An estimation of wage rate elasticity of supply of working hours based on the hedonic wage model—a case of Japanese labor market

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Abstract

We estimate the wage rate elasticity of the supply of working hours based on the hedonic wage model. We obtain very stable estimates, implying the existence of a stable structure of the supply of working hours. Particularly, the estimated wage rate elasticity is stable after the age of 30 years. These are all negative −0.12~−0.20, −0.08~−0.15, −0.20~−0.27, and −0.12~−0.22 for male college graduates, female college graduates, male high school graduates, and female high school graduates respectively.

It is possible to reinterpret our estimation results from the viewpoint of the standard model. This allows the estimated WH contract curve to be reinterpreted as the supply curve of working hours in the standard model, and its wage rate elasticity of working hours as Marshallian elasticity.

Concerning the effect of wage income tax on working hours, we conduct a comparative static analysis. With the estimated results of wage rate elasticity, we conclude that the tax on wage income is not likely to decrease the supply of working hours. In other words, the efficiency loss of the wage income tax will not occur in the Japanese context. (195 words)

Key words: wage rate elasticity, working hours, hedonic wage, contract curve, efficiency loss.

JEL code: J22, J31

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1. Introduction

In this study, we estimate the wage rate elasticity of the supply of working hours based on the hedonic wage model. Subsequently, with the estimated results, we assess whether the tax on wage income would decrease the supply of working hours. (1)

Many empirical studies have been conducted on the supply elasticity of working hours. The basic model of these research works is the standard model of the supply curve of working hours (SMSC). However, as Keane (2011) and Bargain and Peich (2013) have stated, there is no clear consensus on the magnitude of wage rate elasticity. (2)

These inconclusive results may be attributed to deficiencies in the estimation method. Pencavel (1986, 2016) stressed the importance of identifying the demand curve of working hours, arguing that it would be effective if the demand function is properly built into the estimation model. Conversely, we consider that the demand curve of working hours has theoretical problems, and hence we use the hedonic wage model. (3)

The hedonic wage model is a revised model of SMSC. The key difference between them is in their basic assumptions. The standard model assumes that workers determine their working hours unilaterally at a given wage rate and the employing firm accepts it. On the other hand, the hedonic wage model assumes that working hours are determined bilaterally or contractually. Specifically, the equilibrium working hours are determined at the point where the workers' indifference curve and the firms' isoprofit curve become tangential to each other.

The rest of this paper is organized as follows. In Section 2, we explain the hedonic wage model briefly, comparing it with SMSC. In Section 3, we explain the data and procedure of estimation. In Section 4, we present and examine the estimated results. In Section 5, we analyze the effects of the wage income tax on working hours. In Section 6, we provide a brief conclusion.

2. Hedonic wage model of working hours

A key assumption of the hedonic wage model is that employers are not indifferent to the length of working hours and may offer a different hourly wage rate if the length of working hours changes. The primary reason behind this is the quasi-fixed costs of employment. When employers incur training costs or setup costs, the hourly labor costs will decrease as the working hours become longer. In this case, the employer will offer a higher wage rate for longer working hours. (4)

There are two main tools in the hedonic wage model, which are the hedonic wage curve and the wage-hour contract curve. Using these two tools, the market equilibrium of labor markets is explained.

2－1 Hedonic wage curve (HW curve)

A hedonic wage curve depicts the market equilibrium relationship between wage earnings (E) and working hour (t) of workers who have the same quality or productivity level. Figure 1 shows the market equilibrium for a simple case. Here it is assumed that laborers have the same quality (productivity) and preferences. On the other hand, there are two firms (firm A and firm B) with different production functions. Since firm B's quasi-fixed costs are higher, its isoprofit curve shifts to the right. The equilibrium points are E_A and E_B respectively, where the isoprofit curves of firm A and firm B are tangential to an indifference curve. Concerning workers, the points E_A and E_B are indifferent, and both firms maximize their profit respectively. The working hours of firm A are shorter and its workers' wage earnings are smaller. However, we cannot confirm whether the hourly wage rates of firm A's workers are higher or lower. Thus, different hourly wage rates exist for the same quality of labor. Therefore, hourly wage rate cannot be a parametric variable, and the notion of the supply curve of working hour is irrelevant in the hedonic wage model. (5)

