (5) as a Divisia index and their growth rates coincide. So, the aggregate measure of the quality-adjusted labor quantity is also derived as the aggregate labor quantity divided by the aggregate base-year PPP in equation (19); $L^{x|y}_{t} = L^{x}_{t}/PPP^{x|y}_{T}$. The equation of the aggregate measure defined by the quantity-side in (10) can be described as follows,

$$L^{x|y}_{t} = Q^{x|y}_{t} H^{x}_{t}, \tag*{(10)$'$}$$

where

$$Q^{x|y}_{t} = \frac{Q^{x}_{t}}{PPP^{x|y}_{T}}. \tag{21}$$

The aggregate measure of labor quality in the reference country is adjusted by the aggregate PPP in the base year T, which is defined as a Theil-Törnqvist index in equation (19). In each category, the PPP in the base year T coincides with relative labor quality. In the special case of $PPP^{x|y}_{T} = Q^{x}_{T}/Q^{y}_{T}$, the aggregate labor quality in the reference country equals that in the base country; $Q^{x|y}_{T} = Q^{y}_{T}$, and then equation (10)′ in aggregate level is similar to equation (1)′ in each category.

Also, the aggregate measure of simple average hourly labor compensation in (11) can be derived as, using $c_t^{x|y}$ and $p_t^{x|y}$,

$$c_t^{x|y} = Q_t^{x|y} p_t^{x|y}. \tag{11'}$$

From equations (10)′ and (11)′, we can describe relative value equations of the aggregate quantity and price of labor as,

$$RL_t^{x|y} = RQ_t^{x|y} RH_t^{x|y}, \tag{22}$$

$$Rc_t^{x|y} = RQ_t^{x|y} Rp_t^{x|y}, \tag{23}$$

where

$$RQ_t^{x|y} = \frac{Q_t^{x|y}}{Q_t^{y}}, RL_t^{x|y} = \frac{L_t^{x|y}}{L_t^{y}}, RH_t^{x|y} = \frac{H_t^{x}}{H_t^{y}}, Rc_t^{x|y} = \frac{c_t^{x|y}}{c_t^{y}}. \tag{24}$$

Reflecting the difference of labor allocation in both countries in the aggregate measure of relative concepts, the relative aggregate labor quantity, $RQ_t^{x|y}$, does not coincide with the relative aggregate hours worked, $RH_t^{x|y}$, and the relative average per hour compensation, $Rc_t^{x|y}$, also does not coincide with the relative price, $Rp_t^{x|y}$ in equation (20). Only in the special case of equal PPPs across all categories, the relative aggregate quality is unity and the relative values coincide in each equation (22) and (23), ie $RL_t^{x|y} = RH_t^{x|y}$ and $Rc_t^{x|y} = Rp_t^{x|y}$.

In equation (24), $Rc_t^{x|y}$ is defined as the ratio of simple average hourly labor compensations, which are measured by the base-country currency, in each country in equation (9). Additionally, we can also define purchasing power parity as a ratio of average hourly compensation of aggregate labor in both coutries as follows,

$$PPP_{*t}^{x|y} = e_t^{x|y} Rc_{*t}^{x|y}. \tag{25}$$

The alternative measure of the aggregate PPP in equation (25) represents the relative marginal product of aggregate labor input in both countries, defined by the simple aggregation. If workers in each country shift to a category of labor, the marginal product of which is higher, the marginal product of the simple aggregate labor input will increase. So, $PPP_{*t}^{J|U}$ increases in the case of a shift in Japan and decreases in the case of a shift in the U.S. If the PPPs, that is to say the relative marginal productivity, in each category of labor are equalized, the two indices of the aggregate PPP in equations (19) and (25) coincide.

The ratio between the simple aggregate index and the Theil-Törnqvist aggregate index reflects the gap of relative marginal product of labor and allocation of workers across countries. We define again the cross-country aggregate quality index as,

$$RQ_t^{x|y} = \frac{Q_t^{x}/PPP_T^{x|y}}{Q_t^{y}} = \frac{PPP_{*t}^{x|y}}{PPP_t^{x|y}} = \frac{Rc_t^{x|y}}{Rp_t^{x|y}} = \frac{RL_t^{x|y}}{RH_t^{x|y}}. \tag{26}$$

In each country, if the PPPs in each category of labor are equalized, the rate of the relative aggregate quality, $ln(RQ_t^{x|y})$, is zero. If workers in Japan shift to a category of labor, the marginal product of which is higher, the rate of relative quality will be positive. On the other hand, if workers in the U.S. shift to a category of labor, the marginal product of which is higher, the rate of relative quality will be negative.

In the base year, the PPP means not only a relative index of labor price but also a relative index of labor quality. Comparing with the two alternative aggregate PPPs in the base year, $PPP_{*T}^{x|y}$ is the relative quality index which does not adjust for the structural difference of labor allocations in both countries; $PPP_{*T}^{x|y} = Q_T^x/Q_T^y$. On the other hand, $PPP_T^{x|y}$ is the index adjusted by the relative aggregate quality; $PPP_T^{x|y} = (Q_T^x/RQ_T^{x|y})/Q_T^y$. The aggregate measures of relative price based on simple aggregation, $PPP_{*T}^{x|y}$ and $Rc_t^{x|y}$, are frequentry measured due to data constraints. However, they have biases.

The growth of the relative aggregate quality is described as the difference between the growth of the aggregate quality in the reference country and that in the base country, as follows,

$$\frac{\dot{RQ}_t^{x|y}}{RQ_t^{x|y}} = \frac{\dot{Q}_t^x}{Q_t^x} - \frac{\dot{Q}_t^y}{Q_t^y} \tag{27}$$

From equations (25) and (26), the growth rate in the relative price for aggregate labor input can be decomposed as,

$$\frac{\dot{Rp}_t^{x|y}}{Rp_t^{x|y}} = \frac{\dot{PPP}_{*t}^{x|y}}{PPP_{*t}^{x|y}} - \frac{\dot{RQ}_t^{x|y}}{RQ_t^{x|y}} - \frac{\dot{e}_t^{x|y}}{e_t^{x|y}}. \tag{28}$$

3 Data

For both Japan and the U.S., labor inputs are cross-classified by sex, age, education, class of worker, and industry. Since each country's classification is different, the first step is to establish a common classification system. The common classification system allows us to compare homogeneous workers. After classifying the workers by sex, we proceed to split the workers by the other categories.

The U.S. dataset is based on thirty six industries while the Japan data is based on forty-three. We create thirty common industries based on table 1. One of the difficulties in creating a common industry classification is the treatment of activities by public sectors. In the U.S. and Japan data, some public sector activities are included in private industries with similar characteristics. For example, in the U.S., government run power authorities are classified in the electric utilities industry. One industry without a private sector counterpart is sector thirty-five, goverment enterprise, which consists almost entirely of Postal Services. A big difference

Table. 1 Industry Classification

Common	U.S.	Japan
1	1.Agriculture	1.Agriculture
2	3.Coal Mining	2.Coal Mining
3	2.Metal Mining, 4.Petroleum and Gas, 5.Nonmetallic Mining	3.Other Mining
4	6.Construction	4.Construction
5	7.Food Products, 8.Tobacco Products	5.Food Products
6	9.Textile	6.Textile
7	10.Apparel	7.Apparel
8	11.Lumber and Wood	8.Lumber and Wood
9	12.Furniture	9.Furniture
10	13.Paper Products	10.Paper Products
11	14.Printing and Publishing	11.Printing and Publishing
12	15.Chemical Products	12.Chemical Products
13	16.Petroleum Refining	13.Petroleum Refining, 14.Coal Products
14	18.Leather Products	16.Leather Products
15	19.Stone, Clay, and Glass	17.Stone, Clay, and Glass
16	20.Primary Metals	18.Iron and Steel, 19.Nonferrous Metals
17	21.Fabricated Metals	20.Fabricated Metals
18	22.Machinery	21.Machinery
19	23.Electric Machinery	22.Electric Machinery
20	24.Motor Vehicles	23.Motor Vehicles
21	25.Other Trasportation Equipment	24.Other Trasportation Equipment
22	26.Precision Instruments	25.Precision Instruments
23	27.Miscellaneous Manufacturing, 17.Rubber and Plastic	26.Miscellaneous Manufacturing 15.Rubber Products
24	28.Transportation	27.Railway, 28.Road Transportation, 29.Water Transportation, 30.Air Transportation, 31.Storage
25	29.Communication, 35.Goverment Enterprises	32.Communication
26	30.Electric Utilities	33.Electric Utilities
27	31.Gas Utilities	34.Gas Utilities
28	32.Trade	36.Trade
29	33.Finance, Insurance, and Real Estate	37.Finance and Insurance, 38.Real Estate
30	34.Services, 36.General Government	35.Water Supply, 39.Education, 40.Research, 41.Medical Services, 42.Other Services, 43.Government Administration

