Measuring the Gap between Wage and Productivity: Wage-Tenure Profile and Productivity-Tenure Profile Cross Twice

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Abstract

This paper proposes a new empirical method to measure the gap between wage and productivity of workers. Our method aggregates Mincer-type human capital function of all workers of a firm and obtains the total labor input. We put it into the Cobb-Douglas production function and estimate the coefficients of gap between wage and productivity. Applying the method to employer-employee matched panel data, we find that wage-tenure profile and productivity-tenure profile intersect twice. The wage is higher than the productivity in junior years, then surpassed by the productivity in middle age, and becomes higher again in late career. The results are consistent with both of Becker's firm sponsored training model and Lazear's deferred compensation model.

Key words: Productivity; Human capital; Production function; Wage
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I. Introduction

The idea that the wage and productivity of workers are not necessarily equal has long attracted the attention of many economists. The interest in the productivity-wage gap has indeed been a driving force behind developing the study of economics, including the studies by Adam Smith, David Ricardo, Karl Marx, Leon Walras, and John Maynard Keynes.

Modern economists have also developed theoretical models to explain the productivity-wage gap. Becker (1964) establishes a model in which the cost and returns of firm-specific training are attributed to firms. The firm-sponsored training model predicts that wages are higher than the net productivity of workers during training period because firms bear the cost of the training. Once the training has completed, the productivity of workers surpasses their wages and the firms will earn returns from their training investment.

Another representative explanation for the productivity-wage gap is the agency problem between firms and workers. Lazear (1979) proposes a model in which firms offer deferred wage-tenure profile to their workers in order to prevent them from shirking or quitting. In the deferred compensation model, the wage of a worker is lower than productivity in the earlier period of the worker's career and becomes higher in the later stages.

The theoretical models of Becker and Lazear both predict that wage-tenure profile and productivity-tenure profile will intersect, although the predicted geometric position of the two profiles is contrasting. Becker’s model of firm-specific trainings predicts that the productivity-tenure profile starts lower than the wage-tenure profile and grows faster and surpasses the wage-tenure profile when training is finished: Lazear’s model of deferred compensation predicts that the wage-tenure profile stays lower than the productivity-tenure profile in most of the career but becomes higher than the productivity-tenure profile when workers reach near their retirement age.

In order to examine economic theories including the above two models, empirical research is needed that measures the gap between the wage-tenure profile and the productivity-tenure profile. Once the gap, or the gap-tenure profile, is measured, we can locate the geometric position and the intersection of the wage-tenure and productivity-tenure profiles. However, as shown in next chapter, existing empirical studies have never measured the absolute value of gap between the two profiles in the way that can test the theories of Becker and Lazear.

Becker predicted that entry-level young workers are paid more than their net productivity in his theory, but no existing empirical work has measured this gap. Also, Lazear implied compulsory retirement age as an indirect evidence of the deferred payment, but the existing empirical literature has not shown how much more wages than the productivity are paid to the workers near their retirement age. Union leaders and social activists have difficulty in insisting that workers are exploited by capitalists, because they do not know whether a certain group of workers are paid more or less than their productivity. The lack of empirical method to measure the gap between wage and productivity thus hinders the development of economic studies and economic talks.

This paper proposes a new empirical method to measure the gap between the wage and productivity of workers. Based on the standard Mincer-type wage equation, we develop the productivity-wage gap function, including coefficients to be estimated. We then add the gap function to the wage function to get productivity function of a worker. Next, the productivity function is aggregated for all workers within a firm in order to express the labor service input of the firm. The labor service input, together with the other inputs such as capital and materials, plays a component of Cobb-Douglas or trans-log production function of the firm. The estimation of this production function yields the estimation of the coefficients of the productivity-wage gap function of workers.

The advantage of our method is that it is based on, and consistent with, the standard wage function and production function. Especially, the productivity and the gap are measured as a Mincer-type equation of sex, education, tenure, and experience of each worker. Another advantage is that, since our empirical model takes a linear form, this method, if applied to panel data, can control for firm-level heterogeneity and industry specific business cycle difference. They would otherwise generate biases because they are often correlated with the distribution of workers' characteristics across firms and across industries.

Applying the method to Japanese employer-employee matched panel data, we find that, for male, high-school graduate workers, the productivity profile and wage profile cross twice. Their wages are higher than their productivity in early stage of their working life, then their wages are surpassed by their productivity in the middle of their working life. The first crossing is consistent with Becker's firm sponsored training model. In the later career stage of workers, the wage and productivity profiles cross again, and their wage becomes higher again than their productivity. The second crossing is consistent with Lazear's deferred compensation model. We also find that a serious problem for the human capital accumulation of female workers.

II. Existing Empirical Literature to Measure the Gap between Productivity and Wage

The comparison of wage and productivity of a worker requires the estimation of wage function and productivity function of the worker. In contrast to a rich literature on the study of wage function, the measurement of the productivity function and the comparison of wage and productivity of workers are quite limited.

One of the main reasons is that the Mincer (1974) equation, the standard function that is consistent with human capital theories and is widely used to estimate wage function, is difficult to insert into the production function of firms because of its functional form. Economists have not been able to introduce the standard human capital function into standard production function in a way that can be estimated with standard econometric methods. Therefore, economists have addressed the issue of the wage-productivity comparison by other approaches.

The first representative approach is the empirical work of Lazear and Moore (1984), which compares the wage-age profile of salaried workers and the income-age profile of self-employed individuals. They find that the wage-age profiles of the salaried workers are much steeper than the income-age profiles of the self-employed. They consider that the difference of the two profiles reflects the desire of employers to provide work incentives to their workers, while self-employed do not face agency problems.

The approach of Lazear and Moore is innovative but is effective only on the condition that the human capital accumulation profiles do not differ so much between the salaried workers and the self-employed individuals. Kawaguchi (2003) points out that self-employed may invest less in human capital accumulation on their jobs than do salaried workers. If so, the steeper wage profiles of salaried workers is not only due to the incentive effect, but also due to the difference of human capital accumulation profiles between the two groups.

The second approach compares wage profile and productivity profile in the same firm or for the same sample workers. Medoff and Abraham (1980) use the record of each individual's performance rating and wage. They find that there is a positive association between experience and relative wages, but there is either no association or a negative association between experience and its relative rated performance. Although Medoff and Abraham collect the data of wage and personnel rating from the same sample, but using the personnel rating data is often criticized because the personnel rating record by their boss is too subjective.

Shaw and Lazear (2006) compare the wage-tenure and productivity-tenure profiles of newly employed workers of an autoglass plant. They adopt the number of glass shields installed by a worker as a proxy of the productivity of the worker. They show that productivity profiles are much steeper than wage profiles in the first 18 months. Although their work verifies that the wage and productivity of workers do not equally grow with their tenure, their approach can be difficult to apply to white collar workers or work in a team setting.

The third approach, established by Hellerstein and Neumark (1995) and Hellerstein et al. (1999), divides workers into several groups by their attributes and estimates their relative wages and relative productivities. This approach runs the simultaneous nonlinear estimation of the total wage bill constraint equation and the standard production function, such as Cobb-Douglas function or trans-log function. Applying this simultaneous nonlinear estimation to employer-employee matched panel data, this method yields the relative wage and the relative productivity of a given worker group compared with the reference worker group. Hellerstein et al. (1999), using US manufacturing employer-employee matched panel data, consider that the higher pay of prime-aged workers and older workers is reflected in their higher relative marginal product, but the lower relative earnings of women are not reflected in their lower relative marginal products.

