Schooling, employer learning, and the internal labor market effect: wage dynamics and human capital investment in the Japanese steel industry, the 1930-1960s

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Schooling, Employer Learning, and the Internal Labor Market Effect

Wage Dynamics and Human Capital Investment in the Japanese Steel Industry, the 1930-1960s*

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Abstract

The impact of schooling on wages decreases as employers learn about workers' abilities from their experience. While this employer 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 before gaining long-term employment, being dominated by complementarity between schooling experience, and (2) the employer learning effect dominates the complementarity effect after gaining long-term employment; the internal labor market affects workers' human capital investment and asymmetrically facilitates employer learning.

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

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The employer learning model established by Farber and Gibbons (1996) clearly predicts that the impact of schooling on wage decreases during workers' experience in the labor market as employers "publicly" learn about workers' abilities, which are hidden when the workers join the competitive labor market. 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) and Altonji and Pierret (2001) evidenced the prediction, followed by supporting works concerning the US labor market.[1]

Meanwhile, the public employer learning model has been questioned by the diverse reality of the labor market. An approach to address the reality is explicit extension of modeling toward asymmetry in employer learning, as suggested by Pinkston (2009). At the same time, a potentially major example of asymmetric employer learning appears to be in internal labor markets of large firms, within which the primary elements of statistical assumptions of the public learning model are maintained, while internal labor markets themselves are shielded from the outside market. This research intends to extend the scope of the public employer leaning model to study employer learning under such semi-public conditions.

Empirical results here, based on micro data from a Japanese manufacturing firm, show that employer learning is not observed for work experience before employees gain long-term employment with the firm but is observed after the gain long-term employment with the firm. 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. This paper addresses the mechanism by splitting work experience into the experience before and the experience after gaining long-term employment with the case firm. By doing so, it examines a specific effect of internal labor markets on employer learning.

Section 1 reviews related literature, and focuses attention on employer learning in internal labor markets. Section 2 suggests 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 and thus the public employer learning model is allowed to be applied. Then it presents the estimation model that separates work experience into before gaining long-term employment with the firm and after gaining such employment. Our semi-public approach intends, with maintaining tractability of the public employer learning model by Farber and Gibbons (1996), to inquire 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 the expense of tractability.

Section 3 describes the data and then, verifies the existence of the internal labor market at the case firm. Section 4 presents the empirical results, which show that short-term work experience at younger ages and schooling 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 internal labor market both induced investment in firm-specific human capital and facilitated employer learning.

[1]See Farber and Gibbons (1996); Altonji and Pierret (2001); Pinkston (2006); Lange (2007); and Oyer (2008).

1 Review of employer learning in internal labor markets

1.1 Symmetric employer learning questioned

While abilities of individual workers is difficult to observe, a worker's educational background is an observable proxy nd 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; such statistical discrimination could lead to a considerable gap between wages and realized performance.[2] Motivated by this screening hypothesis, the rich empirical results supporting the "sheepskin effects" of schooling have been presented for the United States and several other economies.[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, in developing, even in planned economies and hence basically everywhere. 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.

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

The first is the reality of asymmetry in employer learning, which is suggested by Galindo-Rueda (2003), Schönberg (2007), and especially Pinkston (2009), who explicitly modeled asymmetric employer learning. While explicit modeling is theoretically allegiant, in some cases in which asymmetric learning is observed, statistical assumptions of symmetric learning are maintained. A typical case is internal labor markets of major firms. Establishments within a large firm compete each other, and employees do not leave because of quasi-rent in their wages which is return on the employees' firm-specific human capital on the equilibrium. Then, as discussed below, statistical assumptions of the public learning model by Farber and Gibbons (1996) are retained within the internal labor market, and we can capitalize on tractability of the public learning model to study wage growth asymmetric between inside and outside the internal labor market.

