Acquired Skill and Learned Ability

Wage Dynamics in Internal Labor Markets*

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Abstract

The signaling role of schooling decreases as employers learn about workers' abilities from their experience. Since learning is asymmetric between current and potential employers, the market expects that experience and schooling be complements for workers who have not been promoted, which hides the learning effect, and be substitutes for promoted workers. This market expectation in turn affects workers' skill acquisition. Due to asymmetric learning and its effects on skill acquisition, (1) the employer learning effect is hidden during experience outside of internal labor markets and (2) is apparent within internal labor markets, but (3) attenuates with tenure upon joining internal labor markets.

Key words: skill acquisition, asymmetric employer learning, internal labor markets.
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1 Introduction

Productivity of a worker depends on his/her own skills. People acquire skills at schools before graduation and at workplaces after graduation (Mincer (1974)). Meanwhile, speed and depth of skill acquisition are largely determined by innate ability of the worker. More talented people will acquire broader and/or deeper skills faster than less talented ones at schools and workplaces. Employers are therefore interested in innate abilities of acquiring skills afterwards as well as already acquired skills at the point of recruitment. However, workers' innate abilities are generally private information when they enter the labor market. Thus, employers seek to use some signals to predict workers' innate abilities. If innate abilities affect performance of skill acquisition at schools, educational background can be a proxy of abilities. Employers therefore use educational background us a signal of abilities as well (Hansen, Weisbrod and Scanlon (1970); Spence (1973); Arrow (1973); Mantell (1974); Riley (1979); Hungerford and Solon (1987); Belman and Heywood (1991); Jaeger and Page (1996); Tyler, Murnane and Willett (2000); and Münich, Svejnar and Terrell (2005)). After workers join the labor market, however, employers learn about workers' true on-the-job abilities of skill acquisition from their products (Farber and Gibbons (1996)).

In the labor market, workers' skill acquisition and employers' learning simultaneously proceed and affect each other. While each of these dual processes has been inquired in detail, interaction between them is still to be clarified. Further factors that make issues subtle are specificity of skills, long-term employment, and potential complementarity between institutions for skill acquisition—schools and work places. Firm- and industry- specificity of skills vary over different industries and economies (Abe (2000); Parent (2000); Weinberg (2001); Dustmann and Meghir (2005); Shaw and Lazear (2008); Poletaev and Robinson (2008); and Gathmann and Schönberg (2010)). In addition, long-term employment, a device to induce specific skill acquisition, could potentially make employer learning asymmetric between current and the other employers as well. Longer-term employment might enable current employers to learn about workers true abilities wider and deeper in the longitudinal dimension for each worker (Schönberg (2007); Pinkston (2009); Mansour (2012)). Furthermore, the extent of complementarity between skills earned at schools and workplaces might change in the longitudinal direction in different stages of career path of each worker (Rubinstein and Weiss (2006)). These entangled elements of skill acquisition, signaling of abilities, and learning of abilities compose mixed pictures and are often hard to decompose once crystalized in labor market institutions and firm organizations.

Focusing on skill acquisition side, Mincer (1974) found a mystically negative coefficient of the interaction term between schooling and experience in the wage regression and described as a trace of "apparent convergence of experience profile," but did not provide a clear explanation for why or how workers' experiences could converge, mainly due to pretermitting the signalling role of schooling.[1] Then, following the literature on the signaling role of schooling from Hansen et al. (1970), Farber and Gibbons (1996) introduced a persuasive reasoning of the non-positive coefficient of the interaction term between schooling and experience. As Alós-Ferrer and Prat (2012) mentioned, their employer learning model allows private infor-

[1] See Mincer (1974), pp. 92-93.

mation about workers' abilities to be revealed either by schooling or realized performance in the market. Then, the model predicts that the latter channel dominates the former with workers' acquisition of experience in the market. They attributed the non-positive coefficient of the interaction term between schooling and experience to the decreasing impact of schooling as a signal of ability, as employers learn about the true abilities. Following works—including Altonji and Pierret (2001), Lluis (2005), Pinkston (2006), Lange (2007), Oyer (2008), and Schönberg (2007)—support this prediction.

Meanwhile, the clear-cut argument by Farber and Gibbons (1996) relies on assuming the symmetry of learning between current and potential employers and on omitting skill acquisition. Primarily due to these two omitted factors—asymmetry in learning and skill acquisition—some evidence appears "mixed" to the hypothesis of symmetric employer learning.[2] Pinkston (2009) established that learning is significantly asymmetric between current and potential employers in the United States. On the other hand, if skill acquired from work experience is complementary to those from schooling, then it works to make the interaction term between schooling and work experience positive. Indeed, schooling and work experience tend to be complements in the early stages of workers' career in the United States.[3] Further, about Germany, Bauer and Haisken-DeNew (2001) and Lluis (2005) concluded that evidence of employer learning is not generally observed, and if any, is very weak. If the German school system is closely connected to the apprenticeship and it makes schooling and work experience complements (Pischke and von Wachter (2008)), it it not a puzzle.

Addressing these two critical issues—asymmetric learning and human capital acquisition—the literature from Waldman (1984) to DeVaro and Waldman (2012) presents a consistent and comprehensive perspective. Furthermore, as section 2 shows, from their model we can derive a key implication to ascertain how asymmetry of learning and specificity of skill affect the market's expectation about whether schooling and experience are complements or substitutes, which in turn affect workers' skill acquisition. This paper intends to suggest a theoretical and empirical viewpoint to understand this mixed picture especially focusing on internal labor markets, where employer learning is particularly asymmetric and it affects skill acquisition.

Section 2 presents the underlining framework and our estimation model. Subsection 2.1 first reviews the model by DeVaro and Waldman (2012) and predicts that, in the mid-career market, work experience and schooling are expected by employers to be complements for workers who have not been promoted in previous employment and substitutes for workers who have been promoted. The market expectation of workers' skills in the cross-sectional dimension differs between before and after a worker is promoted.

Then in subsection 2.2, we inquire how these theoretical predictions can be captured in econometric models. Thus we present how the coefficient of the interaction term between schooling and experience is affected by workers' skill acquisition and employers' learning in econometric models, which is the source of the mixed picture in existing empirical evidence. It is shown that in the coefficient of the interaction term, the covariance in the cross-sectional dimension of sample workers is increasing in the complementarity between schooling and experience and the covariance in the longitudinal dimension of each worker is decreasing in

[2] See Gibbons and Waldman (2006), pp. 74-75 and Waldman (2013), pp. 524, 536-537.

[3] See Rubinstein and Weiss (2006), pp. 11-16 and Habermalz (2006), p. 132.

the employer learning effect. The combination of both produces mixed results. Our approach of estimation differs from Farber and Gibbons (1996) in one regard. Farber and Gibbons (1996) emphasized that "[schooling and other observable variables] play a declining role in the market's inference process but have a constant estimated effect."[4] Subsection 2.2, however, decomposes the coefficient of the interaction term between schooling and experience into the cross-sectional dimension and the longitudinal dimension. For the former, our framework assumes that the estimated effect of schooling does not change as in Farber and Gibbons (1996). For the latter, it predicts that the estimated effect of schooling declines as work experience is acquired. We infer that this longitudinal effect generates non-positive coefficient of the interaction term between schooling and work experience.

Subsection 2.3 presents an estimation model. To differentiate learning and skill acquisition between inside and outside of internal labor market, we separate work experience before and after gaining long-term employment. The market expectation on whether schooling and work experience are complements or substitutes depends on whether the worker has been promoted or not, as discussed in subsection 2.1. This market expectation naturally could affect workers' beliefs when they decide whether to invest in more firm-specific skills and hence affect the covariance matrix of skill distributions in the cross-sectional dimension of sample workers. Further, after workers gain long-term employment, the employer learning effect is accelerated in the longitudinal direction for each worker. These effects are expected to change the coefficient of interaction term of schooling and experience between before and after gaining long-term employment. Theoretical prediction in subsection 2-1 is transformed into an econometric prediction that the employer learning effect is more weakly observed before gaining long-term employment and more strongly observed after gaining long-term employment.

Section 3 describes the data and then verifies the existence of an internal labor market in the case plant, a Japanese iron works. Section 4 presents the empirical results, which show that schooling and short-term work experience at younger ages were expected to be complements in the market and that the employer learning effect is hidden, but that the employer learning effect is strongly observed once workers gained long-term employment at the case firm.

2 Theoretical framework

2.1 Human capital acquisition and asymmetric learning

In order to describe the human capital acquisition process under asymmetric learning, our approach is based on the model presented in DeVaro and Waldman (2012). The skeleton of the model was provided by Gibbons and Waldman (1999), which captured both human capital acquisition and learning processes with a symmetric learning setting. Gibbons and Waldman (2006) extended the model to include schooling, and DeVaro and Waldman (2012) introduced the asymmetric learning environment assuming that the labor market is competitive, but realized performance is observed only by current employers and potential employers observe only whether workers have been promoted, which was the essence of Waldman (1984).