between the U.S. and the Japan datasets is the classification of services provided by some other public sectors, like education, which is classfied into the U.S. sector thirty-six, general government, but allocated to the sector thirty-nine, education, with private industries in the Japan dataset. To deal with this inconsistency, we aggregate miscellaneous service sectors and government administration, and move U.S. government enterprises to the common sector twenty-five, the communications industry, where Japanese postal services are included.

The U.S. data has eight age classifications for workers and Japan has eleven. We choose a common classification of six age groups as in table 2.

Table. 2 Age Classification

Common	U.S.	Japan
1.24 years old and less	1.14-15,2.16-17,3.18-24	1.15-19,2-20-24
2.25-34 years old	4.25-34	3.25-29,4.30-34
3.35-44 years old	5.35-44	5.35-39,6.40-44
4.45-54 years old	6.45-54	7.45-49,8.50-54
5.55-64 years old	7.55-64	9.55-59,10.60-64
6.65 years old and more	8.65-	11.65-

In both countries, class of worker is divided into two groups: employed, or self-employed and family workers. However, labor compensation for the self-employed and unpaid family workers is estimated differently in the U.S. and Japanese datasets. The U.S. data assumes that the hourly wage of the self-employed and unpaid family workers equals the hourly wage of the employed. Estimates of hours worked multiplied times the wage for the same category of employed worker yields an estimate of labor compensation for the self-employed and unpaid family workers. In the Japanese data, wage rates of self-employed workers are imputed based on data available for select industries to yield an estimate of labor compensation for the self-employed group. Furthermore, the wage differential between the self-employed and unpaid family workers is estimated to be the same as the differential between full-time and part-time employees. Because of these differences, we consider only employed workers when measuring the purchasing power parity for labor input.

Finally, workers are classified by the educational attainment categories presented in table 3. The definition of educational attainment data in the U.S. has changed over time, but we make use of work done in other studies to create a time series. We assemble our time series from four distinct datasets, corresponding to definitional changes of the educational attainment variable. From 1960-1964, the data is based on the 1960 decennial census, and fit using published totals from 1960-1964. From 1964 onwards microdata is introduced and the second breakpoint is 1980, after which there is additional detail on graduate education. Prior to 1980, the highest education category was college degree and above. After 1980, more detailed data allows us to split workers between those with a college degree, and those with some graduate

Table. 3 Education Classification

Common	U.S.	Japan
Male		
1.less than high school degree	1.elementary school, 2.less than high school degree	1.less than high school degree
2.high school degree	3.high school degree	2.high school degree
3.some college	4.some college[1)]	3.professional school[2)]
4.college degree and above	5.college degree, 6.MA and above	4.college degree and above
Female		
1.less than high school degree	1.elementary school, 2.less than high school degree	1.less than high school degree
2.high school degree	3.high school degree	2.high school degree
3.some college and above	4.some college[1)], 5.college, degree, 6.MA and above	3.professional school[2)] and above

Common education classification in Phase IV (1992-2000)

[1)] Some college in the U.S. includes junior college, associate degrees, professional school, and those attending but not completing four-year college.

[2)] In Japan, some college includes higher professional school, junior college, and its equivalents. Those attending universities but not completing are in 2.

level education. The third break point is in 1992 when the definition of education attainment in the U.S. changed from being based on years of schools completed to being based on degree obtained. For example, prior to 1992 sixteen years of schooling would be equivalent to a BA degree, but the redefinition of the data in 1992 tells us explicitly that the worker completed a BA degree.

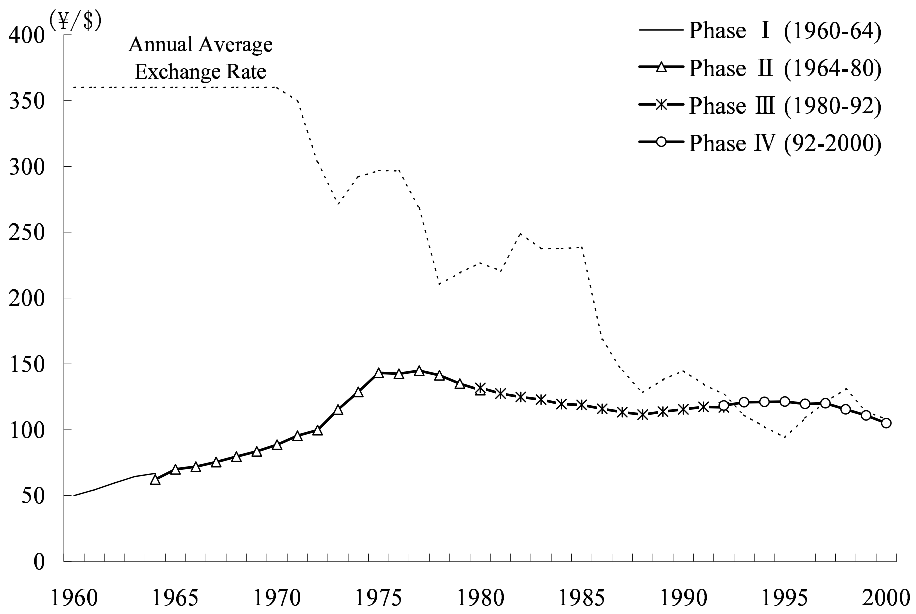
In Japan, there are different levels of detail for the educational attainment of males and females. In the common dataset, we use the most detailed level of data available in the Japanese data. Male workers are split into four educational groups, while the women are split into two before 1980 and three after 1980.

After cross classifying the data by each of these characteristics, we have 1260 groups in total, 720 groups of male employees, and 540 groups of female employees in the 1980-2000 phase of the dataset.

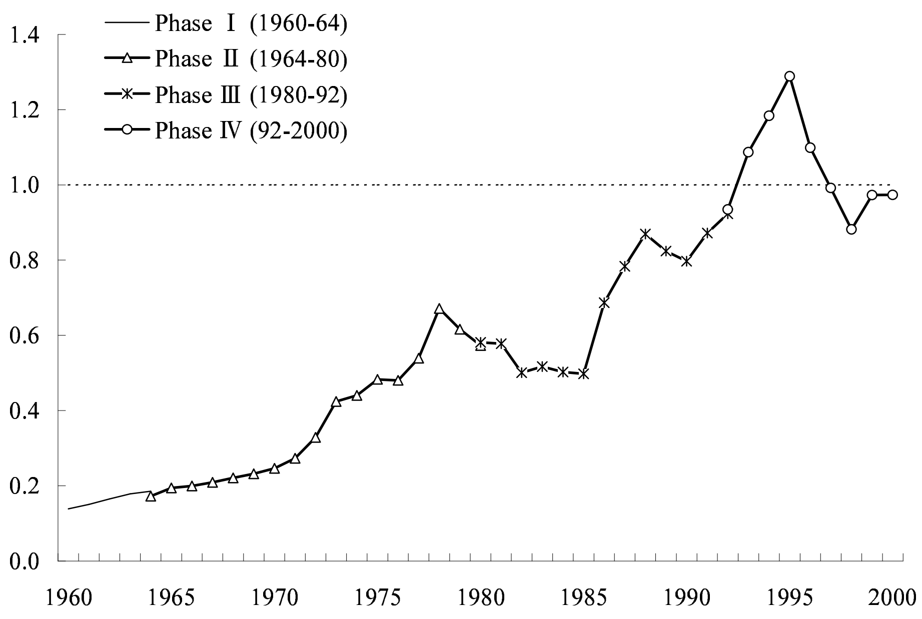
4 Aggregate Level

4.1 Relative Price and Quality

Estimated results of the purchasing power parity for aggregate labor input are in figure 1(a). In each of the four phases, the PPP at the aggregate level is measured every year. The definition of education categories are different among four phases, however there are



(a) Purchasing Power Parity



(b) Relative Price

Fig. 1 PPP and RP for Aggregate Labor Input only slight discrepancies observed at the overlap years in 1964, 1980, and 1992. Hence, we disregard the differences of each phase.