Figure 1　Market equilibrium of one worker and two firms

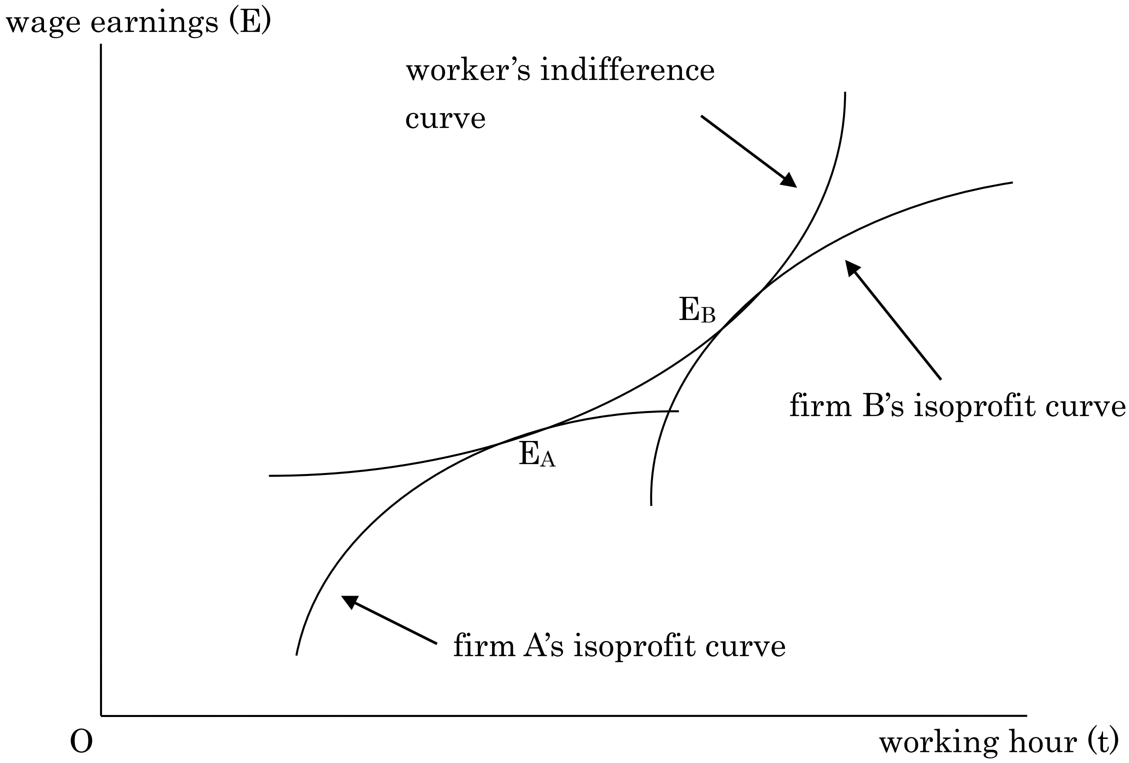


Figure 2 Hedonic wage curve and market equilibrium of two workers and two firms

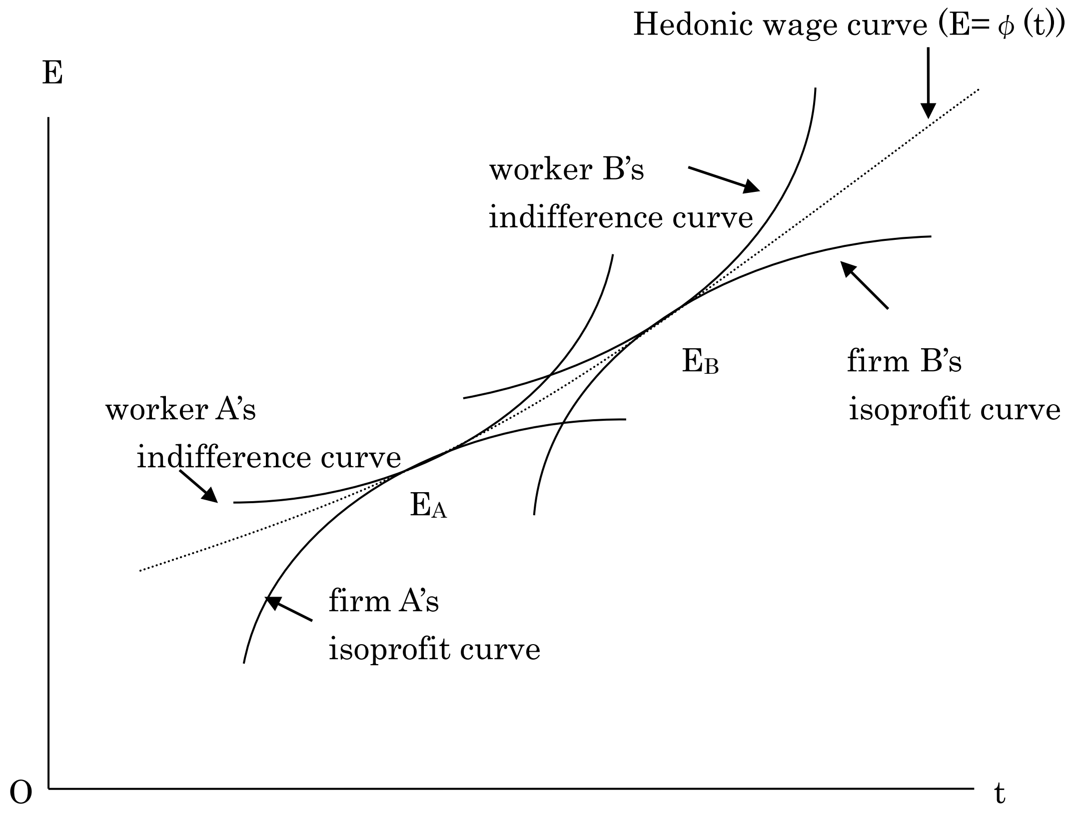


Figure 2 shows the market equilibrium when there are two types of workers (worker A and worker B) and two types of firms (firm A and firm B). Here, we assume that worker A and worker B have identical quality (productivity) but different preferences. Firm A and firm B have different production functions, but their workers have identical quality. In the equilibrium, worker A's indifference curve and firm A's isoprofit curve are tangential to each other. In the same way, worker B's indifference curve and firm B's isoprofit curve are tangential to each other. Their joint envelope is called the hedonic wage curve (HW curve, $E=\phi(t)$). It is evident that the HW curve is an increasing function of working hours ($\phi'(t) > 0$). Firms pay higher wage earnings (E) to compensate for longer working hours. In a more general case (comparing many types of workers and firms), their equilibrium points lie on the HW curve. As is easily known from Figure 2, the HW curve is also the budget constraint for both workers and firms. Additionally, the equilibrium points of workers who prefer long working hours lie towards the right. (6)