[4] Farber and Gibbons (1996), p. 1014.

Following the model by DeVaro and Waldman (2012), let $\phi_i \in (\phi_L, \phi_H)$ denote the innate ability of worker i, $i = 1, 2, \ldots, n$, which is a random draw from probability density function $g(\phi)$ with $g(\phi) > 0$ for $\phi \in (\phi_L, \phi_H)$ and $g(\phi) = 0$ otherwise; S_i denote worker i's years of schooling; and $M_{i,t}$ denote worker i's employment experience until period t. Then, assume that "on-the-job" human capital of worker i who has S_i years of schooling and has M years of work experience M_i in period t is $\eta_{i,t} = (\phi_i + bS_i) \equiv \theta_i f(M_i)$, where $b > 0$, f is increasing in M, and $f(0) > 0$. i All firms have homogenous production functions and each firm consists of job 1 and job 2. The product of worker i assigned to job j in period t is given by

$$y_{i,j,t} = (1 + k_{i,t})(d_j + c_j \eta_{i,t}) + G(S_i), \tag{1}$$

where $0 < d_2 < d_1$, $0 < c_1 < c_2$ and $k_{i,t} > 0$ if worker i was employed at the same firm in period $t-1$. While $M_{i,t}$, S_i, G is increasing in S, $f(\cdot,\cdot)$, $G(\cdot)$, b, d_j, c_j and $k_{i,t}$ are public information, $y_{i,j,t}$ is privately observed by the current employer and ϕ_i is privately known to worker i. We do not specify anything about the possible correlation between ϕ and S, which allows S to potentially depend on ϕ and to function as a signal of ϕ. At the end of worker i's first period, the current employer privately observes $y_{i,j,t}$ and thus learns about θ_i. Hereafter we assume that increase in productivity due to promotion ($c_2 - c_1$) and/or return on firm-specific human capital k is sufficiently large that $k > c_1/(c_2 - c_1)$.

Consider $\eta' = (d_1 - d_2)/(c_2 - c_1)$ that solves $d_1 + c_1\eta' = d_2 + c_2\eta'$ and assume that $(E[\phi \mid S] + bS)\, f(0) \equiv \theta^E(S) f(0) < \eta'$ for any S, which implies that any worker is efficiently assigned to job 1. Further, assume that,

$$(\phi_L + bS)\, f(1) < \eta' < (\phi_H + bS)\, f(1), \tag{2}$$

which implies that some workers in their second period are efficiently assigned to job 1 while the others are assigned to job 2.

The structure of the game is as follows. At the beginning of workers' second period, each firm offers each existing worker it employed in the previous period a job assignment or fires the worker, which is publicly observed. Then wages are determined before each period by spot-market contracting. Observing worker i's job assignment or discharge, employers other than the worker's first-period employer offer a wage, and the worker's first-period employer offers a wage weakly greater than the wage offered by others. For simplicity, no transaction cost and a common discount factor are assumed.

Further, consider $\eta^+(S)$ such that $y_{i,1,t} - w_{i,1,t} = y_{2,t} - w_{i,2,t}$ in worker i's second period if $\eta_{i,t} = \eta^+(S)$, where $w_{i,1,t}$ denotes wage paid to worker i assigned to job 1 and $w_{i,2,t}$ denotes wage paid to worker i assigned to job 2; that is, profit is indifferent regardless of whether worker i is promoted to job 2 or not. Under this setting, DeVaro and Waldman (2012) established that there is a perfect Bayesian equilibrium where in the second period of worker i who was employed by firm A, if $\eta_{i,t} \geq \eta^+(S_i)$, then worker i remains at firm A, assigned to job 2, and is paid $w_{i,2,t}(S_i, \eta_{i,t}) = d_2 + c_2\eta^+(S_i) + G(S_i)$, and that if $\eta_{i,t} \leq \eta^+(S_i)$, then worker i remains at firm A, assigned to job 1, and is paid $w_{i,1,t}(S_i, \eta_{i,t}) = d_1 + c_1 \left[\phi_L + bS_i\right] f(1) + G(S_i)$.

Outside employers offer wages equal to the least on-the-job human capital possible given the public information about promotion at the current employer, and the current employer counteroffers a wage only weakly greater than the wage offered by the others, from which neither current nor outside employers have incentives to deviate. Note that offering expected productivity given the public information, which is equal to or greater than the possible lowest productivity, as wage cannot be an equilibrium strategy. Only workers whose productivity is strictly lower than the offer take it, which result in loss. Employers predict this adverse selection outcome and hence never offer expected productivity.

By the definition of η^+, we have

$$\begin{aligned} y_{i,1,t} - w_{i,1,t} &= (1+k)\left(d_1 + c_1\eta^+(S_i)\right) - [d_1 + c_1(\phi_L + B(S_i)f(1))] \\ &= (1+k)\left(d_2 + c_2\eta^+(S_i)\right) - \left(d_2 + c_2\eta^+(S_i)\right) = y_{i,2,t} - w_{i,2,t}, \end{aligned}$$

which is rearranged to

$$\eta^+(S_i) = \frac{k(d_1 - d_2) - c_1\left(\phi_L f(1) + B(S_i)f(1)\right)}{k(c_2 - c_1) - c_1}.$$

Here is a tradeoff of employer's benefits between promotion and non-promotion is as follows. On the one hand, by suppressing promotion, wage payment is constrained. However, increase in $bSf(1)$ pushes up the wage by the rate c_1 even at job 1. On the other hand, by promotion, productivity increase times human capital specificity $(1+k)(c_2-c_1)$ is reaped. Thus, increase in $bSf(1)$ decreases the promotion threshold η^+ and the asymmetric learning results in that the threshold η^+ determines the wage of promoted worker as the least possible productivity at job 2. Summing up, we have a characteristic of η^+ as follows.

Then, consider a modified two-period setting. Now, when worker i joins the firm, worker $i+1$ is already there and has not been promoted to job 2. In the second period of worker i, which is his/her third period of $i+1$, both workers i and $i+1$ are promoted to job 2 if $\eta_{i,t} > \eta^+$ and $\eta_{i+1,t} > \eta^+$. Then we can derive another lemma for variations of the market expectation in the cross-sectional dimension $i = 1, 2, \ldots, n$.

Lemma 1. *Work experience is expected in the market to be complementary to schooling for workers who have not been promoted and substitute for schooling for workers who have been promoted.*

Proof See the Appendix I.

Lemma 1 tells that under asymmetric employer learning and positive return on firm-specific human capital, work experience and schooling are expected in the market to be complements before workers are promoted but to be substitutes once workers are promoted. A practical aspect of the result is that it holds either in a market where promotion is accompanied by a steep increase in wage, that is $(c_2 - c_1)$ is large, as in the United States or in a market where firm-specificity is strongly required, that is, k is large, as in Japan.[5]

Threshold η' is the critical value of promotion under symmetric learning. That is, difference $D \equiv \eta^+ - \eta'$ captures the efficiency loss due to the asymmetry of information between

[5]See Altonji and Shakotko (1987) and Abe (2000).

the current employer and the other employers about the on-the-job ability of workers. Under the assumption $k > c_1/(c_2 - c_1)$, $D > 0$, which means that less-than-optimal number of workers are promoted in their second period. Related to this efficiency loss due to asymmetric learning, we have the following lemma.

Lemma 2. *The efficiency loss from asymmetry in learning D is, (i) decreasing in the firm-specificity of human capital k; and, (ii) decreasing in the productivity increase due to promotion $(c_2 - c_1)$ if k is sufficiently large.*

Proof See the Appendix I.

Lemma 2, a legacy from Waldman (1984), suggests that internal labor markets being "shielded" due to asymmetric learning could be justified in terms of efficiency if the productivity increase in on-the-job human capital acquisition is large or is strongly firm-specific.

2.2 Benchmark estimation framework of employer learning

On the one hand, **Lemma 1** indicates that the market expects in the cross-sectional dimension that schooling and experience are complements for workers in the mid-career recruiting market who were presumably not promoted by their previous employers for each worker. On the other hand, the market learns about workers' abilities in the longitudinal dimension. Then, both the cross-sectional complementarity effect between schooling and experience and the longitudinal employer learning effect affect the sign of the interaction term between schooling and experience in a wage regression, though in opposite directions. To ascertain this interaction between cross-sectional and longitudinal dimensions, we first revisit the setting in Farber and Gibbons (1996) as a benchmark.

