Schooling, Employer Learning, and Internal Labor Markets
Wage Dynamics with Hidden Abilities and Specific Skills in the Japanese Steel Industry[*]

ISS Discussion Paper Series

F-153

March 2012

Masaki Nakabayashi[†]

Institute of Social Science

The University of Tokyo

Abstract

The impact of schooling on wages decreases as employers learn about workers' abilities from their experience. While such learning often proceeds asymmetrically between incumbent and entrant employers, large firms' internal labor markets could satisfy the statistical assumption of the public learning model. This research utilizes such semi-public properties and shows that (1) employer learning is not observed for experience prior to gaining long-term employment, being dominated by complementarity between schooling and experience, and (2) the employer learning effect dominates the complementarity effect after gaining long-term employment; internal labor markets affect workers' human capital investment and asymmetrically facilitate employer learning.

Key words: employer learning, semi-public properties, internal labor market effect.
JEL: J31, J24, N35.

[*]This research has been funded by the JSPS Grant-in-Aid (22243022) and the Mitsubishi Foundation.

[†]The author is thankful to the Kamaishi Iron Works, Nippon Steel Corporation and appreciates comments from Susumu Cato, Daiji Kawaguchi, Yuji Genda, Hideshi Itoh, Hideo Owan, Carol Scotese, Dan Bogart, Ryuichi Tanaka, Konosuke Odaka, Takashi Kurosaki, Norihito Abe, Shingo Ishiguro, Chiaki Moriguchi, Peter Howlett, Janet Hunter, Naofumi Nakamura, Junichiro Ishida, Keiko Yoshida, and the participants at the Osaka Workshop on Economics of Institutions and Organizations, Contract Theory Workshop, Western Economic Association International Conference, Southern Economic Association Meeting, and seminars at the University of Tokyo, London School of Economics and Political Science, Free University of Berlin, University of Tübingen, Hitotsubashi University, and University of California, Irvine. Corresponding address: Institute of Social Science, The University of Tokyo, Hongo 7-3-1, Tokyo 103-0033, Japan. e-mail: mn@iss.u-tokyo.ac.jp

Workers' abilities are generally private information when they join the labor market. Thus employers use workers' educational backgrounds as a proxy of abilities first. The employer learning model established by Farber and Gibbons (1996) predicts that the impact of schooling on wage decreases during workers' experience in the labor market as employers "publicly" learn about workers' abilities. This learning effect is captured by the non-increasing coefficient of the interaction term of schooling and experience in a wage regression, and the empirical results of Farber and Gibbons (1996) suggest this effect, as do supporting works.[1]

Meanwhile, the public employer learning model is not necessarily consistent with the diverse reality of the labor market. It is directly questioned by the reality of asymmetry in learning (Pinkston (2009)), and the question is related to the specificity of human capital (Shaw and Lazear (2008) and Dustmann and Pereira (2008)), degree of which depends on the complementarity between schooling and work experience (Goldin and Katz (2008) and Pischke and von Wachter (2008)) varying with career stages and with different economies. This diversity is presumed to be often synchronized with the prevalence of internal labor markets in the economy, which affect both employer learning and human capital investment. Shielded internal labor markets especially could generate a large part of asymmetric effects in learning.

At the same time, primary assumptions of the public learning model are maintained within internal labor markets of major firms. This research intends to extend the scope of the public employer leaning model to study employer learning under such semi-public conditions. This study's empirical results, based on micro data from a Japanese manufacturing firm, show that employer learning is not observed for work experience from before employees gain long-term employment with the firm but that such learning is observed after the employees gain such employment. This result is presumed to be due to changes in workers' attitudes toward human capital investment and the strongly asymmetric learning effect between short-term employment and long-term employment.

Section 1 reviews the related literature and focuses on employer learning in internal labor markets. Section 2 suggests the semi-public properties of internal labor markets under which wages are competitively determined, employees' records are continuously accumulated, and arbitrage with the outside market does not occur on the equilibrium path; under such conditions, the public employer learning model is applicable. Then, section 2 presents the estimation model that separates work experience into experience prior to gaining long-term employment with a firm and experience posterior to gaining such employment. Our semi-public approach, while maintaining the tractability of the public employer learning model of Farber and Gibbons (1996), intends to evaluate employer learning in internal labor markets. By doing so, the asymmetric reality of employer learning in the labor market as a whole is expected to be captured without a loss of tractability.

Section 3 describes the data and then verifies the existence of an internal labor market in the case firm. Section 4 presents the empirical results, which show that schooling and short-term work experience at younger ages were complements and do not support the employer learning hypothesis, and that work experience after gaining long-term employment strongly supports the employer learning hypothesis. The complementarity between schooling and work experience makes the sign of the interaction term between schooling and work experience pos-

[1] See Altonji and Pierret (2001); Lluis (2005); Pinkston (2006); Lange (2007); and Oyer (2008).

itive, but the effect disappears after the employees gain long-term employment. Internal labor markets induce investment in firm-specific human capital and facilitate employer learning.

1 Employer learning in internal labor markets

1.1 Symmetric employer learning questioned

While the abilities of individual workers are difficult to observe, a worker's educational background is observable and is assumed to be correlated with the worker's ability. This correlation entices employers to statistically discriminate between employees based on the workers' educational backgrounds; unless the correlation between educational backgrounds and abilities is perfect, such statistical discrimination could lead to a gap between wages and realized performance.[2] Motivated by this hypothesis, the rich empirical results supporting the "sheepskin effects" of schooling have been presented.[3] While schooling could surely enhance productivity, and not merely serve as a signal,[4] "sheepskin effects" have been established to exist in some form in developed, developing, and even planned economies, suggesting the ubiquity of these effects. Thus, the literature has begun to address how the effects differ depending on the institutional arrangements. The public "employer learning" model established by Farber and Gibbons (1996) focused on how the "sheepskin effects" decrease as employers learn about workers' abilities.

For the sake of tractability, Farber and Gibbons (1996) assumed that incumbent and entrant employers symmetrically learn workers' abilities in the competitive market and presented consistent empirical evidence. However, this symmetric employer learning hypothesis has been empirically questioned on two primary bases.

The first is the possibility of asymmetry in employer learning, which is suggested by Schönberg (2007) and Pinkston (2009), who explicitly modeled asymmetric employer learning. At the same time, in some cases in which asymmetry in learning is caused, the statistical assumptions of the public learning model are maintained. A typical case is the internal labor markets of major firms. By internal labor markets, we mean a personnel policy composed of long-term employment and internal promotion, under which quasi-rent of accumulated firm-specific human capital is guaranteed by internal promotion. In the case of a major firm, multiple units within the firm compete with each other, and employees do not leave because of the quasi-rent rewarding the employees' firm-specific human capital at the equilibrium. Then, as discussed below, the statistical assumptions of the public learning model by Farber and

[2] See Hansen, Weisbrod and Scanlon (1970); Spence (1973); Arrow (1973); Tabman and Wales (1973); and Stiglitz (1975).

[3] For the United States, the supporting evidence includes Riley (1979); Lang and Kropp (1987); Hungerford and Solon (1987); Belman and Heywood (1991); Jaeger and Page (1996); Tyler, Murnane and Willett (2000); Bedard (2001); Pinkston (2003); Bollinger and Hirsch (2006); and Clark and Jaeger (2006). For Japan, while Bauer, Dross and Haisken-DeNew (2005), denied the "sheepskin effect," this research suggests the opposite result. For the United Kingdom, see Silles (2008). For Canada, see Ferrer and Riddell (2002); and Caponi and Plesca (2009). For Spain, see Pons and Blanco (2005). For the Czech Republic, which is a transition economy, see Münich, Svejnar and Terrell (2005).

[4] See Card and Krueger (1992); Groot and Oosterbeek (1994); and Dale and Krueger (2002).

Gibbons (1996) are retained within the internal labor market, and we can capitalize on the tractability of the public learning model to study the asymmetry between wage growth within internal labor markets and that outside of internal labor markets.

The other issue concerns the workers' attitudes toward human capital investment. The non-increasing coefficient of the interaction term between schooling and experience, the indicator of employer learning effect, also implies that that the complementarity effect between schooling and experience is weak enough to be dominated by the employer learning effect.[5] However, such a relationship has not always held as industrial economies have experienced technology-skill/education complementarity development since the early twentieth century as presented by Goldin and Katz (2008). For instance, Bauer and Haisken-DeNew (2001) showed that the interaction term between schooling and work experience has a significantly positive coefficient for the German data set and concluded that employer learning is not observed in the German labor market. While Lluis (2005) then mined certain evidence of employer learning from the same data set by controlling for job-rank effects, the evidence is still more weakly observed than the U.S. cases.

1.2 Human capital investment and employer learning

While the educational background of workers has emerged as an important proxy of ability in workplaces exactly in the context of technology-skill/education complementarity since the early twentieth century (Goldin and Katz (2008)), the extent of complementarity between schooling and worker experience could also interact with the extent of human capital specificity, which depends on the institutional arrangements of the labor market in the economy. For instance, the German labor market institutions, the apprentice system especially, encourage concentration in industry-specific human capital, and the Japanese labor market tends to investment in firm-specific human capital.[6] The U.S. labor market appreciates firm-specific human capital, but places more emphasis on industry-specificity than on firm-specificity, staying between the German and the Japanese markets but tending slightly toward the former.[7]

The extent of the schooling-experience complementarity could also change as the worker ages. As Topel and Ward (1992) demonstrated for the U.S. case, young workers typically have several work experiences, so as to achieve better matching, before obtaining long-term employment.[8] Considering that general or industry-specific human capital accumulated through total work experience has a substantial impact on wage growth and that firm-specific human capital accumulated through tenure also has a smaller but definite impact, early-acquired experience in several workplaces is presumed to contribute to the accumulation of general or industry-specific human capital, while later long-term employment is supposed to contribute

[5] See Farber and Gibbons (1996), p. 1017.

[6] See Dustmann and Meghir (2005), pp. 90-96; Pischke and von Wachter (2008), pp. 596-598; Gathmann and Schönberg (2010), pp. 10-36; Altonji and Shakotko (1987), pp. 442-454; and Abe (2000), pp. 261-264.

[7] See Altonji and Shakotko (1987), pp. 442-454; Topel (1991), pp. 166-172; Neal (1995), pp. 660-669; Parent (2000), pp. 308-320; Weinberg (2001), pp. 236-247; Poletaev and Robinson (2008), pp. 402-413; and Shaw and Lazear (2008), pp. 717-720.

