Deferred Compensation: Evidence from Employer-Employee Matched Data from Japan

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Abstract

Wage increases, along with job tenure, are one of the most robust empirical regularities found in labor economics. Several theories explain these empirical regularities, and such theories offer sharp empirical predictions for the relation between productivity-tenure and wage-tenure profiles. The human capital model, with cost and benefit sharing between workers and employers, predicts a steeper productivity-tenure profile than wage-tenure profile. The matching quality model predicts that the two profiles will overlap. Theories that involve the information asymmetry between employers and employees predict a steeper wage-tenure profile than productivity-tenure profile to induce workers' effort and enhance efficiency. This paper first estimate the establishment-level production function using the total wage bill as a measure of labor input using employer-employee matched data from Japan. After conditioning on the total wage bill, those establishments with more of aged workers produce less. Then we estimate the productivity-tenure profile and the wage-tenure profile by estimating the plant-level production function and the wage equation. These estimations offer a comprehensive test for the relative applicability of the two theories on the wage-tenure profile. Estimation results indicate a steeper wage-tenure profile than productivity-tenure profile and point to the relative importance of the deferred wage payment contract.

Key Words: Wage, Productivity, Employer-Employee Matched Data, Japan
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1 Introduction

Wages increase along with workers' job tenure at a declining rate. This concave-shaped wage-tenure profile is one of the most robust empirical findings across countries (e.g. Topel [1991] for the US, Dustmann and Meghir [2005] for the UK, Dostie [2005] for France, Pischke [2001] for Germany, Hashimoto and Raisian [1985] for Japan). Several theories explain this upward-sloping, concave wage-tenure profile. There are roughly three types of theories: the firm-specific human capital accumulation model (i.e., Hashimoto [1981]), the job quality matching model (Jovanovic [1979]), and the contract theory model under the information asymmetry of employers and workers (Lazear [1979], Lazear and Moore [1984]).

Identifying a specific theory that explains the observed, upward-sloping wage-tenure profile has been a challenge for empirical economists because all three theories predict the same shape of the wage-tenure profile. To a certain extent, economists have succeeded in distinguishing the matching components from the other two strands of theories, controlling for job-matching quality and exploiting the information on completed years of job tenure or exogenous separation from the job (Altonji and Shakotko [1987], Abraham and Farber [1987] and Topel [1991]). Even after partialing out the effect of job-matching quality, the remaining wage growth over job tenure can be attributed to either human capital accumulation or the incentive wage payment scheme. To distinguish between these two possibilities, a few studies have estimated the wage-tenure and productivity-tenure profiles using employer-employee matched data.[1] Hellerstein and Neumark [1995] found an overlap of the wage-age and productivity-age profiles using Israeli firm-level data, but their small sample size prohibited them from reaching a definitive conclusion. Hellerstein et al. [1999] again found that the wage-age profile reflects an increase in productivity. Hellerstein and Neumark [2004] used much-improved US employer-employee matched data and found evidence for a back-loaded wage payment scheme.

The purpose of this paper is to estimate wage-tenure and productivity-tenure profiles, using Japanese employer-employee matched data. Along with a typical manufacturers' census, the Japanese government implements a wage survey; it collects individual workers' information by asking establishments to transcribe information from their payroll records. This wage survey also records individual workers' tenure with their current employer. The sampling of the manufacturers' census and the wage survey is based on the same lists of establishments, and these two surveys can be matched. Matching these two data sets results in an establishment-level data set that contains information on output, capital, intermediate inputs, and work hours by sex, education, potential experience, and tenure break down. Each cross- section contains about 5,000 observations and the repeated cross- sections are pooled for the period between 1993 and 2003.

[1]Hutchens [1986] and Hutchens [1987] tested the implication of the Lazear deferred contract, and both rejected the absence of the deferred payment scheme.

This unique and large-scale data set allows us to estimate the relationship between relative wage and productivity by the characteristics of workers. The first strategy we employ is the reduced form approach. In the estimation of production function, we measure the labor input by total wage bill instead of usual person-hour because the total wage bill presumably captures the quality adjusted labor input under the null hypothesis that productivities are equal to wages. Thus if the composition of labor force explains output after conditioning on the total wage bill, this implies that the productivities are not set at the wage level. For example, if higher female proportion in the workforce explains higher output after conditioning on total wage bill and other inputs, relative productivity of female workers to male workers is higher than their relative wage. We then attempt to structurally estimate the productivity-tenure profiles by estimating the establishment-level production function. In parallel with the production function, the wage bill equation is estimated to infer the relative wage rate across workers' characteristics.

The contribution of this paper to the literature is three-fold. First, this study utilizes unusually rich employer-employee matched data that contain workers' job tenure information. This rich data set enables us to estimate experience and tenure profiles separately. Also, the large sample size enables us to precisely estimate the productivity-tenure and wage-tenure profiles. Second, this study utilize both reduced form and structural approach and this enables us to infer the robustness of our results in addition to the estimation of structural parameters. Also the specification allows for demand or productivity shock that is correlated with labor composition appealing to the method by Levinsohn and Petrin [2003]. Third, this study sheds light on the mechanism behind the steep wage-tenure profile in Japan that is often pointed out as a feature of the Japanese labor market (Hashimoto and Raisian [1985]).

The estimation of the production function using the total wage bill as labor input reveals that those establishments with higher female or young worker proportions produce more given the total wage bill. On contrary, establishments with higher college-educated or part-time worker composition do not produce more. These evidence imply that female and young worker are paid less than their productivities. However the higher wage of educated workers and the lower wage of part-time workers, on average, reflects their productivities.

The estimation of the production and wage bill functions renders reasonable results. The return to education is about 7 or 8 percent for both productivity and wage, and these point estimates mirror each other. The potential experience profiles for productivity and wage are estimated as flat, but tenure profiles for productivity and wage are both estimated to be an increasingly concave shape. The estimated wage-tenure profile is steeper than the productivity-tenure profile, which is consistent with the back-loaded wage payment scheme. The estimation results of the relative productivity of female workers and of part-time workers of both genders turns out to be highly sensitive to the control for productivity (or demand) shock, presumably due to the higher employment-adjustment speed of these workers. After controlling for the effect of correlated productivity or demand shock, the relative wage of female workers to male workers reflects their relative productivity. We obtain a suggestive result that part-time workers' wage relative to full-time workers is higher than their relative productivity, which is consistent with the compensating wage differential for part-time workers for their unsecured future employment.

The rest of the paper is organized as follows. Section 2 describes the employer-employee matched data from Japan. Section 3 introduces the reduced form approach and reports the results. Section 4 introduces the structural econometric model. Section 5 reports the estimation results. Section 6 further discusses the estimation results and implements a robustness check. The last section concludes.

2 Data

Two data sets are used to create employer-employee matched data. The employer-side information comes from the annual *Census of Manufacture (CM), Larger Establishment Sample, (Kougyo Toukei Chōsa, Kou Hyo)*, which covers all establishments in the manufacturing sector that hire 30 or more permanent employees.[2] The *CM* includes information on shipping, the book value of capital, intermediate input, the number of employees, the wage

[2]Permanent employee is the English translation of *Joyo Rodo Sha*. This classification includes all employees who are employed without a clearly defined term contract, including part-time workers.

bill, and other values on December 31 of the year prior to the survey. The employee-side information comes from the *Basic Survey of Wage Structure (BSWS)*. This annual survey covers establishments in all sectors that hire 10 or more permanent employees. The survey asks employers to randomly pick its employees at a specific sampling rate, which varies from 1/1 to 1/90, depending on the establishment size. The employer then transcribes individual workers' information on work hours, wage, age, education, tenure in June of the survey year, and annual bonus amount for the year prior to the survey.

Establishments included in the Census of Manufacture and the Basic Survey of Wage Structure are both selected from the *Establishment and Enterprise Census (EEC)*, which covers all private and public establishments in Japan. The Census of Manufacture, Large Establishment Sample, picks every establishment that hires 30 or more permanent employees in the manufacturing sector, while the Basic Survey of Wage Structure randomly picks about 70,000 establishments that hire 10 or more permanent employees. Because the establishments in both surveys are selected from the same list, all of the manufacturing establishments that hire 30 or more permanent employees sampled in *BSWS* are matched to the manufacturers' census in theory. To repeat, *CM* and *BSWS* can be matched through *EEC*. Unfortunately, the Census of Manufacture (*CM*) uses its original ID different from *EEC*, while *BSWS* uses the *EEC* ID. To overcome the problem, we matched *CM* and *SEF* IDs for the year 2002 based on the confidential information from Ministry of Economy Trade and Industry (METI). In addition, the Research Institute of Economy, Trade and Industry (RIETI) has created the panel of *CM* for the period 1993-2003. Each year of *EEC* contains information that allows us to construct establishment panel data. Combining all of this information, the employers' information (*CM*) and employees' information (*BSWS*) are matched given the existence of the establishment in 2002. The procedure is illustrated in Figure 1.