Hereafter, we consider a setting where $t = M$ for $i = 1, 2, \ldots, n$, and for simplicity, assume that $b = 1$ and $f(M) = M = t$, and again let $y_{i,t}$ denote the output of worker i in period t ($t = 1, \ldots, T$), and $\eta_{i,t}$ denote the ith worker's "on-the-job" human capital in period t, which is not observable by employers. Then, suppose that $\eta_{i,t} = (\phi_i + S_i)t = \theta_i t$, where $\theta_i = \phi_i + S_i$ denotes the ith worker's ability, which is time-invariant multiplier of human capital investment. While schooling S_i and experience t are observable to employers, ϕ_i is not observable, and thus $\eta_{i,t}$ is not observable to employers when the worker joins the labor market but is then learned by the employers. Further, let $\boldsymbol{x}_i$ denote a vector of time-invariant characteristics of worker i other than years of schooling, which are observable to employers.

We assume that conditional distribution $F_1(y_{i,t} \mid \theta_i, S_i, \boldsymbol{x}_i)$ can be arbitrary and that outputs $y_{i,t}$ are independently drawn from $F_1(y_{i,t} \mid \theta_i, S_i, \boldsymbol{x}_i)$. We also assume that joint distribution $F_2(\theta_i, S_i, \boldsymbol{x}_i)$ can be arbitrary. All employers are assumed to know $F_2(\theta_i, S_i, \boldsymbol{x}_i)$ and $F_1(y_{i,t} \mid \theta_i, S_i, \boldsymbol{x}_i)$ and to observe $y_{i,1}, \ldots, y_{i,t}$ for each worker $i = 1, \ldots, n$. Thus, both the current and potential employers in the market symmetrically learn about the ith employee's ability in the market.

Furthermore, we assume that, due to the competition between employers, the wage paid to the ith worker in period t equals expected output given all available information in period t about the ith worker:

$$w_{i,t} = E\big(y_{i,t} \mid S_i, \boldsymbol{x}_i, y_{i,1}, \ldots, y_{i,t-1}\big). \tag{3}$$

We also assume that conditional expectation $E\big(y_{i,t} \mid S_i, \boldsymbol{x}_i, y_{i,1}, \ldots, y_{i,t-1}\big)$ is a linear combination of S_i, $\boldsymbol{x}_i$, and $y_{i,1}, \ldots, y_{i,t-1}$.

We now review an example of the panel estimation of the employer learning model. Assuming that the workers' production function is of the Cobb-Douglas type, take a logarithmic expression of wage function and consider a panel least square regression of worker i's wage at time t, $w_{i,t}$, expressed as

$$w_{i,t} = \alpha_0 + \alpha_1 S_i + \alpha_2 t + \alpha_3 S_i t + \alpha_4 x_{4,i} + \cdots + \alpha_j x_{j,i} + \cdots + \alpha_m x_{m,i} + \theta_i^E(S_i) + \epsilon_{i,t}, \tag{4}$$

where $\boldsymbol{x}_i$ denotes an $(m-3)$-dimensional vector whose elements are observable other than years of schooling and are numbered from 4 and $\log \eta_{i,t} = \log \theta_i + \log t$. We then obtain

$$\mathit{\Delta}_t w_{i,t} = \alpha_2 + \alpha_3 S_i + \mathit{\Delta}_t \theta_i^E(S) + \mathit{\Delta}_t \epsilon_{i,t} \equiv \alpha_2 + \alpha_3 S_i + \varphi_{i,t}, \tag{5}$$

where $\mathit{\Delta}_t \epsilon_{i,t}$ is the serially independent innovation.

Then, the linear projection of $\boldsymbol{w}$, which is an n-dimensional vector whose ith element is w_i, denoted by $E^*(\boldsymbol{w} \mid \cdot)$, yields $E^*(\boldsymbol{w} \mid \boldsymbol{X}) = \boldsymbol{X}\hat{\boldsymbol{\alpha}}$,[6] where $\boldsymbol{X}$ is an $n \times m$ matrix whose ith row gives the ith worker's characteristics and the hth column is the hth independent variable in wage equation (4). Normal equations give

$$\hat{\boldsymbol{\alpha}} = [\boldsymbol{X}'\boldsymbol{X}]^{-1}\boldsymbol{X}'\boldsymbol{w}, \tag{6}$$

where the jth element of $\hat{\boldsymbol{\alpha}}$, $\hat{\alpha}_h$, is increasing in the numerator, $\sum_{t=1}^{T}\sum_{i=1}^{n} x_{h,i} w_{i,t}$ and thus increasing in $\sum_{t=1}^{T}\sum_{i=1}^{n} x_{h,i} w_{i,t} - TnE(x_h)E(w) = \mathrm{Cov}(x_{i,h}, w_{i,t})$. The numerator is the only combination that includes $\boldsymbol{w}$, and thus, only the numerator involves a variation of interaction between observable characteristics and $\boldsymbol{w}$. Therefore, from equation (4), with other conditions controlled for, $\hat{\alpha}_3$ is increasing in $\sum_{t=1}^{T}\sum_{i=1}^{n}(S_i t) w_{i,t} - TnE(St)E(w) = \mathrm{Cov}(S_i t, w_{i,t}) = \sum_{\tau=2}^{T} \mathrm{Cov}(S_i \tau, \varphi_{i,\tau})$.

Note that $\mathrm{Cov}(S_i t, w_{i,t})$ contains a two-dimensional effect composed of the cross-sectional effect over workers $i = 1, \ldots, n$ and the longitudinal effect over periods $t = 1, \ldots, T$. In the cross-sectional dimension, for each τ ($\tau = 2, \ldots, T$), $\mathrm{Cov}(S\tau, \varphi_\tau)$ is increasing in the degree of complementarity between years of schooling (S) and work experience (τ). Thus for each period t, the covariance between φ_τ and $S\tau$ should be positive in the cross-sectional dimension of workers $i = 1, \ldots, n$ if schooling (S) and experience (τ) are complements for productivity difference ($\mathit{\Delta}_\tau \epsilon$) among workers $i = 1, \ldots, n$ and non-positive otherwise.

In the longitudinal dimension, let us assume that the employers have learned about the employees' time-invariant abilities that are hidden when recruiting, given as ϕ_i. This is included in θ_i, such that $\mathit{\Delta}_\tau \theta_i^E(S) = \mathit{\Delta}_\tau E(\theta_i \mid S_i, \tau - 1)$ is decreasing in τ and $\lim_{\tau\to\infty} \mathit{\Delta}_\tau E(\theta_i \mid$

[6] Note that $E^*(y \mid S, \boldsymbol{x}) = E(y \mid S, \boldsymbol{x})$ because E is assumed to be linear.

$S_i, \tau - 1) = 0$ as θ_i^E approaches a stationary state, which is worker i's true ability. Then, for each i, $\mathrm{Cov}(S_i\tau, \varphi_i)$ is decreasing in τ and $\lim_{\tau\to\infty} \mathrm{Cov}(S_i\tau, \varphi_i) = 0$.

Thus, we have the following: $\hat{\alpha}_3$ depends on the relative impact of the effect of complementarity between schooling and work experience in the cross-sectional dimension and the effect of employer learning in the longitudinal dimension; $\hat{\alpha}_3$ is increasing in the relative impact of the complementarity effect over the employer learning effect; and fixing the complementarity effect, $\hat{\alpha_3}$ decreases to 0 as the employer learning effect increases. In addition, suppose that wage, with marginal productivity, increases in experience t due to investment in human capital. Then the sign of $\hat{\alpha_3}$ depends also on the relative impact of $S_i t$ on the wage growth compared with other independent variables. Taking the logarithmic terms, if the complementarity effect dominates the employer learning effect, then $\hat{\alpha}_3 > 0$, and if the employer learning effect dominates the complementarity effect, then $\hat{\alpha_3} \leq 0$ instead of $\hat{\alpha_3} = 0$.[7]

2.3 Semi-public estimation framework of employer learning

Next suppose an internal labor market of a major firm on an equilibrium path discussed in subsection 2-1. Suppose the following: the current employer learns about workers' abilities better than the other employers; the other employers can less correctly guess the workers' abilities from publicly available information about job assignments; the return on firm-specific human capital is positive and therefore the current employer produces more by hiring the current workers in the next period than the other employers do; and the current employer faces a competitive market composed of the other employers.