[8] See Topel and Ward (1992), pp. 467-374, and also see Markey and Parks (1989), pp. 7-9, and Parado, Caner and Wolff (2007), pp.445-447.

to the accumulation of firm-specific human capital. For the German case, young workers are expected to usually invest in "portable" general human capital in the early stages of their careers, followed by gaining long-term employment.[9]

Meanwhile, since the early twentieth century, the technology-skill/education complementarity has become augmented with the transition of the production process from artisanal shops to the factory system and then to the continuous production system, under which not only white collar workers but also blue collar workers became required to acquire general cognitive skills. Expanded secondary schools emphasized investment of this kind general human capital, as ascended by the United States.[10] Under such technology-skill/education complementarity, young workers are likely to choose work experiences at which they can invest in general human capital complementary to their educational backgrounds. Then, schooling and experience might be complements in short-term work experiences at young ages. However, if the current employer commits to long-term employment and quasi-rent payment for firm-specific human capital, then the employee has incentives to invest in firm-specific human capital. Such firm-specific human capital might be less complementary to schooling.

On the other hand, internal labor markets in practice serve not only as incentives for investment in firm-specific human capital but also as an employer learning device, as presented by Baker, Gibbs and Holmstrom (1994b).[11] In addition, asymmetric employer learning is not only supported by the internal labor market but also strengthens it.[12]

Important is that both the complementarity between schooling and experience and the employer learning affect the sign of the interaction term between schooling and experience in a wage regression, though to the opposite directions. While the coefficient of the interaction term between schooling and experience is a tractable measure of employer learning, it also measures the degree of complementarity between schooling and experience, and hence the extent of human capital specificity. If we can presume that the labor market diversity comprises an institutional framework that encourages human capital investment and an informational structure, which affects employer learning, then the interaction term between schooling and experience can been seen as a focal point of comparative analysis of diversified labor markets.

Following the classic employer learning model,Schönberg (2007) and Pinkston (2009) presented frameworks conscious also of a possible asymmetry in employer learning. Bauer and Haisken-DeNew (2001) addressed human capital investment complementary to schooling, and Baker et al. (1994b), Lluis (2005), and Eriksson and Ortega (2006) examined the wage dynamics of the internal labor markets. Connecting these three lines of reasoning, this research attempts to distinguish the employer learning effects on wage growth inside and outside the internal labor market using panel data of the Japanese steel industry from the period when the internal labor market policy was formed in Japan.

[9] See Dustmann and Meghir (2005), p. 79; and Gathmann and Schönberg (2010), pp. 10-36.

[10] See Fallon and Layard (1975), p. 295; Goldin and Katz (1996), pp. 253-256; Goldin and Katz (1998), pp. 698-719; Autor, Katz and Kearney (2006), pp. 190-191; and Goldin and Katz (2008), pp.102-125, 176-181.

[11] See Baker et al. (1994b), pp. 952-953; and also Eriksson and Ortega (2006), pp. 661-665.

[12] See Waldman (1984); and Greenwald (1986).

1.3 Internal labor markets

Internal labor markets characterized by long-term employment and internal promotion are widely applied to highly skilled workers of large companies in developed economies when the firm knows the necessary skills well and when the skills are complementary to each other and/or firm-specific. The empirical and descriptive works on the issue in the last two decades have suggested that the internal labor market is an evaluation device for employers to better learn about employees' abilities and to give the employees incentives to invest in firm-specific human capital under asymmetric information between the employer and employees.[13]

Manufacturing in Japan, heavy manufacturing especially as in the United States, began to form internal labor markets in the 1920s, and after the Second World War, even more weighted long-term employment and internal promotion.[14] Transition to internal labor markets in long-existing major industries was accompanied by the dissolution of an autonomous intermediary work organization into a work organization directly and systematically controlled by firms. Such a transition proceeded with technological transformations that provided the firms with informational advantages about relevant skills, making direct control by the firm relatively efficient. As for the Japanese steel industry studied by this research, periods of technological transition were observed in the 1920s and in the 1950s as larger open-hearth furnaces were introduced, and in the 1960s, when converter furnaces were introduced. Work organizations with systematic wage and promotion schemes were constructed along with the transition.

This research addresses study wage growth of blue-collar employees from 1929 to 1969 in the Kamaishi Iron Works, one of the leading iron works then in Japan at that time, and addresses the employer learning and human capital specificity in wage dynamics during the formation of the internal labor market.

2 Estimation model

2.1 Theoretical framework of symmetric employer learning

We begin with a theoretical framework of public employer learning, following Farber and Gibbons (1996) and motivated by and Gibbons and Waldman (1999).[15] Let $y_{i,t}$ denote the output of the ith worker ($i = 1, \dots, n$) in the tth period ($t = 1, \dots, T$), $\theta_{i,t}$ denote the ith worker's ability in the period t, which is not observable by employers. Then suppose $\theta_{i,t} = \eta_i t$, where η_i denotes the ith worker's time-invariant multiplier of human capital investment, which is not observable by employers when the worker joins the labor market but is learned about by employers. Let also yos_i denote the years of schooling the ith worker completed, which is observable by employers, $\boldsymbol{x}_i$ denote a vector of time-invariant characteristics of the ith

[13] See Alexander (1974); Williamson, Wachter and Harris (1975); ; Rosen (1988); Aoki (1988), pp. 49-98; Osterman (2011); Baker, Gibbs and Holmstrom (1994a), pp. 881-884; and Baker and Holmstrom (1995), pp. 256-257.

[14] See Hashimoto and Raisian (1985); Aoki (1988), pp. 59-69; Mincer and Higuchi (1988); Moriguchi (2003); and Ono (2010).

[15] See Farber and Gibbons (1996), pp. 1010-1014; and Gibbons and Waldman (1999), pp. 1327-1329.

worker other than the years of schooling, which are observable to employers and are included in the data, and $\boldsymbol{z}_i$ denote a vector of time-invariant characteristics of the ith worker that are observable by employers but are not included in the data.

We assume that the conditional distribution $G(y_{i,t} \mid \eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ can be arbitrary and that the outputs $y_{i,t}$ are independently drawn from $G(y_{i,t} \mid \eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$. We also assume that the joint distribution $F(\eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ can be arbitrary. All employers are assumed to know $F(\eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and $G(y_{i,t} \mid \eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and to observe $y_{i,1}, \ldots, y_{i,t}$ for each of workers $i = 1, \ldots, n$. Thus both incumbent and entrant employers 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 worker,

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

We additionally assume that the conditional expectation $E\big(y_{i,t} \mid \mathrm{yos}_i, \mathbf{x}_i, \mathbf{z}_i, y_{i,1}, \ldots, y_{i,t-1}\big)$ is a linear combination of yos_i, $\boldsymbol{x}_i$, $\boldsymbol{z}_i$, and $y_{i,1}, \ldots, y_{i,t-1}$.

2.2 Example of public employer learning as a benchmark

We next review an example of the random effect estimation of the employer learning model. Take a logarithmic expression of wage determination and consider a random effect model of the panel least square regression of the ith employee's wage at time t, $w_{i,t}$, expressed as

$$w_{i,t} = \alpha_0 + \alpha_1 \mathrm{yos}_i + \alpha_2 t + \alpha_3 \mathrm{yos}_i \times t + \alpha_4 x_{4,i} + \cdots + \alpha_j x_{j,i} + \cdots + \alpha_m x_{m,i} + \eta_i + \epsilon_{i,t}, \tag{2}$$

where $\boldsymbol{x}_i$ is an $m-3$ dimensional vector whose factors are observable characteristics included in data other than the years of schooling and are numbered from 4, and $\log \theta_{i,t} = \log \eta_i + \log t$.

Then we have,

$$\Delta_t w_{i,t} = \alpha_2 + \alpha_3 \mathrm{yos}_i + \Delta_t E(\eta_i \mid \mathrm{yos}_i, x_i) + \Delta_t \epsilon_{i,t} \equiv \alpha_2 + \alpha_3 \mathrm{yos}_i + \varphi_{i,t}, \tag{3}$$

where $\Delta_t \epsilon_{i,t}$ is the serially independent innovation.

Then, the linear projection of $\boldsymbol{w}$, which is an n dimensional vector whose ith factor is w_i, denoted by $E^*(\boldsymbol{w} \mid \cdot)$, yields[16]

$$E^*(\boldsymbol{w} \mid \boldsymbol{X}) = \boldsymbol{X}\hat{\boldsymbol{\alpha}},$$

where $\boldsymbol{X}$ is an $n \times m$ matrix whose ith row is the ith worker's characteristics and the jth column is the jth independent variable in wage equation (2). Normal equations give,

$$\hat{\boldsymbol{\alpha}} = [\boldsymbol{X}'\boldsymbol{X}]^{-1}\boldsymbol{X}'\boldsymbol{w}, \tag{4}$$

where the jth factor of $\hat{\boldsymbol{\alpha}}$, $\hat{\alpha}_j$, is increasing in the numerator, $\sum_{t=1}^{T}\sum_{i=1}^{n} x_{j,i} w_{i,t}$ and thus in the standardized one, $\sum_{t=1}^{T}\sum_{i=1}^{n} x_{j,i} w_{i,t} - TnE(x_j)E(w) = \mathrm{Cov}(x_{i,j}, w_{i,t})$. The numerator

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

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 (3), with other conditions controlled for, $\hat{\alpha}_2$ is increasing in

$$\begin{aligned}(5)\qquad &\sum_{t=1}^{T}\sum_{i=1}^{n}(\text{yos}_i \times t) \times w_{i,t} - TnE(\text{yos} \times t)E(w)\\ =&\text{Cov}(\text{yos}_i \times t, w_{i,t}) = \sum_{\tau}^{T}\text{Cov}(\text{yos}_i \times \tau, \varphi_{i,\tau}).\end{aligned}$$

It is important to note that $\text{Cov}(\text{yos}_{i,t} \times t, w_{i,t})$ 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, $\text{Cov}(\text{yos} \times \tau, \varphi_\tau)$ is increasing in the degree of complementarity between the years of schooling (yos) and work experience (τ) for each τ ($\tau = 2, \ldots, T$). The covariance between w_τ and $\text{yos} \times \tau$ should be positive in the cross-sectional dimension of workers $i = 1, \ldots, n$ if schooling (yos) and experience (τ) are complements for productivity difference ($\Delta\epsilon$) and non-positive otherwise for each period t.

In the longitudinal dimension, let us assume that the employers have learned about the employees' time-invariant hidden characteristics when recruiting, which are captured by η_i, and that η_i approaches a stationary state such that $\Delta_\tau E(\eta_i \mid \text{yos}_i, \tau - 1)$ is decreasing in τ and that $\lim_{\tau\to\infty} \Delta_\tau E(\eta_i \mid \text{yos}_i, \tau - 1) = 0$. Thus $\text{Cov}(\text{yos}_i \times \tau, \varphi_i)$ is decreasing in τ and $\lim_{\tau\to\infty} \text{Cov}(\text{yos}_i \times \tau, \varphi_i) = 0$ for each i.