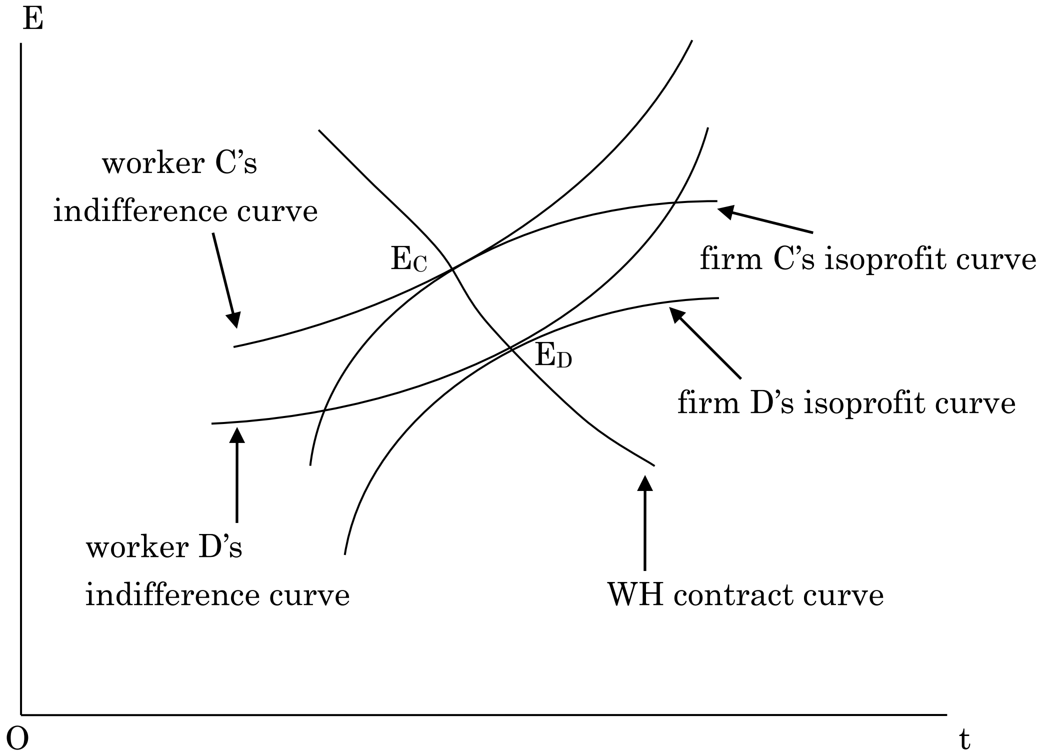
Another necessary condition for market equilibrium is that the demand and supply of workers should be equal at the equilibrium points. The formal statement is as follows: Let the market demand and supply for laborers with working hours t be $L^D(t)$ and $L^S(t)$, respectively. Subsequently, $L^D(t) = L^S(t)$ for all t. Therefore, the shape of the HW curve is determined by the distribution of laborers' preferences and firms' production technologies. (7)

2－2 Wage-hour (WH) contract curve

In this section, we explain the wage-hour (WH) contract curve. The WH contract curve depicts the market equilibrium relationship between wage earnings (E) (or wage rate, w) and working hours (t) of workers who have the same preference but different productivity levels and wage rates. Here we assume that there are two types of workers (worker C and worker D) having different quality standards but identical preferences. The market equilibrium is illustrated in Figure 3. E_C is the equilibrium point of worker C wherein worker C's indifference curve is tangential to firm C's isoprofit curve. In the same way, E_D is the equilibrium point of worker D wherein worker D's indifference curve is tangential to firm D's isoprofit curve. The worker C obtains higher wage rates than worker D, owing to the former higher productivity.