In 1960, the PPP for labor input at the aggregate level was less than fifty yen/dollar in figure 1(a). The relative price of labor was just 0.13 because the exchange rate, fixed in those days, was three hundred sixty yen/dollar. The labor PPP increased by 6.4 percent annually in 1960s. From the beginning of 1970s, although economic growth in Japan slowed, the price of labor input in Japan increased relative to the U.S. until 1975. Between 1970 and 1975, the annnual average growth rate of the labor PPP was 9.6 percent, which was higher than that during the Japanease high growth periods of the 1960s. After 1975, the PPP for labor input decreased moderately until the end of the 1980s. Through the middle of the 1990s, the PPP decreased moderately, reflecting the Japanese depression.

In contrast to the moderate movement of the PPP for labor input, the annual average exchange rate was more volatile and the yen exhibited rapid strengthening a few times over the sample period. The fixed exchange rate between the U.S. and Japan was loosened at the Smithonian Agreement in 1971 and moved to the floating exchange rate system in 1973. After dropping the fixed exhange rate, the annual average growth rate of the relative price for labor input was a very high 12.9 percent during 1971-78. From the middle of 1980s, through the Plaza Agreement in 1985, the Japanese yen strengthened rapidly and the relative price increased by 9.4 percent annualy until 1995. In 1995, during which the yen recorded its strongest rate of 79.75 in April, the annual average exchange rate was ninety-four yen/dollar, and the relative price of labor input in Japan reached its peak, as it was higher by 28.9 percent. After 1995, the relative price declined to below 1.0, reaching 0.97 in 2000. Labor services in Japan were slightly cheaper than in the U.S., given the exchange rate of one hundred eight yen/dollar in 2000.

Figure 2 shows the quality indices of aggregate labor input in the U.S. and Japan. The time series is constructed using the growth rates of labor quality in the individual countries and relative labor quality in 1995 as the difference between aggregate labor quality in the U.S. and Japan. During 1960-2000, the average annual growth rate of the aggregate labor quality was 0.33 percent in the U.S. and 0.71 percent in Japan. Since the quantity of the aggregate labor in both countries increased by 2.11 percent and 2.17 percent respectively, the quality change in each country contributes 15.5 precent of the growth of labor quantity in the U.S. and 32.4 percent in Japan. [*3] In 1995, the relative quality, $RQ_{1995}^{J|U}$, was 0.93. The quality of labor in Japan, which was lower by more than 16 percent relative to the U.S. in 1960, increased faster

[*3] Here, we compare labor inputs of employees, because of the difficulties of comparison including self-employed and family workers in both countries as discussed in previous section. Considering total labor input during 1960-2000, quality change contributes more than quater of growth of labor quantity in the U.S. and more than half in Japan.

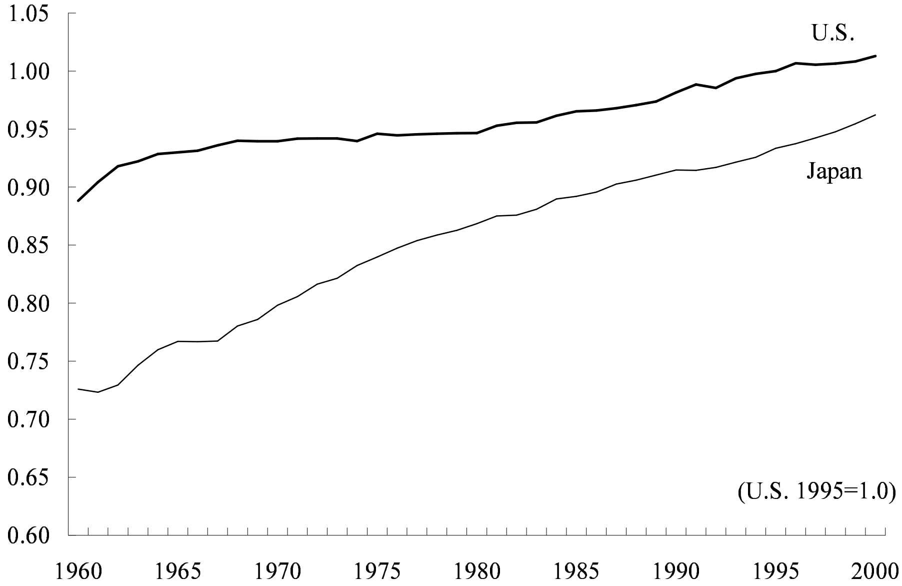


Fig. 2 Quality and Relative Quality of Aggregate Labor Input

than the quality of labor in the U.S. in the 1960s and was 4-7 percent lower after 1980.

4.2 Decomposition of Relative Price

We decompose the growth rate of the relative price for labor input into the contribution of the PPP for labor input, the relative quality, and the exchange rate, by equation (28). Figure 3 shows the growth rate of relative price for aggregate labor, as the circle connected by a dotted line, and its contributions as the cumulative bars.

Overall, the contribution of the change in the relative quality, which is the difference of quality change and efficiency of allocation of labor in both countries, was relatively slight. However, during the Japanese high growth periods until the beginning of 1970s, the relative quality had a negative contribution to the growth of the relative price, meaning labor moved in a more efficient direction in Japan compared to the U.S. in this period, as shown in figure 2. It is important to note that the increase of relative price for labor input was mainly due to the increase of the labor PPP until the middle of 1970s, and futher strengthened by the exchange rate until 2000.

Also, we can decompose the change in the relative price in terms of changes in hourly wages in the U.S. and Japan, as in figure 4. In this figure, higher wages or a change of allocation of workers towards workers with a higher wage in the U.S., tend to decrease the relative price of labor input. We can clearly see how changes in the work force structure in Japan increased

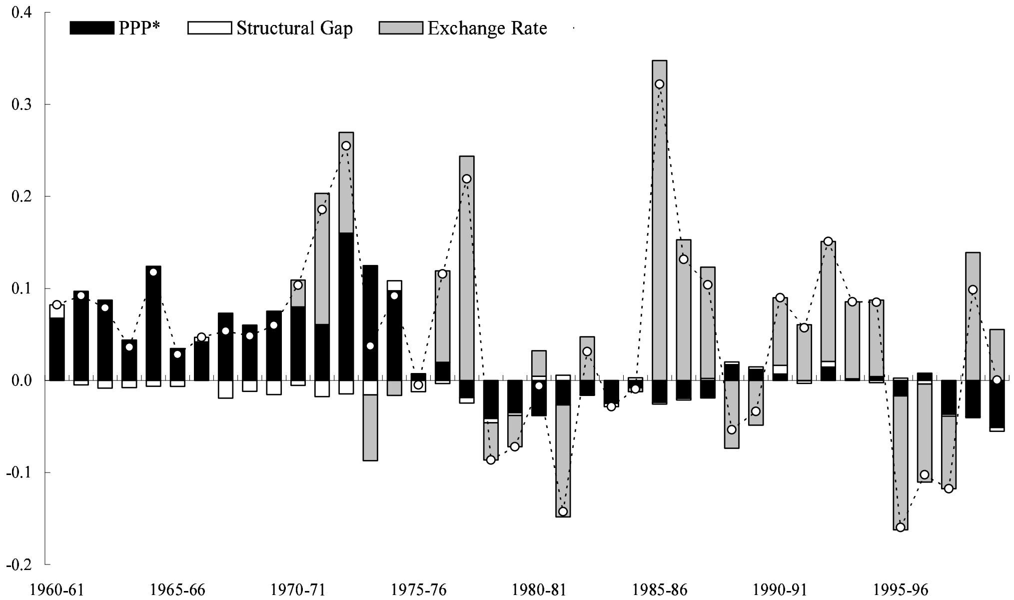


Fig. 3 Growth of Relative Price for Labor and Its Contributions

the growth of the relative price of labor through the early 1970's and how movements in the relative price of labor were dominated by the exchange rate in the late 1980's and early 1990's. After the middle of the 1990s, the growth rate of hourly wage in Japan was very small. On the other hand, the U.S. growth rate expanded gradually. The wage growth in the U.S. pushed down the relative price for labor input, regardless of yen's strengthening after 1998.