Then, the firm that currently employs a worker offers wages weakly greater than what the other employers offer in the next period, and the current employee does not leave on the equilibrium path. Here, we can assume that the current employer of worker i knows $F_1(y_{i,t} \mid \theta_i, S_i, \boldsymbol{x}_i)$ and $F_2(\theta_i, S_i, \boldsymbol{x}_i)$ for $i = 1, \ldots, n$ and $t = 1, \ldots, T$, and that the firm observes $y_{i,1}, \ldots, y_{i,t}$. That is, wage growth depends on the current employer's learning with arbitrage with the outside market, where worker i's ability is signaled by her/his job assignment. The competitive environment guarantees that $w_{i,t} = lE(y_{i,t} \mid S_i, \boldsymbol{x}_i, y_{i,1}, \ldots, y_{i,t-1})$, where $l \leq 1$, which is the internal labor market's "shielding" effect from the outside market and captures the efficiency loss due to asymmetric learning in internal labor markets discussed in **Lemma 2**. While employees' abilities are learned within the internal labor market, $F_1(y_{i,t} \mid \theta_i, S_i, \boldsymbol{x}_i)$ and $F_2(\theta_i, S_i, \boldsymbol{x}_i)$ for the current employees $i = 1, \ldots, n$ remain only imperfectly known to outside employers by job assignment. We refer to these properties as semi-public, which is public in the sense that the current employers face a competitive market and wages are determined by spot-contracting, but is "semi" in the sense that the wages offered in spot-contracting are affected by the asymmetry of employer learning between inside and outside of the internal labor markets.

[7]As shown by Farber and Gibbons (1996), $\hat{\alpha}_3$ should be non-positive in the antilogarithmic specification if employers learn about workers' abilities. Assuming a Cobb-Douglas production function of workers, in this research the regressors are also logarithmically transformed, which allows the experience and tenure effects to be marginally decreasing. A Mincerian regression whose regressors contain the antilogarithmic level and squared level terms of experience for comparison with previous works is given in **Table 4**.

Lemma 1 argues that the mid-career recruiting market expects workers who have not been promoted by previous employers to have acquired work experiences complementary to schooling. This equilibrium belief of employers that yet-to-be promoted workers have acquired work experiences complementary to schooling is considered as given by workers when they decide whether to invest in general skills complementary to schooling or specific skills likely less complementary to schooling. On the other hand, **Lemma 1** suggests that the market expects workers who have been promoted to have acquired work experiences substitutive to schooling. This belief shared by employers reduces workers' opportunity cost of time to acquire firm-specific skills, which are likely less complementary to schooling. Further, long-term employment helps current employers learn about their employees' abilities by tracking human capital accumulation.

To capture this effect of internal labor markets, we simply separate the ith employee's experience into two components, such that $t = t_T = t_p + t_e$, where t_T is total labor market experience, t_p is labor market experience prior to joining the case firm and t_e is tenure after employed by this firm. Then, taking logarithmic expression and assuming $\boldsymbol{\beta} = l\boldsymbol{\alpha}$, wage equation (4) can be reformulated as

$$w_{i,t} = \beta_0 + \beta_1 S_i + \beta_2 t_p + \beta_3 t_e + \beta_4 S_i t_p + \beta_5 S_i t_e + \boldsymbol{\gamma}'\boldsymbol{x_i} + \boldsymbol{\delta}'\boldsymbol{x_i} t_e + \theta_i + \epsilon_{i,t}. \tag{7}$$

Lemma 1 concerns an implication for variations in the cross-sectional dimension that work experience and schooling are expected to be complements for non-promoted workers who have left short-term employment for the mid-career market, which is presumed to be captured in "t_p" period. Meanwhile, work experience and schooling are expected to be substitutes for already promoted workers, which is presumed to be captured in "t_e" period. Then, combining the theoretical prediction from **Lemma 1** with the structure of panel estimation discussed above, a prediction about the market expectation formed by employer learning and about human capital acquisition is as follows.

Prediction 1. *If employer learning is asymmetric inside and outside of an internal labor market and the return on firm-specific human capital is sufficiently large, then the coefficient of the interaction term between years of schooling and previous experience before gaining employment with a firm that commits to long-term employment* (St_p) *is greater than that of the interaction term between years of schooling and the tenure after gaining employment with the firm* (St_e)*; thus,* $\hat{\beta}_4 > \hat{\beta}_5$.

3 Case firm and data

3.1 Case plant

The case iron works is one of the oldest modern iron works in Japan. From the 1950s to the 1960s, steel companies were induced to invest in new technology with long-term financing coordinated by the government. As a part of a company-wide investment plan, the company that operated the case iron works decided to build a new state-of-the-art plant in a city far from the case iron works. The company also decided to decrease the case iron works capacity and to relocate the skilled workers of the case iron works and other old iron works to the new plants. Selection for relocation was handled in cooperation with the union, and in principle, anyone who was willing to move was allowed to be relocated.

3.2 Data

This research uses the preserved personnel documents for 1,558 employees relocated from the case iron works, tracking them from the late 1920s or later, depending on the year when the employee joined, to the 1960s, when they left the case iron works. The documents contain all important employee information from when they were employed. Definitions and descriptive statistics of variables used are in **Appendix II**. The number of total observations is 23,210.

An important feature of the data set is that it is not dominated by those who were employed immediately after graduation. The mean of previous experience (years after graduating from school and before employment with the firm, t_p) is not even monotonically decreasing. Workers had on average 3 to 8 years of previous work experience often at smaller workplaces through the sample period.[8] During the early twentieth century, when heavy manufacturing was introduced from the Western world, the typical career pattern for male skilled workers involved gaining experience at several workplaces to acquire the relevant skills and then either gaining employment with a large firm on a long-term basis or starting one's own workshop.

Compulsory education was extended from 6 years to 9 years in 1947. Therefore, the difference in educational background across the employees who graduated before 1947 is distributed mainly between those with 6 years who attended mandatory elementary schools and those with 8 years attending an additional 2-year high elementary school, with high elementary school graduates as the majority. The difference in the employees who graduated after 1947 is distributed mainly between those who spent 9 mandatory years attending a 6-year elementary school and a 3-year junior high school and those who spent 12 years attending an additional 3-year high school, with junior high school graduates as the majority.

3.3 Learning within an internal labor market

The existence of an internal labor market policy, which somehow "shields" wage determination from the outside market, is to be empirically established. Persistent cohort effects are thought to be an indicator of internal labor markets (Baker, Gibbs and Holmstrom (1994)). Provided that the market environment would be fully reflected only at the entry and following that, internal wage dynamics would be shielded from the market if there exists an internal labor market in the manner discussed in **Lemma 1**. **Table 1** regresses the real wage w_t on the interaction terms of the 2-year joined dummy and the first and second lagged terms such as $D_{ye}^{1928-1929}\log w_{t-1}$, $D_{ye}^{1930-1931}\log w_{t-1}$, etc., and such as $D_{ye}^{1928-1929}\log w_{t-2}$, $D_{ye}^{1930-1931}\log w_{t-2}$, etc. Changes in return on schooling through the sample period are controlled for by interaction terms of year dummies and years of schooling ($D_y^{19XX}S$). The interaction between completion of training programs (D_{dcy}, D_{sy}, D_{dct}, and D_{dc}) described below

[8]See Nakabayashi (2013), **Table 1**.

and tenure (t_e) are controlled for as well. To control for shocks from the outside market, growth rate of real gross national expenditure (ΔY) is inserted as a regressor. Then, for all cohorts, cohort effects are significant. Furthermore, while the results look similar, significantly non-parallel wage curves are observed even between adjacent cohorts. This result implies that we need to carefully control for the cohort effects to examine **Prediction 1**.

If ϕ included in θ was learned, then $\Delta\theta^E(S)$ should converge to 0 for each i in the longitudinal direction within this internal labor market. It follows that $\Delta\left[w_i - \mathrm{E}[w_i]\right]$ should be serially correlated and converge to a unique stationary state. It can be examined by panel unit root tests whether the residuals were serially correlated and converged. Suppose that $\mathrm{E}[w]$ is the estimated value based on model 2-1 in **Table 2** below. Then, for $\Delta\left[w_i - \mathrm{E}[w_i]\right]$, possibilities of both a common unit root and an individual unit root are rejected.[9] Thus, for each worker's wage history, $\Delta\left[w_i - \mathrm{E}[w_i]\right]$ is a contraction mapping and has a unique stationary state, where true value of θ_i has been learned. This result is consistent with an assumption that employer learning proceeded in the case firm.

4 Empirical results

4.1 Standard test of employer learning

Before directly proceeding to the estimation of equation (7), let us show the benchmark results for equation (4). **Table 2** gives the results of the random effect estimation regressing real wage (w) on employee height when employed by the firm (h);[10] years of schooling (S); total experience in the labor market (t_T); tenure at the firm (t_e); the interaction term between height and total labor market experience (ht_T), the interaction term between height and tenure (ht_e); the interaction between years of schooling and total labor market experience (St_T); the interaction between years of schooling and tenure (St_e); the dummy variables of completing in-house training programs, Development Center for Youth (D_{dcy}, operated in 1927-1935), School of Youth (D_{sy}, operated in 1935-1948), Development Center for Technicians (D_{dct}, operated in 1939-1946), and Development Center (D_{dc}, operated in 1946-1973); and the interaction of these dummy variables with tenure ($D_{dcy}t_e$, $D_{sy}t_e$, $D_{dct}t_e$, $D_{dc}t_e$).[11] The potential impact of extended compulsory schooling is controlled for by the postwar education generation dummy (D_{psw}).