The implication of Figure 3 is as follows. If worker D's productivity increases and the worker gets a higher wage rate, then the worker's equilibrium point will move from E_D to E_C. The locus from E_D to E_C is a type of contract curve, and we refer to it as the "wage-hour contract curve" (WH contract curve). The WH contract curve is an extension of the supply curve of working hours in the standard model. Its slope is determined by the income effects and the substitution effects of both workers and firms. (8)

Figure 3 Wage-hour contract curve

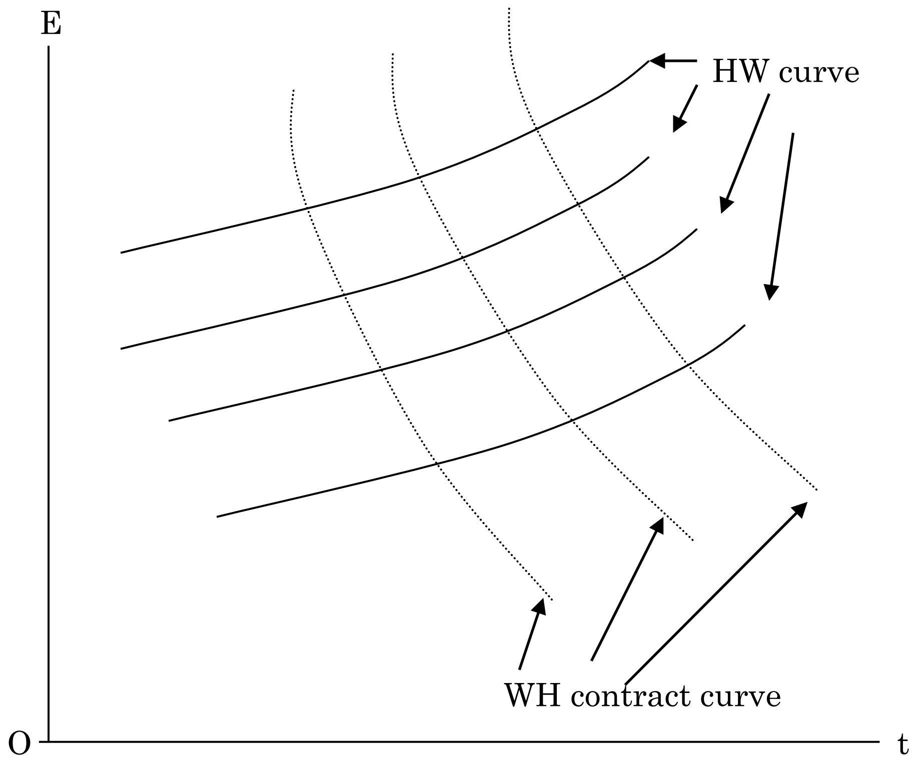


2－3 Market equilibrium in the general case

Figure 4 illustrates market equilibrium in a general case. Workers with (relatively) equal productivity form a labor market, and their wage earnings (E) increase with an increase in their working hours (t). The relationship $E=\phi(t)$ is called the HW curve. The HW curves are in parallel positions, and higher productivity workers lie on higher HW curves as they command higher wage rates.

The WH contract curve is a locus of equilibrium points of workers with the same preferences but with different productivity levels. The WH contract curves and the HW curves intersect and form a mesh. Every intersection is an equilibrium point where a worker's indifference curve and a firm's isoprofit curve are tangential to each other.