4.3 Relative per Worker Price

As an alternative to the relative price of labor input per hour, we consider the relative compensation of labor per worker, that is to say the relative per worker price for labor, as displayed in figure 5.

Over the sample period, the relative per worker price of labor was higher than the per hour relative price, reflecting the higher average hours worked per worker in Japan. The figure shows that while the per hour relative price of labor input in Japan caught up to the U.S. in 1993, the per worker price caught up in 1987. The figure also shows a decrease in the difference between the two measures, reflecting a combination of increased average hours worked in the U.S. and a decrease in Japan since the middle of 1990s. In 2000, the per hour price of labor was lower by 2.7 percent in Japan, however, the per worker price of labor was 12.0 percent higher in Japan. This figure emphasizes the viewpoint from the employer's perspective that per worker prices in Japan are high, and shows the importance of including

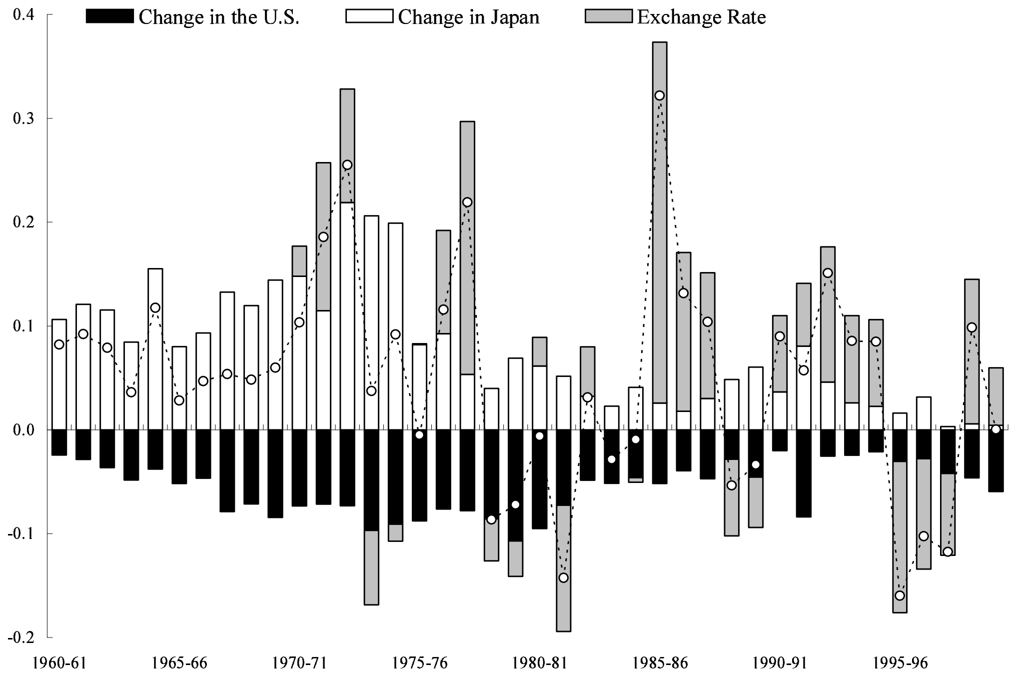


Fig. 4 Contribution of Each Country to the Growth of Relative Price

total hours worked when considering relative prices.

Comparing the relative price for gross domestic expenditure by OECD [*4] and the relative per worker price, as in figure 5, shows that the gap between the relative price for GDP exeeded the relative price for labor over the entire sample. This gap indicates the difference of real purchashing power between the U.S. and Japan. Labor income per worker in Japan surpassed the U.S. in 1987, however, the real purchasing power in Japan was beneath that in the U.S. because of the higher price for domestic expenditure. In 1970, the relative price for GDP, 0.683, was higher than the relative price of labor, 0.253 and the the relative price per worker, 0.328. In 1995, when the exchange rate was ninety-four yen/dollar, the relative price for GDP was 1.807, above the relative price of labor, 1.289 and the price per worker, 1.574. By 2000, the gap between the prices subsided as the relative price for GDP was 1.443, still higher than the relative price of labor, 0.973 the the price per worker, 1.120.

[*4] Annual National Accounts - volume I - Exchange Rate, PPPs, and Population, Vol 2003 release 02. The data is available from OECD National Accounts Statistics, www.sourceoecd.org.

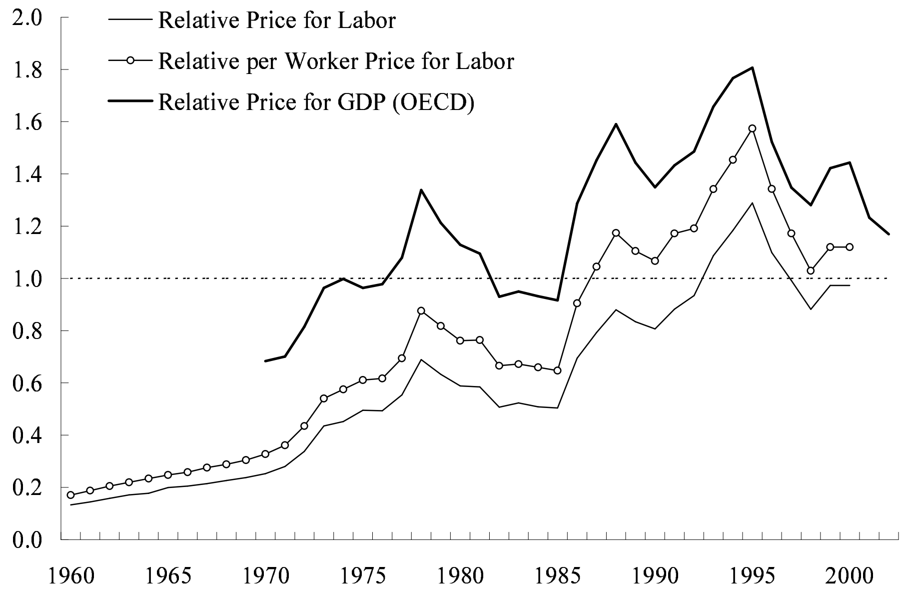


Fig. 5 Relative per Worker Price for Labor

4.4 Relative Price by Sex, Age and Education

We can compare the purchasing power parity for labor input of different groups by aggregating over a subset of the detailed types of labor. We derive estimates of the PPP by sex by aggregating over age, education, and industry. Formally, in equation (19) the sex dimension, s, is set to either male or female, and we aggregate over the other categories. The relative price of labor input by gender is simply the gender specific PPP divided by the annual exchage rate as in eqaution (20). The purchasing power for labor input by gender is presented in figure 6.

Over the entire sample period the relative prices of male and female labor input followed a similar pattern. In 1960 the relative price for males was 0.14, while the relative price of females was 0.11, meaning female labor was relatively cheaper in Japan than in the U.S. Both trended upwards between 1960 and 1978 as the series converged to 0.69 and 0.68, for males and females, respectively. In 1979 the relative price of female labor actually was slighly above the relative price of male labor. From 1979 through 1985 the relative price of both groups trended downwards, although the relative price of male workers increased slightly in 1983. Over the same time period the relative price gap opened up a bit, as the relative price of female labor became cheaper, but the difference remained small until 1986.