In **Table 2**, the large coefficient of tenure (t_e), with total labor market experience (t_T) controlled for, implies that the return on firm-specific human capital is considerable. Then, the interaction of years of schooling with total labor market experience after graduation (St_T)

[9](1)Common panel unit root test; t statistic: -35.0697^{***}; Cross sections included: $1,3666$; Total observations: $18,983$. (2)Individual panel unit root test (Im, Pesaran and Chin test); W statistic: -88.0594^{***}; Cross sections included: $1,318$; Total observations: $18,839$. Optimal lags are determined by the Akaike Information Criterion; *** denotes significance at the 1 percent level.

[10]To control for the improved nutrition throughout the period, we use relative height as compared to the national average height sourced from the Ministry of Education's statistics for estimation. Thus, (observed height)/(national average height at employee's age in the year) is used as "height (h)."

[11]The information on height, weight, and lung capacity is not included in the wage records of the employees who joined the firm before 1939.

has significantly negative coefficients in models 2-1 and 2-3, and that with tenure (St_e) has significantly negative coefficients in models 2-2 and 2-4. The employer learning effect is clearly observed.

Along with years of schooling, proxies of the abilities observable to the employer are physiological characteristics such as height. Physical strength was important to bule-collar workers, and height is a good proxy of such physical strength. Indeed, with regard to height, the employer learning effect is observed. The interaction terms of height with both total labor market experience and tenure (ht_T, ht_e) have negative coefficients in models 2-3 and 2-4.

4.2 Learned ability and acquired skill in the internal labor market

Next, we examine equation (7) and **Prediction 1**. A straightforward specification without control for the cohort effect by the random effect estimation is presented in **Table 3**. With the changes in return on schooling controlled for by inserting the interaction between the year dummies and years of schooling ($D_y^{19XX}S$), real wage (w) is regressed on years of schooling (S), labor market experience after graduation and before employment with the firm (t_p), tenure after employment with the firm (t_e), the interaction term between years of schooling and previous labor market experience (St_p), and the interaction between years of schooling and tenure (St_e). Then, the coefficient of the interaction between years of schooling and previous labor market experience (St_p) is significantly positive ($\hat{\beta}_4 > 0$), differing from the symmetric learning assumption, and that of the interaction between years of schooling and tenure (St_e) is significantly negative ($\hat{\beta}_5 < 0$), implying that **Prediction 1** holds: $\hat{\beta}_4 > \hat{\beta}_5$.

As the first robustness check, **Table 4** gives an estimation based on Mincerian wage equation whose independent variables are in an antilogarithmic form by both of random effect and fixed effect model. Again, both in random and fixed effect models, St_p and St_e have significant coefficients and $St_p > St_e$. Thus, **Prediction 1** is supported: $\hat{\beta}_4 > \hat{\beta}_5$.

Similar but non-parallel wage curves in **Table 1** urge us to control for the cohort effects when checking the robustness of the results in **Table 3**. Therefore, as the second robustness check, **Table 5** presents a regression of real wage (w) with random effects on years of schooling (S); previous labor market experience (t_p); tenure (t_e); and motivated by **Table 1**, the interaction terms of the 2-year joined dummy, years of schooling and previous labor market experience ($D_{ye}^{1928-1929}St_p$, $D_{ye}^{1930-1931}St_p$, etc.), and the interaction terms of the 2-year joined dummy, years of schooling, and tenure ($D_{ye}^{1928-1929}St_e$, $D_{ye}^{1930-1931}St_e$, etc.), to control for the cohort effects on the interaction between schooling and labor market experience. **Table 5** also controls for training programs (D_{dcy}, D_{sy}, D_{dct}, D_{dc}), the interactions between training programs and tenure ($D_{dcy}t_e$, $D_{sy}t_e$, $D_{dct}t_e$, $D_{dc}t_e$), and the interactions between the year dummy and years of schooling ($D_y^{19XX}S$) to capture the changes in the return on schooling during the period.

Then, except for the earliest cohorts, the interaction terms between years of schooling and previous labor market experience (St_p) again has a significantly positive coefficient ($\hat{\beta}_4 > 0$), while the interaction term between years of schooling and tenure (St_e) has a significantly negative coefficient ($\hat{\beta}_5 < 0$). Thus, we have $\hat{\beta}_4 > \hat{\beta}_5$, which supports **Prediction 1**.

While the regression of wages on the interaction term between years of schooling and total labor market experience (St_T) in **Table 2** suggests that employer learning hypothesis holds after all, the results in **Tables 3-5** indicate that the effect should be divided into before and after gaining employment with the firm (St_p, St_e)—the coefficients of which, $\hat{\beta}_4$ and $\hat{\beta}_5$, have opposite signs. An immediate interpretation of the results in **Tables 3-5** with **Lemma 1** is that the workers were expected in the market to have chosen workplace experience in the initial phases of their careers given their educational backgrounds such that the experience was complementary to their schooling before gaining employment with the firm, and after gaining employment with the firm, were expected to invest in firm-specific human capital not necessarily complementary to schooling, as the firm then learned about their abilities not informed by their educational backgrounds.

Table 5 also shows that the negativity of the coefficient of interaction between years of schooling and tenure (St_e) increases as the cohort nears the end of the covered period. First, if workers went out to the mid-career recruiting market, long-term employment acquired at the case firm implies that they found a better match. Better match seems to have had larger impacts at earlier stages, which results in larger positive coefficient of tenure t_e for cohorts closer to the end. Second, the coefficients with larger negativity of cohorts closer to the end imply that the learning effect had a larger impact in the earlier tenure in internal labor markets as Lluis (2005) inferred based on the German intra-firm data set.[12] Third, given that the employer learning effect shifts the coefficient of St_e in the antilogarithmic levels toward zero, the negativity of the coefficient in the logarithmic specification hypothetically captures the effect of wage growth from the increase in labor productivity over tenure. Because changes in the return on schooling are controlled for by the interactions between the year dummies and years of schooling ($D_y^{19XX}S$), the productivity increase is attributed to the increase in the return on human capital investment by individual employees. Then, the larger negativity of closer-to-the-end cohorts implies that the return on human capital investment is marginally decreasing in tenure as indicated by the negative coefficient of tenure squared (t_e^2) in a Mincerian specification in **Table 4**.

4.3 Statistical discrimination through trainee selection

We now assess how employer learning and human capital investment are connected. Here we focus on the systematic training programs because they were open to employees who were selected in the early stages after joining the firm, that is, before the firm learned well about their abilities. **Table 6** provides the estimated probabilities of acceptance to in-house training programs (D_{dcy}, D_{sy}, D_{dct}, D_{dc}), given age (a), years of schooling (S), and total labor market experience (t_T). Regulations behind the programs differed before and after the Second World War. Before the war, from 1939, the government required major firms to have a Development Center for Youth or a School for Youth (D_{dcy}, D_{sy}) for employees who had not completed junior high school. The prewar systematic programs were designed to complement shorter schooling, and prewar programs (D_{dcy}, D_{sy}, D_{dct}) were more likely to accept less-

[12] See Lluis (2005), pp. 745-755. With other conditions controlled for, quick learning in the early stages is also observed in the United States. See Gibbons, Katz, Lemieux and Parent (2005), pp. 698-714, and Lange (2007), pp. 9-19.

educated employees and/or employees with more previous experience. This requirement was abandoned when junior high school became compulsory in 1947. The post-war program, Development Center (D_{dc}), then was more likely to accept better-educated employees and/or employees with less previous experience. Therefore, when choosing employees for training programs, the firm statistically discriminated against better-educated employees till the mid-1940s, and less-educated employees from the late 1940s. The gateway for in-house human capital investment was affected by schooling whether downward or upward.

Table 7 inserted the probabilities of D_{dcy}, D_{sy}, D_{dct}, and D_{dc} estimated by **Table 6** as regressors in wage regressions. A noteworthy result is that the interaction term between years of schooling and tenure (St_e) has a positive coefficient, and hence, the effect of employer learning disappears. When controlling for the probability of acceptance to in-house training programs, the positive coefficient of St_e in **Table 7** captures the complementary effect between schooling and work experience. The interaction between years of schooling and previous experience(St_p) has a negative coefficient. The market's expectation that young workers' experience and schooling are complements was also contained in the statistical discrimination in the selection of trainees and hence, controlling for this discrimination, the coefficient of (St_p) extracts the employer learning effect that was hidden in the specification of **Table 3**.