The other issue concerns the workers' attitudes toward human capital investment. The non-increasing coefficient of the interaction term between schooling and experience, the in-

[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), pp. 323-331 denied the "sheepskin effect," this research provides the opposite result. For the United Kingdom, see McGuinnes (2003); and 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).

dicator 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] a relationship that does not seem to always hold as industrial economies have experienced technology-skill/education complementary 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 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 US 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 as emphasized by Goldin and Katz (2008), the extent of complementarity between schooling and worker experience is largely affected by the extent of human capital specificity, which depends on the institutional arrangements of the labor market. The German labor market encourages concentration in industry-specific human capital, while the Japanese labor market tends to investment in firm-specific human capital.[6] Meanwhile, the US labor market places more emphasis on industry-specificity than firm-specificity while firm-specific human capital has a positive impact on the wage growth, staying between the German and the Japanese markets but tending slightly toward the former.[7]

The extent of the schooling-experience complementarity could change also as the worker ages. As Topel and Ward (1992) demonstrated for the US 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 considerable 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 supposed to contribute to general human capital, while later long-term employment is supposed to contribute to firm-specific human capital. For the German case, young workers are expected to typically invest in “portable” general human capital as evidenced by regular job changes in the early stages of their careers, followed by gaining into long-term employment.[9]

People in the competitive market, especially under short-term employment contracts, are

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

[6] See Dustmann and Meghir (2005), pp. 90-96; 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 Wollf (2007), pp.445-447.

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

likely to choose work experiences that complement their schooling if the other conditions are fixed. This strategy of human capital investment has become even more desirable since the early twentieth century, as the technology-skill/education complementarity has become augmented by 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 learn general skills at secondary schools.[10]

Under the technology-skill/education complementary development, workers are likely to choose work experiences such that they invest in general human capital complementary to their educational backgrounds at young ages. Thus, 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 internal promotion, that is, an internal labor market policy, then the employee has incentives to invest in firm-specific human capital. Such firm-specific human capital might be less complementary to schooling. The degree of technology-skill/education complementarity could interact with the institutional arrangement in the labor market, and accordingly, the employer learning process. The German labor market appears to be designed as friendly to investment in human capital standardized at the industry level by the apprentice system,[11] as compared with the labor markets of the United States, the United Kingdom,[12] and Japan examined in this research.

Meanwhile, internal labor markets in practice serve as a device of employer learning by current employers as presented by Baker, Gibbs and Holmstrom (1994b) and Eriksson and Ortega (2006).[13] In addition, asymmetric employer learning is not only supported by the internal labor market but also strengthens it.[14]

While the coefficient of the interaction term between schooling and experience is a tractable measure of employer learning, this also measures extent of human capital specificity. The labor market diversity comprises an institutional framework that encourages human capital investment and an informational structure, such as that of internal labor markets, which enables employers to learn about workers' abilities. Therefore the interaction term between schooling and experience is a focal point of comparative analysis of the diversified labor markets.

Following the classic employer learning model, Galindo-Rueda (2003), Schönberg (2007), and Pinkston (2009) are conscious of a possible asymmetry in employer learning. Bauer and Haisken-DeNew (2001) address 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 both inside and outside the internal labor market using panel data of the Japanese steel industry from the period when the the internal labor market policy was formed.

[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 Dustmann and Meghir (2005), p. 79.

[12]See Galindo-Rueda (2003), pp. 8-17,

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

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

1.3 Internal labor markets

The internal labor markets characterized by long-term employment and internal promotion are widely observed for highly skilled workers of large companies in developed economies when the firm knows the necessary skills well and 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 to make the wages sensitive to the employees' performance through employer learning and to give the employees incentives to invest in firm-specific human capital under asymmetric information between the employer and employees.[15]

Japanese heavy manufacturing, as in the United States, began to form internal labor markets in the 1920s, and after the Second World War, it became even more internal-labor-market-oriented.[16] Transition to the internal labor markets in long-existing major industries was accompanied by the dissolution of an autonomous intermediary labor organization into a labor organization systematically planned and directly controlled by firms. Such a transition would proceed with a technological transformation that provides the firms with informational advantages in the acquisition of relevant human capital, 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. As with the US steel industry, the core of the transition was to construct a work organization with a systematic wage and promotion scheme.

This research addresses the 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 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).[17] Let $y_{i,t}$ denote the output of the ith worker, $i = 1, \dots, n$, in the tth period, $t = 1, \dots, T$, η_i denote the ith worker's ability that is not observable by employers when the worker joins the labor market but is learned about by employers, yos_i denote the years of schooling the ith worker completed that is observable by employers, $\boldsymbol{x}_i$ denote a vector of time-invariant characteristics of the ith worker other than the years of schooling that are

[15]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.