The matching rate is tabulated for each sample year in Table 1. The matching is based on the 2002 round survey, but the matching rate is the highest in 2003 at 56%. This part is rather counter intuitive but this is because those establishments sampled in 2003 *BSWS* are more likely to survive between 2002 and 2003, and consequently they are more likely to be matched with *CM* in 2003. The matching rate decreases for ascending years because some firms that were in the sample in 2002 were not in the sample in the earlier year. As tabulated in Table 2, a comparison of the pre-match and post-match *BSWS* statistics reveals that matched observations tend to be smaller establishments in terms of the number of employees, perhaps because the confidential information used for matching tends to be more non-unique for larger establishments than smaller establishments. Fortunately, the compositions of workers, in terms of such characteristics as average age, average hours worked, and the female ratio, are quite similar for the pre-match and post-match samples. The matching procedure seems to distort the size of the employers, but the characteristics of the establishments seem to be representative of the pre-match sample. For *CM*, the pre-match sample consists of more smaller establishment than the post-match sample. This is simply because *BSWS* oversamples larger establishments. This has nothing to do with matching bias, but we should keep in mind that our sample consists of larger establishments than is the average in Japan.

The successfully matched sample is further restricted to establishments that belong to single-establishment firms because otherwise, the input and output do not necessarily correspond with the between-plant transactions of inputs and outputs. The descriptive statistics for the analysis sample are reported in Table 3. We further divide the sample into three major industries.[3]

Due to the sample being restricted to establishments of single- establishment firms, the firm size in terms of the amount of output becomes half. The output and input variables are defined as follows. The output is defined as the final product shipment + the revenue from product processing + the revenue from repair work. The capital is measured by the capital service flow, which is defined by the beginning period book value of capital stock × the industry's real/book values ratio × the industry's capital cost. All the output and input variables are deflated to the real values using the industry level price

[3]The light manufacturing sector includes food, beverages, tobacco and feed, textile, fabrics, apparel, lumber and wood products, furniture and fixtures, publishing, printing, and allied industries, leather tanning, leather products, and fur skins. The heavy manufacturing sector includes pulp, paper and paper products, chemical and allied products, petroleum and coal products, plastic products, rubber products, ceramic, stone and clay products, iron and steel, non-ferrous metals and products, and fabricated metal products. The machinery manufacturing sector includes general machinery, electrical machinery, equipment and supplies, transportation equipment, and precision instruments and machinery.

deflators. For industry level price deflator, capital cost and real/book values ratio of capital stock, see JIP(2006).[4] The intermediate goods are defined as the sum of the material, fuel, and electricity expenditures and the cost of outsourcing. The wage bill is the annual total payment to regular employees (*Joyo Rodo Sha*), including the basic wage, compensation, and bonus taken from the *Census of Manufacture*. The labor inputs are constructed from the *Basic Survey of Wage Structure*. The hours of work is aggregated at establishment level by sex, education, potential experience, tenure and part-time status. Because *BSWS* does not sample all the workers in a establishment, we inflated the hours of work by the inverse of the sampling probability of workers constructed from the number of workers who actually appears in the sample and the total number of regular employees reported in *BSWS*.

Figure 2 illustrates the distribution of the proportion of hours worked by full-time employees by tenure year. The vertical axis is the across-establishments average of the proportion. The distribution is skewed to the left, which means that short-tenured workers work more hours. The female proportion is about half of the male proportion, and this corresponds to the female proportion of work hours, which is 0.31, as reported in Table 3. From this figure, we can learn that there is sufficient variation in the tenure years such that the tenure-productivity or tenure-wage profiles are identified.

[4]The document is downloadable from http://www.rieti.go.jp/jp/database/d04.html

3 Reduced Form Estimation

As a first step reduced form analysis, we estimate the following Cobb-Douglas production function:

$$\ln y_{it} = \beta_{0i} + \beta_1 \ln ql_{it} + \beta_2 \ln k_{it} + \beta_3 \ln m_{it} + ind + year + u_{it}, \qquad (1)$$

where i and t are the subscripts for firm and time, respectively, y_{it} is total sales, ql_{it} is the labor input that is measured in efficiency units, k_{it} is capital input, m_{it} is the intermediate input, ind is industry dummy variables and $year$ is year dummy variables, and u_{it} is the unobserved idiosyncratic shock to production.

The quality adjusted labor input is $ql_{it} = \sum_{j=1}^{J} q_{itj} \times l_{itj}$ where q_{itj} is marginal productivity and l_{itj} is man-hour labor input of worker type j in firm i at time t. If workers are paid according to their marginal productivity, $q_{itj} = w_{itj}$ where w is hourly rate of pay and the wage bill (i.e. $\sum_{j=1}^{J} w_{itj} \times l_{itj}$) captures the quality adjusted labor input.

Under the null hypothesis that all workers are paid according to their marginal products, the error term u_{it} should not be correlated with labor force composition. However, if the female relative wage to male is lower than the female relative productivity to male, higher female proportion results in the higher amount of sales given wage bill and other inputs. The same discussion applies to the age composition of workers. If younger workers are paid less than their productivity and elder workers are paid more then their productivity, the establishments with more younger workers produce more than the establishments with more elder workers.

Table 3 reports the results of this reduced form regression. Column (1) reports the result of fitting Cobb-Douglas production function with usual person-hour as a measure of labor input. Column (2) reports the regression result for the specification with labor quality adjustment by using average hourly wage. This result indicates that the marginal increase in person-hour and average hourly rate of pay increases the output by the same amount. More specifically 10 percent increase in person-hour and average hourly rate of pay increases sales by about 4.7 percent. This rather surprising result is consistent with the establishment's profit maximizing behavior because both 10 percent increase in either person-hour or average wage increase the total wage bill by 10 percent. If, for example, the coefficient for person-hour is larger than the coefficient for average hourly pay, the establishment should increase person-hour by giving up the labor quality: this reallocation between quantity and quality of labor input increases output keeping the total wage bill constant. The result reported in column (2) confirms the appropriateness of using hourly rate of pay as the proxy for the labor quality. The usage of the wage bill available from the Census of Manufactures does not essentially change the coefficient for labor input. This fact implies that the total wage bills calculated from the Census of Manufactures and Basic Survey of Wage Structure are comparable.

Table 3 Column (4) reports the specification with worker composition. The coefficient for female ratio indicates that 10 percentage points more women results in 0.5 percent higher level of production given other inputs. The results of these reduced form regression indicates that relative pay for women is smaller than the relative productivity of women compared with men. The coefficients for part-time worker proportion and college graduates proportion do not significantly affect the output. These estimates imply that part-time workers and college graduates are paid according to their productivity on average. The notable findings are the negative coefficients for the proportion of elder workers. Those establishments that hire more of elder workers produce less than the establishments that hire more of younger workers. This finding implies that elder workers are paid more than their productivity and this is consistent with the existence of deferred payment contract.

Although the result so far suggest the existence of deferred wage payment contract, it is generally believed that female and part-time workers are less likely to be in this contract because they generally have short job tenure. Table 3 Column (5) reports the specification that allows for the difference in the discrepancy between wage and productivity by age across worker types. The interaction term between middle or high age employee proportion and female proportion are positive. This results imply that aged female workers do not reduce the establishment's output as much as aged male workers holding the total wage bill constant; the discrepancy between wage and productivity among elder workers is larger for male workers. This evidence is consistent with the notion that long-term employment is men's thing. In addition, the interaction terms with part-time dummy variables indicate that younger part-timer are paid more than their productivity while elder part-time workers are paid less than their productivity.

4 Structural Econometric Model

This section explains the econometric model for the production function and the wage equation. To estimate the productivity of workers by each characteristic, we assume the following Cobb-Douglas production function:

$$\log(y) = \alpha_1 \log(ql) + \alpha_2 \log(k) + \alpha_3 \log(m) + ind + year + v_1, \qquad (2)$$

where y is output, ql is quality-adjusted labor, k is capital, m is intermediate input, ind is the industry dummy variables, and $year$ is the year dummy variables. The error term v_1 is due to unobserved input or measurement error of output, and this error is assumed to be exogenous from all the inputs.