From 1985 to 1995, the relative price of male labor increased rapidly, with a few downward swings in 1989, 1990, and 1992. Over the same time period, the relative price of female labor

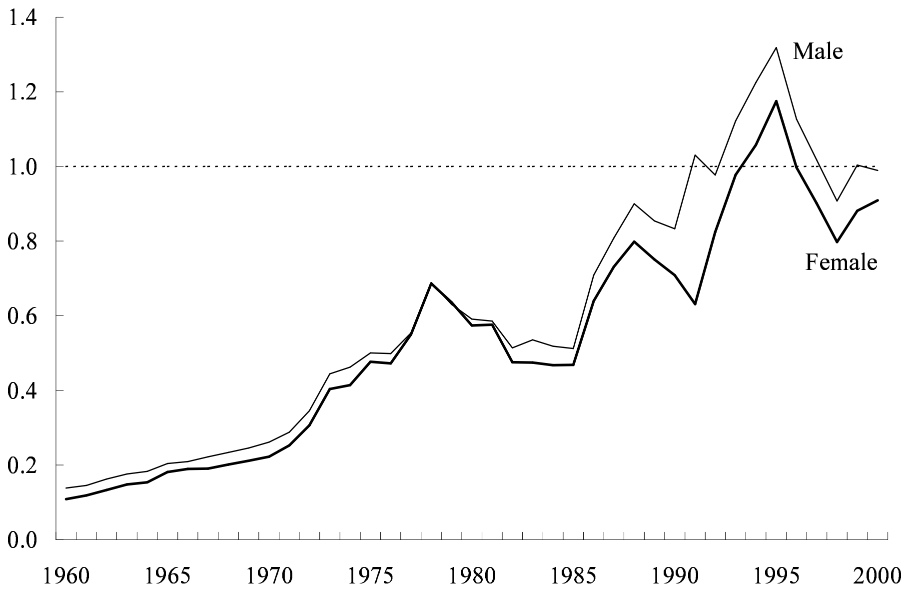


Fig. 6 Relative Price for Aggregate Labor Input by Sex

input increased, but not as rapidly, and the price actually showed a steep dip in 1991. As a result, the relative price gap between male and female labor increased.

In the first half of the 1990s, both indices crossed 1.0 for the first time, the male group did so in 1991, and the female group crossed in 1994. Both series reached their peak in 1995 when the relative price of male labor was 1.33 and the relative price of female labor was 1.20. From 1995-1998 the relative prices of male and female labor decreased, showed a small increase in 1999, then settled at 0.99 and 0.93, respectively, in 2000.

While considering the changes in the relative prices by gender over time, it is also important to consider the participation rates of male and female workers. In the U.S., the role of women in the workforce became more important. The share of women as a share of total workers, and the share of women who chose to work increased steadily. Participation rates by age changed over time. Prior to 1970, the 45-54 age group had the highest participation rate, but by 1980 the 35-44 group had the highest participation rate. Furthermore, the effect of child-bearing on the participation rate of women diminished over time, and by 1990 the were almost no signs of a negative impact of child-bearing years on the participation rate of women. In addition to more women workers, the growth rate of labor compensation of women increased significantly in the late 1970's and early 1980's, outpacing the growth rate of labor compensation of men.

While the role of women increased in the U.S., the role of women in the workforce remained very limited in Japan. Participation rates did not increase at the same rate as in the U.S. and gains in wage rates were minimal. However, there does appear to be some evidence that the changes that occured in the U.S. in the late 1970's and early 1980's are starting to take place in Japan. In the 1995-2000 period, the growth of labor input supplied by women actually exceeded the growth of labor input supplied by men. Going forward, if this structural change is allowed to continue, and is supported by policy and institutional factors, women workers could play a significant role in the future growth of the Japanese economy.

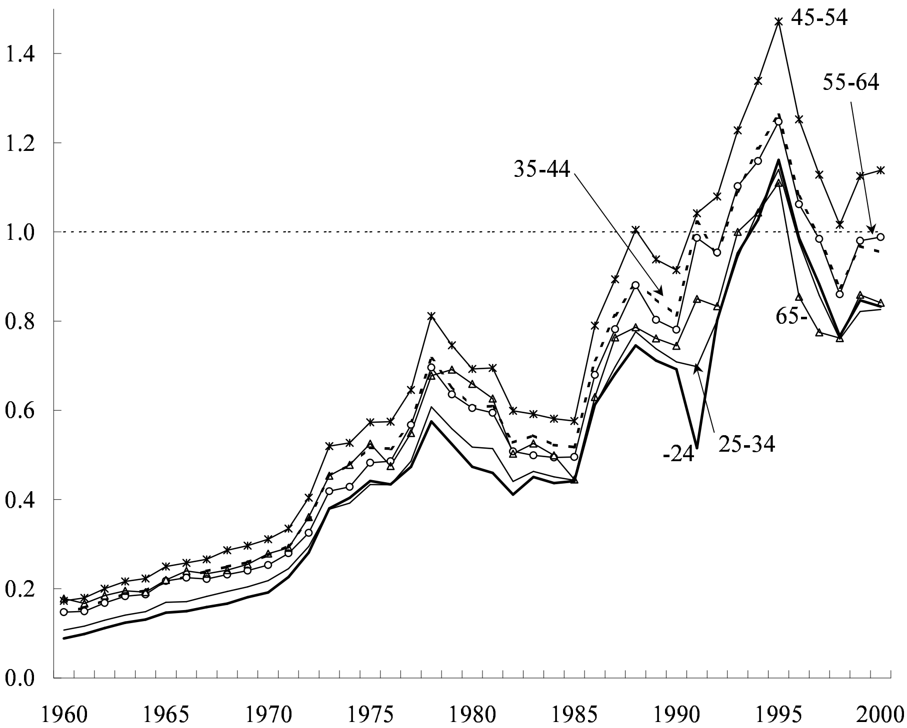
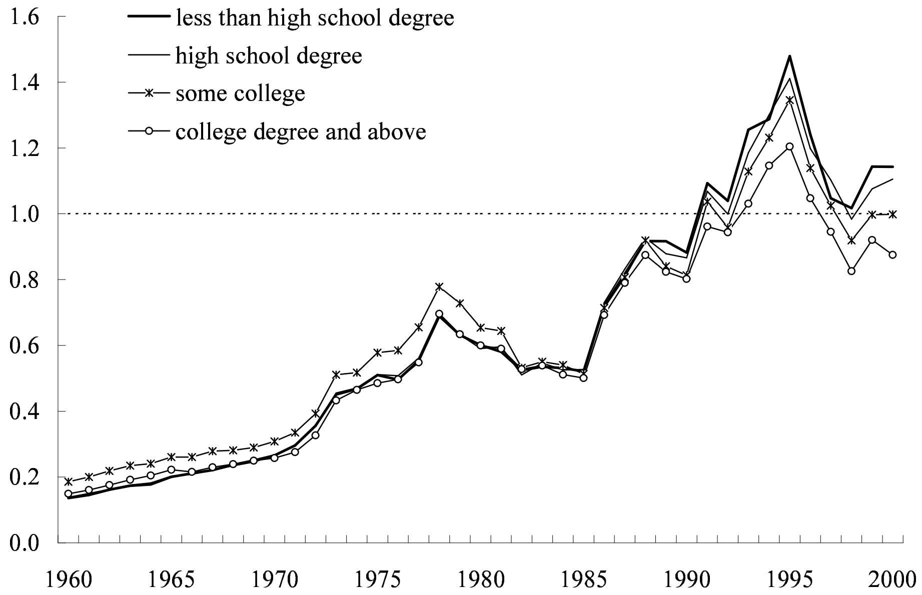
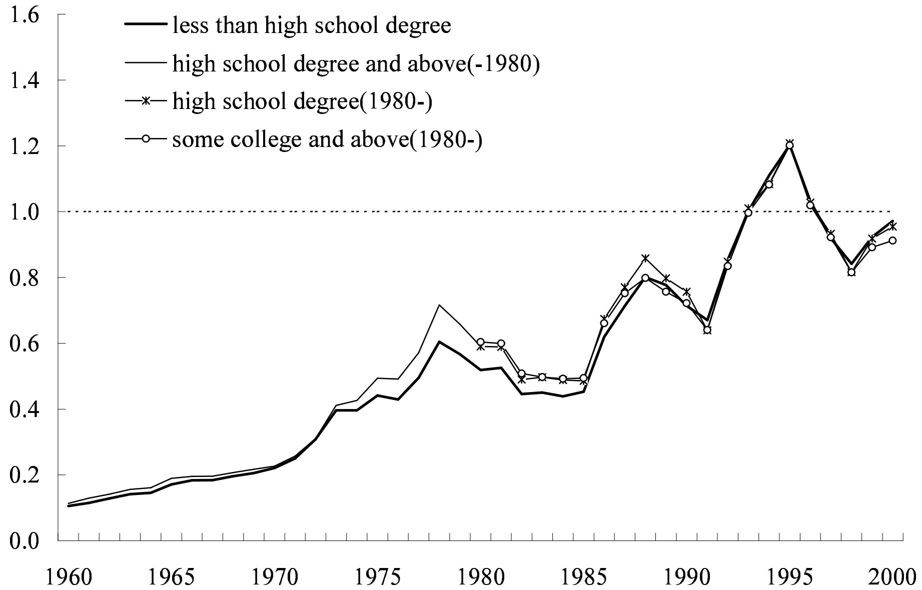