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

[17]See Farber and Gibbons (1996), pp. 1010-1014.

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 $G(y_{i,t} \mid \eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ can be arbitrary and that the outputs $y_{i,t}$ are independently drawn from $G(y_{i,t} \mid \eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$. We also assume the joint distribution $F(\eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ can be arbitrary. All employers are assumed to know $F(\eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and $G(y_{i,t} \mid \eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and to observe $y_{i,1}, \ldots, y_{i,t}$. Thus both incumbent and entrant employers symmetrically learn about the ith employee's ability in the market.

Finally, we assume that the wage paid to the ith worker in period t equals expected output given all available information in period t about the worker,

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

which is realized by the competition between employers. We additionally assume that the conditional expectation $E\big(y_{i,t} \mid \text{yos}_i, \mathbf{x}_i, \mathbf{z}_i, y_{i,1}, \ldots, y_{i,t-1}\big)$ 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 employer learning model to fit to the random effect estimation. Consider a random effect model of the panel least square regression of the ith employee's wage at time t, $w_{i,t}$, with $\boldsymbol{x}_i$, which is an $m-2$ dimensional vector whose factors are observable characteristics included in data other than the years of schooling and are numbered from 3,

$$w_{i,t} = \alpha_0 + \alpha_1 \text{yos}_i + \alpha_2 \text{yos}_i \times t + \alpha_3 x_{3,i} + \cdots + \alpha_j x_{j,i} + \cdots + \alpha_m x_{m,i} + \eta_i + \epsilon_{i,t}, \tag{2}$$

where the stochastic variable η_i captures the time-invariant characteristics unobserved by the employer.

Furthermore,

$$\mathit{\Delta}_t w_{i,t} = \alpha_2 \text{yos}_i + \mathit{\Delta}_t E(\eta_i \mid \text{yos}_i, x_i) + \mathit{\Delta}_t \epsilon_{i,t} \equiv \alpha_2 \text{yos}_i + \varphi_{i,t}, \tag{3}$$

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 factor is w_i, denoted by $E^*(\boldsymbol{w} \mid \cdot)$, yields[18]

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

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

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

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

where the jth factor of $\hat{\boldsymbol{\alpha}}$, $\hat{\alpha}_j$ is increasing in the numerator, $\sum_{t=1}^{T}\sum_{i=1}^{n} x_{j,i}w_{i,t}$. The numerator is the only combination including $\boldsymbol{w}$, and thus variation of interaction between observable characteristics and $\boldsymbol{w}$ is involved only in the numerator.

Therefore, with other conditions controlled for, $\hat{\alpha}_2$ is increasing in $\sum_{t=1}^{T}\sum_{i=1}^{n}(\text{yos}_i \times t) \times w_{i,t}$ and hence is increasing in the value standardized by a non-stochastic number $TnE(\text{yos} \times t)E(w)$, $\sum_{t=1}^{T}\sum_{i=1}^{n}(\text{yos}_i \times t) \times w_{i,t} - TnE(\text{yos} \times t)E(w) = \text{Cov}(\text{yos}_i \times t, w_{i,t})$. In addition, from equation (3), we have

$$\text{Cov}(\text{yos}_i \times t, w_{i,t}) = \sum_{\tau}^{T} \text{Cov}(\text{yos}_i \times \tau, \varphi_{i,\tau}) \tag{5}$$

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 period $t = 1, \ldots, T$.

In the cross-sectional dimension, $\text{Cov}(\text{yos} \times \tau, \varphi_\tau)$ is increasing in the degree of complementarity between 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' hidden characteristics when recruiting, which are captured by η_i, and that η_i approaches a stationary state at some point $\bar{t}$ such that $\Delta_\tau E(\eta_i \mid \text{yos}_i, \tau - 1)$ is decreasing in $\tau \leq \bar{t}$ and $\Delta_\tau E(\eta_i \mid \text{yos}_i, \tau - 1) = 0$ for $\tau > \bar{t}$. Then $\text{Cov}(\text{yos}_i \times \tau, \varphi_i)$ is decreasing in $\tau \leq \bar{t}$ and $\text{Cov}(\text{yos}_i \times t, \varphi_i) = 0$ for $\tau > \bar{t}$ for each i. Thus, $\text{Cov}(\text{yos}_i \times \tau, w_{it})$ is decreasing for $t \leq \bar{t}$ and 0 for $t > \bar{t}$ in the longitudinal dimension over t for each individual worker i.