An hour of labor is assumed to have different productivity depending on individuals' education, potential experience, job tenure, and sex. An hour of labor is multiplied by $\exp(x\beta)$, where x is each worker's characteristics to capture the difference in productivity depending on x. This indexation is consistent with the Mincer wage equation, $\ln w = x\beta$, under the null hypothesis that the wage rate is determined by productivity. Under this functional form assumption, the quality- adjusted labor is defined as:

$$ql \quad = \quad (\sum_{full} hour_{(educ,exp,ten,sex)} \exp[\beta_0 + \beta_1 educ + \beta_2 exp + \beta_3 exp^2/100$$

$$
\begin{aligned}
&+\beta_4 ten + \beta_5 ten^2/100 + \beta_6 female]) \\
&+(\sum_{part} hour \exp[\beta_0 + \beta_1 \cdot 12 + \beta_7]) \times \exp(v_2), \qquad (3)
\end{aligned}
$$

where *hour* is hours worked by workers indexed by education (*educ*), potential experience (*exp*), job tenure (*ten*), and the female indicator (*female*). The measurement error in quality-adjusted labor is entered in a multiplicative way for the ease of treatment. The subscript *full* stands for full-time workers. The returns to education, experience, and job tenure are restricted to be equal across sexes. The subscript *part* stands for part-time workers. The Basic Survey of Wage Structure (*BSWS*) unfortunately does not record part-time workers' educational background. Thus, we assume that all part-time workers are high school graduates. Because the number of part-timer is relatively small, and their human capital accumulation may not be significant, the productivity - experience and productivity - tenure profiles are not precisely estimated. Thus we assume that the experience and tenure coefficients for part-time workers are zeros. Finally, we define the composite error term $v = v_1 + \alpha_1 v_2$, which is exogenous from all the inputs.

The estimated parameters βs recovers the contribution of workers' characteristics on their productivity. The parameter β_1 indicates the return to education, β_2 and β_3 indicate the experience profile, β_4 and β_5 indicate the tenure profile, and β_6 indicates the relative productivity of females to males. In addition, the parameter β_7 stands for the relative productivity of part-time workers compared with high-school graduate, full-time workers with zero years of experience and tenure.

In parallel with the production function, we estimate the following wage equation:

$$\begin{aligned}\log(wagebill) &= \log\{(\sum_{full} hour_{(educ,exp,ten,sex)} \exp[\gamma_0 + \gamma_1 educ + \gamma_2 exp + \gamma_3 exp^2/100 \\ &\quad +\gamma_4 ten + \gamma_5 ten^2/100 + \gamma_6 female]) \\ &\quad +(\sum_{part} hour \exp[\gamma_0 + \gamma_1 \cdot 12 + \gamma_7])\} + u. \qquad (4)\end{aligned}$$

This equation is more of a definitional equation than a behavioral one. The parameters γs indicate the return to education, the experience and tenure profiles, gender, and the part- and full-time wage differentials. The error term u is assumed not to be correlated with any of the explanatory variables.

By comparing the estimated values of the βs and γs, we can discover the gap between productivity and pay. The production function and wage equation are separately estimated by the non-linear, least- squares estimation under the moment condition that the error terms and explanatory variables are not correlated.

We must note that the quality-adjusted labor in our sample is subject to measurement error because not all workers are sampled from each establishment. The random sampling from each establishment results in sampling error in the composition of workers from each establishment. However, this measurement error presumably causes biases for the production function and the wage equation in a similar way.

5 Estimation Results

This section reports and discusses the estimation results of the basic models. Table 5 shows the estimation results of the production function and the wage equation. Columns 1 and 2 are the results for the sample of all manufacturing establishments. Overall, the coefficients in the production function and the wage equation roughly mirror each other.

The returns to education are between 7 and 8 percent for both productivity and wage. This magnitude is quite reasonable, considering that the estimation results from the Mincer wage equation are based on individual data (See Appendix Table 1). The coefficients for experience are not statistically significant for the production function and the odd convex shape (the bottom of the curve is at 10.5 years) for the wage equation. These results are rather difficult to interpret in a causal sense, considering the general human capital accumulation and the reward to it. However, these coefficients may suffer from endogeneity bias because the establishments that hire more of experienced workers, holding workers' tenure distribution constant, are the establishments that fail to keep workers for long period. These establishments may be less productive and low paying for unobserved reasons. Due to this possible endogeneity, we avoid interpreting these results.[5]

Contrary to the estimation results for potential experience, the coefficient

[5]Readers might think that these results are due to the measurement error of the potential experience for women; however, the results for males are still unstable even though different coefficients are allowed for males and females.

for job tenure is reasonably estimated; both tenure-productivity and tenure-wage profiles are basically increasing and concave. Both productivity and wage are peaked out at 37.5 years and 70 years of job tenure, respectively. As the larger linear and quadratic coefficients imply, the tenure-wage profile is steeper and less concave than the tenure-productivity profile. To articulate this point, Figure 3 illustrates the tenure-productivity/wage profiles. The productivity is normalized at one for the productivity at zero years of tenure, and the constant term of the wage profile is set so that the total productivity and wage are equal after 40 years. This 40-year assumption is based on the standard retirement age at 60 and an assumption that workers start working at age 20. This figure clearly indicates that the wage payment is backloaded. At the beginning of their careers, workers receive 10 to 15 percent less wage than their productivity would warrant. The wage surpasses productivity around 20 to 22 years of job tenure, and at the time of mandatory retirement (i.e., 40 years of job tenure), workers' wages are about 20 percent higher than their productivity. Although this illustration is based on the strong assumption that workers have a typical tenure of 40 years, the figure is reasonable. We should note that the wage bill does not include a severance payment at the time of retirement. Considering the existence of a severance payment at the time of mandatory retirement, the tendency of the delayed wage payment is even stronger.[6]

[6] The Actual Survey of Private Firms' Severance Payment (*Minkan Kigyo Taishoku Kin Jittai Chosa*) implemented by the Ministry of Internal Affairs and Communications in 2001 reports that those workers who leave employers due to mandatory retirement after

The coefficients for the female dummy variables indicate that female workers are about 50% less productive than male workers, but they receive 70% lower wages. This productivity and wage gap is consistent with sex discrimination against women. However, before reaching a conclusion, we must be careful about the possible correlation between a positive productivity shock and the proportion of female employment because female workers often are regarded as marginal workers and are subject to a more frequent employment adjustment in Japan (Houseman and Abraham [1993]). We deal with this problem in the next section.

As for the coefficients for the part-time dummy variable, the estimates indicate that part-time workers are about 75% less productive and receive 70% less wages than full-time workers. These estimates indicate that part-timers receive much less than full-time workers; however, they are also much less productive. The same argument for female workers applies to part-time workers, and we must be cautious about the causal interpretation of this result.

The estimation results for the industry subsamples are reported in columns (3) to (8) in Table 5. The returns to education for productivity and wage are stably estimated across industries with small variations. The returns are smaller in the light manufacturing sector and larger in the machinery manufacturing sector. Obtaining reasonable results for experience profiles is still

35 years of job tenure received 24 million yen (240 thousand US dollars; 100 yen = US$1) on average. The sample includes white- collar workers who are high school and college graduates.

difficult for these subsamples. The tenure profiles are almost all estimated with a concave shape across industries, but the slope and the degree of concavity differ across industries. The illustrations for the tenure-productivity and tenure-wage profiles appear in Figures 4 through 6. Notable findings are that both the productivity and wage profiles closely overlap for the light and heavy manufacturing sectors, but these two profile do not overlap at all for machine manufacturing.

6 Control for Establishment Heterogeneity

The results therefore are obtained under the assumption that all explanatory variables are exogenous. Econometricians, however, have long argued that unobserved heterogeneity across firms induces a change in the input, which results in the endogeneity of the explanatory variables in the production function. The fixed-effects estimation, which could be applied to our case given our panel data, is often suggested as a remedy for endogeneity, but the variation of input tends to be small and the within-plant variation of input tends to have a strong correlation with temporary productivity shock. Recent studies by Olley and Pakes [1996] and Levinsohn and Petrin [2003] even pointed out that the fixed-effects estimation may even exacerbate the endogeneity bias.