Hence, in the antilogarithmic specification, if the employer learning effect in the longitudinal dimension dominates the complementarity effect between schooling and experience in the cross-sectional dimension, $\hat{\alpha}_2$ should be non-positive. Furthermore, suppose that the wages, with marginal productivity, increase over experience, and then take the logarithmic expression of all variables.[17] Then, $\hat{\alpha}_2$ depends on the relative impact of the effect of complementarity between schooling and work experience and the effect of employer learning. Therefore, a) if the former effect dominates the latter, then $\hat{\alpha}_2 > 0$; and b) if the latter effect dominates the former, then $\hat{\alpha}_2 < 0$.

2.3 Semi-public employer learning in internal labor markets

Next suppose an internal labor market of a multi-unit firm,[18] in which multiple units compete each other and the return on firm-specific human capital is positive, thus implying that the quasi-rent of firm-specific human capital is positive. Therefore employees do not leave on the equilibrium path, and so arbitrage of wages between inside and outside of the firm does not occur. Then, we can assume that all the units within the firm symmetrically know $G(y_{i,t} \mid \eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and $F(\eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ for $i = 1, \ldots, n$ and $t = 1, \ldots, T$, and that

[17] For tractability, in this research the regressors are also logarithmically transformed to allow the experience and tenure effects to be marginally decreasing instead of the squared terms of the antilogarithmic level.

[18] We typically assume a firm described by Chandler (1977), pp. 1-12.

they observe $y_{i,1}, \dots, y_{i,t}$. That is, all the units continuously learn employees' abilities, the wage growth depends on the units' learning without arbitrage with the outside market, and the competitive situation guarantees $w_{i,t} = E(y_{i,t} \mid \cdot)$. While wages are competitively determined and employees' abilities are symmetrically learned within the internal labor market, the wage growth trajectories are asymmetric between inside and outside the internal labor market because the quasi-rent earned from firm specific-human capital prevents employees from leaving; thus $G(y_{i,t} \mid \eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and $F(\eta_i, \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ remain unknown to outside employers. We define these properties as semi-public. Then we have

$$w_{i,t} = kE(y_{i,t} \mid \mathrm{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i, y_{i,1}, \dots, y_{i,t-1}), \tag{6}$$

where the non-stochastic constant k captures the internal labor market's "shielding" effect from the outside market. We standardize k as 1 for estimation.

Workers are expected to invest in general human capital at both school and workplace if their employers do not commit to long-term employment. Meanwhile, employees would willingly invest in firm-specific human capital if their employers commit to long-term employment and if the quasi-rent from firm-specific human capital is positive. Also, a long-term employment helps current employers learn about their employees' abilities through tracking human capital accumulation.

To capture this effect of the internal labor market, we simply separate the ith employee's experience into two components, such that $t = \mathrm{exp} = \mathrm{pre} + \mathrm{ten}$, where exp is total experience, pre is work experience prior to joining the firm, and ten is tenure at the firm. Then, taking logarithmic specification, the wage equation (2) can be reformulated as

$$\begin{aligned} w_{i,t} = \beta_0 &+ \beta_1 \mathrm{yos}_i \\ &+ \beta_2 \mathrm{pre} + \beta_3 \mathrm{ten} \\ &+ \beta_4 \mathrm{yos}_i \times \mathrm{pre} + \beta_5 \mathrm{yos}_i \times \mathrm{ten} + \boldsymbol{\gamma}'\boldsymbol{x_i} + \boldsymbol{\delta}'\boldsymbol{x_i} \times \mathrm{ten} + \eta_i + \epsilon_{i,t}. \end{aligned} \tag{7}$$

A critical condition of the semi-public properties is that return on firm-specific human capital is sufficiently large to prevent employees from deviating from the internal labor market at the equilibrium. Thus, necessary is significantly positive coefficient of ten in a regression with total experience exp controlled for. We check this in **Table 4** below.

While the complementarity between schooling and work experience is greater during shorter-term employment in the earlier stages of workers' careers, employers learn about workers' abilities better in longer-term employment. Then, taking the logarithmic specification, the prediction from employer learning combined with workers' concerns about investment in human capital is as follows:

Prediction 1. *The coefficient of the interaction term between the years of schooling and previous experience before employment with a firm that commits to the long-term employment* $(\mathrm{yos} \times \mathrm{pre})$ *is expected to be greater than the interaction term between the years of schooling and the tenure after employment with the firm* $(\mathrm{yos} \times \mathrm{ten})$*; thus* $\hat{\beta}_4 > \hat{\beta}_5$.

Next, we need a sample set that satisfies the semi-public properties discussed above.

3 Case firm and data

3.1 The Kamaishi Iron Works: Historical context

The Kamaishi Iron Works opened by the Nambu Domain in 1857 is the oldest modern iron works in Japan. After being nationalized in 1873 and privatized again in 1884, new blast furnaces were built, and the integrated production of pig iron and steel began in 1903. After ownership from 1924 to 1934 by the Mitsui Holdings, then the largest conglomerate, Kamaishi Iron Works was merged with other major iron works in 1934 to form Nippon Iron and Steel in 1934 under the governmental coordination.

After the Second World War, Nippon Iron and Steel was split into Fuji and Yawata under the U.S. occupation. After the U.S. occupation, steel companies and other important manufacturing companies were induced to invest in new technology with the long-term financing coordinated by the government from the 1950s to the 1960s. For the Kamaishi Iron Works, then part of Fuji, this coordinated modernization effort emphasized efficiency improvements in iron and steel production but the replacement of old blast furnaces was not planned.

A large change during the post-1950s modernization of the production lines was the standardization, or "manualization," of the production procedures. Before the Second World War, in the iron and steel industry, sophisticated production procedures were developed by employees and taught to the younger employees by the senior employees of the company. After the 1950s, however, the production line procedures became manualized by better-educated engineers, and the best practices at the shop floor came to be known to the firm.[19]

As part of a company-wide investment plan, Fuji decided to build Tokai, a new state-of-the-art plant in Nagoya, a large city far from Kamaishi. The firm also decided to decrease Kamaishi's capacity, so as to increase the capacity of other new plants such as Tokai, and to relocate the skilled workers of Kamaishi and other old iron works to Tokai. Selection for relocation was handled in cooperation with the union, and in principle, anyone who was willing to move was allowed to be relocated. Thus, the measure of selection was just the employees' willingness. Consequently, 1,678 skilled workers moved from Kamaishi to Tokai from 1964 to 1969.[20]

This brief history indicates that Fuji constituted a rigorous internal labor market, iron works within the company competed with each other, and the firm-specific human capital was commonly productive in different iron works within the same company. Thus, this data set is an appropriate sample in terms of our semi-public properties.

3.2 Data

This research uses the preserved panel data of wages for 1,544 relocated Kamaishi employees, tracking them from the late 1920s or later, depending on the employee, to the 1960s, when

[19] See Nakamura (2010), pp. 8-21.

[20] In addition to the 1,678 workers from Kamaishi, 908 workers moved from Muroran, 972 workers moved from Hirohata, and 127 workers moved from Kawasaki. See Umezaki (2010), pp. 33-38, 47-49. Fuji and Yawata merged into Nippon Steel in 1970s and both Kamaishi and Tokai, which was renamed as Nagoya, have since belonged to Nippon Steel.

they left Kamaishi. The number of total observations is 24,022.

The data set has advantages specifically with regards to this research. The original personnel documents contain all important employee information from when they were employed. We are able to recover employees' entire lives from when they were born to when they were relocated in the late 1960s. In addition, the record itself implies that the firm learned about employees' abilities through experience and job assignment.

Each individual wage record includes:

1. Educational background (yos).
2. Physiological characteristics when employed: height (hgt), weight and lung capacity.
3. Panel record of work experience previous to entry to the firm, assignment of rank, department, and jo, wage, training, and personal information:
   (1) Previous experience.
   (2) Promotion and deployment: rank, division, department, and job.
   (3) Basic wage.
   (4) The record of whether the employee any of the following in-house training:
      ▷ Systematic programs for elected employees
        1927-1935: "Youth Development Center (*Seinen Kunrenjo*)" (ydc); three days a week, 4 years, 800 hours in total.
        1935-1948: "School for Youth (*Seinen Gakko*)" (sy); half-time, three days a week, 4 years.
        1939-1946: "Development Center for Technicians (*Ginosha Yoseijo*)" (dct); full-time, 3 years, 6,453 hours in total.
        1946-1973: "Development Center (*Kyoshujo*)" (dc); three days a week, 2 years (by 1950), 6 days a week (from 1950).
      ▷ Short-term programs (for example, elementary calculus).
   (5) Licenses the employee held.
   (6) Family composition.
   (7) Clinical history.

The composition of the cohorts is as shown in **Table 1**. An especially important feature of the data set is that it is not dominated by those who were employed immediately after graduation, unlike contemporary Japanese firms, which are so dominated. Employing mainly new graduates, the common recruitment policy of contemporary major Japanese firms, has become prevalent for blue-collar workers since the early 1970s and was not common before that. The mean of previous experience (years after graduating from school and before employment with the firm, pre) is not even monotonically decreasing.

During the early twentieth century, when heavy manufacturing was introduced from the Western world, the career pattern that 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 became typical for male skilled workers. This tradition is well exploited by this research strategy in the form of equation (7).

Compulsory education was extended from 6 years to 9 years in 1947. Therefore, in **Table 1**, 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 Verifying the existence of the internal labor market

The existence of the internal labor market policy, which somehow "shields" wage determination from the outside market, is to be empirically established, though we have assumed that so far. We follow the strategy presented by Baker et al. (1994b).