Hence, in the antilogarithmic specification, if the employer learning effect in the longitudinal dimension dominates the complementary effect between schooling and experience in the cross-sectional dimension, $\hat{\alpha}_2$ should be non-positive. Suppose that the wages, with marginal productivity, increase over experience, and then take the logarithmic expression of all variables.[19] 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,[20] in which plural units compete each other, return on firm-specific human capital is positive, thus 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

[19] 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.

[20] We typically assume the one described by Chandler (1977), pp. 1-12.

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 observe $y_{i,1}, \ldots, y_{i,t}$. 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 about within the internal labor market, trajectories of wage growth are asymmetric between inside and outside the internal labor market because employees do not leave due to quasi-rent earned from firm specific-human capital and thus $G(y_{i,t} \mid \eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ and $F(\eta_i, \text{yos}_i, \boldsymbol{x}_i, \boldsymbol{z}_i)$ remain unknown to outside employers. We define these properties as semi-public.

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 quasi-rent from firm-specific human capital is positive.. Furthermore, long-term employment also helps current employers learn about their employees' abilities.

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

$$\begin{aligned} w_{i,t} = \beta_0 &+ \beta_1 \text{yos}_i \\ &+ \beta_2 \text{yos}_i \times \text{pre} + \beta_3 \text{yos}_i \times \text{ten} \\ &+ \beta_4 \text{exp} + \beta_5 \text{ten} + \boldsymbol{\gamma}^T \boldsymbol{x_i} + \boldsymbol{\delta}^T \boldsymbol{x_i} \times \text{ten} + \eta_i + \epsilon_{i,t}. \end{aligned} \tag{6}$$

Recall that $\boldsymbol{x_i}$ represents the vector of time-invariant characteristics other than educational background.

A critical condition of the semi-public properties is that return on firm-specific human capital is sufficiently large to prevent employees from deviating the internal labor market on the equilibrium. Thus, significantly positive coefficient of ten, $\beta_5 > 0$, is necessary.

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* $(\text{yos} \times \text{pre})$ *is expected to be greater than the interaction term between the years of schooling and the tenure after employment with the firm* $(\text{yos} \times \text{ten})$*; thus* $\hat{\beta}_2 > \hat{\beta}_3$.

Then 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 US occupation. After the US 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 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 modernization post-1950s 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.[21]

As part of a company-wide investment plan, Fuji decided to build a new state-of-the-art plant Tokai in Nagoya, a large city distant from Kamaishi. The firm also decided to decrease Kamaishi's capacity, 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. Consequently, 1,678 skilled workers moved from Kamaishi to Tokai in 1964, 1967, 1968, and 1969.[22]

This brief history mentions that Fuji constituted a rigorous internal labor market, iron works within the company competed each other, and the firm-specific human capital was commonly productive in different iron works within the same company, and hence the data set is 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 they left Kamaishi. The number of total observations is 24,022. Selection for relocation was handled in cooperation with the union, and in principle, anyone who was willing to move was

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

[22] 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. Fuji and Yawata merged into the Nippon Steel in 1970s and both Kamaishi and Tokai, which was renamed as Nagoya, have since belonged to Nippon Steel.

allowed to be relocated. Thus, the measure of selection was just the employees' willingness.[23]

The data set has advantages specifically with regard 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 data of training, promotion, wage and personal information:
   - (1) 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).
   - (2) Licenses the employee held.
   - (3) Family composition.
   - (4) Clinical history.
   - (5) Basic wages.
   - (6) Promotion and deployment: classes, division, and department assignment, and job assignment.

The panel data of the basic wage begin when the employee joined the firm and end when he moved to the Tokai Iron Works, varying from 1964 to 1969.

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, in contrast with contemporary Japanese firms. 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.

[23] See Umezaki (2010), pp.47-49.

From the late nineteenth 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 (6). Also, the empirical results of this research could be compared with those obtained from the other industrial economies.