5 Conclusion

We theoretically conjectured that young workers are expected in the market to have work experience complementary to schooling in the cross-sectional dimension. This complementarity of acquired skills in cross-sectional variations could hide the employer learning effect.

Then, we have shown that the employer learning effect in the longitudinal dimension is dominated by the cross-sectional complementarity expectation and is hidden for previous work experience before workers gain long-term employment with the case firm, which is the stage when they are expected in the market to invest in general human capital complementary to schooling and they behaved as expected. We have then shown that employer learning is clearly observed once they gain long-term employment in the case firm, as skill acquisition become less complementary to schooling under long-term employment and internal promotion with asymmetric employer learning and the employer learning effect in the longitudinal dimension dominates. At the same time, the learning effect is more weakly observed in the later stages of the workers' internal careers.

While this research addresses the Japanese experience, some results consistent with this research have been presented based on an American data set.[13] Furthermore, persistent cohort effects, an indicator of prevalent internal labor markets, are widely observed in the United States, Germany, and Canada as in Japan.[14] Internal labor markets of major firms in developed economies are thus naturally thought to affect the wage dynamics through both employer learning and skill acquisition. This research intends to provide a viewpoint on the feature.

[13] See Habermalz (2006), pp. 130-133, which deals with degrees instead of years of schooling.

[14] See Kahn (2010); von Wachter and Bender (2006); Oreopoulos, von Wachter and Heisz (2012) and Genda, Kondo and Ohta (2010).

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Appendix I

Proof of Lemma 1. For worker $i+1$ who is promoted in his/her third period, we have

$$w_{i+1,2,t}(S_{i+1},\eta_{i+1,t}) = d_2 + c_2\frac{k(d_1-d_2) - c_1(\phi_L f(2) + bS_{i+1}f(2)+)}{k(c_2-c_1)-c_1} + G(S_{i+1}).$$

Therefore,

$$\begin{aligned}&w_{i+1,2,t}(S_{i+1},\eta_{i+1,t}) - w_{i,2,t}(S_i,\eta_{i,t})\\ =&-\frac{c_1c_2(bS_{i+1}f(2)-bS_if(1))}{k(c_2-c_1)-c_1} - \frac{c_1c_2\phi_L(f(2)-f(1))}{k(c_2-c_1)-c_1} + G(S_{i+1}) - G(S_i).\end{aligned}$$

For worker $i+1$ who is not promoted in his/her second or third period, we have

$$w_{i+1,1,t}(S_{i+1},\eta_{i+1,t}) = d_1 + c_1(\phi_L + bS_{i+1})f(2) + G(S_{i+1}).$$

Thus,

$$\begin{aligned}&w_{i+1,1,t}(S_{i+1},\eta_{i+1,t}) - w_{i,1,t}(S_i,\eta_{i,t})\\ =&c_1(bS_{i+1}f(2)-bS_if(1)) + c_1\phi_L(f(2)-f(1)) + G(S_{i+1}) - G(S_i).\end{aligned}$$

Suppose that $S_{i+1} > S_i$. The term $(bS_{i+1}f(2) - bS_if(1))$ has a positive multiplier if work experience and schooling are complements and a negative one if substitutes in the cross-sectional dimension $i = 1,2,\ldots,n$. Since $k > c_1/(c_2-c_1)$, $c_1 > 0 > -c_1c_2/\left[k(c_2-c_1)-c_1\right]$, which implies that work experience and schooling are expected to be complements for non-promoted workers and substitutes for promoted workers. □

Proof of Lemma 2. (i) Since

$$D = \eta^+(S_i) - \eta^{'} = \frac{k(d_1-d_2) - c_1\left[\phi_L + bS_i\right]f(1)}{kc_2 - (1+k)c_1} - \frac{d_1-d_2}{c_2-c_1} = c_1\frac{\eta^{'} - \left[\phi_L + bS_i\right]f(1)}{k(c_2-c_1)-c_1}$$

and $\eta^{'} > \left[\phi_L + bS_i\right]f(1)$, D is decreasing in k.
(ii)

$$\frac{\partial D}{\partial[c_2-c_1]} = c_1\frac{\left[\phi_L + bS_i\right]f(1)c_1 - k(d_1-d_2)}{\left[k(c_2-c_1)-c_1\right]^2}$$

□

Appendix II Definition and descriptive statistics of variables.

Variable	Definition	Mean	Median	Maximum	Minimum	Standard deviation	Skewness	Number of observation
w	Real daily wage: yen per day.	3.5784	3.3700	72.0600	0.3400	1.9653	2.4469	23,121
h	Relative height when employed by the firm: (observed height)/(national average height at his age in the year).	0.9954	1.0000	1.1000	0.8000	0.0408	-0.4860	16,830
a	Age.	30.2968	30.0000	55.0000	12.0000	8.1607	0.3773	24,068
S	Years of schooling: (years of schooling)+1.	8.6944	8.0000	15.0000	5.0000	1.6131	1.2024	24,068
D_{psw}	Postwar education generation dummy: =1 if 12 years old or younger in 1947, and 0							
t_T	Total labor market experience: $a-(6+S)+1$.	15.5848	15.0000	42.0000	0.0000	8.5544	0.3358	24,068
t_p	Previous labor market experience prior joining the firm: $a-(6+S+t_e)+1$. Note that every sample employee had worked at the firm until the last year of his record	6.3006	6.0000	35.0000	0.0000	5.1320	0.7731	24,068
t_e	Tenure: (years after employed by the firm)+1.	9.9485	9.0000	38.0000	38.0000	6.9279	0.6441	24,067
D_{ye}^{19XX}	=1 if joined the firm in 19XX, and 0 otherwise.							
$D_{ye}^{19XX\text{-}19YY}$	=1 if joined the firm from 19XX to 19YY, and 0 otherwise.							
D_y^{19XX}	Year dummy.							
D_{dcy}	=1 if completed Development Center for Youth (operated from 1927 to 1935), and 0 otherwise.							
D_{sy}	=1 if completed School for Youth (operated from 1935 to 1948), and 0 otherwise.							
D_{dct}	=1 if completed Development Center for Technician (operated from 1939 to 1946).							
D_{dc}	=1 if completed Development Center (operated from 1946 to 1973), and 0 otherwise.							
Y	Real gross national expenditure.							

Sources : Consumer prices (to deflate nominal wages): Nippon Tokei Kyokai (Japan Statistical Association), ed., *Nippon Choki Tokei Soran (Historical Statistics of Japan)* , Tokyo: Nippon Tokei Kyokai (Japan Statistical Association), 1988, p. 362. National average height: the School Health Statistics surveyed by the Ministry of Education, Science, Sports and Culture (http://www.e-stat.go.jp/). Real gross national expenditure: Kazushi Ohkawa, Nobukiyo, Takamatsu, and Yuzo Yamamoto, *Estimates of Long-Term Economic Statistics of Japan since 1868, volume 1, National Income* , Tokyo: Toyo Keizai Shinposha, 1974, pp. 232 (1885-1929)-233 (1930-1970); to connect series before and after 1955, when governmental statistic are not continuous, a deflator from Kazushi Ohkawa, Tsutomu Noda, Nobukiyo Takamatsu, Saburo Yamada, Minoru Kumazaki, Yuichi Shionoya, and Ryoshin Minami, *Estimates of Long-Term Economic Statistics of Japan since 1868, 8 Prices* , Tokyo: Toyo Keizai Shinposha, 1967, p. 134 is used. Other items: Wage records of the case firm.

Table 1 Cohort effect on wage curves.