The solution suggested by Olley and Pakes [1996] is quite straightforward. Under weak assumptions, they showed that the investment, which does not enter the production function *Per Se*, is an increasing function of the positive technology or demand heterogeneity that a firm experiences. Because the investment is a function of unobserved heterogeneity and capital stock, the unobserved heterogeneity can be written as a function of investment and capital stock using the inverse function.[7] Once this inverse function is approximated by a higher-order polynomial, the polynomial of investment and capital stock is included in the production function as a proxy for firm heterogeneity. The caveat of Olley and Pakes [1996] is that when there is an adjustment cost of investment, the investment is not strictly increasing in unobserved characteristics, and the investment function is not invertible. To overcome this non-trivial limitation, Levinsohn and Petrin [2003] showed that the intermediate input can be written as a function of capital stock and firm heterogeneity. Accordingly, higher order polynomials of intermediate input and capital stock can be used as a proxy for firm heterogeneity, as suggested by Wooldridge [2005], while Levinsohn and Petrin [2003] originally suggested using a nonparametric estimation of this inverse function.

We adopt the method by Levinsohn and Petrin [2003] by approximating the heterogeneity with the third-order polynomial of log capital and log material. Once the polynomial of log capital and log material are included

[7] Levinsohn and Petrin [2003] assumes that the intermediate input is the function of capital stock and current shock, i.e. $m = f(k, u)$. The prices do not enter because the prices of output and input are assumed to be homogeneous within industry and time. The capital stock detemines intermediate input becasue it is a state variable that cannot be immediately adjusted. Readers might think our coposite labor input ql is also a state variable because it contains workers' job tenure, however, we assume that ql as a whole is a control variable because labor input is adjustable at youth, female or part-time margin. In addition, ql measures quality adjusted hours of work. We assume the hours of work is easily adjustable.

in the production function estimation, the structural coefficients for capital and intermediate goods cannot be identified without putting the assumption on the temporal dependence of firm heterogeneity. This problem, which is a serious issue in the context of the usual production function estimation, is not an issue in our application because instead we are interested in the coefficients for the labor composition variables.

Table 6 reports the results of the production function and wage equation estimations. Because the specification of the wage equation is identical to the specification in Table 5, the columns for wage equations are just repetitions. In the production function, the coefficients for education do not change in a meaningful way from those in Table 5. The estimated experience-productivity profiles are still U-shaped, except for machinery industry, and this tells us the difficulty of obtaining a consistent estimation of the experience-productivity profile once the distribution of tenure is conditioned. The results for the tenure-productivity profiles are quite similar to the ones reported in Table 5. Figures 7 through 10 illustrate the inferred profiles from the estimation results under the assumption that a typical worker works for an employer continuously for 40 years. The shapes of the profiles are comparable to the shapes obtained in Table 5.

The striking difference of the estimation results by controlling for establishment heterogeneity appears in the coefficients for the female and part-time dummy variables. The coefficients for females drops further in Table 6. This change in the results suggests that high, unobserved productivity firms tend to hire more female workers. This result is understandable, considering that firms tend to adjust female labor more rapidly than male labor in response to positive demand or technology shocks, as reported by Houseman and Abraham [1993]. After controlling for firm heterogeneity by the proxy variables, the relative productivity of female workers is even smaller than their relative wage compared with male workers. This result is not consistent with the existence of discrimination against female workers.

The relative productivity coefficients for part-time workers also declined significantly. This is again because the positive correlation between unobserved heterogeneity and part-time proportion caused a positive bias in the coefficient reported in Table 4. Part-time workers receive less than full-time workers, but their relative productivity is even less than their relative pay. The results for female and part-time workers suggest the importance of controlling for firm heterogeneity. The change in the results in an expected way assures the validity of Levinsohn and Petrin [2003]'s approach.

7 Conclusion

This paper reports the estimation results of the establishment-level production function and wage equation, using a large-scale employer-employee matched data set from Japan that covers the period between 1993 and 2003. This unique matched data set includes information on the detailed composition of workers' characteristics by establishments. The workers' characteristics include educational attainment, potential experience, job tenure, sex, and full- or part-time status. Using the estimations of the production function and the wage equation, we compared the relative productivity and payment by workers' characteristics.

The estimation results suggest that the wage return to education almost corresponds to the productivity return to education. We also found that the lower wage of female workers than male workers corresponds to their lower productivity. The estimated productivity of part-time workers is significantly lower than their wage. This result is consistent with the compensating wage differential for part-time workers because part-time workers do not enjoy the stable employment that full-time workers experience. These results imply that offering equal payment for male and female or full-time and part-time workers would reduce the labor demand for these two types of workers.

Most strikingly, our data set includes workers' job tenure information in addition to their age. This allowed us to estimate the tenure-productivity and tenure-wage profiles separately from the experience-productivity and experience-wage profiles. We consistently found steeper tenure-wage profiles than tenure-productivity profiles, and these findings are consistent with the deferred wage contract suggested by Lazear [1979] and Lazear and Moore [1984]. These results are consistent with the results by Hellerstein and Neumark [2004] for the US. We believe our results are clearer evidence than theirs because our data set allows us to estimate tenure profiles that are more direct predictions from deferred payment contract theory. However, we must admit the difficulty of estimating experience profiles due to the endogeneity of the experience distribution after conditioning on the tenure distribution.

Our approach also extends the series of studies by Hellerstein and Neumark [1995], Hellerstein et al. [1999], and Hellerstein and Neumark [2004] by proposing a functional form that is consistent with the Mincer wage equation. Imposing this parametric assumption renders more efficient and more interpretable estimates that are comparable to the results of the wage equation based on individual data. In addition, our application proves the usefulness of Levinsohn and Petrin [2003]'s approach to controlling for unobserved firm heterogeneity. We hope our approach offers a benchmark for similar estimations using data from other countries.

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Table 1: The Matching Rate of Employee Data and Employer Data.

Year	Number of Establishments in *BSWS* that Hire More than 30 employees. (Theoretically possible to match with *CM*)	Number of Observations Matched With *CM*	Matching Rate
1993	9,422	3,916	0.408
1994	8,795	3,635	0.405
1995	9,396	3,860	0.403
1996	11,004	5,054	0.446
1997	11,127	5,046	0.441
1998	10,418	5,039	0.472
1999	10,187	5,055	0.482
2000	9,697	4,906	0.491
2001	9,524	4,803	0.491
2002	9,004	4,902	0.525
2003	8,865	5,138	0.556
Total	107,439	51,354	0.465

Note: *BSWS* stands for Basic Survey of Wage Structure. This is the data set that contains employees' information. *CM* stands for Census of Manufacturers. This is the data set that contains employers' information. Two surveys are matched using establishment information in 2002. The matching rate of 2003 is higher than that of 2002 because those establishments sampled in 2003 BSWS have higher rate of survival between 2002 and 2003 and consequently they are more likely to be matched with *CM*.

Table 2: Establishments Characteristics Before and After Matching

Variable	Pre-Matching	Post-Matching	Single Establishment
Number of Permanent Employees ≥ 30		N=51354	N=18520
From Basic Survey of Wage Structure (N=107,439)			
Regular Employee	326.23	227.91	133.39
	(678.37)	(420.69)	(215.37)
Within-Establishment Average Yeas of Education	12.37	12.16	12.01
	(1.13)	(0.92)	(0.94)
Female Ratio	0.32	0.33	0.36
	(0.23)	(0.23)	(0.23)
Junior College & College Graduates Ratio	0.25	0.20	0.18
	(0.23)	(0.18)	(0.17)
Age 15~34 Ratio	0.37	0.37	0.35
	(0.19)	(0.18)	(0.19)
Age 35~54 Ratio	0.50	0.50	0.50
	(0.16)	(0.15)	(0.16)
Age 55~ Ratio	0.13	0.13	0.15
	(0.12)	(0.12)	(0.13)
Within-Establishment Average Age	39.96	40.01	40.76
	(5.26)	(5.23)	(5.53)
Within-Establishment Average Years of Tenure	12.84	12.44	11.50
	(5.57)	(5.21)	(4.83)
Part-time Ratio	0.06	0.07	0.07
	(0.15)	(0.15)	(0.14)
Full-time Work Hours (Hours per Month)	55023.77	38436.08	23672.46
	(115896.6)	(71324.40)	(36891.02)
Part-time Work Hours (Hours per Month)	1310.44	1369.64	925.159
	(4963.81)	(5271.37)	(2683.511)
Within Establishment Average Work Hours	176.74	178.63	180.93
(Hours per Month)	(19.86)	(19.86)	(19.92)
Within Establishment Average Full-time	179.96	181.87	184.40
Work Hours (Hours per Month)	(18.99)	(18.95)	(18.82)