Figure 4 Market equilibrium in a general case



3. Data and Estimation

3－1 Data

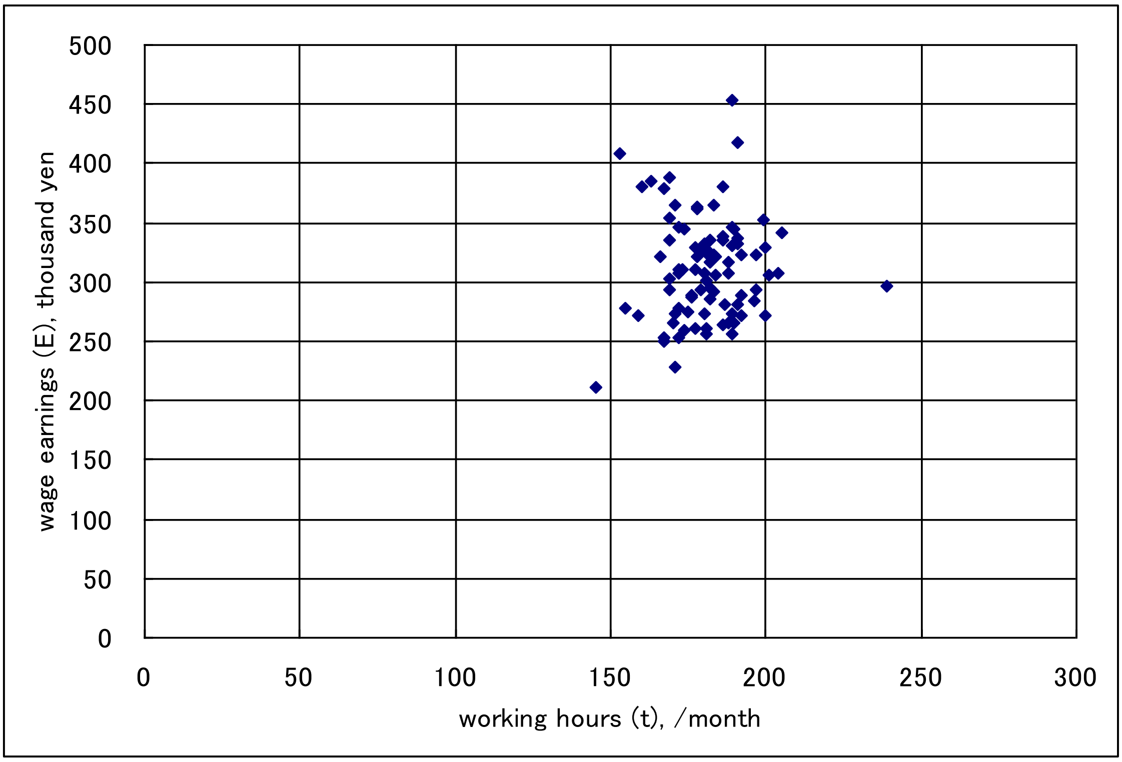
We use the Basic Survey in Wage Structure (BSWS), published by the Japanese Ministry of Health, Labour and Welfare (MHLW). This national survey is conducted by MHLW every June. A questionnaire is distributed to employers who are chosen at random. As it is not workers but employers who provide the responses to this questionnaire, we assume that the data with respect to working hours and wage earnings are without measurement error and considerably reliable.

The survey classifies about 90 industries and further differentiates firms by the number of its employees categorized into the following three groups: (1) more than 1000 employees, (2) 100~999 employees, and (3) 10~99 employees. The survey also indicates workers' age, academic career (college graduates or high school graduates) and gender (male or female). Therefore, we are able to exploit four data sets.

From the BSWS, we select "scheduled working hours" (SWH) and overtime working hours (OTH). The former are the standard working hours, as provided by office regulations. Therefore, the total working hours (t) that we use is t = SWH+OTH. As wage earnings (E), we select the "contractual cash earnings" before tax (CCE). This includes payments for both SWH and OTH but does not include bonus payments. We do not include bonus payments because they fluctuate with the business cycle. Thus, the hourly wage rate (w) is simply calculated as w = E/t = CCE/(SWH+OTH).

Figure 5 Working hours (t) and wage earnings (E), 2015

(male college graduates, age 25~29 years, firms with more than 1,000 employees)



Data source: Basic Survey in Wage Structure, Ministry of Health, Labour and Welfare of Japan

Figure 5 depicts the plotting of male college graduates in 2015 (more than 1000 employees; age group 25~29 years). The sample number is 87. Working hours (t) range from 145 to 239 hours per month and the wage earnings (E) range from 210.5 to 453.0 (thousand yen).

3－2 Estimation of the hedonic wage curve

A hedonic wage curve (E= Φ (t)) depicts the market equilibrium relationship between wage earnings (E) and working hours (t) of workers who maintain the same productivity level. To explain the estimation procedure, we take the case of male college graduates in the 25 ~29 age group. The procedure of estimation is as follows:

1. The data are classified into approximately 90 industries and arranged according to the hourly wage rate for each firm size.
2. We assume that the hourly wage rate reflects the laborer's productivity (quality) and divide these into 7~8 tiers. We regard each tier as a labor market and estimate its HW curve. We consider that the width of the hourly wage rates of each tier should be around 0.1 thousand yen (≒1 dollar).
3. The HW curve is approximated by a line estimated by ordinary least squares (OLS). The HW curve might be nonlinear, but we have no information about its shape. We believe that if R^2 is large enough, then the linear approximation will be satisfactory.

Tables 1~3 are the estimated results of the HW curve for each firm size. The estimation is made by a simple linear equation E= a + bt and OLS. The adjusted coefficients (Adj. R^2) are greater than 0.9 in 9 tiers and 0.8~0.9 in 7 tiers, which is a satisfactory result. Generally, the Adj. R^2 of the lowest and the highest tiers are smaller.