		1-1		
Estimation method		panel extended generalized least squares		
Dependent variable		$\log(w_t)$		
Cross-section		random effect		
Period (year)		pooled (no year dummies inserted)		
Independent variables		coefficient	t statistic	
	c	0.2117	10.7055	***
	$\log(S)$	0.0373	4.0600	***
1st lagged	$D_{ye}^{1930\text{-}1931}\log(w_{t-1})$	1.0030	8.2783	***
	$D_{ye}^{1932\text{-}1933}\log(w_{t-1})$	0.7269	8.3187	***
	$D_{ye}^{1934\text{-}1935}\log(w_{t-1})$	0.7071	13.0765	***
	$D_{ye}^{1936\text{-}1937}\log(w_{t-1})$	0.7363	16.8076	***
	$D_{ye}^{1938\text{-}1939}\log(w_{t-1})$	0.7427	38.9167	***
	$D_{ye}^{1940\text{-}1941}\log(w_{t-1})$	0.7152	46.6733	***
	$D_{ye}^{1942\text{-}1943}\log(w_{t-1})$	0.6713	32.4418	***
	$D_{ye}^{1944\text{-}1945}\log(w_{t-1})$	0.6084	30.4309	***
	$D_{ye}^{1946\text{-}1947}\log(w_{t-1})$	0.5471	20.7739	***
	$D_{ye}^{1948\text{-}1949}\log(w_{t-1})$	0.6483	78.8545	***
	$D_{ye}^{1950\text{-}1951}\log(w_{t-1})$	0.5901	19.1235	***
	$D_{ye}^{1952\text{-}1953}\log(w_{t-1})$	0.7402	8.9689	***
	$D_{ye}^{1954\text{-}1955}\log(w_{t-1})$	0.7454	9.5983	***
	$D_{ye}^{1956\text{-}1957}\log(w_{t-1})$	0.8747	16.7632	***
	$D_{ye}^{1958\text{-}1959}\log(w_{t-1})$	0.9087	9.6958	***
	$D_{ye}^{1960\text{-}1961}\log(w_{t-1})$	0.7694	6.6099	***
	$D_{ye}^{1962\text{-}1963}\log(w_{t-1})$	1.1134	9.1058	***
	$D_{ye}^{1964\text{-}1965}\log(w_{t-1})$	0.7390	6.2703	***
	$D_{ye}^{1966\text{-}1967}\log(w_{t-1})$	1.0293	2.1006	**
2nd lagged	$D_{ye}^{1930\text{-}1931}\log(w_{t-2})$	-0.1959	-1.5637	
	$D_{ye}^{1932\text{-}1933}\log(w_{t-2})$	0.1649	1.7995	*
	$D_{ye}^{1934\text{-}1935}\log(w_{t-2})$	0.1624	2.8867	***
	$D_{ye}^{1936\text{-}1937}\log(w_{t-2})$	0.1358	2.9867	***
	$D_{ye}^{1938\text{-}1939}\log(w_{t-2})$	0.1378	6.9732	***
	$D_{ye}^{1940\text{-}1941}\log(w_{t-2})$	0.1626	10.2851	***
	$D_{ye}^{1942\text{-}1943}\log(w_{t-2})$	0.2083	9.7529	***
	$D_{ye}^{1944\text{-}1945}\log(w_{t-2})$	0.2731	13.1950	***
	$D_{ye}^{1946\text{-}1947}\log(w_{t-2})$	0.3284	12.4317	***
	$D_{ye}^{1948\text{-}1949}\log(w_{t-2})$	0.2043	26.0392	***
	$D_{ye}^{1950\text{-}1951}\log(w_{t-2})$	0.2683	8.3128	
	$D_{ye}^{1952\text{-}1953}\log(w_{t-2})$	0.0852	0.9695	
	$D_{ye}^{1954\text{-}1955}\log(w_{t-2})$	0.0725	0.8715	
	$D_{ye}^{1956\text{-}1957}\log(w_{t-2})$	-0.0744	-1.3396	
	$D_{ye}^{1958\text{-}1959}\log(w_{t-2})$	-0.1380	-1.3684	
	$D_{ye}^{1960\text{-}1961}\log(w_{t-2})$	-0.0155	-0.1240	
	$D_{ye}^{1962\text{-}1963}\log(w_{t-2})$	-0.3584	-2.7150	***
	$D_{ye}^{1964\text{-}1965}\log(w_{t-2})$	0.1647	1.2189	
	$D_{ye}^{1966\text{-}1967}\log(w_{t-2})$	-0.2782	-0.4786	
	$D_y\log(S)$	yes		
	ΔY	yes		
	cross-sections included	1,433		
	periods included (years)	39(1931-1969)		
	included observations	18,578		
	adjusted R^2	0.9054		
	F statistic		4,445.5193	***

Notes : The control cohort is $D_{ye}^{1928\text{-}1929}$. ***, ** and * respectively denote significance at the 1, 5, and 10 percent levels.

Table 2 Wage regressions: decomposition of wage growth to physiological characteristics, schooling, experience, and employer learning.

	2-1			2-2			2-3			2-4		
Estimation method	panel extended generalized least squares											
Dependent variable	$\log(w)$											
Cross-section	random effect											
Period (year)	pooled (no year dummies inserted)											
Independent variables	coefficient	t statistic		coefficient	t statistic		coefficient	t statistic		coefficient	t statistic	
c	-5.1761	-44.2703	***	-2.9398	-34.8859	***	-5.7292	-49.1632	***	-3.0111	-38.4841	***
$\log(h)$							2.1148	10.9071	***	1.3705	9.0884	***
$\log(S)$	1.9032	35.8923	***	0.8833	23.1377	***	2.1624	41.9376	***	0.9495	27.3838	***
D_{psw}	0.4017	47.6436	***	0.4570	53.5175	***	0.4431	58.3628	***	0.4676	58.6648	***
$\log(t_T)$	1.6736	40.3544	***	0.3935	66.5720	***	1.8902	44.8040	***	0.2934	45.9169	***
$\log(t_e)$	0.4643	106.5132	***	1.0429	30.3666	***	0.5684	132.3873	***	1.3141	41.8334	***
$\log(h)\log(t_T)$							-0.6261	-8.5649	***			
$\log(h)\log(t_e)$										-0.3732	-5.7861	***
$\log(S)\log(t_T)$	-0.5835	-31.3674	***				-0.7154	-38.9585	***			
$\log(S)\log(t_e)$				-0.2619	-16.3386	***				-0.3337	-22.9266	***
D_{dcv}	-2.4877	-5.4473	***	-2.4819	-5.4095	***						
$D_{dcv}\log(t_e)$	0.7530	4.6729	***	0.7566	4.6825	***						
D_{sv}	-0.4928	-11.2649	***	-0.5511	-12.4599	***						
$D_{sv}\log(t_e)$	0.1605	9.5920	***	0.1774	10.5209	***						
D_{dct}	-0.4825	-12.0908	***	-0.5036	-12.4591	***						
$D_{dct}\log(t_e)$	0.1514	9.9511	***	0.1549	10.0862	***						
D_{dc}	0.4605	22.2900	***	0.4080	19.5307	***						
$D_{dc}\log(t_e)$	-0.1977	-21.0533	***	-0.1919	-20.1281	***						
cross-sections included	1,558			1,558			1,246			1,246		
periods included (years)	41(1929-1969)			41(1929-1969)			31(1939-1969)			31(1939-1969)		
included observations	23,210			23,210			16,637			16,637		
adjusted R^2	0.7109			0.7066			0.8104			0.8037		
F statistic		4,373.1960	***		4,283.6989	***		10,159.1981	***		9,733.1955	***

Notes : *** denotes significance at 1 percent level. The information about physiological characteristics is not included in the wage records of the employees who joined the firm before 1939.

Table 3 Interaction of schooling previous experience/tenure.

	3-1		
Estimation method	panel extended generalized least squares		
Dependent variable	$\log(w)$		
Cross-section	random effect		
Period (year)	pooled (no year dummies inserted)		
Independent variables	coefficient	t statistic	
c	0.1727	3.6001	***
$\log(S)$	-0.3223	-7.3618	***
$\log(t_p)$	-0.2972	-13.6520	***
$\log(t_e)$	0.8729	87.4001	***
$\log(S)\log(t_p)$	0.1821	18.3948	***
$\log(S)\log(t_e)$	-0.2970	-64.8860	***
$D_y^{19XX}\log(S)$	yes		
cross-sections included	1,490		
periods included (years)	41(1929-1969)		
included observations	21,902		
adjusted R^2	0.9760		
F statistic		19,764.2971	***

Notes: *** and ** respectively denote significance at 1 and 5 percent levels.

Table 4 Interaction of schooling previous experience/tenure: Mincer-type wage equation controlling for random and fixed effects.

	4-1			4-2		
Estimation method	panel extended generalized least squares			panel extended generalized least squares		
Dependent variable	$\log(w)$			$\log(w)$		
Cross-section	random effect			fixed effect		
Period (year)	pooled (no year dummies inserted)			pooled (no year dummies inserted)		
Independent variables	coefficient	t statistic		coefficient	t statistic	
c	-0.2017	-12.5524	***	-0.3193	-2.0736	**
S	0.0150	1.3334	***	-0.0110	-0.6499	
t_p	0.0250	14.5661	***	0.0243	0.4126	
t_p^2	-0.0004	-12.3891	***	0.0011	0.2618	
t_e	0.1095	153.0228	***	0.1150	155.4201	***
t_e^2	-0.0006	-48.5018	***	-0.0006	-45.0864	***
St_p	0.0005	2.7713	***	-0.0038	-2.1391	**
St_e	-0.0055	-79.3579	***	-0.0097	-46.6075	***
$D_y^{19XX}\log(S)$	yes			yes		
cross-sections included	1,490			1,490		
periods included (years)	41(1929-1969)			41(1929-1969)		
included observations	21,902			21,902		
adjusted R^2	0.9768			0.9799		
F statistic		19,646.5937	***		694.9540	***

Notes: *** and ** respectively denote significance at 1 and 5 percent levels.