Within Establishment Average Part-time	135.82	136.57	135.94
Work Hours (Hours per Month)	(30.86)	(30.92)	(30.75)
Wage Bill (Annual: 10 thousands yen)	186884.1	116348.7	59429.84
	(465208.5)	(268017.4)	(110885.8)
From Census of Manufacturers (N=585,630)			
Shipment (Annual: 10 thousand yen)	477177.4	990731.4	408384.2
	(2865251.0)	(3612672.0)	(1107177)
Wage Bill (Annual: 10 thousand yen)	60554.6	114701.7	59552.3
	(209612.0)	(266366.2)	(110326.2)
Fixed Assets	115821.4	243336.8	97777.82
(Beginning of the period: 10 thousand yen)	(635537.8)	(799540.0)	(349126.5)
Intermediate Input	275181.1	577254.0	257115.3
(Annual: 10 thousand yen)	(2113080.0)	(2383771.0)	(848217.5)
Wage Bill from CM/Wage Bill from BSWS	ー	1.01	1.03
		(0.19)	(0.19)
Regular Employee from CM/ Regular Employee	ー	1.07	1.09
from BSWS		(0.42)	(0.33)

Note: Wage bill is calculated as Average Wage Rate × Whole Work Hours(per month) × 12

Table 3: Reduced Form Production Function Estimation

Dependent Variable; Log (Output)

Sample: Single Establishment Firm; Observation unit is establishment.

	(1)	(2)	(3)	(4)	(5)
Log (Person-Hour)	0.447	0.467	-	-	-
from BSWS	(0.004)	(0.004)			
Log (Average Hourly Wage)	-	0.465	-	-	-
from BSWS		(0.009)			
Log (Wage Bill)	-	-	0.479	0.477	0.478
from CM			(0.004)	(0.004)	(0.004)
Log (Capital)	0.087	0.064	0.060	0.054	0.054
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Log (Intermediate Inputs)	0.520	0.483	0.480	0.480	0.479
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Female Ratio	-	-	-	0.049	0.045
				(0.013)	(0.013)
Part-time Ratio	-	-	-	0.014	-0.037
				(0.016)	(0.019)
Age35〜54Ratio	-	-	-	-0.147	-0.198
				(0.014)	(0.025)
Age55〜 Ratio	-	-	-	-0.248	-0.326
				(0.018)	(0.032)
Junior College& College	-	-	-	0.010	0.010
Graduates Ratio				(0.014)	(0.014)
Female Ratio×{Age35〜54Ratio	-	-	-	-	0.058
-mean(Age35〜54Ratio)}					(0.061)
Female Ratio×{Age55〜Ratio	-	-	-	-	0.188
-mean(Age55〜Ratio)}					(0.072)
Part-time Ratio×{Age35〜54Ratio	-	-	-	-	0.544
-mean(Age35〜54Ratio)}					(0.107)
Part-time Ratio×{Age55〜Ratio	-	-	-	-	0.219
-mean(Age55〜Ratio)}					(0.113)
Constant	0.106	1.306	1.264	1.419	1.459

	(0.040)	(0.044)	(0.027)	(0.032)	(0.034)
R^2	18520	18520	18520	18520	18520
N	0.95	0.95	0.95	0.95	0.95

Note: Standard errors are in parenthesis. All specification includes industry and year dummy variables. Educational background is available only for full-time workers. Thus, junior college and college graduates ratio is calculated only for full-time workers. 8 Establishments in the sample only hire part-time workers. For those establishments, zeros are assigned for junior college and college graduates ratio.

Table 4: Descriptive Statistics for Analysis Sample

Sample Period: 1993-2003

Sector Variable	Manufacturing	Light	Heavy	Machinery
Output	408384.2	211569.5	278570.2	810642.7
	(1107177.00)	(383709.00)	(570116.60)	(1854087.00)
Wage Bill of Regular Employees	59552.3	35728.17	48045.94	104007.9
	(110326.20)	(45694.29)	(88743.98)	(165750.00)
Full-time Total Hours	23672.46	16868.09	18345.02	39186.4
	(36891.02)	(19548.65)	(24868.04)	(56843.02)
Part-time Total Hours	925.159	1125.077	601.543	1058.602
	(2683.51)	(3296.03)	(1592.95)	(2913.43)
Fixed Assets	97777.82	48830.68	94052.08	166500.7
	(349126.50)	(99708.67)	(305004.10)	(545293.70)
Intermediate Input	257115.3	115257.3	153487.4	558420.8
	(848217.50)	(225546.80)	(355870.50)	(1465301.00)
Labor Hour Composition among Regular Employees				
Junior High School Graduates	0.19	0.22	0.19	0.16
High School Graduates	0.63	0.62	0.63	0.64
2-yr College Graduates	0.07	0.07	0.06	0.08
4-yr College Graduates	0.11	0.10	0.11	0.13
Female	0.31	0.39	0.25	0.27
Age 31-45	0.33	0.31	0.32	0.36
Age 46-	0.39	0.43	0.41	0.32
Sample Size	18520	6291	6349	5205

Note: 2-yr college graduates include those who graduated from technical polytechnic (*Koto Senmon Gakkou*).

Table 5: Estimation of Production Function and Wage Bill Function

Sample: Single-establishment firms; observation unit is establishment.

	Manufacturing		Light		Heavy		Machinery	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (all in logarithm)	Output	Wage Bill	Output	Wage Bill	Output	Wage Bill	Output	Wage Bill
Full-time • Education	0.079	0.073	0.061	0.051	0.077	0.072	0.110	0.086
	(0.008)	(0.003)	(0.013)	(0.005)	(0.013)	(0.005)	(0.014)	(0.005)
Full-time • Experience	-0.004	-0.009	0.009	-0.007	-0.035	-0.019	0.009	0.001
	(0.006)	(0.002)	(0.011)	(0.004)	(0.011)	(0.004)	(0.013)	(0.005)
Full-time • Experience^2	-0.019	0.015	-0.059	0.003	0.052	0.039	-0.042	0.006
/ 100	(0.014)	(0.005)	(0.023)	(0.008)	(0.023)	(0.008)	(0.031)	(0.010)
Full-time • Tenure	0.018	0.021	0.017	0.017	0.033	0.025	0.001	0.019
	(0.006)	(0.002)	(0.010)	(0.004)	(0.010)	(0.003)	(0.012)	(0.004)
Full-time • Tenure^2	-0.024	-0.015	-0.018	-0.006	-0.050	-0.022	-0.001	-0.018
/ 100	(0.017)	(0.005)	(0.028)	(0.010)	(0.027)	(0.008)	(0.036)	(0.011)
Full-time • Female	-0.506	-0.718	-0.644	-0.645	-0.766	-0.700	-0.185	-0.767
	(0.043)	(0.017)	(0.074)	(0.028)	(0.094)	(0.028)	(0.075)	(0.032)
Part-time	-0.749	-0.702	-0.896	-0.668	-0.821	-0.719	-0.756	-0.690
(Educ=12, Exp=0, Ten=0)	(0.082)	(0.031)	(0.132)	(0.048)	(0.159)	(0.055)	(0.177)	(0.060)
Cobb-Douglas Coeff.								
Log (Labor)	0.515	—	0.479	—	0.521	—	0.555	—
	(0.008)		(0.015)		(0.016)		(0.014)	
Log(Capital)	0.072	—	0.079	—	0.076	—	0.063	—
	(0.003)		(0.004)		(0.005)		(0.005)	
Log(Intermediate Inputs)	0.508	—	0.520	—	0.480	—	0.517	—
	(0.002)		(0.004)		(0.004)		(0.004)	
R^2	0.947	0.931	0.933	0.891	0.921	0.912	0.965	0.952
N	18520	18520	6291	6291	6349	6349	5205	5205

Note: Standard errors are in parentheses. All specifications include industry dummy variables.