With the increased availability of employer-employee matched panel data, many empirical works are performed using this relative-wage-relative-productivity approach. Hellerstein and Neumark (2007) use the same approach of Hellerstein et al. (1999) with a larger data set and find that the relative wage-age profile is steeper than the relative productivity-age profile. Crepon et al. (2002) estimate the differences in relative marginal products and relative wages using both production function and earning equation where the share of hours in Hellerstein et al. (1999) is replaced by the share of total cost. They find no or little wage discrimination against women, who appear to hold less productive jobs, while older workers are relatively overpaid, or equivalently, and younger workers are underpaid. Ilmakunnas et al. (2004) examined the relationships between worker characteristics and firm productivity using a matched worker-plant data set from Finnish manufacturing. The strong assumptions that labor quality affects both capital and labor neutrally enable them to simply regress TFP of a firm and its total wage on the average employee characteristics of the firm. Due to the assumptions, they can control for the firm specific fixed effects. Kawaguchi et al. (2007), using employer-employee matched data of Japanese manufacturing firms, estimate production function and wage equation separately using nonlinear least-squares estimation under the moment condition that the error terms and explanatory variables are not correlated.

They found steeper tenure-wage profiles than tenure-productivity profiles, and supported the deferred wage contract suggested by Lazear (1979).

The shortages of the third approach are as follows: First, some of them have not controlled for the firm level fixed effects because of the nonlinear functional form of its empirical model, though the firm level productivity differences are often correlated with the human capital variables and thus could cause bias. Another problem is that they have not compared the wage and the productivity of a worker, but estimated relative wage and relative productivity based on the reference group. We can learn that the wage of some workers is 10% higher than that of the reference group, and their productivity is 20% higher from relative wage and relative productivity. However, this information does not enable us to answer how much more or less these workers are paid than their productivity. This method can draw wage-age profile and productivity-age profile, but two profiles are on the separate sheets and we cannot find a crossing point.

The existing empirical literature commonly faces the difficulty in comparing wage and productivity of workers. While the wage is well analyzed by using the Mincer equation and standard econometric method, the productivity of workers with a given human capital attributes have not been estimated with the same functional form. Especially, the estimation of the constant term of the productivity of a worker is essential. With this constant term, we can not only compare the steepness of the wage-tenure and the productivity-tenure profiles, but also specify the crossing point of the two profiles.

III. Empirical Method to Measure the Gap between Wage and Productivity

This chapter develops a new empirical method to measure the gap between wage and productivity of a worker. First, we formalize the gap function between wage and productivity of a worker on the basis of the standard Mincer-type equation. We then add the gap function to wage function to get the productivity function of a given human capital of a worker. Next, the workers' productivity function is aggregated across all workers employed in a firm, which accounts for the labor service input of the firm. Finally, we plug the labor service input function into the standard production function.

Formalizing the productivity-wage gap

We start with the standard Mincer-type wage equation. The hourly wage of a worker i with attribute category s is expressed as

$$\ln w_i = \varphi_0^s + \varphi_1^s ex_i + \varphi_2^s ex_i^2 + \varphi_3^s ten_i + \varphi_4^s ten_i^2 + \varepsilon_i \qquad (eq.1)$$

where w_i represents the hourly wage of a worker *i, ex_i* experience in years, ex_i^2 the square of experience in years, ten_i the tenure in years, and $ten_i^2$the square of tenure in years of worker *i*. We divide the workers into nine groups, *s* = 1 to 9: eight for regular workers by sex and education, and one for part-time workers. The shape of the wage profiles are allowed to differ across the attributes of the workers. Therefore, five parameters—φ_0 to φ_4—could vary across *s*, the attribute category of the workers.

The productivity of a worker is not necessarily equal to his wage rate. The productivity per hour of a worker *i* of attribute category *s* is expressed as

$$\ln l_i = \theta_0^s + \theta_1^s ex_i + \theta_2^s ex_i^2 + \theta_3^s ten_i + \theta_4^s ten_i^2 + \nu_i \qquad (eq.2)$$

where l_i is the labor service per hour—the productivity—of a worker *i*. The shape of the productivity profiles also differ across the attributes of workers. Therefore, we allow the five parameters, θ_0 to θ_4, to vary across attribute category *s*.

Now, we define the gap function as the difference between the log productivity and log wage.

$$gap_i = \ln l_i - \ln w_i \qquad (eq.3)$$

The gap_i is defined as the ratio that the productivity exceeds the wage. In other words, this gap represents the ratio with which the employers “squeeze” or “exploit” their workers. A negative gap means that the wage is higher than the productivity of the worker, which means the total cost of training and wage or a worker exceeds his productivity.

Subtracting (eq. 1) from (eq. 2), the gap function (eq. 3) can be expressed as

$$gap_i = \delta_0^s + \delta_1^s ex_i + \delta_2^s ex_i^2 + \delta_3^s ten_i + \delta_4^s ten_i^2 + \nu_i - \varepsilon_i \qquad (eq.4)$$

where gap coefficients δ_0^s to δ_4^s are defined as

$$\delta_k^s = \theta_k^s - \varphi_k^s \qquad (eq.5)$$

where k is 0 to 4.

We allow that the gap coefficients differ across the categories *s*. Using the gap function, the productivity of a worker *i* is expressed as the sum of the wage and the gap,

$$\ln l_i = \ln w_i + gap_i \qquad (\text{eq. } 6)$$

Suppose the absolute value of gap_i is much less than one, we can apply the Taylor series approximation and rewrite (eq. 6) as

$$l_i = w_i\,(1 + gap_i) \qquad (eq.7)$$

It should be noted that both l_i and w_i, productivity and wage, are expressed in a non-logarithmic form in (eq. 7).

Aggregating labor service input of a firm

Labor service input of a firm is the sum of each worker's labor service belonging to the company. The aggregation of the labor service of workers with different human capital has been a difficult process for empirical economists. Using hourly labor service input of a worker *i* with attribute *s* is expressed in the standard Mincer-type equation as (eq. 2), the labor service input of firm *j* is

$$L_j = \sum_{i\in J} l_i h_i = \sum_{i\in J} h_i \exp(\theta_0^s + \theta_1^s ex_i + \theta_2^s ex_i^2 + \theta_3^s ten_i + \theta_4^s ten_i^2 + v_i) \qquad (eq.8)$$

where L_j is the labor service input of a firm *j* and h_i is the working hours of a worker *i*. The right-hand side of (eq. 8) is the summation of the exponential terms across all workers in a firm *j*. Because (eq. 8) has as many nonlinear terms as the number of workers in the firm, it is quite difficult to empirically estimate the parameters[1].

In contrast, we already have the productivity of a worker *i* in (eq. 7). Because the left-hand side of (eq. 7) is in non-logarithmic form, we can easily aggregate the labor service input within a firm.

$$L_j = \sum_{i\in J} l_i h_i = \sum_{i\in J} w_i h_i (1 + gap_i) = W_j (1 + \sum_{i\in J} \mu_i gap_i)$$

$$\text{where} \quad W_j = \sum_{i\in J} w_i h_i, \qquad \mu_i = w_i h_i / W_j \qquad (eq.9)$$

Here, $W_j = \Sigma w_i h_i$ is the total wage paid by firm *j*, and $\mu_{ij} = w_i h_i / W_j$ is the wage share of worker *i* in the total wage W_j.