If a firm offers competitive wages with respect to the observable signals such as the educational background in the market when recruiting, and if the firm adopts the internal labor market policy under which wages are determined based on the internal rules that more or less shield the internal wage dynamics from the market price, then the wage growth of each cohort preserves the trace of the outside market pricing only at the point of recruitment; it is shielded from the market price thereafter, and could share common traits. Thus, the survival of the cohort effect is a useful indicator of the existence of the internal labor market.[21]

Table 2 contains regressions of real daily wages (rw) on experience in the labor market (exp), tenure (ten), the 2-year joined dummies such as $\mathrm{yj}1928 - 1929$, $\mathrm{yj}1930 - 1931$, $\mathrm{yj}1932 - 1933$, etc., and the interactions between the 2-year joined dummies and tenure such as $(\mathrm{yj}1928-1929) \times \mathrm{ten}$, $(\mathrm{yj}1930-1931) \times \mathrm{ten}$, $(\mathrm{yj}1932-1933) \times \mathrm{ten}$, etc. To control for the effect of educational background, the years of schooling (yos) is also inserted as a regressor. The period saw a rapid growth in average productivity, which is controlled for by the year dummies. In model 2-2, to allow the cohort effect to be decreasing in tenure, the interaction term of the 2-year joined dummies and tenure $(\mathrm{yj} \times \mathrm{ten})$, rather than (ten), is inserted as a regressor.[22] The cohort effects survive among the employees of all cohorts. The internal labor market at the Kamaishi Iron Works seems to have been formed in the 1930s. This statistical inference is consistent with the descriptive picture based on documents and hearings.[23]

[21] See Baker et al. (1994b), pp. 923, 933-940 and Baker and Holmstrom (1995), pp. 258-259.

[22] Our approach differs from that of Baker et al. (1994b) in some important regards. To avoid the identification difficulty and still extract the cohort effect, Baker et al. (1994b) assumed that the tenure effect on wage growth is linear, estimated the coefficient of the linear regression of wages on tenure, deducted the estimated tenure effect from the cohort average wage, and regressed this adjusted cohort average wage on the cohort dummies. However, in this data set, as the decreasing impact of past wages on the current wage in **Table 3** shows, the tenure effect is not linear. Hence, to avoid the identification problem, we simply bind the adjacent two cohorts together into one group and then regress the wages on the dummies of the two-cohort groups.

[23] See Umezaki (2010), pp. 42-51.

As Baker et al. (1994b) described, the serial correlation of wage growth is another useful indicator of the internal labor market.[24] In the competitive market in which wage increments are serially independent, the wage history should have a unit root and be a random walk. However the result would be different in an internal labor market. For this case firm, wage histories are serially correlated, the probability of a common panel unit root of rw in the level term is statistically rejected, and an individual panel unit root of the first difference of rw ($\Delta\mathrm{rw}$) is also rejected.[25] Therefore each trajectory of individual wage growth $\Delta\mathrm{rw}_{\mathrm{ten}}$ is a contraction mapping, has a unique fixed point, and is moving toward the unique fixed point.

The steady state to which each wage history verges is supposed to be the true value of the employee's hidden ability. If the employer, for instance, uses the accumulated information for the assignment of employees, then such a regularly serial correlation can be observed [26]

Meanwhile, these trajectories differ over cohorts. **Table 3** regresses the real wage $\mathrm{rw}_{\mathrm{ten}}$ on the interaction terms of the 2-year joined dummy and the first and second lagged terms such as $(\mathrm{yj}1928 - 1929) \times \log \mathrm{rw}_{\mathrm{ten}-1}$, $(\mathrm{yj}1930 - 1931) \times \log \mathrm{rw}_{\mathrm{ten}-1}$, $(\mathrm{yj}1932 - 1933) \times \log \mathrm{rw}_{\mathrm{ten}-1}$, etc., $(\mathrm{yj}1928 - 1929) \times \log \mathrm{rw}_{\mathrm{ten}-2}$, $(\mathrm{yj}1930 - 1931) \times \log \mathrm{rw}_{\mathrm{ten}-2}$, $(\mathrm{yj}1932 - 1933) \times \log \mathrm{rw}_{\mathrm{ten}-2}$, etc. Though the results look similar, significantly different 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** in section 2.3.

4 Empirical results

4.1 Overview: Tenure, employer learning, and in-house training

Before directly proceeding to the estimation of equation (7), let us provide an overview based on the ordinary regression equation (2) as a benchmark. **Table 4** gives the results of the random effect estimation regressing real wage (rw) on employee height when employed by the firm (hgt),[27] the years of schooling (yos), total experience in the labor market (exp), tenure at the firm (ten), the interaction of height and total experience ($\mathrm{hgt} \times \mathrm{exp}$), the interaction of height and tenure ($\mathrm{hgt} \times \mathrm{ten}$), the interaction of the years of schooling and total experience ($\mathrm{yos} \times \mathrm{exp}$), the interaction of the years of schooling and tenure ($\mathrm{yos} \times \mathrm{ten}$), the dummy variables of completing in-house training programs, Development Center for Youth (dcy, operated in 1927-1935), School of Youth (sy, operated in 1935-1948), Development Center for Technicians (dct, operated in 1939-1946), and Development Center (dc, operated in 1946-1973), and the interaction of these dummy variables and tenure ($\mathrm{dcy} \times \mathrm{ten}$, $\mathrm{sy} \times \mathrm{ten}$, $\mathrm{dct} \times \mathrm{ten}$,

[24] See Baker et al. (1994b), pp. 943-953.

[25] Common panel unit root test (Levin, Lin and Chu test) of rw: t statistic: -11.0441^{**}, cross sections included: $1,395$, total panel observations: $20,410$. Individual panel unit root test (Im, Pesaran and Chin test) of $\Delta\mathrm{rw}$: W statistic: -60.8254^{**}, cross sections included: $1,309$, observations: $18,419$. Optimal lag is determined by the Akaike Information Criterion, and $**$ denotes significance at the 1 percentage level.

[26] See Baker et al. (1994b), pp. 924, 926-927, 952-954.

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

$\mathrm{dc} \times \mathrm{ten}$).[28] The potential impact of the extended compulsory schooling[29] is captured by the postwar education generation dummy (psw).

The significantly large coefficient of ten, with total experience exp controlled for, implies that the return on the firm-specific human capital is considerable, a finding consistent with our semi-public properties. Thus, the employer learning hypothesis strongly holds. In **Table 4**, the interaction term of the years of schooling with total work experience after graduation ($\mathrm{yos} \times \mathrm{exp}$) has significantly negative coefficients in models 4-1 and 4-3, and that with tenure ($\mathrm{yos} \times \mathrm{ten}$) has significantly negative coefficients in models 4-2 and 4-4.

Along with the years of schooling, proxies of the abilities observable to the employer are physiological characteristics such as height. In the case of blue-collar workers in the steel industry, physical strength was critical, and height is a good proxy of such physical strength. Indeed, with regard to height, the employer learning hypothesis holds. The interaction term of height with tenure ($\mathrm{hgt} \times \mathrm{ten}$) has a significantly negative coefficient in models 4-3 and 4-4.

Table 4 also shows that the role of training programs changed throughout the sample period. The interaction of the postwar program with tenure ($\mathrm{dc} \times \mathrm{ten}$) has a significantly negative coefficient while the interaction terms of the prewar programs with tenure ($\mathrm{dcy} \times \mathrm{ten}, \mathrm{sy} \times \mathrm{ten}, \mathrm{dct} \times \mathrm{ten}$) have significantly positive coefficients in models 4-1, 4-2, 4-3, and 4-4. The change in the sign of the interaction terms with tenure from the prewar programs to the postwar program indicates that the prewar program contents were complementary with tenure, while the postwar program contents became substitutes.

4.2 Internal labor market effect

Next, we examine equation (7) and **Prediction 1**. The first approach comprising a straightforward specification without control for the cohort effect by the random effect estimation is presented in **Table 5**. With the changes in return on schooling controlled for by inserting the interaction between the year dummy and the years of schooling ($\mathrm{dy} \times \mathrm{yos}$), the interaction term between the years of schooling and previous work experience ($\mathrm{yos} \times \mathrm{pre}$, β_4 in equation (7)) has a significantly positive coefficient, differing from the symmetric employer learning hypothesis. In contrast, the interaction term between the years of schooling and tenure ($\mathrm{yos} \times \mathrm{ten}$, β_5 in (7)) has a significantly negative coefficient, implying that **Prediction 1** holds, $\hat{\beta}_4 > \hat{\beta}_5$.

Similar but different wage curves in **Table 3** urge us to control for the cohort effects when checking robustness of the results in **Table 5**. Therefore, **Table 6** presents a regression of the real wage (rw) with random effects on the years of schooling (yos), work experience after graduation and before employment with the firm (pre), tenure after employment with the firm (ten), and motivated by **Table 3**, the interaction terms of the 2-year joined dummy, the years of schooling and previous work experience before employment with the firm, $(\mathrm{yj}1928 - 1929) \times \mathrm{yos} \times \mathrm{pre}$, $(\mathrm{yj}1930 - 1931) \times \mathrm{yos} \times \mathrm{pre}$, etc., and the interaction terms of the 2-year joined dummy, the years of schooling, and tenure, $(\mathrm{yj}1928 - 1929) \times \mathrm{yos} \times \mathrm{ten}$, $(\mathrm{yj}1930 - 1931) \times \mathrm{yos} \times \mathrm{ten}$, etc., to control for the cohort effects on the interaction between schooling and work experience. **Table 6** also controls for the training programs (dcy, sy, dct, dc), the interactions

[28] Some samples lack the information on height, weight, and lung capacity.

[29] See Oreopoulos (2005), pp. 158-170.

between the training programs and tenure ($\mathrm{dcy} \times \mathrm{ten}$, $\mathrm{sy} \times \mathrm{ten}$, $\mathrm{dct} \times \mathrm{ten}$, $\mathrm{dc} \times \mathrm{ten}$), and the interactions between the year dummy and the years of schooling ($\mathrm{dy} \times \mathrm{yos}$) to capture the changes in the return on schooling during the period.

Then, the interaction term between the years of schooling and previous work experience ($\mathrm{yos} \times \mathrm{pre}$, β_4) again has a significantly positive coefficient, differing from the symmetric employer learning hypothesis and supporting **Prediction 1**, while the interaction term between the years of schooling and tenure ($\mathrm{yos} \times \mathrm{ten}$, β_5) has a significantly negative coefficient. Thus $\hat{\beta}_4 > \hat{\beta}_5$, supporting **Prediction 1**. The feature showed in **Table 5** was uniformly shared among all cohorts; its results are robust.

4.3 Employer learning and human capital investment

An immediate interpretation of the results in **Table 5** and **Table 6**, considering that employees had previously acquired experience for several years on average in **Table 1**, is that the workers had chosen the 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, they invested in firm-specific human capital not necessarily complementary to schooling, as the firm then also learned about their abilities not informed by the educational backgrounds. The workers invested in general human capital at schools and workplaces before they joined the internal labor market, and they turned to investment in human capital less complementary to schooling after they joined the firm.