Fig. 7 Relative Price for Aggregate Labor Input by Age

In addition to constructing relative prices of labor input by sex, we constuct relative prices by age in figure 7 and education in figure 8. Like the relative price by gender, the relatives prices of labor input by age followed a similar pattern over the sample period. Prices increased from 1960-1978, dipped somewhat prior to 1985, increased rapidly until 1995, then fell off a bit through 2000. From 1960-2000, the wage group with the highest relative price was the 45-54 group. The 55-64 and 35-44 groups, which had very similar relative prices over time, were the next highest. The labor input in under 24 and 25-34 groups was relatively cheaper in Japan than in the U.S., almost over the entire sample period. The relative price of the eldest group, those over 65, was high relative to the other age groups until the middle of the 1980s, compared to the period after the last half of the 1980s when the relative price of the eldest group was one of the cheapest of all the age groups.



(a) Male



(b) Female

Fig. 8 Relative Price for Aggregate Labor Input by Education

The relative price of labor input by education is plotted in two panels; (a) and (b) in figure 8, representing the educational classification of males and females. The relative price of labor input by education followed a similar pattern to the relative price by gender and age. For males, the relative price was generally inversely proportional to educational attainment. In the years 1985-2000, the male group with the highest relative price was those with less than a high school degree, while prior to 1985 those having some college had the highest relative price. For the female group, the relative price of labor input did not vary much by education attainment in the years 1990-2000. From 1960 to 1980, the relative price of those in the less than high school group was higher.

4.5 Index Numbers for Relative Price

In this section, in order to consider the effect of the Theil-Tornqvist aggregation, table 4 compares the results of aggregate relative price for labor using different aggregation schemes. Here, we compare each index number; Theil-Törnqvist; $Rp_t^{x|y}$, Laspeyres, Paasche, Fisher, Stuvel, and simple aggregation; $Rc_t^{x|y}$. Since the Laspeyres index is defined by using the weight of the base-country, the U.S., it is upward biased. The Paasche index is the opposite case. The Theil-Törnqvist index we accepted is between the Laspeyres and Paasche and very similar to the Fisher index, which is a simple geometric average of both indices. Stuvel index numbers satisfy a circular test, which the others do not satisfy. The measured Theil-Törnqvist index is also similar to the Stuvel index.

The index by simple aggregation; $Rc_t^{x|y}$ was downward biased over the entire sample period. In our terminology, the downward bias means that the relaive quality, $RQ_t^{x|y}$ in a particular period t, between the U.S. and Japan was over one. The relative quality reflects that the labor allocation in the U.S. was more efficient than that in Japan. Consequently, in aggregate measures of relative price based on simple aggregation, as is frequently done due to data constraints, the PPPs are underestimated in the case of more efficient labor allocation in the base country.

Table. 4 Comparison of Indices for Relative Price

	1960	1970	1980	1985	1990	1995	2000
Theil-Törnqvist	0.139	0.246	0.581	0.498	0.797	1.289	0.973
Laspeyres	0.158	0.257	0.595	0.506	0.806	1.300	0.983
Paasche	0.127	0.236	0.567	0.488	0.785	1.272	0.960
Fisher	0.140	0.246	0.581	0.497	0.795	1.286	0.972
Stuvel	0.131	0.242	0.580	0.496	0.797	1.291	0.975
Simple	0.116	0.220	0.563	0.478	0.762	1.203	0.917

5 Industry Level

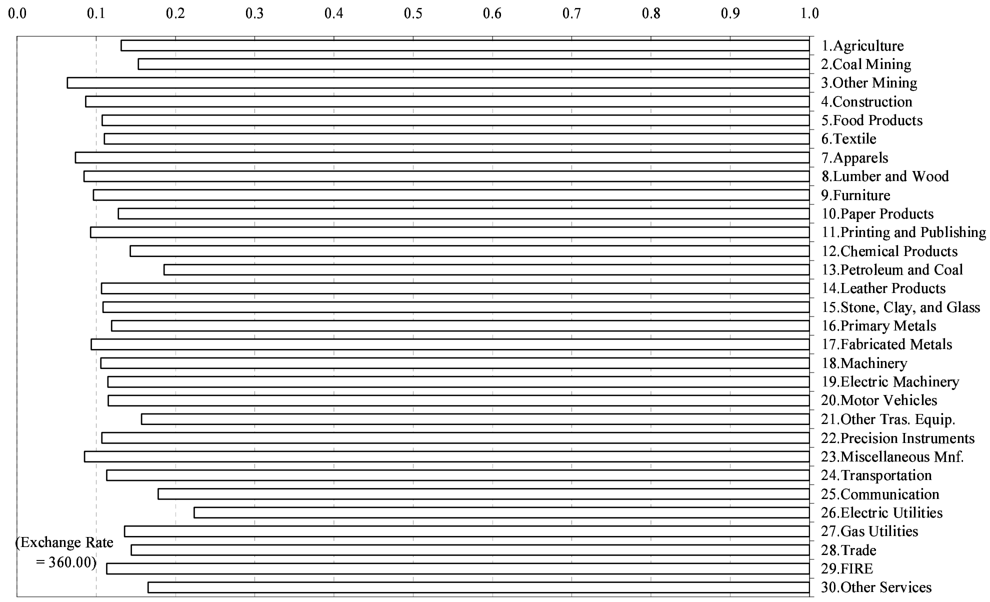
Finally, we present detailed indices of the relative price of labor by industry. Figure 9, 10, and 11 show the relative prices of labor input by industry for 1960, 1970, 1980, 1990, 1995, and 2000. In 1960, all of the industry relative prices of labor input ranged between 0.0 and 0.25. The lowest relative prices were in the Other Mining, Apparel, Miscellaneous Manufacturing, Construction, and Lumber and Wood industries. The industries with the highest prices were Electric Utilities and Petrolem and Coal, but there was not much deviation by industry. The standard deviation was 0.044.

In 1970, the standard deviation increased to 0.069. Other Mining continued to have the lowest relative price, Apparel had the second lowest price, and Printing and Publishing had the third. Agriculture showed a huge increase in the relative price of labor input, and had the highest price of any industy in 1970. Electric Utilities and Coal Mining were the two industries with the next highest relative price of labor input. From 1970 to 1980, as the exchange rate peg loosened and the yen became stronger, the relative prices by industry continued to increase overall. Agriculture continued to be the most expensive in 1980, followed by FIRE, and Electric Utilities. Other Mining continued to have the lowest relative price of labor input. The variation of prices by industry increased, as the standard deviation increased to 0.099.