The term $\Sigma\, \mu_i\, gap_i$ is the wage-share-weighted average of the individual worker's productivity-wage gap, so the magnitude of the term is close to zero. Therefore, taking the logarithm of both sides of (eq. 9) and applying the Taylor series approximation yields

[1] Because of the difficulty in aggregating the labor service input, economists have often used total man-hour or total wage as a proxy of the labor service input.

$$\ln L_j = \ln W_j (1 + \sum_{i \in J} \mu_i gap_i) = \ln W_j + \sum_{i \in J} \mu_i gap_i \qquad (eq.10)$$

Equation (eq. 10) shows that the log of the total labor service input of a firm is the summation of the log of the total wage and the wage-share-weighted average of the gap function of individual workers.

Inserting the Mincer-type expression of the individual gap function (eq4) into (eq. 10) yields

$$lnL_j = lnW_j + \sum_S \left\{ \delta_0^s \sum_{i \in J,S} \mu_i + \delta_1^s \sum_{i \in J,S} \mu_i\, ex_i + \delta_2^s \sum_{i \in J,S} \mu_i\, ex_i^2 + \delta_3^s \sum_{i \in J,S} \mu_i\, ten_i + \delta_4^s \sum_{i \in J,S} \mu_i\, ten_i^2 + \sum_{i \in J,S} \mu_i\,(v_i - \varepsilon_i) \right\} \qquad (\text{eq. } 11)$$

Note that if the data of wage, tenure, and experience of each worker are available, this equation gives us a semi-log expression of the total labor service input of a firm as a linear combination of undetermined gap coefficients.

Estimating the gap coefficients by regressing production function.

The Cobb-Douglas production function and trans-log production function are widely used for estimating the production function and for analyzing productivity. Both of these production functions include ln L, the total labor service input of a logarithmic form. The left-hand side of (eq. 11) is the log of the total labor input, and the right-hand side of the equation is the sum of the log total wage and a linear combination of coefficients δ_0^s to δ_4^s. Therefore, (eq11) can be easily introduced to the production function and estimated by standard econometric methods.

First, we begin with the Cobb- Douglas production function,

$$\ln Y_{jt} = lnA_{jt} + \beta_{Kjt} lnK_{jt} + \beta_{Ljt} lnL_{jt} + \beta_{Mjt} lnM_{jt} \qquad (\text{eq.} 12)$$

where Y_{jt}, A_{jt}, K_{jt}, L_{jt}, and M_{jt} represent the output, total factor productivity, capital service, labor service, and intermediate materials, respectively, of firm j at time t, and

β_{Kjt}, β_{Ljt}, and β_{Mjt} are the factor cost shares of capital, labor, and intermediate materials, respectively. The ln A_{jt}, productivity of the firm j at time t, is decomposed in three terms, fct_j, ind_i and u_{it}. The fct_j is the firm specific constant fixed effect and ind_i reflects the business cycle effect that varies by industry by year. After these two effects are removed, the remaining u_{it} is considered to be the error term that satisfies the standard conditions for the linear regression.

By introducing the total labor service (eq.11), the Cobb- Douglas production function (eq.12) can be rewritten as,

$$\begin{aligned}&\ln Y_{jt} - (S_{Kjt} lnK_{jt} + S_{Ljt} lnW_{jt} + S_{Mjt} lnM_{jt})\\ &= S_{Ljt} \sum_{S} \left\{ \delta_0^s \sum_{i \in J,S} \mu_i + \delta_1^s \sum_{i \in J,S} \mu_i\, ex_i + \delta_2^s \sum_{i \in J,S} \mu_i\, ex_i^2 + \delta_3^s \sum_{i \in J,S} \mu_i\, ten_i + \delta_4^s \sum_{i \in J,S} \mu_i\, ten_i^2 \right.\\ &\left. + \sum_{i \in J,S} \mu_i\, (v_i - \varepsilon_i) \right\} + \mathrm{fct}_j + ind_t + u_{jt} \qquad (\text{eq. }13)\end{aligned}$$

where, S_{Kjt}, S_{Ljt}, and S_{Mjt} are input cost share of capital, labor, and intermediate materials respectively and fct_j is firm-level fixed effect and ind_t is the industry by year business cycle fixed effect. The left hand side can be calculated using firm level operation data and the right hand side can be calculated using employee personnel data. The rest is a linear function of the gap coefficients and the fixed effects, so standard panel fixed effects analysis yields unbiased estimation of the gap coefficients.

We also want to check the scale elasticity of the production function to be equal to one. For this purpose, we by introduce the scale elasticity adjusting coefficients. The production function (eq13) can be expressed as,

$$\begin{aligned}&lnY_j\\ &= \eta_K S_{Kjt} lnK_{jt} + \eta_L S_{Ljt} lnW_{jt} + \eta_M S_{Mjt} lnM_{jt}\\ &+ \eta_L S_{Ljt} \sum_{S} \left\{ \delta_0^s \sum_{i \in J,S} \mu_i + \delta_1^s \sum_{i \in J,S} \mu_i\, ex_i + \delta_2^s \sum_{i \in J,S} \mu_i\, ex_i^2 + \delta_3^s \sum_{i \in J,S} \mu_i\, ten_i + \delta_4^s \sum_{i \in J,S} \mu_i\, ten_i^2 \right.\\ &\left. + \sum_{i \in J,S} \mu_i\, (v_i - \varepsilon_i) \right\} + \mathrm{fct}_j + ind_t + u_{jt} \qquad (\text{eq. }14)\end{aligned}$$

where η_K, η_L, and η_M are adjusting coefficients between the input elasticities and the factor cost shares. Applying (eq.14) to employer-employee matched panel data, η_K, η_L, η_M, and $\eta_L\, \delta^s{}_0$ to $\eta_L\, \delta^s{}_4$ will be estimated. We expect that each of η is close to one.

Finally, we demonstrate how our gap function approach can be applied to trans-log production function, another representative functional form that economists often use. The trans-log production function has second-order cross terms as

$$lnY_{jt} = lnA_{jt} + \beta_{Kjt} lnK_{jt} + \beta_{Ljt} lnW_{jt} + \beta_{Mjt} lnM_{jt} + s.o.t \qquad \text{(eq. 15)}$$

where s.o.t is second order terms of lnK_{jt}, lnW_{jt} and lnM_{jt}. Taking a difference between two periods, second order terms can be ignored as

$$\triangle\, lnY_{jt} = \triangle\, lnA_{jt} + \overline{\beta_{Kjt}}\, \triangle\, lnK_{jt} + \overline{\beta_{Ljt}}\, \triangle\, lnW_{jt} + \overline{\beta_{Mjt}}\, \triangle\, lnM_{jt} + s.o.t \qquad \text{(eq. 16)}$$

where $\bar{\beta}$ is the average of β at term t and (t+1). By introducing the total labor service (eq.11), the time differenced trans-log production function (eq.16) can be rewritten as

$$\begin{aligned}
&\Delta \mathrm{lnY}_{jt} - (\overline{S_{Kjt}}\Delta lnK_{jt} + \overline{S_{Ljt}}\Delta lnW_{jt} + \overline{S_{Mjt}}\Delta lnM_{jt}) \\
&= \overline{S_{Ljt}} \sum_{S} \Bigg\{ \delta_0^s \sum_{i \in J,S} (\mu_{i\,t+1} - \mu_{it}) + \delta_1^s \sum_{i \in J,S} (\mu_{i\,t+1}\, ex_{i\,t+1} - \mu_{it} ex_{it}) + \delta_2^s \sum_{i \in J,S} (\mu_{i\,t+1}\, ex_{i\,t+1}^2 \\
&- \mu_{it} ex_{it}^2) + \delta_3^s \sum_{i \in J,S} (\mu_{i\,t+1}\, ten_{i\,t+1} - \mu_{it} ten_{it}) + \delta_4^s \sum_{i \in J,S} (\mu_{i\,t+1}\, ten_{i\,t+1}^2 - \mu_{it} ten_{it}^2) \\
&+ \sum_{i \in J,S} (\mu_{i\,t+1}\,(v_{i\,t+1} - \varepsilon_{i\,t+1}) - \mu_{it}(v_{it} - \varepsilon_{it})) \Bigg\} + \Delta ind_t + \Delta u_{jt} \qquad (eq.17)
\end{aligned}$$

This equation can also be easily handled because the left hand side can be calculated by firm level operation data and right hand side can be calculated by personnel data of the firm. Undetermined coefficients, the gap coefficients, can be estimated by linear regression with industry by year fixed effects and standard error terms.