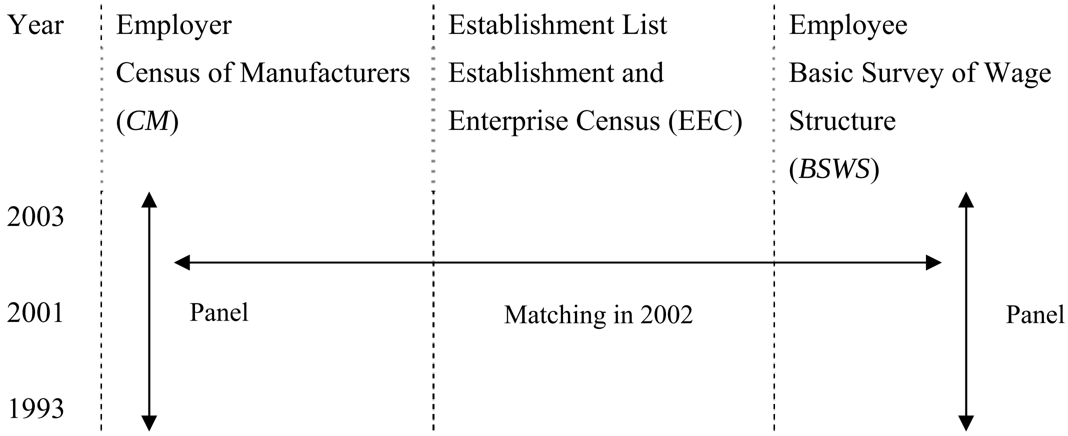
Table 6: Estimation of the Production Function and the Wage Bill Function

Sample: Single-establishment firm; observation unit is establishment.

	Manufacturing		Light Manufacturing		Heavy Manufacturing		Machinery Manufacturing	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable (all in logarithm)	Shipment	Wage Bill	Shipment	Wage Bill	Shipment	Wage Bill	Shipment	Wage Bill
Full-time • Education	0.087	0.073	0.083	0.051	0.061	0.072	0.101	0.086
	(0.008)	(0.003)	(0.013)	(0.005)	(0.013)	(0.005)	(0.014)	(0.005)
Full-time • Experience	-0.011	-0.009	-0.006	-0.007	-0.041	-0.019	0.008	0.001
	(0.006)	(0.002)	(0.010)	(0.004)	(0.010)	(0.004)	(0.012)	(0.005)
Full-time • Experience^2	0.004	0.015	-0.021	0.003	0.071	0.039	-0.016	0.006
	(0.013)	(0.005)	(0.022)	(0.008)	(0.021)	(0.008)	(0.027)	(0.010)
Full-time • Tenure	0.023	0.021	0.030	0.017	0.029	0.025	0.008	0.019
	(0.006)	(0.002)	(0.010)	(0.004)	(0.009)	(0.003)	(0.011)	(0.004)
Full-time • Tenure^2	-0.036	-0.015	-0.055	-0.006	-0.041	-0.022	-0.019	-0.018
	(0.016)	(0.005)	(0.028)	(0.010)	(0.025)	(0.008)	(0.031)	(0.011)
Full-time • Female	-0.779	-0.718	-0.730	-0.645	-0.788	-0.700	-0.866	-0.767
	(0.047)	(0.017)	(0.075)	(0.028)	(0.086)	(0.028)	(0.089)	(0.032)
Part-time	-1.121	-0.702	-1.012	-0.668	-0.950	-0.719	-1.590	-0.690
(Educ=12, Exp=0, Ten=0)	(0.088)	(0.031)	(0.131)	(0.048)	(0.149)	(0.055)	(0.213)	(0.060)
Cobb-Douglas Coeff.								
Log (Labor)	0.356	—	0.367	—	0.367	—	0.342	—
	(0.006)		(0.011)		(0.007)		(0.010)	
R^2	0.960	0.931	0.945	0.891	0.942	0.912	0.976	0.952
N	18520	18520	6291	6291	6349	6349	5205	5205

Note: Standard errors are in parentheses. All specifications include industry dummy variables. All production functions include 3rd order polynomials of log(capital) and log(material) to capture unobserved demand or technology shock (Levinsohn and Petrin (2002)).

Figure 1: Construction of Employer-Employee Matched Data



Note: The matching of employer and employee is possible only if the establishment existed in 2002.

Figure 2: Across-Establishments Average of the Proportion of Total Hours of Full-Time Workers by Tenure Year (Hours Worked per Month)

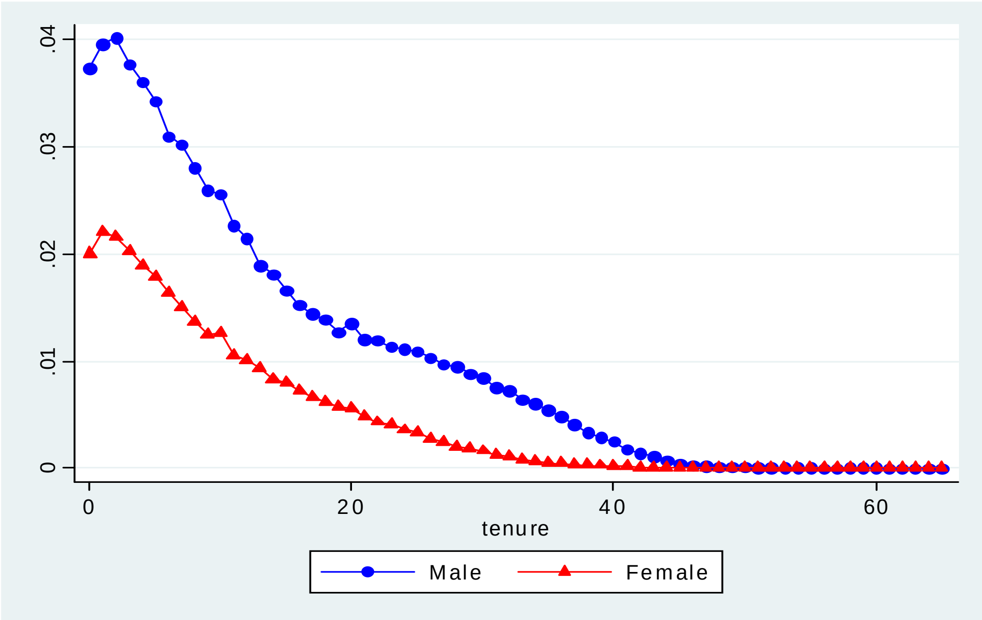


Figure 3: Male Productivity and Wage Profiles

Sample: All Manufacturing Establishments Belonging to Single-Establishment Firms, N=18520

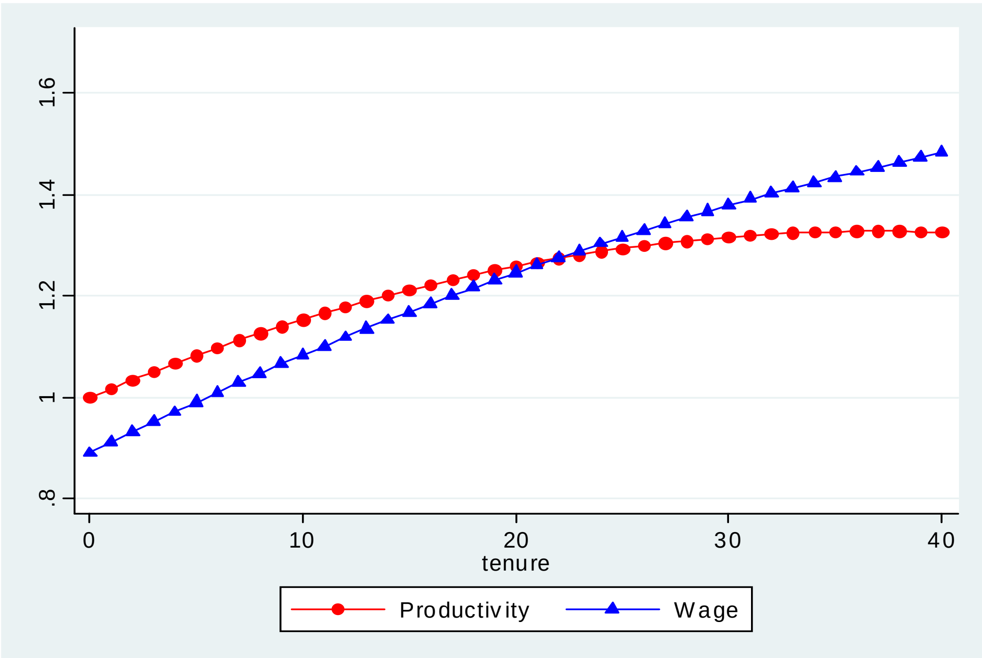


Figure 4: Male Productivity and Wage Profiles

Sample: Light Manufacturing Establishments Belonging to Single-Establishment Firms, N=6291