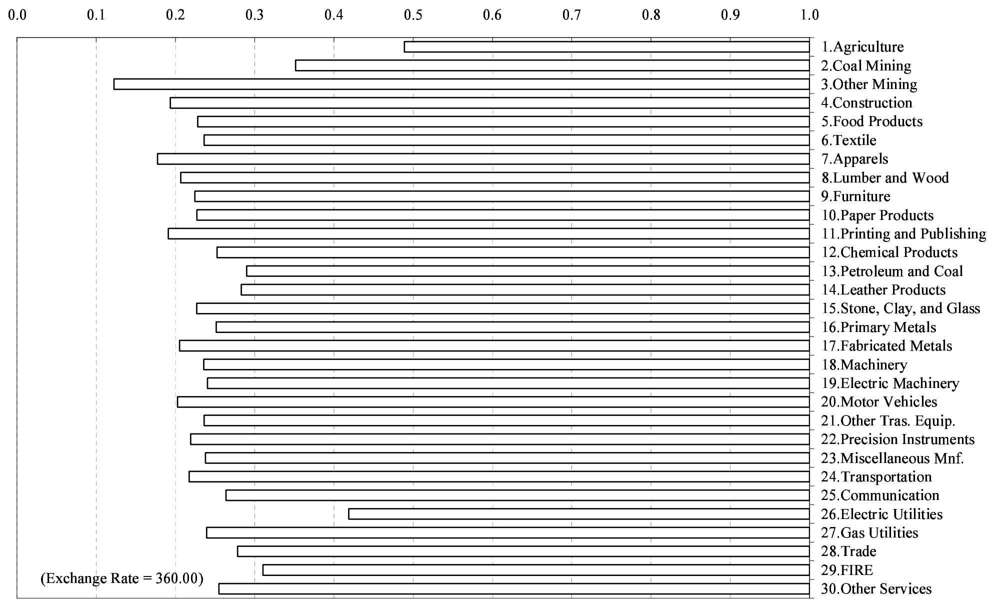
The gap in prices by industry continued to grow through 1990. In 1990, all industry relative prices were below 1.0, but maintained their upward trend. The Agriculture industry was surpassed by Communication as the most expensive industry. Petroleum and Coal, Trade and Coal Mining were industries with comparitively high relative prices of labor input. Other Mining continued to be the relatively cheapest industry, followed by Transportation, Precision Instruments, and Apparel.

Between 1990-1995, as the yen strengthened from 144.81 to 94.06, most of the relative prices of labor input were above 1.0, indicating relatively higher labor costs in Japan. Petroleum and Coal had the highest relative price of labor input, followed by Communication, and Trade. Other Mining, Motor Vehicles, and Precision Instruments, the only indusries with a relative price of labor input of less than one, were the industries with the lowest relative price.

By 2000, with the weakening of the yen, the trend towards higher prices had reversed. Nineteen of the thiry industries had relative prices below 1.0, with the lowest in the Other Mining, Leather Products, Precision Instruments, and Chemical industries. Of the eleven industries that had relative prices above 1.0, the highest prices were in the Coal Mining and Petroleum and Coal industries. Looking at the Motor Vehicle and Electric Machinery industries, we observe the diversity of change of the relative price by industry. In the Electric Machinery industry, the relative price dropped from 1.16 in 1995 to 0.80 in 2000. On the other hand, the relative wages for workers in the Motor Vehicle industry changed, as the average

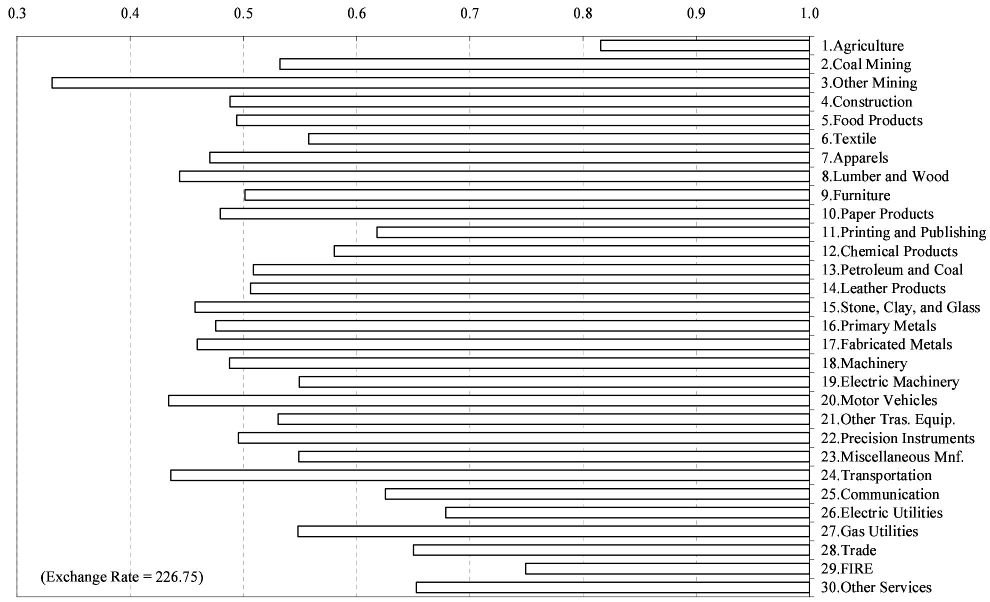


(a) 1960

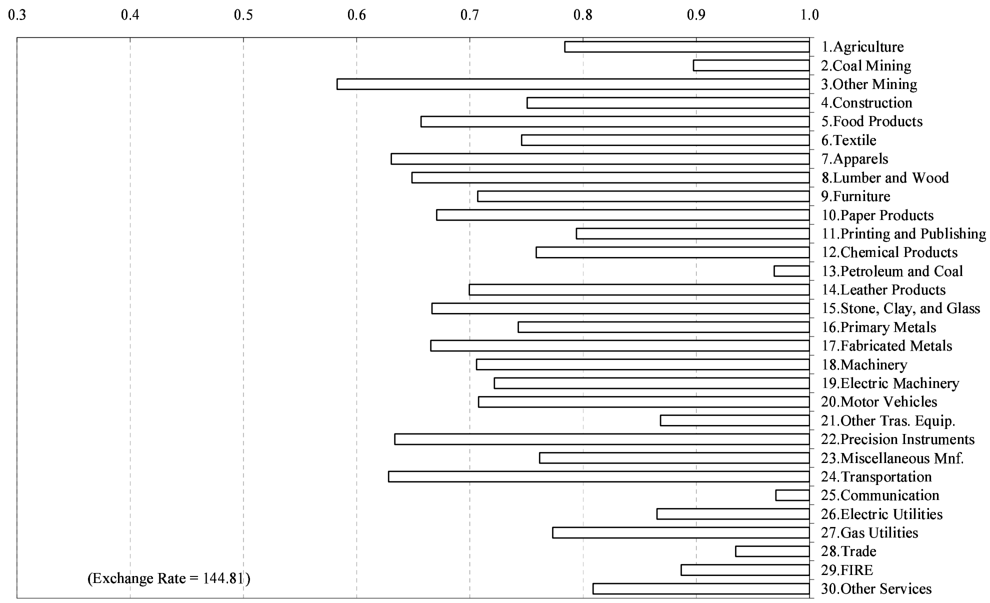


(b) 1970

Fig. 9 Relative Price for Labor Input in Industry Level(1)