While the regression of wages on the interaction term between the years of schooling and total work experience ($\mathrm{yos} \times \mathrm{exp}$) in **Table 4** suggests that employer learning holds, the results in **Table 5** and **Table 6** indicate that the coefficient of the interaction term between the years of schooling and total work experience ($\mathrm{yos} \times \mathrm{exp}$) could be divided into two parts—before and after gaining employment with the firm ($\mathrm{yos} \times \mathrm{pre}$, $\mathrm{yos} \times \mathrm{ten}$)—the coefficients of which, $\hat{\beta}_4$ and $\hat{\beta}_5$, have opposite signs.

The interaction term between the years of schooling and total work experience ($\mathrm{yos} \times \mathrm{exp}$) in **Table 4** supports employer learning because the long-term employer learned much better after the employees were incorporated into the internal labor market. The coefficient of the interaction term between the years of schooling and previous work experience ($\mathrm{yos} \times \mathrm{pre}$), $\hat{\beta}_4$, is significantly positive in **Table 5** and **Table 6**, while that between the years of schooling and work experience after gaining employment with the firm ($\mathrm{yos} \times \mathrm{ten}$), $\hat{\beta}_5$ is significantly negative. Because the latter effect is sufficiently large, the coefficient of the interaction between the years of schooling and experience ($\mathrm{yos} \times \mathrm{exp}$) in **Table 4** is negative. The significantly negative coefficient of the interaction term between the years of schooling and experience ($\mathrm{yos} \times \mathrm{exp}$) seems to capture the internal labor market effect.

The symmetric employer learning hypothesis assumed small significance of the complementarity between schooling and work experience. However, the result here indicates that the learning effect does not dominate the complementarity effect of schooling and experience in early career stages because the workers invested in general capital, a phenomenon that is observed for an even longer duration in the German case as described by Bauer and Haisken-

DeNew (2001). The result also shows that asymmetric employer learning is much more effective, as in the U.S. and British cases presented by Pinkston (2009) and Galindo-Rueda (2003), after the workers entered into long-term employment.

Table 6 also shows that the negativity of the coefficient of interaction between the years of schooling and tenure ($\mathrm{yos} \times \mathrm{ten}$) increases as the cohort nears to the end of the covered period. First, 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 the internal labor markets as Lluis (2005) inferred based on the German intra-firm data set.[30] Second, given that the employer learning effect shifts the coefficient of ($\mathrm{yos} \times \mathrm{ten}$) 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. Because establishment-wide productivity growth is controlled for by the interaction terms of the year dummy and the years of schooling ($\mathrm{yd} \times \mathrm{yos}$), the 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 a wage increase marginally decreasing in tenure. Both the faster learning in earlier stages and the decreasing return on human capital investment are shown in **Table 6**.

5 Conclusion: Implication of the empirical result

We have shown that employer learning is not observed in previous work experience before the workers gained long-term employment with the firm, the stage when they invested in general human capital complementary to schooling, and that employer learning is clearly observed once they gained long-term employment in our case of the Japanese steel industry from the 1930s to the 1960s. The internal labor market directed workers to invest in more specific human capital and accelerated employer learning.

After the public employer learning model was established by Farber and Gibbons (1996), the recent results for the U.S., German, and British cases have suggested that more research is required concerning the asymmetric learning by current employers (Pinkston (2009), Lluis (2005), and Galindo-Rueda (2003)). While explicit modeling of asymmetry in employer learning is a promising approach, not a few cases that provide asymmetric reality of employer learning can be described under the same theoretical framework as the public employer learning model by Farber and Gibbons (1996). A typical example is internal labor markets of large firms. Empirical evidence presented by Baker et al. (1994b), Gibbons et al. (2005), Lluis (2005), and Eriksson and Ortega (2006) does not contradict the assumption that employer learning asymmetrically proceeds between inside and outside an internal labor market, but symmetrically proceeds within the internal labor market. Relying on the semi-public properties, we can extend our study of employer learning without a significant loss of the tractability of the model by Farber and Gibbons (1996), as shown in this research.

While this research addresses Japanese experience, long-term employment is observed and

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

has a positive impact on wages and job protection also in U.S. workplaces to encourage the accumulation of industry-, firm-, and/or skill-specific human capital.[31] In addition, since the 1930s, the wages in the United States have been even more shielded to the macroeconomic shocks owing to the institutional settings of the labor market and implicit contracts within internal labor markets.[32] Prevalence of internal labor markets, captured as cohort effects persistent in the labor market, is observed in the United States, Germany, and Canada as in Japan.[33] Internal labor markets of major firms in developed economies are naturally thought to affect the wage dynamics in the labor market.

The extent of the asymmetry in employer learning and the extent of the complementarity between schooling and experience can vary over economies. Employer learning is slightly more asymmetric in the United Kingdom than in the United States.[34] Meanwhile, investment in human capital in Germany seems to concentrate in industry-specificity instead of firm-specificity more than in the U.S. labor market. If skill is highly standardized within each industry and if compulsory schooling and the apprenticeship system are seamlessly connected, then schooling and work experience would be highly complementary.[35]

As compared to the previous evidence for the United States, the United Kingdom, and Germany, the result of this research suggests that the Japanese labor market in the first half of the twentieth century was closer to the contemporary British market than to the contemporary U.S. market in terms of the symmetry of informational structure for employer learning, and closer to the contemporary U.S. market than to the contemporary German market in terms of the comparative emphasis on the industry- or firm-specificity of human capital investment.

Proceeding with such a comparative analysis on the interaction between the firm organization and the labor market requires inquiry based on intra-firm panel data of employees who work for specific large firms, which theoretically would allow for the application of the public employer learning model and tractable comparison. This research intends to be a first step.

References

Abe, Yukiko, "A comparison of wage structures in the United States and Japan: Results from cell mean regressions," *The Japanese Economic Review*, June 2000, *51* (2), 252–267.

Alexander, Arthur J., "Income, experience, and the structure of internal labor markets," *The Quarterly Journal of Economics*, February 1974, *88* (1), 63–85.

[31] See Parent (1999), pp. 305-315; Weinberg (2001), pp. 236-251; Poletaev and Robinson (2008), pp. 400-413; Shaw and Lazear (2008), pp. 717-720.

[32] See Gordon (1982), pp. 18-42; Beaudry and DiNardo (1991), pp. 675-685; and Dohmen (2004), pp. 746-752.

[33] For the United States, see Kahn (2010); and Genda, Kondo and Ohta (2010); for Germany, see von Wachter and Bender (2006, 2008); for Canada, see Oreopoulos, von Wachter and Heisz (2012); and for Japan, see Genda et al. (2010).

[34] See Galindo-Rueda (2003) pp. 13-15; Schönberg (2007), pp. 672-675; and Pinkston (2009), pp. 381-389.

[35] For the United States, see Weinberg (2001), pp.236-247; and for Germany, see Bauer and Haisken-DeNew (2001), pp.l66-177; Dustmann and Meghir (2005), pp. 90-96; Dustmann and Pereira (2008), pp. 383-388; and Pischke and von Wachter (2008), pp. 596-598.

Altonji, Joseph G. and Charles R. Pierret, "Learning and statistical discrimination," *The Quarterly Journal of Economics*, February 2001, *116* (1), 313–350.

____ **and Robert A. Shakotko**, "Do wages rise with job seniority?," *The Review of Economic Studies*, January 1987, *54* (3), 437–459.

Aoki, Masahiko, *Information, incentives, and bargaining in the Japanese economy*, Cambridge: Cambridge University Press, 1988.

Arrow, Kenneth, "Higher education as a filter," *Journal of Public Economics*, July 1973, *2* (3), 193–216.

Autor, David H., Lawrence F. Katz, and Melissa S. Kearney, "The polarization of the U.S. labor market," *The American Economic Review*, May 2006, *96* (2), 189–194.

Baker, George and Bengt Holmstrom, "Internal labor markets: Too many theories, too few facts," *The American Economic Review*, May 1995, *85* (2), 255–259.

____ **, Michael Gibbs, and Bengt Holmstrom**, "The internal economics of the firm: Evidence from personnel data," *The Quarterly Journal of Economics*, November 1994a, *109* (4), 881–919.

____ **,** ____ **, and** ____ , "The wage policy of a firm," *The Quarterly Journal of Economics*, November 1994b, *109* (4), 921–955.

Bauer, Thomas K. and John P. Haisken-DeNew, "Employer learning and the returns to schooling," *Labour Economics*, May 2001, *8* (2), 161–180.

Bauer, Thomas, Patrick J. Dross, and John P. Haisken-DeNew, "Sheepskin effects in Japan," *International Journal of Manpower*, 2005, *26* (4), 320–379.

Beaudry, Paul and John DiNardo, "The effect of implicit contracts on the movement of wages over the business cycle: Evidence from micro data," *The Journal of Political Economy*, August 1991, *99* (4), 665–688.

Bedard, Kelly, "Human capital versus signaling models: University access and high school dropouts," *The Journal of Political Economy*, August 2001, *109* (4), 749–775.

Belman, Dale and John S. Heywood, "Sheepskin effects in the returns to education: An examination of women and minorities," *The Review of Economics and Statistics*, November 1991, *73* (4), 720–724.

Bollinger, Christopher and Barry T. Hirsch, "Match bias from earnings imputation in the Current Population Survey: The case of imperfect matching," *Journal of Labor Economics*, December 2006, *24* (3), 483–519.

Caponi, Vincenz and Miana Plesca, "Post-secondary education in Canada: Can ability bias explain the earnings gap between college and university graduates?," *Canadian Journal of Economics*, July 2009, *42* (3), 1100–1131.

Card, David and Alan B. Krueger, “Does school quality matter?: Returns to education and the characterization of public schools in the United States,” *The Journal of Political Economy*, February 1992, *100* (1), 1–40.

Chandler, Jr. Alfred D., *The visible hand: The managerial revolutoin in American business*, Cambridge, MA: The Belknap Press of Harvard University Press, 1977.

Clark, Melissa A. and David A. Jaeger, “Natives, the foreign-born and high school equivalents: New evidence on the returns to the GED,” *Journal of Population Economics*, October 2006, *19* (4), 769–793.

Dale, Stacy Berg and Alan B. Krueger, “Estimating the payoff to attending a more selecctive college: An application of selection on observables and unobservables,” *The Quaterly Journal of Economics*, November 2002, *117* (4), 1491–1527.

Dohmen, Thomas J., “Performance, seniority, and wages: Formal salary systems and individual earnings profiles,” *Labour Economics*, December 2004, *11* (6), 741–763.

Dustmann, Christian and Costas Meghir, “Wages, experience and seniority,” *The Review of Economic Studies*, January 2005, *72* (1), 77–108.

____ **and Sonia C. Pereira**, “Wage growth and job mobility in the United Kingdom and Germany,” *Industrial and Labor Relations Review*, April 2008, *61* (3), 375–393.