Row (5) shows the ratio of "b" and the average wage rate w* of the tier (hereafter, we refer to this compensating wage ratio as the "CW ratio"). The standard model will expect $\Phi(t)=w^*t$ because every worker can choose working hours at a given wage rate. Therefore, if the estimated HW curve is a straight line that passes through the origin with slope w*, then "CW ratio =1" and the standard model will not show any contradiction. In Table 1, the CW ratios of the Tier 3 (1.160), Tier 4 (1.126), and Tier 6 (1.346) are significantly larger than 1.0. This result might counter the validity of the implication of the standard model.

Row (7) shows the spread of working hours in a tier. In each tier, although the hourly wage rates remain almost the same, the working hours vary (20~40 hours). This suggests that the employers' influence on working hours cannot be ignored. Row (8) is the total number of workers in each tier. Row (9) is the sample number, which reflects the number of industries.

3－3 Estimation of the WH contract curve

We assume that the contract between a laborer and a firm will consist of a package of wage earnings (E) and working hours (t). Therefore, the WH contract curve is considered to be the locus of the package. In other words, the WH contract curve will show how an increase in the wage rate (by laborers' productivity growth) is divided between an increase in wage earnings and a reduction (or increase) in working hours.

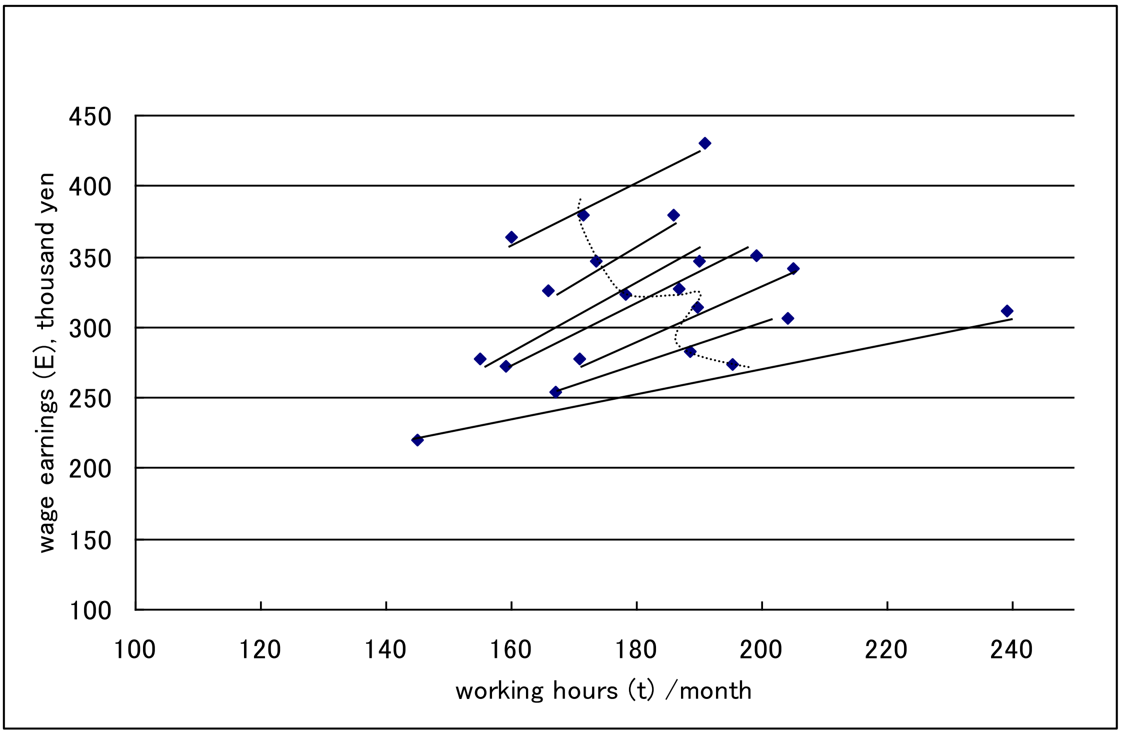
For example, when a worker in the first tier moves to the second tier according to his wage rate increase, which position will he occupy in the second tier? We made the simple assumption that the representative worker of the first tier moves into the place of a representative worker of the second tier. After a further wage rate increase, the worker will move to the place of a representative worker of the third tier. We also assume that the representative worker earns the average wage and maintains the average working hours of a representative tier. Additionally, we assume that the representative worker of each tier has the same preferences (indifference curve) and the corresponding representative firm has the same isoprofit curve (production function). Thus, the WH contract curve is the curve that connects them.

Figure 6 shows the estimated HW curves in Table 1. The two ends of the HW curve show the longest and shortest working hours of each tier. For example, in the first tier, the left-end represents 145 hours (timber industry) and the right-end 239 hours (truck driver). Next, the average wage earnings and average working hours are calculated by the weighted average of the number of employees in each industry. The points of the weighted average are plotted in the figure and connected with dotted lines. These points are, as it were, contract points.