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 spent attending mandatory elementary schools and those with 8 years who attended 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 the 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

Before estimating equation (6), the existence of the internal labor market policy, which somehow "shields" wage determination from the outside market, is to be empirically established. 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 a common traits. Thus, the survival of the cohort effect is a useful indicator of the existence of the internal labor market.[24]

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 ($\mathrm{ten}$), is inserted as a regressor.[25] The cohort effects survive among the employees of all cohorts. The internal labor

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

[25] 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

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.[26]

As Baker et al. (1994b) described, the serial correlation of wage growth is another useful indicator of the internal labor market.[27] 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.[28] 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 [29]

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 (6), let us give 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),[30] 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

group and then regress the wages on the dummies of the two-cohort groups.

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

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

[28]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.

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

[30]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)."

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 ($\mathrm{dcy} \times \mathrm{ten}$, $\mathrm{sy} \times \mathrm{ten}$, $\mathrm{dct} \times \mathrm{ten}$, $\mathrm{dc} \times \mathrm{ten}$).[31] The potential impact of the extended compulsory schooling[32] is captured by the postwar education generation dummy (psw).

Significantly large coefficient of ten implies that return on the firm-specific human capital is considerable, which is consistent with our semi-public properties. Then 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 (6) 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**. The coefficient of ten, β_5 in equation (6), is significantly positive with large absolute value, indicating that the return on the firm-specific human capital is considerable, which is consistent with our semi-public properties. 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_2 in equation (6)) 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_3 in (6)) has a significantly negative coefficient, implying that **Prediction 1** holds, $\hat{\beta}_2 > \hat{\beta}_3$.

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

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

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

(ten), and motivated by the **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 $(\mathrm{dcy}, \mathrm{sy}, \mathrm{dct}, \mathrm{dc})$, the interactions 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 $(\mathrm{yos}\times\mathrm{pre}, \beta_2)$ 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 $(\mathrm{yos}\times\mathrm{ten}, \beta_3)$ has a significantly negative coefficient, thus $\hat{\beta}_2 > \hat{\beta}_3$, 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, invested in firm-specific human capital not necessarily complementary to schooling, as thereafter the firm 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 $(\mathrm{yos}\times\mathrm{pre}, \mathrm{yos}\times\mathrm{ten})$—signs of whose coefficients $\hat{\beta}_2$ and $\hat{\beta}_3$ 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 to the internal labor market. The coefficient of the interaction term between the years of schooling and previous work experience $(\mathrm{yos}\times\mathrm{pre})$, $\hat{\beta}_2$ 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 $(\mathrm{yos}\times\mathrm{ten})$, $\hat{\beta}_3$ 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 in fact capture the internal labor market effect.

The symmetric employer learning hypothesis assumed small significance of the complementarity between schooling and work experience in the workers' young days. However, the result here indicates that the learning effect does not dominate the complementary effect of schooling and experience because the workers invested in general capital in their early stages of career, 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 US 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 comes closer to the end of the covered period. First, the coefficients with larger negativity of cohorts closer to the end implies 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.[33] 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. Therefore **Table 6** shows that employer learning progresses in the earlier stages and return on investment in human capital is also larger in earlier stages.

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 investment 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 United States, German, and British cases have suggested that more research is required on 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 in fact 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

[33] 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.

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 on employer learning without expense of great tractability of the model by Farber and Gibbons (1996), as shown in this research.

While excessive generalization of this Japanese experience might not be conducive, long-term employment is observed and has a positive impact on wages and job protection in US workplaces to encourage the accumulation of industry-, firm-, and/or skill-specific human capital.[34] 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.[35] 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.[36] 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.[37] Meanwhile, investment in human capital in Germany seems to concentrate in industry-specificity instead of firm-specificity more than in the US 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.[38]

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 US market in terms of the symmetry of informational structure for employer learning, and closer to the contemporary US market than to the contemporary German market in terms of the comparative emphasis on the industry- or firm-specificity of human capital investment.

To proceed with such a comparative analysis on the interaction between the firm organization and the labor market, further inquiry based on the intra-firm panel data of employees who work for specific large firms, which theoretically enables application of the public employer learning model and tractable comparison.

[34] 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.

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

[36] For the US, 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).

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

[38] 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.

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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	
yj1960	46	265	12	8	9	10.19	26	0	3	4.85	Rapid growth began
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. Some samples lack the information about somatic 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		
	adiusted 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/).