The advantage of our empirical method is that, because of its linear functional form, it can control for the firm-level productivity difference and industry by yearly business cycle effect. Another advantage is that this method can estimate the term δ_0^s even after controlling for firm-level fixed effect. The term δ_0^s is quite important term to pin the wage profile and the productivity profile on a single chart, while this term has never been measured in the existing literature.

IV. Japanese Employer-Employee Matched Panel Data

We create the new employer-employee matched panel data from 1998 to 2003. Our employer-side data come from the Basic Survey of Japanese Business Structure and

Activities (BSJBSA), and the employees' data come from the Basic Survey on Wage Structure (BSWS), using Establishment and Enterprise Census (EEC) as key.

BSJBSA is a survey conducted every year targeting about 30,000 firms in the manufacturing, commerce and service (partially) industry, and some service industry, such as finance, real estate, hospital and schools, are excluded. In addition, as the survey only targets firms which have either 50 or more employees or 30 million yen or more capital, small-sized firms are not included. The items which are surveyed include the sales, the cost of goods sold (COGS), the selling and general administrative expenses (SGA), the total wages, the depreciation, rent, the tax and dues, R&D expenditure, and the number of employee.

BSWS is the yearly survey targeting establishments in private establishments with 5 or more permanent employees. Using EEC as parent population, the survey selects a random sample of establishments to be surveyed. Each selected establishment is asked to randomly pick its employees at a specific sampling rate, which varies from 1/1 to 1/90, depending on the establishment size and industry. In each year, the number of surveyed establishments and employees are about 70,000 and 1,600,000, respectively. The employers transcribe individual employees' information on wage, age, sex, educational background, tenure, hours worked in June of the survey year, and annual bonus amount for the year prior to the survey.

We merged BSJBSA and BSWS using the text data of company name, phone number, and zip code. We use the matching data set with 16,492 firms in manufacturing industry. The total number of employees' using the estimation of wage function is 854,000. The matching rate is 21 percent, as shown in Table 1.

Table 1. The matching Rate of Employee Data and Employee Data

Year	Number of firms in BSJBSA	Number of frims used for analysis	Number of employees used for analysis	Matching rate
	A	B	C	B/A
1998	13,855	2,660	142,312	0.19
1999	13,629	2,544	145,460	0.19
2000	13,256	2,601	139,542	0.20
2001	13,247	2,675	141,456	0.20
2002	12,946	2,674	143,110	0.21
2003	12,450	3,338	142,120	0.27
Total	79,383	16,492	854,000	0.21

Note: The number of colume "A" include firms who answered the total sales.
The number of colume "B" is counted when both BSJBSA and BSWS data are matched in the same year.

Table 2 shows Descriptive Statistics. The average number of employees per company for our analysis is 781, and the average sales are 42,418 million yen. The average size of employees and sales of pre-matched sample in BSJBSA are 388 employees and 19,009 million yen, so the size of company we use for our estimation is larger than that of the representative of the pre-match sample. The ratios of female, male, and part-time workers are 19 percent, 81 percent, and 3 percent, respectively. The ratios of male high-school graduates, female high-school graduates, male 4-year college graduates, and female 4-year college graduates are 45 percent, 10 percent, 22 percent, and 1 percent, respectively. The average tenure (years of working in the current company) of workers is 15.7 years. Cost shares of capital, labor, and materials are 8 percent, 22 percent, and 70 percent, respectively.

Table 2. Descriptive Statistics	
Variable	
Number of Firms	15757
Total Sales	42418
Cost Share of Capital	0.08
Cost Share of Labor	0.22
Cost Share of Intermediate Materials	0.70
Total Employment	781
Number of Regular Workers	734
Number of Part-time Workers	53
Ratio of Manufacturing	1.00
Ratio of Service Industry	0.00
Number of Employees	819480
Years of Tenure	15.7
Years of Working Experiment	22.7
Male Ratio	0.81
Female Ratio	0.19
Part-time Workers Ratio	0.03
Age -29	0.20
Age 30-39	0.24
Age 40-49	0.26
Age 50-	0.30
Junior High School Gaduates	0.11
High School Graduates	0.56
2-yr College Graduates	0.07
4-yr College Graduates	0.23
Male, Junior High School Gaduates	0.09
Male, High School Graduates	0.45
Male, 2-yr College Graduates	0.05
Male, 4-yr College Graduates	0.22
Female, Junior High School Gaduates	0.02
Female, High School Graduates	0.10
Female, 2-yr College Graduates	0.02
Female, 4-yr College Graduates	0.01
Note: 2-yr college graduates include special training school grads.	

V. Empirical Results

Table 3 shows the estimation results of the production function and wage equation for manufacturing industry. Column 1 in Table 3 is the estimation of production function of (eq.14) in the previous section and column 2 is the estimation of wage equation of (eq.1). η_K in the (eq.14), the coefficient of $S_{Kjt}\ln K_{jt}$, is 0.98. η_L and η_M are 1.18 and 0.94, respectively. The scale coefficient, $\eta_K \overline{S_{Kjt}} + \eta_L \overline{S_{Ljt}} + \eta_M \overline{S_{Mjt}}$, is 0.99. We can confirm the scale coefficient is almost one. The coefficient for the part-time workers dummy variable is -1.14, which indicates that the part-time workers get more wages than their productivity.

Table 3. Production Function and Wage Equation (Manufacturing industries)