The above contract points are plotted on the E-t plane. In Figure 7, it is converted into the w-t plane. In the figure, we added the contract points of other firm sizes (100~999 employees and 10~99 employees) as plotting points, resulting in a total of 22 plotting points. From these plotting points, we estimate a WH contract curve. (This is the WH contract curve of the representative worker, and the WH contract curve of an individual worker will be parallel to this curve as in Figure 2.) The estimated result is shown in the second column of Table 4. The wage rate elasticity of working hour is −0.190 and Adj. R^2 is 0.622.

Figure 6 HW wage curve and contract points

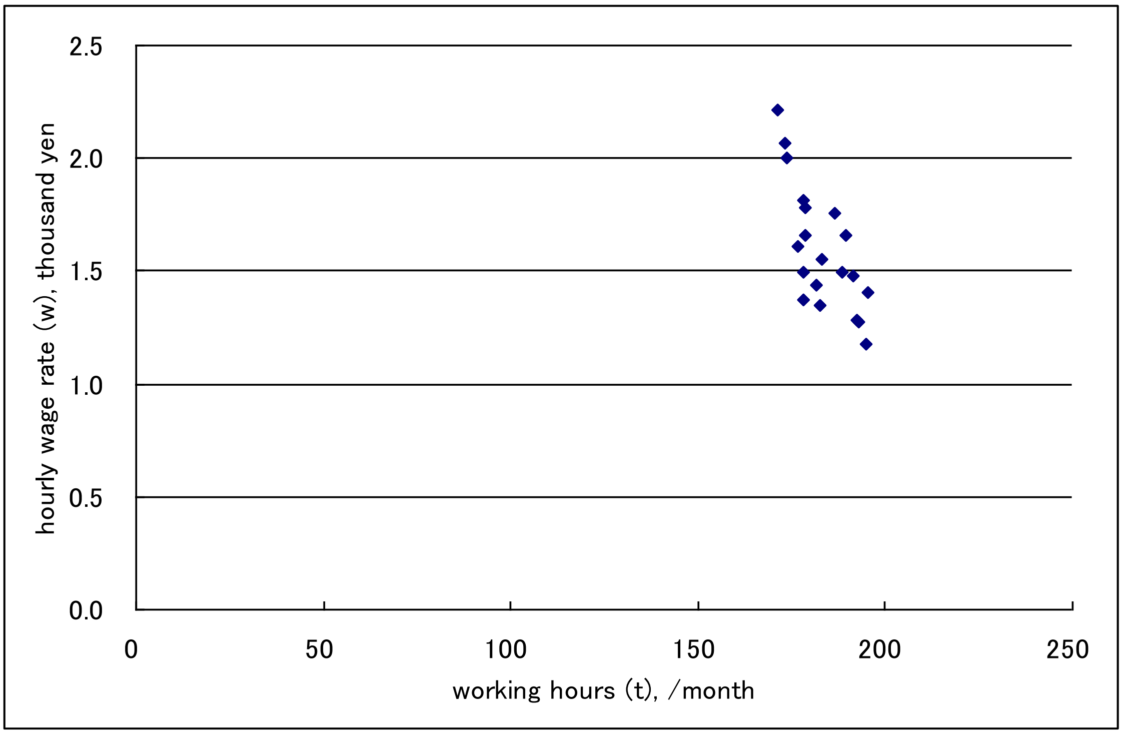
(male college graduates; age group 25~29 years; firms with more than 1000 employees)



Data source: Basic Survey in Wage Structure, Ministry of Health, Labour and Welfare of Japan.

Figure 7 Plots of a WH contract curve

(male college graduates; age group 25~29 years, in 2015)



Data source: Basic Survey in Wage Structure, Ministry of Health, Labour and Welfare of Japan.

3−4 Reinterpretation from the viewpoint of the standard model

It may be possible to reinterpret the estimated results from the viewpoint of the standard model. In this case, the WH contract curve will be reinterpreted as the supply curve of working hours.

The basic assumption of the standard model is that workers can choose working hours at a given wage rate, and employers will accept these working hours. In Figure 6, the HW curve is regarded as a budget constraint for workers. A worker unilaterally determines his working hours and chooses the desired industry. It is remarkable that in a tier although the hourly wage rates are almost at the same level, the working hours of industries vary considerably. This implies that the preferences of workers and accordingly the related supply curve of working hours vary significantly among industries.

The dispersion of the supply curves indicates that it will be difficult to specify the shift parameters of the supply curve of working hours. Hence we use the same technique associated with the representative worker as in Section 3－3. We assume that according to the increase in the wage rate, the first tier's representative worker moves to the place of the second tier's representative worker. After a further wage rate increase, the worker moves to the place of the third tier's representative worker. At this point, the WH contract curve can be reinterpreted as the supply curve of working hours in the standard model, and its wage rate elasticity is considered to be the uncompensated wage rate elasticity of working hours (Marshallian elasticity). Thus, it can be stated that both the standard model and the hedonic wage model adopted in this study will lead to the same estimation results with respect to the wage rate elasticity.