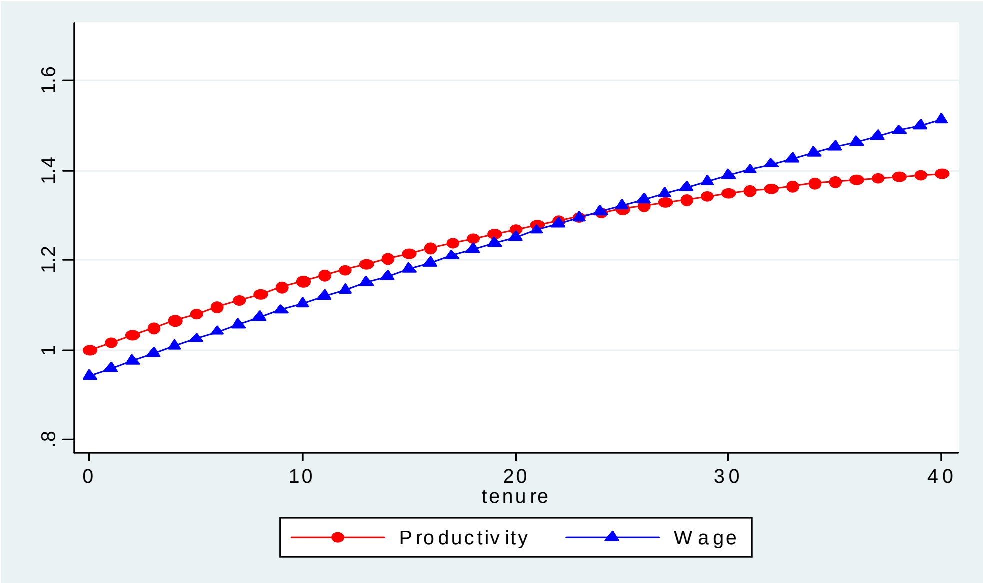


Figure 5: Male Productivity and Wage Profiles

Sample: Heavy Manufacturing Establishments Belonging to Single-Establishment Firms, N=6349

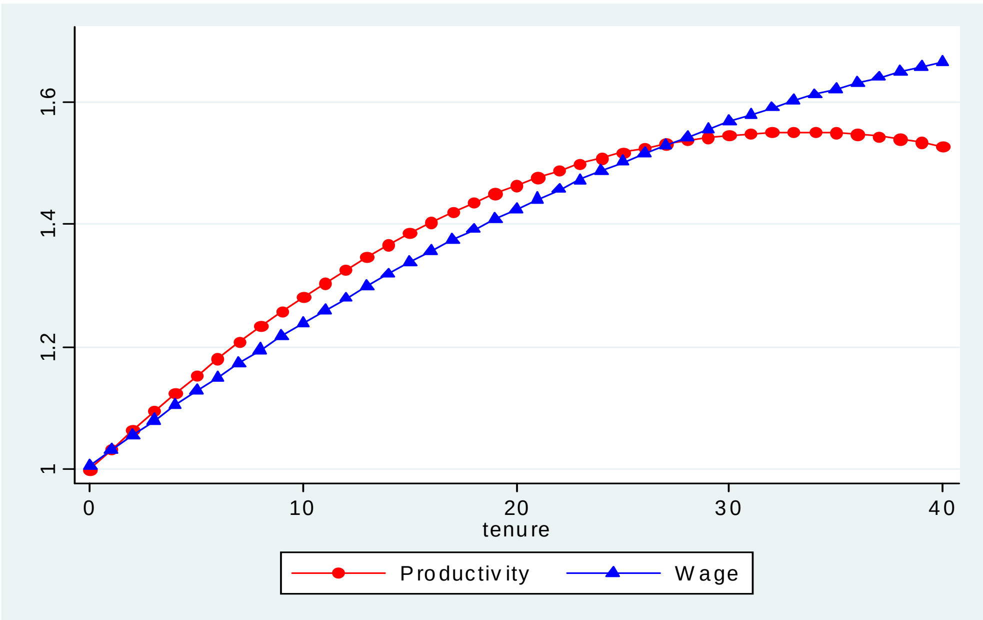


Figure 6: Male Productivity and Wage Profiles

Sample: Machine Manufacturing Establishments Belonging to Single-Establishment Firms, N=5205

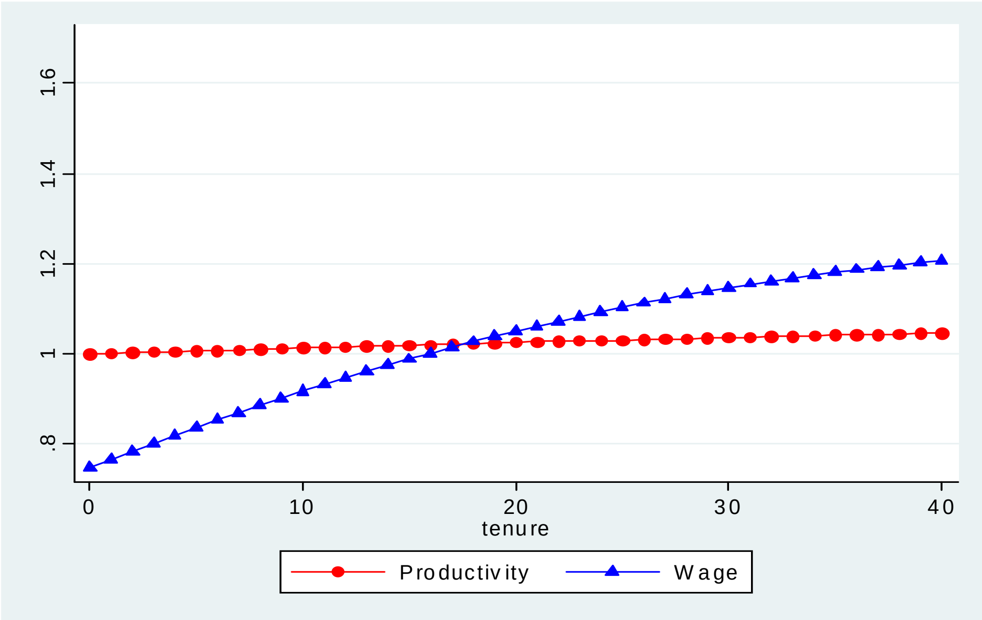


Figure 7: Male Productivity and Wage Profiles after Demand Shock Control

Sample: All Manufacturing Establishments Belonging to Single-Establishment Firms, N=18520

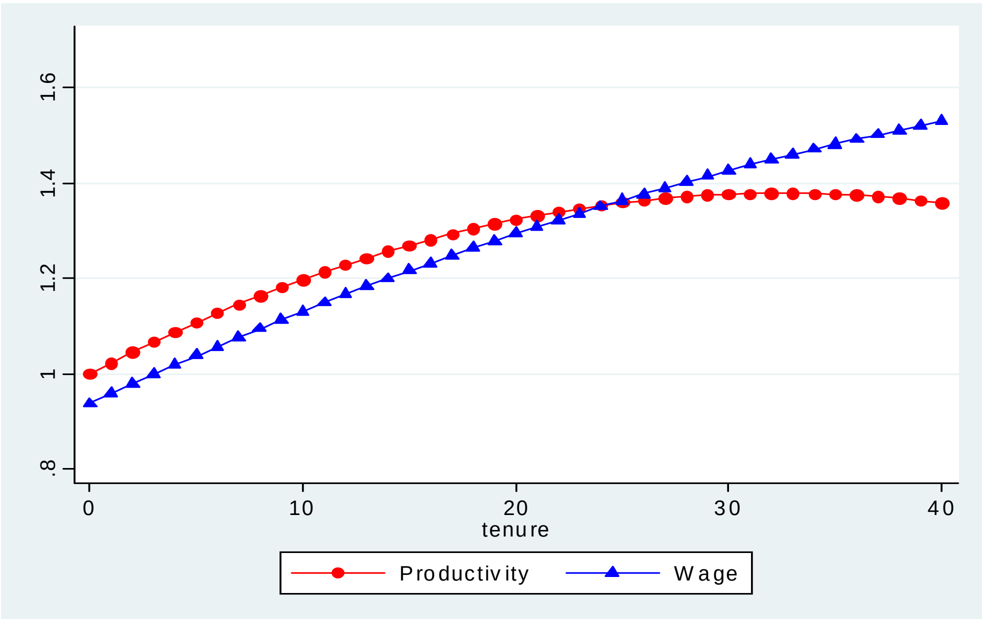


Figure 8: Male Productivity and Wage Profiles after Demand Shock Control

Sample: Light Manufacturing Establishments Belonging to Single-Establishment Firms, N=6291