lnY	Coef.	Std. Err.	t	P>|t|	lnw	Coef.	Std. Err.	t	P>|t|
SKjt * lnKjt	0.98	0.03	35.11	0.00					
SMjt * lnMjt	0.94	0.00	277.38	0.00					
SLjt * lnLjt	1.18	0.02	50.72	0.00					
SLjt * Part-time worker	-1.14	0.22	-5.28	0.00	Part-time worker	0.11	0.02	4.69	0.00
SLjt * Male Junior High Grad.	-0.54	0.61	-0.88	0.38	Male Junior High Grad.				
SLjt * Female Junior High Grad.	-3.35	1.53	-2.19	0.03	Female Junior High Grad.	-0.04	0.04	-1.02	0.31
SLjt * Male High Grad.	-1.08	0.18	-5.93	0.00	Male High Grad.	0.34	0.02	15.37	0.00
SLjt * Female High Grad.	-1.00	0.32	-3.11	0.00	Female High Grad.	0.28	0.02	12.17	0.00
SLjt * Male 2-yr college Grad.	-0.86	0.29	-2.91	0.00	Male 2-yr college Grad.	0.35	0.02	14.39	0.00
SLjt * Female 2-yr college Grad.	-1.64	0.45	-3.69	0.00	Female 2-yr college Grad.	0.32	0.02	13.45	0.00
SLjt * Male 4-yr college Grad.	-1.20	0.25	-4.75	0.00	Male 4-yr college Grad.	0.46	0.02	19.93	0.00
SLjt * Female 4-yr college Grad.	-0.93	0.45	-2.07	0.04	Female 4-yr college Grad.	0.41	0.02	17.00	0.00
SLjt * Male Junior High Grad. * exp	-0.04	0.04	-1.12	0.26	Male Junior High Grad. * exp	0.04	0.00	29.50	0.00
SLjt * Male Junior High Grad. * exp^2	0.00	0.00	1.18	0.24	Male Junior High Grad. * exp^2	0.00	0.00	-29.33	0.00
SLjt * Female Junior High Grad. * exp	0.16	0.09	1.79	0.07	Female Junior High Grad. * exp	0.02	0.00	9.21	0.00
SLjt * Female Junior High Grad. * exp^2	0.00	0.00	-1.77	0.08	Female Junior High Grad. * exp^2	0.00	0.00	-10.95	0.00
SLjt * Male High Grad. * exp	0.00	0.01	-0.26	0.79	Male High Grad. * exp	0.03	0.00	41.08	0.00
SLjt * Male High Grad. * exp^2	0.00	0.00	0.11	0.92	Male High Grad. * exp^2	0.00	0.00	-36.05	0.00
SLjt * Female High Grad. * exp	-0.01	0.03	-0.30	0.76	Female High Grad. * exp	0.00	0.00	1.00	0.32
SLjt * Female High Grad. * exp^2	0.00	0.00	-0.04	0.97	Female High Grad. * exp^2	0.00	0.00	-13.29	0.00
SLjt * Male 2-yr college Grad. * exp	0.00	0.04	0.03	0.98	Male 2-yr college Grad. * exp	0.03	0.00	25.95	0.00
SLjt * Male 2-yr college Grad. * exp^2	0.00	0.00	-0.06	0.95	Male 2-yr college Grad. * exp^2	0.00	0.00	-16.86	0.00
SLjt * Female 2-yr college Grad. * exp	0.02	0.06	0.33	0.75	Female 2-yr college Grad. * exp	0.01	0.00	4.49	0.00
SLjt * Female 2-yr college Grad. * exp^2	0.00	0.00	0.26	0.80	Female 2-yr college Grad. * exp^2	0.00	0.00	-9.90	0.00
SLjt * Male 4-yr college Grad. * exp	0.00	0.02	0.22	0.82	Male 4-yr college Grad. * exp	0.04	0.00	38.91	0.00
SLjt * Male 4-yr college Grad. * exp^2	0.00	0.00	-0.31	0.76	Male 4-yr college Grad. * exp^2	0.00	0.00	-24.73	0.00
SLjt * Female 4-yr college Grad. * exp	0.05	0.10	0.46	0.64	Female 4-yr college Grad. * exp	0.03	0.00	9.79	0.00
SLjt * Female 4-yr college Grad. * exp^2	0.00	0.00	0.02	0.98	Female 4-yr college Grad. * exp^2	0.00	0.00	-9.73	0.00
SLjt * Male Junior High Grad. * ten	0.00	0.02	-0.08	0.93	Male Junior High Grad. * ten	0.02	0.00	18.13	0.00
SLjt * Male Junior High Grad. * ten^2	0.00	0.00	-0.20	0.84	Male Junior High Grad. * ten^2	0.00	0.00	-3.19	0.00
SLjt * Female Junior High Grad. * ten	-0.07	0.05	-1.50	0.13	Female Junior High Grad. * ten	0.02	0.00	13.25	0.00
SLjt * Female Junior High Grad. * ten^2	0.00	0.00	1.54	0.12	Female Junior High Grad. * ten^2	0.00	0.00	0.63	0.53
SLjt * Male High Grad. * ten	-0.01	0.01	-0.85	0.40	Male High Grad. * ten	0.03	0.00	28.59	0.00
SLjt * Male High Grad. * ten^2	0.00	0.00	0.79	0.43	Male High Grad. * ten^2	0.00	0.00	-5.97	0.00
SLjt * Female High Grad. * ten	0.01	0.02	0.50	0.62	Female High Grad. * ten	0.04	0.00	36.51	0.00
SLjt * Female High Grad. * ten^2	0.00	0.00	-0.33	0.74	Female High Grad. * ten^2	0.00	0.00	-5.57	0.00
SLjt * Male 2-yr college Grad. * ten	-0.07	0.03	-2.24	0.03	Male 2-yr college Grad. * ten	0.03	0.00	20.64	0.00
SLjt * Male 2-yr college Grad. * ten^2	0.00	0.00	2.21	0.03	Male 2-yr college Grad. * ten^2	0.00	0.00	-5.65	0.00
SLjt * Female 2-yr college Grad. * ten	-0.01	0.07	-0.21	0.83	Female 2-yr college Grad. * ten	0.05	0.00	22.81	0.00
SLjt * Female 2-yr college Grad. * ten^2	0.00	0.00	0.33	0.75	Female 2-yr college Grad. * ten^2	0.00	0.00	-6.18	0.00
SLjt * Male 4-yr college Grad. * ten	0.01	0.02	0.46	0.65	Male 4-yr college Grad. * ten	0.03	0.00	22.78	0.00
SLjt * Male 4-yr college Grad. * ten^2	0.00	0.00	-0.58	0.56	Male 4-yr college Grad. * ten^2	0.00	0.00	-9.62	0.00
SLjt * Female 4-yr college Grad. * ten	-0.06	0.12	-0.50	0.62	Female 4-yr college Grad. * ten	0.04	0.00	11.17	0.00
SLjt * Female 4-yr college Grad. * ten^2	0.00	0.00	-0.39	0.70	Female 4-yr college Grad. * ten^2	0.00	0.00	-2.57	0.01
_cons	0.97	0.04	22.19	0.00	_cons	6.67	0.03	258.94	0.00
Number of obs	15757				Number of obs	817648			
Prob > F	0.00				Prob > F	0.00			
R-squared	1.00				R-squared	0.71			

The results of cross section analysis are assumed that all explanatory variables are exogenous. We should argue that unobserved heterogeneity across firms. As a remedy for endogeneity, the fixed-effects estimation is often suggested.

Tables 4 show the estimation results of the production function and wage equation using fixed effect model for manufacturing. η_K , η_L and η_M in the (eq.14) are 1.11, 1.06 and 0.98, respectively. The scale coefficient is 1.01. We can confirm the scale coefficient is almost one. The coefficient for the part-time workers dummy variable is insignificant, which indicates that the part-time workers wages almost correspond with their productivity.