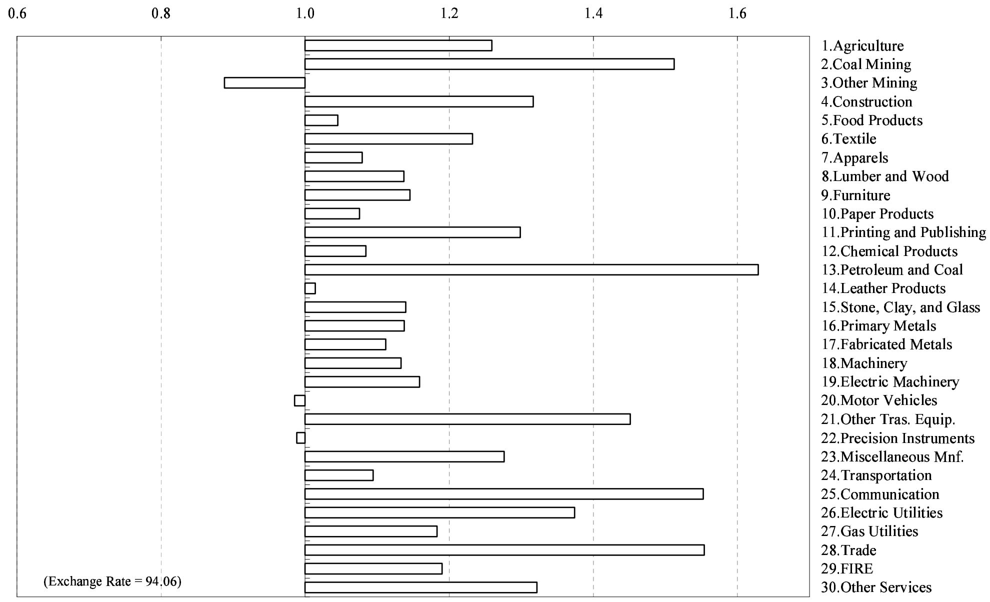


(a) 1980

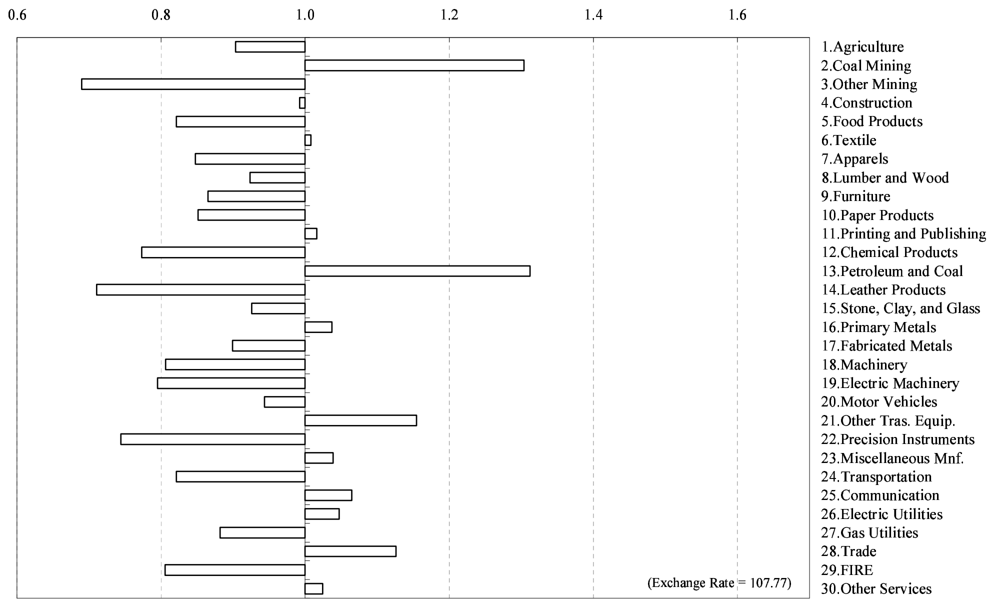


(b) 1990

Fig. 10 Relative Price for Labor Input in Industry Level(2)



(a) 1995



(b) 2000

Fig. 11 Relative Price for Labor Input in Industry Level(3)

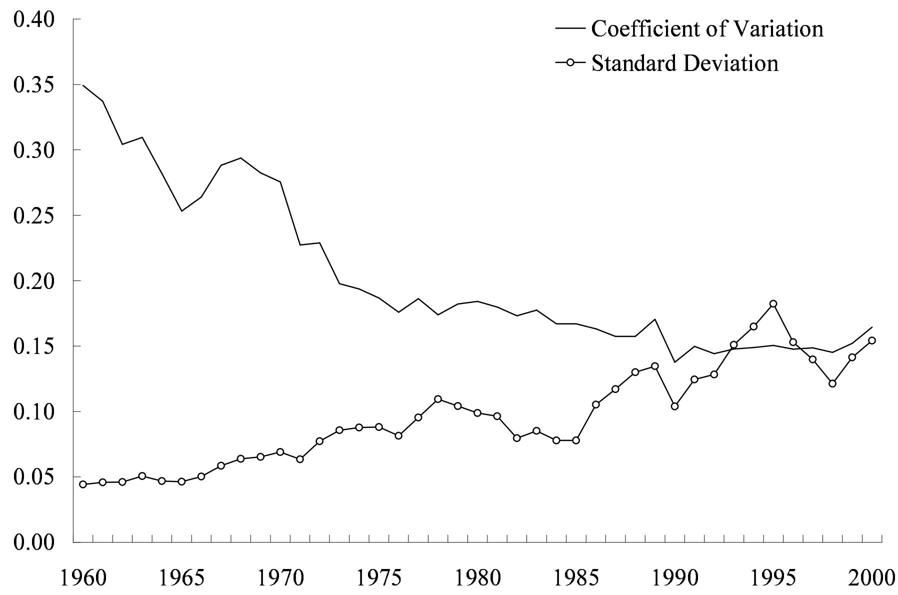


Fig. 12 Industry Variation of Relative Price for Labor Input

wage for motor vehicle workers in the U.S. decreased from 1995. As a result, the labor PPP increased. The weakening of the exchange rate outweighed the increase of the PPP, so the net effect of the increase of the PPP and the exchange rate was a small decrease in the relative price of labor input from 0.99 in 1995 to 0.94 in 2000.

Over the 1960-2000 time period the standard deviation trended updwards from 0.044 to 0.154 in 2000, as seen in figure 12. On the other hand, the coefficient of variation decreased over time, reflecting the convergence of price levels for labor input in the U.S. and Japan. From this measure, the indutry discrepancy of the relative price shrinked gradually.

6 Conclusion

In this paper, we propose the framework for the cross-country comparison of labor input and measure the relative price and quality and the purchasing power parity for labor input between the U.S. and Japan during 1960-2000, based on detailed cross-classified labor data; Jorgenson data at Harvard University covers the U.S. and Keio Economic Observatory Database (KDB) at Keio University covers Japan. We observe:

- The price of aggregate labor input in Japan was slightly less than fifteen percent of that in the U.S. in the beginning of the 1960s. However, it caught up the U.S. level in 1993 and the wage rates in both countries are almost equivalent, when the exchange rate is about one hundred five yen/dollar, which is the purchasing power parity for aggregate labor input in 2000.

- The increase of relative price for labor input was mainly due to the increase of the PPP for labor input until the middle of 1970s, and was futher strengthened by the exchange rate until 2000.
- The aggregate quality index of labor in Japan, which was lower by more than 16 percent relative to the U.S. in 1960, increased faster than the quality of labor in the U.S. in the 1960s and was 4-7 percent lower after 1980.
- The labor compensation per worker, that is to say the per worker price of labor, in Japan surpassed that in the U.S. in 1987, six years earier than the catching up period from the viewpoint of the relative price, reflecting the higher average hours worked per worker in Japan.
- The relative price for female labor was relatively lower than that for male. The gap of the relative price between male and female labor shrank during the late 1970s, however it increased from the beginning of the 1980s.
- The labor input in under 24 and 25-34 groups was relatively cheaper in Japan than in the U.S., almost over the entire sample period. After the last half of the 1980s, the relative price of the eldest group, those over 65, was also one of the cheapest of all the age groups.
- For males, the relative price was generally inversely proportional to educational attainment. In the years 1985-2000, the male group with the highest relative price was those with less than a high school degree. For the female group, the tendency was simliar to males though the gap is relatively slight.
- By computing aggregate PPP using different index numbers, we conclude the Theil-Törnqvist index was measured similar to the Fisher index and the Stuvel index over the sample period. On the other hand, the index by simple aggregation was downward biased over the entire sample period.

The purchasing power parities for labor input estimaed in this paper are used for an industry-level comparison of labor productivity and total factor productivity between the U.S. and Japan.

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