Table 5 Interaction of schooling and previous experience/tenure: Robustness check with control for cohort effects.

		5-1		
Estimation method		panel extended generalized least squares		
Dependent variable		$\log(w)$		
Cross-section		random effect		
Period (year)		pooled (no year dummies inserted)		
Independent variables		coefficient	t statistic	
	c	-0.0983	-2.9269	***
	$\log(t_p)$	-0.0494	-2.9579	***
	$\log(t_e)$	0.5600	77.2421	***
previous experience	$D_{ye}^{1930\text{-}1931}\log(S)\log(t_p)$	-0.0668	-1.4042	
	$D_{ye}^{1932\text{-}1933}\log(S)\log(t_p)$	-0.1185	-4.4659	***
	$D_{ye}^{1934\text{-}1935}\log(S)\log(t_p)$	0.0353	3.3299	***
	$D_{ye}^{1936\text{-}1937}\log(S)\log(t_p)$	0.0677	7.2400	***
	$D_{ye}^{1938\text{-}1939}\log(S)\log(t_p)$	0.0725	8.6548	***
	$D_{ye}^{1940\text{-}1941}\log(S)\log(t_p)$	0.0629	7.7401	***
	$D_{ye}^{1942\text{-}1943}\log(S)\log(t_p)$	0.0630	7.4894	***
	$D_{ye}^{1944\text{-}1945}\log(S)\log(t_p)$	0.0576	6.2401	***
	$D_{ye}^{1946\text{-}1947}\log(S)\log(t_p)$	0.0816	7.6477	***
	$D_{ye}^{1948\text{-}1949}\log(S)\log(t_p)$	0.0973	12.7654	***
	$D_{ye}^{1950\text{-}1951}\log(S)\log(t_p)$	0.0798	10.2642	***
	$D_{ye}^{1952\text{-}1953}\log(S)\log(t_p)$	0.0795	8.2405	***
	$D_{ye}^{1954\text{-}1955}\log(S)\log(t_p)$	0.0451	4.8589	***
	$D_{ye}^{1956\text{-}1957}\log(S)\log(t_p)$	0.0558	7.3134	***
	$D_{ye}^{1958\text{-}1959}\log(S)\log(t_p)$	0.0219	2.8603	***
	$D_{ye}^{1960\text{-}1961}\log(S)\log(t_p)$	0.0244	3.1516	***
	$D_{ye}^{1962\text{-}1963}\log(S)\log(t_p)$	0.0273	3.6168	***
	$D_{ye}^{1964\text{-}1965}\log(S)\log(t_p)$	0.0781	9.5732	***
	$D_{ye}^{1966\text{-}1967}\log(S)\log(t_p)$	0.0384	4.0048	***
tenure	$D_{ye}^{1930\text{-}1931}\log(S)\log(t_e)$	-0.0835	-5.3427	***
	$D_{ye}^{1932\text{-}1933}\log(S)\log(t_e)$	-0.0624	-7.9540	***
	$D_{ye}^{1934\text{-}1935}\log(S)\log(t_e)$	-0.1096	-23.9410	***
	$D_{ye}^{1936\text{-}1937}\log(S)\log(t_e)$	-0.1323	-30.5295	***
	$D_{ye}^{1938\text{-}1939}\log(S)\log(t_e)$	-0.1336	-35.5717	***
	$D_{ye}^{1940\text{-}1941}\log(S)\log(t_e)$	-0.1343	-37.3809	***
	$D_{ye}^{1942\text{-}1943}\log(S)\log(t_e)$	-0.1344	-36.6690	***
	$D_{ye}^{1944\text{-}1945}\log(S)\log(t_e)$	-0.1346	-36.2816	***
	$D_{ye}^{1946\text{-}1947}\log(S)\log(t_e)$	-0.1319	-34.2277	***
	$D_{ye}^{1948\text{-}1949}\log(S)\log(t_e)$	-0.1872	-55.5504	***
	$D_{ye}^{1950\text{-}1951}\log(S)\log(t_e)$	-0.1825	-51.3815	***
	$D_{ye}^{1952\text{-}1953}\log(S)\log(t_e)$	-0.1889	-38.4673	***
	$D_{ye}^{1954\text{-}1955}\log(S)\log(t_e)$	-0.1770	-42.5580	***
	$D_{ye}^{1956\text{-}1957}\log(S)\log(t_e)$	-0.2033	-57.0155	***
	$D_{ye}^{1958\text{-}1959}\log(S)\log(t_e)$	-0.2038	-55.4942	***
	$D_{ye}^{1960\text{-}1961}\log(S)\log(t_e)$	-0.2223	-54.1988	***
	$D_{ye}^{1962\text{-}1963}\log(S)\log(t_e)$	-0.2525	-59.5302	***
	$D_{ye}^{1964\text{-}1965}\log(S)\log(t_e)$	-0.2524	-39.2097	***
	$D_{ye}^{1966\text{-}1967}\log(S)\log(t_e)$	-0.2842	-34.7292	***
	$D_{dcy}, D_{sy}, D_{dct}, D_{dc}$	yes		
	$D_{dcy}\times\log(t_e)$, $D_{sy}\log(t_e)$, $D_{dct}\log(t_e)$, $D_{dc}\log(t_e)$	yes		
	$D_y^{19XX}\log(S)$	yes		
	cross-sections included	1,490		
	periods included (years)	41(1929-1969)		
	included observations	21,902		
	adjusted R^2	0.9821		
	F statistic		15,055.3808	***

Notes : Control cohort is $D_{ye}^{1928\text{-}1929}$. *** denotes significance at the 1 percent level.

Table 6 Probability of acceptance as a trainee for in-house training programs.

	6-1				6-2				6-3				6-4			
Estimation method	binary probit				binary probit				binary probit				binary probit			
Dependent variable	D_{dcy}				D_{sy}				D_{dct}				D_{dc}			
Independent variables	coefficient	marginal effect	z statistic		coefficient	marginal effect	z statistic		coefficient	marginal effect	z statistic		coefficient	marginal effect	z statistic	
c	0.1424		0.0973		0.4525		1.2097		3.3074		9.1952	***	5.0828		17.7852	***
$\log(a)$	-3.5142	0.0000	-10.9136	***	-1.1597	-0.0429	-7.4103	***	-1.6033	-0.0006	-11.1875	***	-1.9799	0.0000	-17.9613	***
$\log(S)$	-0.1375	-0.0001	-0.3119		0.1029	0.0061	1.2133		-0.5487	-0.1948	-6.1433	***	0.1904	0.0160	2.5321	**
$\log(t_T)$	3.0467	0.0000	8.1555	***	0.5736	0.0012	8.1122	***	0.6162	0.0011	9.7171	***	-0.0641	-0.0126	-1.6480	*
included observations	24,068				24,068				24,067				24,068			
Log likelihood			-123.1386				-4,240.5354				-4,799.0570				-7,640.8778	
McFadden R^2			0.3268				0.0088				0.0211				0.1489	
LR statistic			119.5454	***			75.5922	***			206.8056	***			2,672.6581	***

Notes : Marginal effects are calculated by mean values of independent variables. ***, ** and * respectively denote significance at 1, 5 and 10 percent levels.

Table 7 Wage and estimated probability of completing training programs.

	7-1		
Estimation method	panel extended generalized least squares		
Dependent variable	$\log(w)$		
Cross-section	random effect		
Period (year)	pooled (no year dummies inserted)		
Independent variables	coefficient	t statistic	
c	-1.0745	-11.2880	***
D_{psw}	0.2447	5.2029	***
$\log(S)$	0.5221	72.9258	***
$\log(t_p)$	0.1543	4.3891	***
$\log(t_e)$	0.2398	6.9083	***
$\log(S)\log(t_p)$	-0.0956	-5.8984	***
$\log(S)\log(t_e)$	0.1384	9.2257	***
$E[D_{dcy}]+E[D_{sy}]+E[D_{dct}]$	-0.0475	-11.7541	***
$(E[D_{dcy}]+E[D_{sy}]+E[D_{dct}])\log(t_e)$	0.0533	21.6346	***
$E[D_{dc}]$	-0.3780	-22.1586	***
$E[D_{dc}]\log(t_e)$	-0.1359	-23.9659	***
cross-sections included	1,558		
periods included (years)	41(1929-1969)		
included observations	23,120		
adjusted R^2	0.7675		
F statistic		7,633.5597	***

Notes : $E[D_{dcy}]$, $E[D_{sy}]$, $E[D_{dct}]$, and $E[D_{dc}]$ are calculated by regression equations 6-1 to 6-4 in **Table 6**. *** denotes significance at 1 percent level.