Eriksson, Tor and Jaime Ortega, “The adoption of job rotation: Testing the theories,” *Industrial and Labor Relations Review*, July 2006, *59* (4), 653–666.

Fallon, P. R. and P. R. G. Layard, “Capital-skill complementarity, income distribution, and output accounting,” *The Journal of Political Economy*, April 1975, *83* (2), 279–302.

Farber, Henry S. and Robert Gibbons, “Learning and wage dynamics,” *The Quarterly Journal of Economics*, November 1996, *111* (4), 1007–1047.

Ferrer, Ana M. and W. Craig Riddell, “The role credentials in the Canadian labour market,” *Canadian Journal of Economics*, November 2002, *35* (4), 879–905.

Galindo-Rueda, Fernando, “Employer learning and schooling-related statistical discrimination in Britain,” May 2003. Institute for the Study of Labor, Germany, IZA Discussion Paper series, No. 778.

Gathmann, Christina and Uta Schönberg, “How general is human capital?: A task-based approach,” *Journal of Labor Economics*, January 2010, *28* (1), 1–49.

Genda, Yuji, Ayako Kondo, and Souichi Ohta, “Long-term effects of a recession at labor market entry in Japan and the United States,” *Journal of Human Resources*, Winter 2010, *45* (1), 157–196.

Gibbons, Robert and Michael Waldman, "A theory of wage and promotion dynamics inside firms," *The Quarterly Journal of Economics*, November 1999, *114* (4), 1321–1358.

____ **, Lawrence F. Katz, Thomas Lemieux, and Daniel Parent**, "Comparative advantage, learning, and sectoral wage determination," *Journal of Labor Economics*, October 2005, *23* (4), 681–724.

Goldin, Claudia and Lawrence F. Katz, "Technology, skill and the wage structure: Insights from the past," *The American Economic Review*, May 1996, *86* (2), 252–257.

____ **and** ____ , "The origins of technology-skill complementarity," *The Quarterly Journal of Economics*, August 1998, *113* (3), 693–732.

____ **and** ____ , *The race between education and technology*, Cambridge, MA: The Belknap Press of Harvard University Press, 2008.

Gordon, Robert J., "Why U.S. wage and employment behavior differs from that in Britain and Japan," *The Economic Journal*, March 1982, *92* (365), 13–44.

Greenwald, Bruce C., "Adverce selection in the labour market," *The Review of Economic Studies*, July 1986, *53* (3), 325–347.

Groot, Wim and Hessel Oosterbeek, "Earning effects of different components of schooling: Human capital versus screening," *The Review of Economics and Statistics*, May 1994, *76* (2), 317–321.

Hansen, W. Lee, Burton A. Weisbrod, and William T. Scanlon, "Schooling and earnings of low achievers," *The American Economic Review*, June 1970, *60* (3), 409–418.

Hashimoto, Masanori and John Raisian, "Employment tenure and earnings profiles in Japan and the United States," *The American Economic Review*, September 1985, *75* (4), 721–735.

Hungerford, Thomas and Gary Solon, "Sheepskin effects in the returns to education," *The Review of Economics and Statistics*, February 1987, *69* (1), 175–177.

Jaeger, David A. and Marianne E. Page, "Degrees matter: New evidence on sheepskin effects in the returns to education," *The Review of Economics and Statistics*, November 1996, *78* (4), 733–740.

Kahn, Lisa B., "The long-term labor market consequences of graduating from college in a bad economy," *Labour Economics*, 2010, *17* (2), 303–316.

Lang, Kevin and David Kropp, "Human capital versus sorting: The effects of compulsory attendance laws," *The Quarterly Journal of Economics*, August 1987, *101* (3), 609–624.

Lange, Fabian, "The speed of employer learning," *Journal of Labor Economics*, January 2007, *25* (1), 1–35.

Lluis, Stéphanie, "The role of comparative advantage and learning in wage dynamics and intrafirm mobility: Evidence from Germany," *Journal of Labor Economics*, October 2005, *23* (4), 725–767.

Markey, James P. and William Parks II, "Occupational change: Pursuing a different kind of work," *Monthly Labor Review*, September 1989, *112* (9), 3–12.

Mincer, Jacob and Yoshio Higuchi, "Wage structure and labor turnover in the United States and Japan," *Journal of the Japanese and International Economies*, June 1988, *2* (2), 97–133.

Moriguchi, Chiaki, "Implicit contracts, the Great Depression, and institutional change: A comparative analysis of U.S. and Japanese employment relations, 1920-1940," *The Journal of Economic History*, September 2003, *63* (3), 625–665.

Münich, Daniel, Jan Svejnar, and Katherine Terrell, "Returns to human capital under communist wage grid and during the transition to a market economy," *The Review of Economics and Statistics*, February 2005, *87* (1), 100–123.

Nakamura, Naofumi, "Sengo Kamaishi seitetsujo ni okeru jukuren no saihen: hozen shokuba no jirei (From apprenticeships to firm-specific skills: a case of the maintenance workshop in the post-war Kamaishi Steel Works)," *Shakai Kagaku Kenkyu (The Journal of Social Science)*, March 2010, *61* (5-6), 3–26. Institute of Social Science, The University of Tokyo.

Neal, Derek, "Industry-specific human capital: Evidence from displaced workers," *Journal of Labor Economics*, October 1995, *13* (4), 653–677.

Ono, Hiroshi, "Lifetime employment in Japan: Concepts and measurements," *Journal of the Japanese and International Economies*, March 2010, *24* (1), 1–27.

Oreopoulos, Philip, "Estimating average and local average treatment effects of education when compulsory schooling laws really matter," *The American Economic Review*, March 2005, *96* (1), 152–175.

——, Till von Wachter, and Andrew Heisz, "The short- and long- term career effects of graduating in a recession," *American Economic Journal: Applied Economics*, January 2012, *4* (1), 1–29.

Osterman, Paul, "Institutional labor economics, the new personnel economics, and internal labor markets: A reconsideration," *Industrial and Labor Relations Review*, July 2011, *64* (4), 637–653.

Oyer, Paul, "Ability and employer learning: Evidence from the economist labor market," *Journal of the Japanese and International Economies*, June 2008, *22* (2), 268–289.

Parado, Eric, Asena Caner, and Edward N. Wollf, "Occupational and industrial mobility in the United States," *Labour Economics*, June 2007, *14* (3), 435–455.

Parent, Daniel, "Wages and mobility: The impact of employer-provided training," *Journal of Labor Economics*, April 1999, *17* (2), 298–317.

——, "Industry-specific capital and the wage profile: Evidence from the National Longitudinal Survey of Youth and the Panel Study of Income Dynamics," *Journal of Labor Economics*, April 2000, *18* (2), 306–323.

Pinkston, Joshua C., "Screening discrimination and the determinants of wages," *Labour Economics*, December 2003, *10* (6), 643–658.

——, "A test of screening discrimination with employer learning," *Industrial and Labor Relations Review*, January 2006, *59* (2), 267–284.

——, "A model of asymmetric employer learning with testable implications," *The Review of Economic Studies*, 2009, *76* (1), 367–394.

Pischke, Jörn-Steffen and Till von Wachter, "Zero returns to compulsory schooling in Germany: Evidence and interpretation," *The Review of Economics and Statistics*, August 2008, *90* (3), 592–598.

Poletaev, Maxim and Chris Robinson, "Human capital specificity: Evidence from the Dictionary of Occupational Titles and displaced worker survey, 1984-2000," *Journal of Labor Economics*, July 2008, *26* (3), 387–420.

Pons, Empar and Juan M. Blanco, "Sheepskin effects in the Spanish labour market: A public-sector analysis," *Education Economics*, September 2005, *13* (3), 331–347.

Riley, John G., "Testing the educational screening hypothesis," *The Journal of Political Economy*, October 1979, *87* (5-2), s227–s252.

Rosen, Sherwin, "Transaction costs and internal labor markets," *Journal of Law, Economics, & Organization*, Spring 1988, *4* (1), 49–64.

Schönberg, Uta, "Testing for asymmetric employer learning," *Journal of Labor Economics*, October 2007, *25* (4).

Shaw, Kathryn and Edward P. Lazear, "Tenure and output," *Labour Economics*, August 2008, *15* (4), 705–724.

Silles, Mary, "Sheepskin effects in the returns to education," *Applied Economics Letters*, February 2008, *15* (3), 217–219.

Spence, Michael, "Job market signaling," *The Quarterly Journal of Economics*, August 1973, *87* (3), 355–374.

Stiglitz, Joseph E., "The theory of "screening," education, and the distribution of income," *The American Economic Review*, June 1975, *65* (3), 283–300.

Tabman, Paul J. and Terence J. Wales, "Higher education, mental ability, and screening," *The Journal of Political Economy*, January 1973, *81* (1), 28–55.

Topel, Robert, "Specific capital, mobility, and wages: Wages rise with job seniority," *The Journal of Political Economy*, February 1991, *99* (1), 145–176.

Topel, Robert H. and Michael P. Ward, "Job mobility and the careers of young men," *The Quarterly Journal of Economics*, May 1992, *197* (2), 439–479.

Tyler, John H., Richard J. Murnane, and John B. Willett, "Estimating the labor market signaling value of GED," *The Quarterly Journal of Economics*, May 2000, *115* (2), 431–468.

Umezaki, Osamu, "Keiei gorika to tokai tenshutsu: 1960 nendai ni okeru naibu rodo shijo keisei no ichi sokumen (Restructuring of Kamaishi Iron and Steel Works and the transfer of emoloyees to Tokai Iron and Steel Works: an analysis of the internal labour market formation in the 1960s)," *Shakai Kagaku Kenkyu (The Journal of Social Science)*, March 2010, *61* (5-6), 27–54. Institute of Social Science, The University of Tokyo.

von Wachter, Till and Stefan Bender, "In the right place at the wrong time: The role of firms and luck in young workers," *The American Economic Review*, December 2006, *96* (5), 1679–1705.

____ and ____, "Do initial conditions persist between firms?: An analysis of firm-entry cohort effects and job losers using matched employer-employee data," in Stefan Bender, Julia Lane, Kathryn Shaw, Fredrik Andersson, and Till von Wachter, eds., *The analysis of firms and employees: Quantitative and qualitative approaches*, Chicago University Press Chicago 2008, pp. 135–162.

Waldman, Michael, "Job assignments, signalling, and efficiency," *Rand Journal of Economics*, Summer 1984, *15* (2), 255–267.

Weinberg, Bruce A., "Long-term wage fluctuations with industry-specific human capital," *Journal of Labor Economics*, January 2001, *19* (1), 231–264.