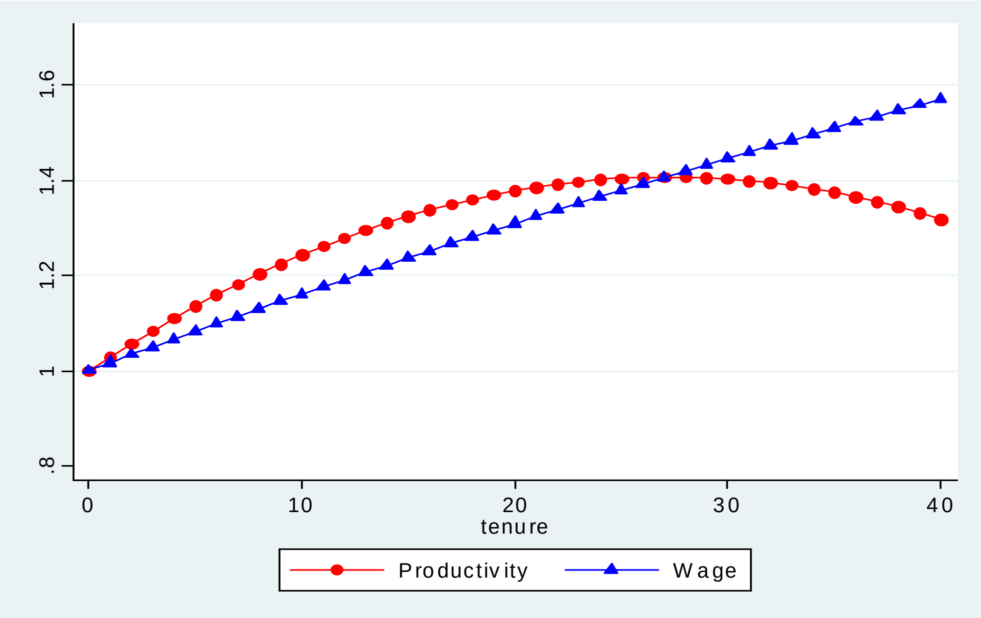


Figure 9: Male Productivity and Wage Profiles after Demand Shock Control

Sample: Heavy Manufacturing Establishments Belonging to Single-Establishment Firms, N=6349

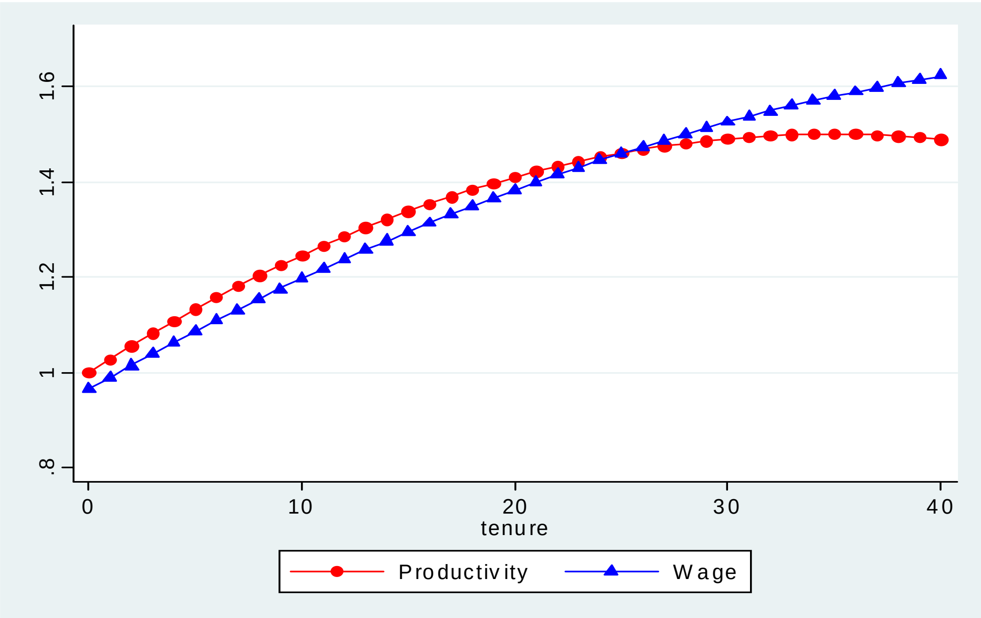
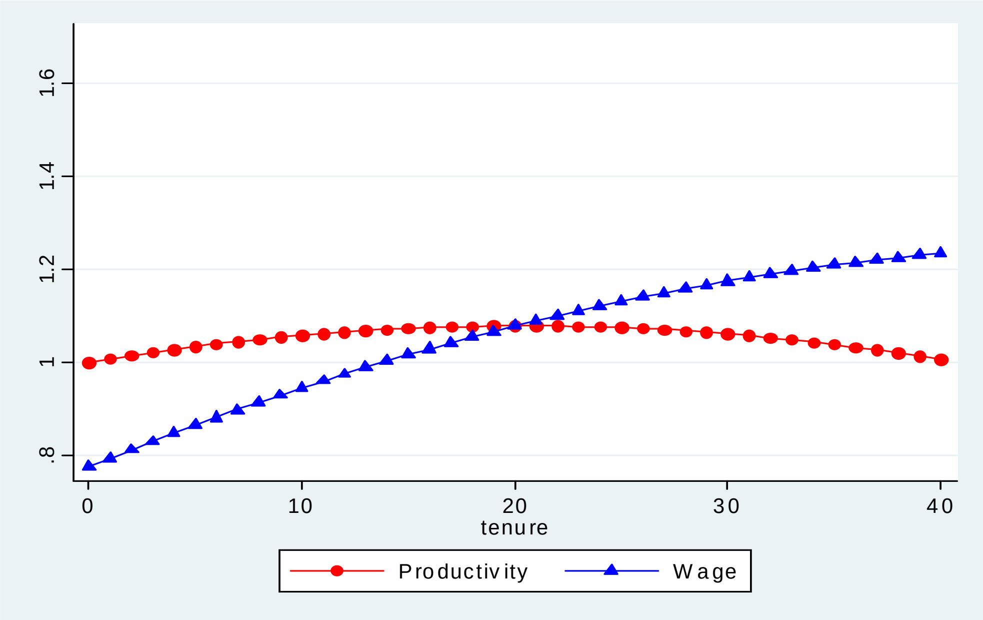


Figure 10: Male Productivity and Wage Profiles after Demand Shock Control

Sample: Machine Manufacturing Establishments Belonging to Single-Establishment Firms, N=5205



Appendix Table 1: Wage Equation Based on Individual Data, 1993-2003

Dependent Variable: log (wage)

Sample: Workers in manufacturing establishments that hire 30 or more employees.

	(1)	(2)	(3)
Education	0.070	0.071	0.067
	(0.000)	(0.000)	(0.000)
Experience	0.018	0.018	0.019
	(0.000)	(0.000)	(0.000)
$Experience^2/100$	-0.039	-0.040	-0.040
	(0.000)	(0.000)	(0.000)
Tenure	0.032	0.032	0.030
	(0.000)	(0.000)	(0.000)
$Tenure^2/100$	-0.015	-0.014	-0.014
	(0.000)	(0.000)	(0.000)
Female	-0.363	-0.364	-0.337
	(0.000)	(0.000)	(0.000)
Part	-0.378	-0.374	-0.375
	(0.001)	(0.001)	(0.001)
Constant	1.739	1.683	1.687
	(0.001)	(0.001)	(0.002)
Year-Dummy	No	Yes	Yes
Industry-Dummy	No	No	Yes
Observations	3800960	3800960	3800960
R-squared	0.68	0.68	0.70

Note: The sample is from the Basic Survey of Wage Structure. The wage rate is defined as (total monthly compensation in June + total bonus payment / 12) / total hours worked (overtime inclusive) in June. Part-time workers are assumed to have 12 years of education.