Table 4. Production Function and Wage Equation using Fixed Effect Model (Manufacturing industries)

lnY	Coef.	Std. Err.	t	P>|t|	lnw	Coef.	Std. Err.	t	P>|t|
SKjt * lnKjt	1.11	0.01	209.13	0.00					
SMjt * lnMjt	0.98	0.00	287.36	0.00					
SLjt * lnLjt	1.06	0.01	108.83	0.00					
SLjt * Part-time worker	0.02	0.11	0.19	0.85	Part-time worker	0.03	0.01	2.45	0.01
SLjt * Male Junior High Grad.	-0.23	0.39	-0.58	0.57	Male Junior High Grad.				
SLjt * Female Junior High Grad.	-1.64	0.68	-2.42	0.02	Female Junior High Grad.	0.05	0.02	2.75	0.01
SLjt * Male High Grad.	-0.15	0.12	-1.24	0.22	Male High Grad.	0.23	0.01	19.05	0.00
SLjt * Female High Grad.	-0.06	0.16	-0.39	0.70	Female High Grad.	0.20	0.01	16.00	0.00
SLjt * Male 2-yr college Grad.	0.32	0.19	1.73	0.08	Male 2-yr college Grad.	0.25	0.01	18.88	0.00
SLjt * Female 2-yr college Grad.	-0.59	0.26	-2.23	0.03	Female 2-yr college Grad.	0.20	0.01	15.39	0.00
SLjt * Male 4-yr college Grad.	-0.04	0.14	-0.25	0.80	Male 4-yr college Grad.	0.30	0.01	22.84	0.00
SLjt * Female 4-yr college Grad.	-0.29	0.32	-0.92	0.36	Female 4-yr college Grad.	0.27	0.01	19.07	0.00
SLjt * Male Junior High Grad. * exp	0.02	0.02	0.71	0.48	Male Junior High Grad. * exp	0.04	0.00	41.77	0.00
SLjt * Male Junior High Grad. * exp^2	0.00	0.00	-0.93	0.35	Male Junior High Grad. * exp^2	0.00	0.00	-38.68	0.00
SLjt * Female Junior High Grad. * exp	0.09	0.04	2.21	0.03	Female Junior High Grad. * exp	0.02	0.00	12.98	0.00
SLjt * Female Junior High Grad. * exp^2	0.00	0.00	-1.76	0.08	Female Junior High Grad. * exp^2	0.00	0.00	-15.51	0.00
SLjt * Male High Grad. * exp	0.01	0.01	1.78	0.08	Male High Grad. * exp	0.03	0.00	62.32	0.00
SLjt * Male High Grad. * exp^2	0.00	0.00	-2.16	0.03	Male High Grad. * exp^2	0.00	0.00	-50.95	0.00
SLjt * Female High Grad. * exp	-0.02	0.01	-1.34	0.18	Female High Grad. * exp	0.01	0.00	10.57	0.00
SLjt * Female High Grad. * exp^2	0.00	0.00	1.54	0.13	Female High Grad. * exp^2	0.00	0.00	-18.19	0.00
SLjt * Male 2-yr college Grad. * exp	-0.01	0.02	-0.66	0.51	Male 2-yr college Grad. * exp	0.04	0.00	38.28	0.00
SLjt * Male 2-yr college Grad. * exp^2	0.00	0.00	0.04	0.97	Male 2-yr college Grad. * exp^2	0.00	0.00	-19.76	0.00
SLjt * Female 2-yr college Grad. * exp	0.03	0.04	0.71	0.48	Female 2-yr college Grad. * exp	0.01	0.00	9.96	0.00
SLjt * Female 2-yr college Grad. * exp^2	0.00	0.00	-0.32	0.75	Female 2-yr college Grad. * exp^2	0.00	0.00	-10.82	0.00
SLjt * Male 4-yr college Grad. * exp	0.01	0.01	0.54	0.59	Male 4-yr college Grad. * exp	0.04	0.00	55.04	0.00
SLjt * Male 4-yr college Grad. * exp^2	0.00	0.00	-0.49	0.62	Male 4-yr college Grad. * exp^2	0.00	0.00	-30.73	0.00
SLjt * Female 4-yr college Grad. * exp	0.03	0.06	0.49	0.63	Female 4-yr college Grad. * exp	0.02	0.00	9.36	0.00
SLjt * Female 4-yr college Grad. * exp^2	0.00	0.00	0.09	0.93	Female 4-yr college Grad. * exp^2	0.00	0.00	-7.34	0.00
SLjt * Male Junior High Grad. * ten	-0.01	0.01	-0.60	0.55	Male Junior High Grad. * ten	0.02	0.00	20.85	0.00
SLjt * Male Junior High Grad. * ten^2	0.00	0.00	0.91	0.36	Male Junior High Grad. * ten^2	0.00	0.00	-5.43	0.00
SLjt * Female Junior High Grad. * ten	-0.02	0.03	-0.60	0.55	Female Junior High Grad. * ten	0.02	0.00	19.35	0.00
SLjt * Female Junior High Grad. * ten^2	0.00	0.00	-0.24	0.81	Female Junior High Grad. * ten^2	0.00	0.00	-1.88	0.06
SLjt * Male High Grad. * ten	0.00	0.01	0.74	0.46	Male High Grad. * ten	0.02	0.00	27.55	0.00
SLjt * Male High Grad. * ten^2	0.00	0.00	-0.82	0.41	Male High Grad. * ten^2	0.00	0.00	-6.22	0.00
SLjt * Female High Grad. * ten	0.03	0.01	2.43	0.02	Female High Grad. * ten	0.03	0.00	44.46	0.00
SLjt * Female High Grad. * ten^2	0.00	0.00	-2.56	0.01	Female High Grad. * ten^2	0.00	0.00	-12.04	0.00
SLjt * Male 2-yr college Grad. * ten	-0.01	0.02	-0.80	0.42	Male 2-yr college Grad. * ten	0.02	0.00	22.91	0.00
SLjt * Male 2-yr college Grad. * ten^2	0.00	0.00	0.96	0.34	Male 2-yr college Grad. * ten^2	0.00	0.00	-5.95	0.00
SLjt * Female 2-yr college Grad. * ten	0.00	0.04	0.11	0.92	Female 2-yr college Grad. * ten	0.03	0.00	20.79	0.00
SLjt * Female 2-yr college Grad. * ten^2	0.00	0.00	-0.14	0.89	Female 2-yr college Grad. * ten^2	0.00	0.00	-6.50	0.00
SLjt * Male 4-yr college Grad. * ten	-0.01	0.01	-0.96	0.34	Male 4-yr college Grad. * ten	0.02	0.00	26.07	0.00
SLjt * Male 4-yr college Grad. * ten^2	0.00	0.00	1.12	0.26	Male 4-yr college Grad. * ten^2	0.00	0.00	-11.46	0.00
SLjt * Female 4-yr college Grad. * ten	0.04	0.06	0.57	0.57	Female 4-yr college Grad. * ten	0.03	0.00	10.36	0.00
SLjt * Female 4-yr college Grad. * ten^2	0.00	0.00	-1.52	0.13	Female 4-yr college Grad. * ten^2	0.00	0.00	-2.77	0.01
_cons	0.54	0.03	15.74	0.00	_cons	6.90	0.01	474.45	0.00
Number of obs	15757				Number of obs	817648			
Number of groups	5905				Number of groups	5574			
Obs per group: min	1				Obs per group: min	5			
avg	2.7				avg	146.7			
max	6				max	6885			
R-sq: within	0.932				R-sq: within	0.75			
between	0.995				between	0.60			
overall	0.995				overall	0.69			
Prob > F	0.000				Prob > F	0.00			

The "non-mid career" rates by years after a college or a high school are presented in Table 5. Male, high school graduates survive 80 percent after 10 years, 60 percent after

20 years, and 65 percent after 30 years. Female, high school graduates survive 81 percent after 10 years, 50 percent after 20 years, and only 23 percent after 30 years. Male, 4-year college graduates survive 84 percent after 10 years, 69 percent after 20 years, and 72 percent after 30 years. Female, 4-year college graduates survive 82 percent after 10 years, 53 percent after 20 years, and 43 percent after 30 years.