Williamson, Oliver, Michael Wachter, and Jeffrey Harris, "Understanding the employment relation: the analysis of idiosyncratic exchange," *The Bell Journal of Economics*, Spring 1975, *6* (1), 250–278.

Table 1 Emplyee numbers, years of schooling, and previous experience across cohorts.

Year joined	Number of employees who joined	Number of observations	Years of schooling (yos)				Years of previous experience (pre)				Nationwide events
			max	min	median	mean	max	min	median	mean	
yj1928	1	35	9	9	9	9.00	3	3	3	3.00	
yj1929	1	38	8	8	8	8.00	1	1	1	1.00	
yj1930	1	34	8	8	8	8.00	2	2	2	2.00	
yj1931	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
yj1932	0	0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
yj1933	3	92	8	8	8	8.00	5	2	2	2.75	
yj1934	2	62	8	6	6	6.94	11	5	5	7.81	
yj1935	5	158	8	8	8	8.00	9	1	1	3.94	
yj1936	7	220	8	8	8	8.00	9	1	6	5.77	
yj1937	7	214	8	6	8	7.74	12	1	8	6.51	
yj1938	18	534	8	6	8	7.54	13	0	6	5.30	
yj1939	41	1,175	8	6	8	7.91	13	0	5	5.15	
yj1940	43	1,196	8	6	8	7.81	12	0	6	5.29	War effort
yj1941	44	1,162	9	6	8	7.88	13	0	4	4.70	
yj1942	31	788	9	6	8	7.71	16	0	2	4.33	
yj1943	25	605	9	0	8	7.61	14	0	3	4.39	
yj1944	27	626	8	0	8	7.42	16	0	2	4.44	
yj1945	18	399	8	6	8	7.78	3	0	1	0.85	
yj1946	19	388	8	6	8	7.78	22	0	1	3.37	
yj1947	12	226	8	6	8	7.84	3	0	1	0.89	
yj1948	293	5,664	12	6	8	8.01	23	0	9	9.64	
yj1949	266	4,795	12	6	8	8.05	21	0	8	8.64	
yj1950	38	634	12	6	9	8.38	26	0	6	5.83	Reconstruction
yj1951	54	889	9	6	8	7.66	21	5	9	9.41	
yj1952	7	105	9	6	8	7.82	10	5	7	7.31	
yj1953	13	154	12	9	9	9.16	4	0	3	2.77	
yj1954	19	238	12	9	9	9.79	3	0	3	2.31	
yj1955	11	124	9	9	9	9.00	3	2	3	2.88	
yj1956	93	973	12	7	9	8.81	20	1	7	7.43	
yj1957	71	657	12	6	9	8.90	18	0	6	7.03	
yj1958	26	199	9	9	9	9.00	9	2	3	3.10	
yj1959	89	610	14	8	9	10.08	15	0	3	3.84	Rapid growth began
yj1960	46	265	12	8	9	10.19	26	0	3	4.85	
yj1961	37	161	12	9	9	9.15	12	1	3	4.07	
yj1962	89	312	12	8	12	10.73	9	0	2	2.08	
yj1963	43	117	12	0	9	7.60	36	2	12	10.30	
yj1964	17	88	9	6	8	8.13	35	2	20	20.63	
yj1965	9	35	12	8	12	11.09	5	1	1	1.91	
yj1966	10	31	12	12	12	12.00	13	0	1	2.06	
yj1967	8	19	12	9	9	10.42	14	1	5	6.47	
total	1,544	24,022									

Notes : Previous experience: Years after graduating school, before employed by the firm.

Table 2 Cohort effect in panel estimations.

	2-1			2-2		
Estimation method	panel least squares					
Dependent variable	log(rw)					
Cross-section	pooled (no cross-section dummy)					
Period (year)	fixed (year dummies inserted)					
Indepedent variables	coefficient	*t* statistic		coefficient	*t* statistic	
c	0.4680	25.0154	**	-0.2692	-5.3959	***
log(yos)	0.1396	31.7046	**	0.1372	31.6735	***
log(exp)	0.2116	112.8607	**	0.2087	111.7480	***
log(ten)	0.0349	17.2919	**			
yj1930-1931	-0.0331	-1.5826		0.1614	3.0335	***
yj1932-1933	-0.0488	-3.1105	**	0.0275	0.7193	
yj1934-1935	-0.0752	-5.4992	**	0.0937	2.7562	***
yj1936-1937	-0.0924	-7.0411	**	0.0986	2.8601	***
yj1938-1939	-0.1171	-9.3742	**	0.0786	2.2733	**
yj1940-1941	-0.1575	-12.6004	**	0.1100	3.0945	***
yj1942-1943	-0.1990	-15.6638	**	0.1298	3.5129	***
yj1944-1945	-0.2690	-20.8844	**	0.0929	2.4309	**
yj1946-1947	-0.3049	-23.0515	**	0.0810	2.0336	**
yj1948-1949	-0.3176	-24.9450	**	0.1468	3.6206	***
yj1950-1951	-0.3907	-29.8522	**	0.1254	2.9612	***
yj1952-1953	-0.4265	-29.9381	**	0.1681	3.7131	***
yj1954-1955	-0.4467	-31.5828	**	0.2185	4.7186	***
yj1956-1957	-0.5752	-42.2726	**	0.1104	2.3354	**
yj1958-1959	-0.6238	-43.9963	**	0.1559	3.1455	***
yj1960-1961	-0.6643	-44.8111	**	0.1656	3.2143	***
yj1962-1963	-0.6663	-43.5349	**	0.2260	4.2484	***
yj1964-1965	-0.6600	-38.8257	**	0.2381	4.0795	***
yj1966-1967	-0.6611	-30.2358	**	0.3515	4.6687	***
yj1928-1929×log(ten)				0.0293	16.2214	***
yj1930-1931×log(ten)				0.0214	8.9992	***
yj1932-1933×log(ten)				0.0314	18.7486	***
yj1934-1935×log(ten)				0.0289	19.9306	***
yj1936-1937×log(ten)				0.0307	22.6879	***
yj1938-1939×log(ten)				0.0339	26.6975	***
yj1940-1941×log(ten)				0.0328	25.8876	***
yj1942-1943×log(ten)				0.0325	25.1261	***
yj1944-1945×log(ten)				0.0343	25.9873	***
yj1946-1947×log(ten)				0.0376	26.7625	***
yj1948-1949×log(ten)				0.0364	29.2215	***
yj1950-1951×log(ten)				0.0381	28.4383	***
yj1952-1953×log(ten)				0.0362	19.5862	***
yj1954-1955×log(ten)				0.0339	18.7833	***
yj1956-1957×log(ten)				0.0416	28.5900	***
yj1958-1959×log(ten)				0.0377	19.9354	***
yj1960-1961×log(ten)				0.0372	13.5988	***
yj1962-1963×log(ten)				0.0337	9.3925	***
yj1964-1965×log(ten)				0.0591	8.9090	***
yj1966-1967×log(ten)				0.0443	1.9670	**
year dummies	yes			yes		
cross-sections included	1,489			1,489		
periods included (years)	41 (1929-1969)			41 (1929-1969)		
included observations	22,038			22,038		
adjusted R^2	0.9785			0.9793		
F statistic	16,194.9638 ***			12,870.9100 ***		

Notes : Base year joined dummy is yj1928-1929. *** and ** respectively denote significance at the 1 percentage point and 5 percentage points.

Table 3 Cohort effect on wage curves.

		3-1		
Estimation method		panel generalized least squares		
Dependent variable		$\log(rw_{ten})$		
Cross-section		random effect		
Period (year)		pooled (no year dummies inserted)		
Indepedent variables		coefficient	*t* statistic	
	c	0.2768	33.7436	***
	log(yos)	-0.0058	-0.9670	
1st lagged	yj1928-1929×$\log(rw_{ten-1})$	0.6591	17.8795	***
	yj1930-1931×$\log(rw_{ten-1})$	0.7896	16.1036	***
	yj1932-1933×$\log(rw_{ten-1})$	0.7523	23.6394	***
	yj1934-1935×$\log(rw_{ten-1})$	0.7800	43.1213	***
	yj1936-1937×$\log(rw_{ten-1})$	0.7588	48.3209	***
	yj1938-1939×$\log(rw_{ten-1})$	0.6790	70.5484	***
	yj1940-1941×$\log(rw_{ten-1})$	0.6975	89.0630	***
	yj1942-1943×$\log(rw_{ten-1})$	0.6963	68.9359	***
	yj1944-1945×$\log(rw_{ten-1})$	0.6504	66.6299	***
	yj1946-1947×$\log(rw_{ten-1})$	0.6890	58.7092	***
	yj1948-1949×$\log(rw_{ten-1})$	0.6510	79.5999	***
	yj1950-1951×$\log(rw_{ten-1})$	0.6307	43.2827	***
	yj1952-1953×$\log(rw_{ten-1})$	0.5976	17.6353	***
	yj1954-1955×$\log(rw_{ten-1})$	0.5719	17.5231	***
	yj1956-1957×$\log(rw_{ten-1})$	0.6604	21.4470	***
	yj1958-1959×$\log(rw_{ten-1})$	0.7144	17.9427	***
	yj1960-1961×$\log(rw_{ten-1})$	0.6696	13.7528	***
	yj1962-1963×$\log(rw_{ten-1})$	0.8186	16.7073	***
	yj1964-1965×$\log(rw_{ten-1})$	0.5956	12.3413	***
	yj1966-1967×$\log(rw_{ten-1})$	0.6237	3.2366	***
2nd lagged	yj1928-1929×$\log(rw_{ten-2})$	0.2417	6.2659	***
	yj1930-1931×$\log(rw_{ten-2})$	0.0905	1.7982	**
	yj1932-1933×$\log(rw_{ten-2})$	0.1367	4.0860	***
	yj1934-1935×$\log(rw_{ten-2})$	0.0974	5.1763	***
	yj1936-1937×$\log(rw_{ten-2})$	0.1196	7.3772	***
	yj1938-1939×$\log(rw_{ten-2})$	0.2021	20.6744	***
	yj1940-1941×$\log(rw_{ten-2})$	0.1755	22.6940	***
	yj1942-1943×$\log(rw_{ten-2})$	0.1735	17.1059	***
	yj1944-1945×$\log(rw_{ten-2})$	0.2133	22.0184	***
	yj1946-1947×$\log(rw_{ten-2})$	0.1680	14.5816	***
	yj1948-1949×$\log(rw_{ten-2})$	0.2124	27.8185	***
	yj1950-1951×$\log(rw_{ten-2})$	0.2254	15.3842	***
	yj1952-1953×$\log(rw_{ten-2})$	0.2485	6.9029	***
	yj1954-1955×$\log(rw_{ten-2})$	0.2702	7.7968	***
	yj1956-1957×$\log(rw_{ten-2})$	0.1670	5.1291	***
	yj1958-1959×$\log(rw_{ten-2})$	0.0862	2.0206	**
	yj1960-1961×$\log(rw_{ten-2})$	0.1212	2.3170	**
	yj1962-1963×$\log(rw_{ten-2})$	-0.0564	-1.0533	
	yj1964-1965×$\log(rw_{ten-2})$	0.2478	4.5225	***
	yj1966-1967×$\log(rw_{ten-2})$	0.1691	0.7385	
	interaction of year dummy and yos: dy×yos	yes		
	cross-sections included	1,433		
	periods included (years)	39 (1931-1969)		
	included observations	18,786		
	adjusted R^2	0.9853		
	F statistic	15,966.5019 ***		

Notes : *** and ** respectively denote significance at the 1 percentage point and 5 percentage points.

Table 4 Wage regressions: decomposition of wage growth to somatic characteristics, schooling, experience, and employer learning.

	4-1			4-2			4-3			4-4		
Estimation method	panel generalized least squares											
Dependent variable	log(rw)											
Cross-section	random effect											
Period (year)	pooled (no year dummies inserted)											
Indepedent variables	coefficient	*t* statistic		coefficient	*t* statistic		coefficient	*t* statistic		coefficient	*t* statistic	
c	-7.7667	-52.1003	***	-3.3614	-46.0811	***	-9.5217	-62.2208	***	-3.4895	-50.1303	***
log(hgt)							0.9889	4.8336	***	0.8989	7.5772	***
log(yos)	3.0015	46.0606	***	1.0541	34.0716	***	3.7511	57.5712	***	1.1400	40.3621	***
psw	0.4091	44.0165	***	0.5185	56.1763	***	0.3730	41.9127	***	0.5044	55.1572	***
log(exp)	2.5869	48.7570	***	0.4717	68.3996	***	3.2810	57.5520	***	0.3871	51.0462	***
log(ten)	0.3719	87.4122	***	1.1359	36.3905	***	0.4711	113.1134	***	1.5802	46.9811	***
log(hgt)×log(exp)							-0.3351	-4.4371	***			
log(hgt)×log(ten)										-0.3788	-7.4829	***
log(yos)×log(exp)	-0.9376	-40.6812	***				-1.2597	-52.0852	***			
log(yos)×log(ten)				-0.3381	-23.6940	***				-0.4868	-31.7665	***
dcy	-0.4059	-3.6801	***	-0.4247	-3.7687	***	-0.2035	-2.3178	**	-0.2212	-2.4282	**
dcy×log(ten)	0.1496	3.2500	***	0.1545	3.3118	***	0.0504	1.3983		0.0547	1.4871	
sy	-0.3353	-19.4785	***	-0.3537	-20.1587	***	-0.2591	-17.8232	***	-0.2906	-19.3064	***
sy×log(ten)	0.1423	19.6474	***	0.1465	20.0213	***	0.0933	15.8574	***	0.1033	17.2067	***
dct	-0.2985	-9.6032	***	-0.3345	-10.5615	***	-0.2028	-6.3568	***	-0.1967	-5.9452	***
dct×log(ten)	0.0967	7.8552	***	0.1043	8.3757	***	0.0868	6.6855	***	0.0865	6.5389	***
dc	0.3518	21.8293	***	0.2909	17.7911	***	0.5078	38.2092	***	0.3858	28.4641	***
dc×log(ten)	-0.1375	-18.3605	***	-0.1328	-17.4057	***	-0.2372	-38.2659	***	-0.2193	-34.3170	***
cross-sections included	1,537			1,537			1,219			1,219		
periods included (years)	41(1929-1969)			41(1929-1969)			31(1939-1969)			31(1939-1969)		
included observations	23,172			23,172			16,486			16,486		
adjusted R^2	0.7332			0.7256			0.8560			0.8447		
F statistic	4,899.0627 ***			4,715.3657 ***			6,534.1880 ***			5,978.7079 ***		

Notes : *** and ** respectively denote signifnicance at the 1 percentage level and at 5 percatage level. The records before 1939 lack the information about physiological characteristics.

Table 5 Interaction of schooling previous epxerience/tenure: without conrol of cohort effects.

	5-1		
Estimation method	panel generalized least squares		
Dependent variable	log(rw)		
Cross-section	random effect		
Period (year)	pooled (no year dummies inserted)		
Indepedent variables	coefficient	*t* statistic	
c	1.0566	17.7992	***
log(yos)	0.0550	2.1187	**
log(pre)	-0.3464	-13.4326	***
log(ten)	0.6582	63.8259	***
log(yos)×log(pre)	0.1932	17.0794	***
log(yos)×log(ten)	-0.1987	-43.1558	***
interaction of year dummy and yos: dy×yos	yes		
cross-sections included	1,489		
periods included (years)	41(1929-1969)		
included observations	22,038		
adjusted R^2	0.9720		
F statistic	16,994.0390 ***		

Notes : *** and ** respectively denote significance at the 1 percentage point and 5 percentage points.

Table 6 Interaction of schooling and previous epxerience/tenure: robustness check with control of cohort and other effects.

		6-1		
Estimation method		panel generalized least squares		
Dependent variable		log(rw)		
Cross-section		random effect		
Period (year)		pooled (no year dummies inserted)		
Indepedent variables		coefficient	*t* statistic	
	c	1.2964	81.2347	***
	log(pre)	-0.4820	-39.1322	***
	log(ten)	0.4613	47.0426	***
previous experience	yj1928-1929×log(yos)×log(pre)	0.1284	4.6176	***
	yj1930-1931×log(yos)×log(pre)	0.2534	5.8745	***
	yj1932-1933×log(yos)×log(pre)	0.1460	8.1160	***
	yj1934-1935×log(yos)×log(pre)	0.2532	27.1733	***
	yj1936-1937×log(yos)×log(pre)	0.2721	35.5659	***
	yj1938-1939×log(yos)×log(pre)	0.2591	40.6432	***
	yj1940-1941×log(yos)×log(pre)	0.2722	44.5023	***
	yj1942-1943×log(yos)×log(pre)	0.2794	44.2258	***
	yj1944-1945×log(yos)×log(pre)	0.2576	39.1331	***
	yj1946-1947×log(yos)×log(pre)	0.2464	35.3082	***
	yj1948-1949×log(yos)×log(pre)	0.2804	50.3265	***
	yj1950-1951×log(yos)×log(pre)	0.2643	46.0690	***
	yj1952-1953×log(yos)×log(pre)	0.2635	39.7984	***
	yj1954-1955×log(yos)×log(pre)	0.2575	37.7142	***
	yj1956-1957×log(yos)×log(pre)	0.2325	42.3614	***
	yj1958-1959×log(yos)×log(pre)	0.2064	37.2464	***
	yj1960-1961×log(yos)×log(pre)	0.2010	35.3942	***
	yj1962-1963×log(yos)×log(pre)	0.1943	34.5856	***
	yj1964-1965×log(yos)×log(pre)	0.2470	39.5138	***
	yj1966-1967×log(yos)×log(pre)	0.2103	26.6658	***
tenure	yj1928-1929×log(yos)×log(ten)	-0.0328	-3.2824	***
	yj1930-1931×log(yos)×log(ten)	-0.0893	-5.9885	***
	yj1932-1933×log(yos)×log(ten)	-0.0404	-4.9408	***
	yj1934-1935×log(yos)×log(ten)	-0.0941	-15.9109	***
	yj1936-1937×log(yos)×log(ten)	-0.1072	-19.7566	***
	yj1938-1939×log(yos)×log(ten)	-0.0998	-20.5446	***
	yj1940-1941×log(yos)×log(ten)	-0.1154	-24.2276	***
	yj1942-1943×log(yos)×log(ten)	-0.1236	-25.8829	***
	yj1944-1945×log(yos)×log(ten)	-0.1204	-25.1002	***
	yj1946-1947×log(yos)×log(ten)	-0.1183	-24.0692	***
	yj1948-1949×log(yos)×log(ten)	-0.1513	-33.5383	***
	yj1950-1951×log(yos)×log(ten)	-0.1505	-32.5777	***
	yj1952-1953×log(yos)×log(ten)	-0.1623	-31.7789	***
	yj1954-1955×log(yos)×log(ten)	-0.1619	-33.6151	***
	yj1956-1957×log(yos)×log(ten)	-0.1622	-36.3124	***
	yj1958-1959×log(yos)×log(ten)	-0.1661	-36.7977	***
	yj1960-1961×log(yos)×log(ten)	-0.1744	-35.5727	***
	yj1962-1963×log(yos)×log(ten)	-0.1864	-35.9705	***
	yj1964-1965×log(yos)×log(ten)	-0.1939	-26.6854	***
	yj1966-1967×log(yos)×log(ten)	-0.2286	-20.1566	***
	dcy, sy, dct, dc	yes		
	dcy×log(ten), sy×log(ten), dct×log(ten), dc×log(ten)	yes		
	interaction of year dummy and yos: dy×yos	yes		
	cross-sections included	1,489		
	periods included (years)	41(1929-1969)		
	included observations	22,038		
	adjusted R^2	0.9808		
	F statistic	12,494.1280 ***		

Notes : *** denotes significance at the 1 percentage point.

Appendix List of variables.

variable	definition	
rw	real daily wage.	
hgt	relative height when employed by the firm: (observed hight)/(average hight at his age in the year).	
yos	years of schooling: (years of schooling)+1.	
psw	postwar education generation (12 years old or younger in 1947).	dummy variable
exp	experience in the labor market: age–(6+yos)+1.	
pre	previous experience: age–(6+yos+ten)+1. Note that every sample emolyee had worked at the firm until the last year of his record.	
yj19XX	dummy of year joined: =1 if joined the firm in 19XX.	dummy variable
yj19XX-19YY	dummy of year joined: =1 ifjoined the firm from 19XX to 19YY.	dummy variable
dy19XX	year dammy.	dummy variable
ten	tenure: (years after employed by the firm)+1.	
dcy	1 if completed Development Center for Youth (from 1927 to 1935).	dummy variable
sy	1 if completed School for Youth (from 1935 to 1948).	dummy variable
dct	1 if completed Development Center for Technician (from 1939 to 1946).	dummy variable
dc	1 if completed Development Center (from 1946 to 1973).	dummy variable

Notes : The source of average height is the School Health Statistics surveyed by the Ministry of Education, Science, Sports and Culture (http://www.e-stat.go.jp/).