Table 5. The "non-mid career" rates by gender and education background

	Exp is 10yrs	Exp is 20yrs	Exp is 30yrs
Male High Grads	0.80	0.60	0.65
Female High Grads	0.81	0.50	0.23
Male 4-yr college Grads	0.84	0.69	0.72
Female 4-yr college Grads	0.82	0.53	0.43
Note: We show rate of those who join a company right after a high school or college.			
Tenure(year of working in the current company) almost equals experience year. (Experience year−3<=Tenure<=Experience year+1)			
Exp is experience year after graduating a high school or college.			

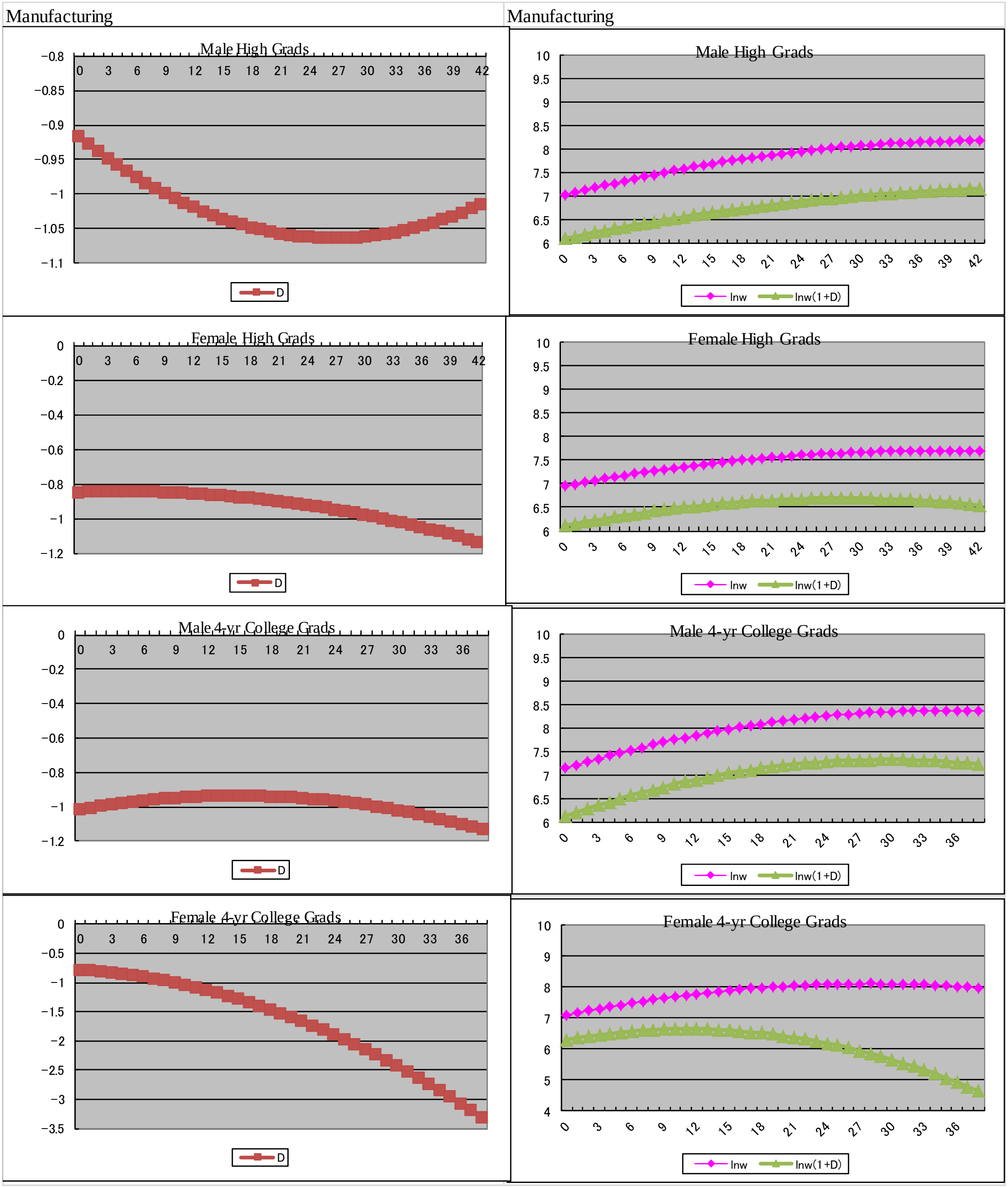
VI. Discussion

Column 1 of Figure 1 shows gap profile and column 2 is tenure-productivity profile and tenure-wage profile of male high school graduates (row 1), female high school graduates (row 2), male 4-year college graduates (row 3), and female 4-year college graduates (row 4) using cross section model. In manufacturing industries, workers' productivity is measured lower than their wages in all their working period.

This cross sectional analysis may have a problem. The firm specific fixed effect, which means TFP and formalized as fct_j in the production function of (eq.13) and (eq.14), is often correlated with the explanatory variables and causes bias in estimation. Typically, firms with higher fixed effect, which means larger fct_j, often expand their labor inputs thus recruit younger workers. On the other hand, firms with lower fixed effect, which means smaller fct_j, often shrink their labor inputs thus stop recruiting. This difference results in the tendency that average tenure and experience of workers are smaller in the firms with higher firm level fixed effect. This tendency then causes bias which underestimates the effect of tenure and experience of workers, because tenure and experience years correlate negatively with fct_j. Indeed, Figure 1 indicates the serious problem of the estimation without controlling for the firm level fixed effects.

The method of this paper, due to its linear functional form, can control for the firm level fixed effects. Furthermore, this empirical method enables to measure the constant term of the gap equation, δ_0, after controlling for the firm level fixed effects. The Figure 2 shows the panel estimation of the productivity and wage profiles after controlling for the fixed effects, fct_j. The clear contrast between Figure 1 and Figure 2 insists the need to control for the firm level fixed effects.

Figure 1. Gap Profile and Tenure-Productivity, Tenure-Wage Profile (Manufacturing Industries)



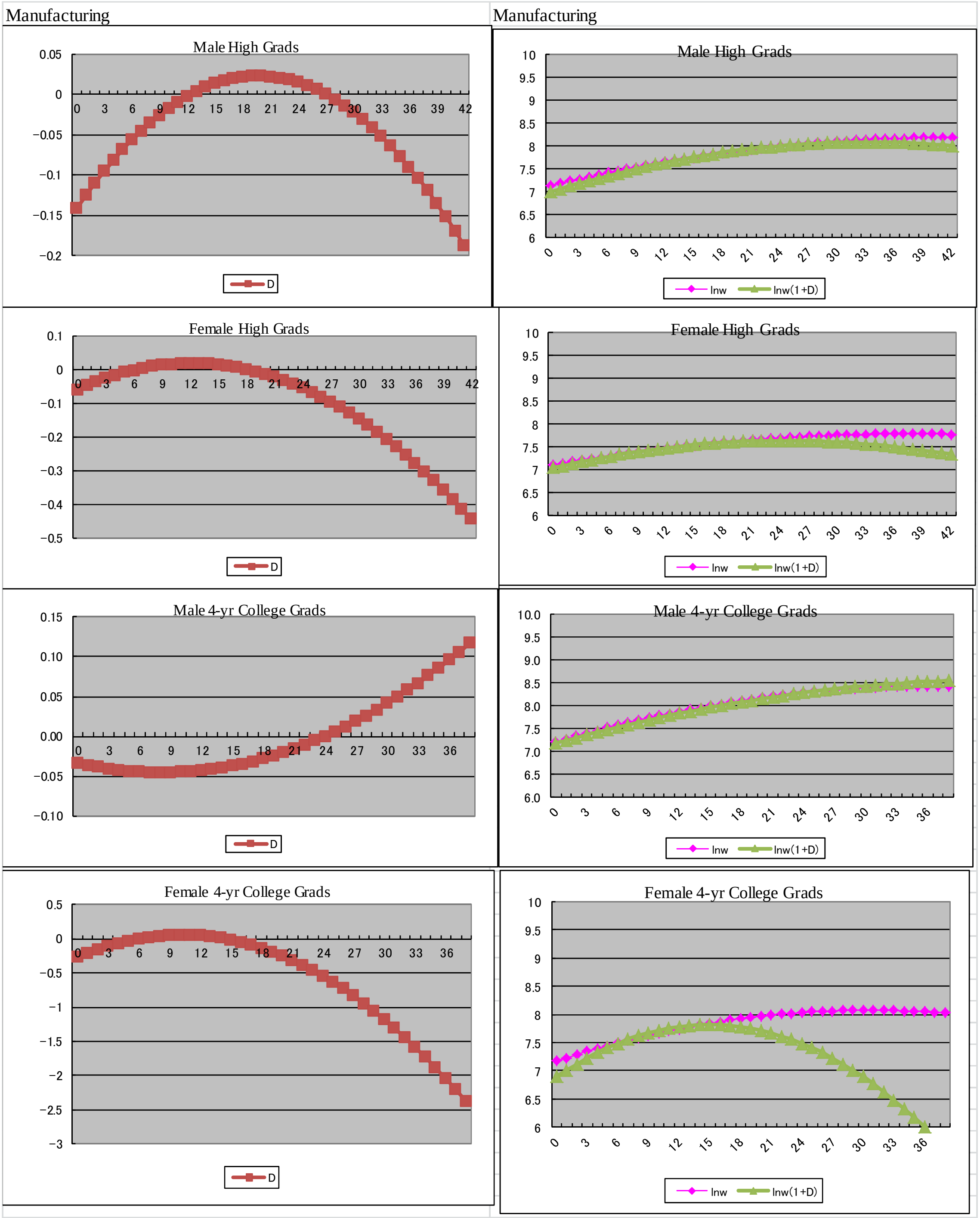
We show in Figure 2 that tenure-productivity profile and tenure-wage profile of male high school graduates in manufacturing industries using fixed effect model. The shape of tenure-productivity profile and tenure-wage profile of male high school graduates are convex shape. In manufacturing industries, the value of the gap function as the difference between the log productivity and the log wage is -0.14 when both working year in the current company and experience year are zero. The negative value of the gap function changes to positive when working year is 13, peaks out when working year is 20, and becomes to negative again when working year is 27. Hourly wage is 1,244 yen when working year is zero, and increases for 42 years; 1,931 yen in 10 years, 2,665 yen in 20 years, and 3,269 yen in 30 years. The productivity of male high school graduates is lower than their wages during the early stages of their careers, higher than wages during the mid-stage, and once again lower than their wages during the years prior to retirement. The observation of the two crossings is consistent with the theories of Becker and Lazear, and it is, of course, the first finding in the economic literature.

Tenure-productivity profile and tenure-wage profile of female high school graduates are illustrated in row 2 in Figure 2. Productivity of female high school graduates is almost as high as their wage for 20 years from the beginning. Though their wage profiles are basically increasing and convex shape, their productivity starts to decrease from 20 years of tenure. Hourly wage of female high school graduates is 1,208 yen at zero years of tenure, 1,615 yen at 10 years, 2,052 yen at 20 years, and 2,319 yen at 30 years. Their productivity overlaps wage at the beginning of their career and surpluses wage when female high school graduates are near their retirement age. This implies that they are neither invested nor accumulated human resource investment. We need to keep in mind that ratio of female high school graduates to all workers is 10 percent. Moreover, there are a few long-tenure female workers, for example, the survival rates in the current company of female high school graduates after 30 years from graduation is 24 percent. The wage and productivity profiles of female high school graduate workers indicate a serious problem for the human capital management of Japanese less educated female workers. The smaller negative gap in the entry period means the females are less trained than male counterparts. Their productivity profile is, therefore, flatter than males. Their productivity profile is surpassed by their wage profile much earlier than males, partly because the regulation to suppress male-female wage gap. The lower productivity growth than wage growth is considered to be the main reason that the less educated female workers are often forced to retire earlier.

Row 3 in Figure 2 shows tenure-productivity profile and tenure-wage profile of male 4-year college graduates. The value of gap function is slightly negative at zero year of tenure or office, increases gradually, and turns to positive at 24 years. Productivity and wage are overlapping through their working life. Hourly wage of male 4-year college graduates is 1,244 yen at zero years of tenure, 2,380 yen at 10 years, 3,527 yen at 20 years, and 4,371 yen at 30 years. The productivity of male college graduate workers is almost equal to their wages in the first half of their careers. The up or out personnel management for the workers of this category is considered to be the main reason of the discrepancy between the productivity and wage in the latter stage of their careers.

Tenure-productivity profile and tenure-wage profile of female 4-year college graduates are shown in row 4 in Figure 2. As for female 4-year college graduates, the value of gap function is negative at zero years of tenure, turns to positive at 7 years, and turns to negative again after 15 years. After 25 years of job tenure, there are a large difference between tenure-productivity profile and tenure-wage profile. When we interpret these results, we need to pay attention to the fact that the ratio of female 4-year college graduates is only 1 percent, and moreover the ratio of workers who continue to work in the current company over 10 years is under 20 percent. Period of investment and recoupment in the human resource investment to female 4-year college graduates is shorter than that to male 4-year college graduates, because female’s tenure of office is shorter than that of male. This finding matches the human resource investment model.

Figure 2. Gap Profile and Tenure-Productivity, Tenure-Wage Profile Using Fixed Effects Model (Manufacturing Industries)



VII. Concluding Remarks

Economists have long been facing the difficulty in measuring the productivity of a worker with a given human capital attributes. Existing empirical works can measure the slopes of wage profile and productivity profile, but the gap between the two profiles has never been examined. The lack of the measurement of wage productivity gap has hindered the development of economics, especially the testing for economic theories including those of Becker and Lazear.

The contribution of this paper is to formalize a new empirical model to measure the gap between the value of a worker's marginal product and the wage. The definition of our gap function is consistent with the Mincer-type standard equations for human capital service and its wage. Because of its linearity, our empirical model can easily be applied to standard econometric methods, including those for panel data analysis. Among all, this empirical model can estimate the constant terms of the productivity function of workers, which enables to compare not only the slopes but also the levels of wage and productivity profiles with a given human capital attributes.

We demonstrate the new empirical method using the employer-employee matched panel data of Japanese manufacturing industry. The important finding is that the productivity of male high school graduate workers is lower than their wages during the early stages of their careers, then turns higher than their wages during the mid-stage, and once again becomes lower than their wages during the years prior to retirement. This is the first observation of the two crossings of wage profile and productivity profile, which is consistent with the theories of Becker and Lazear.

We conclude this paper by commenting on the possibility of the further development of this new method. Since our empirical model is based on the standard production function and has linear functional form, advanced empirical methods can be applied to this model. For example, empirical treatment for the endogeneity of less flexible inputs can be applied as Olley and Pakes (1996) and Levinsohn and Petrin (2003) recommends. The effect of the ICT investments, the HRM systems, and the corporate governance reforms can also be examined with this method because it is simple, flexible, and consistent with standard theories of human capital, production function, and econometrics.

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