4. Estimates of the WH contract curve and its wage rate elasticity

We obtained quite stable estimates of the WH contract curve and its wage rate elasticity. Tables 4, 5, 6, and 7 present the estimates for male college graduates, female college graduates, male high school graduates, and female high school graduates respectively.

The estimated equation is a simple linear form "$t = \alpha + \beta w$" made by OLS. In Table 4, Column (1) presents the estimate for the 22~24 age group. Column (2) depicts the estimate for the 25~29 age group, and so on. Row (1) and Row (2) represent the estimates of α and β, respectively. Row (3) presents the range of hourly wage rates, which increases with workers' age. Row (4) presents the adjusted coefficient of determination (Adj. R^2). Row (5) presents the number of samples that reflects the number of HW curves. Row (6) depicts the wage rate elasticity of the working hours of the WH contract curve. This estimate is obtained by performing a separate regression via a log-linear equation (see note below Table 4). Row (7) depicts the number of total employees in the age group. (9)

Figure 8,9,10, and 11 show the estimated WH contract curves for male college graduates, female college graduates, male high school graduates, and female high school graduates respectively. The lowest line is the WH contract curve of the youngest group (22~24 years for college graduates and 18~19 years for high school graduates respectively). For example, in Figure 8, the wage rate of the left end of the lowest line is 1.790 thousand yen and that of its right end is 1.081 thousand yen respectively (refer to Table 4).

4－1 Male college graduates (Table 4, Figure 8)

The results for male college graduates are summarized as follows.

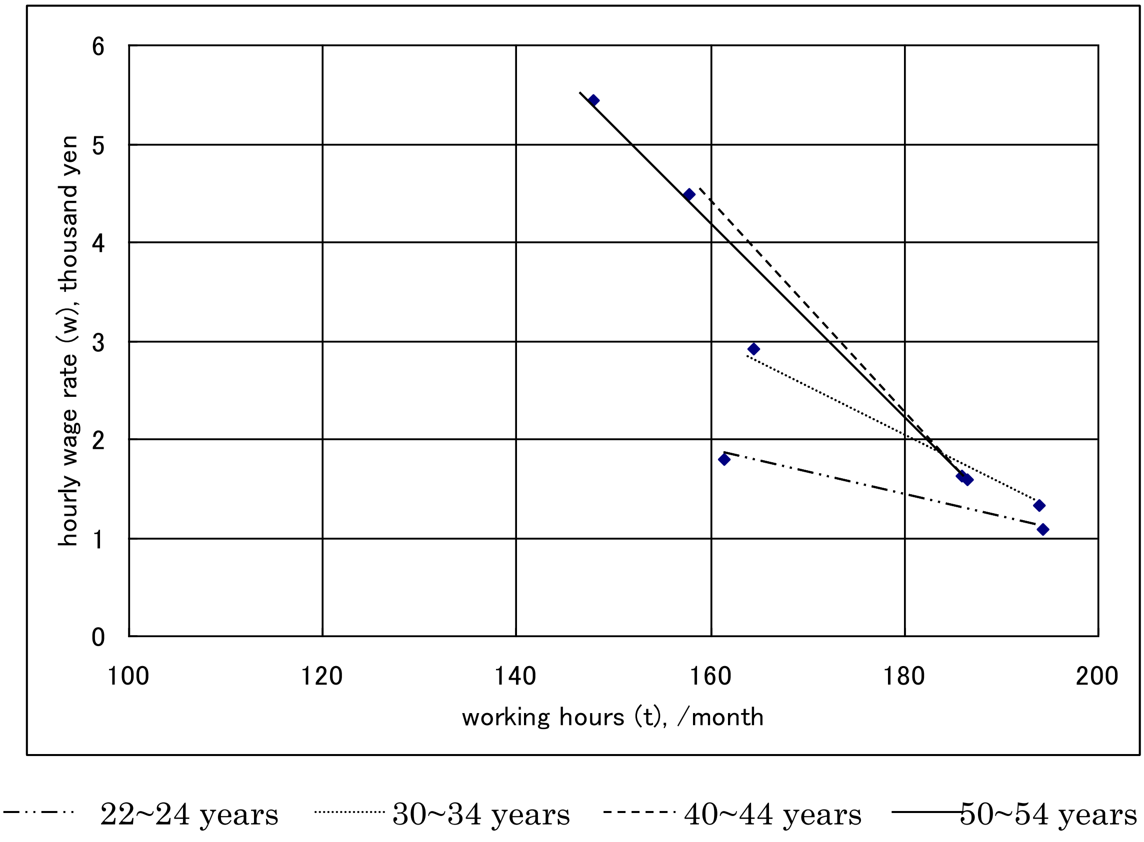
(a) The wage rate elasticity (Row 6) is the highest (－0.358) in the 22~24 age group. They are new employees (having graduated at the age of 22) and within three years after entering a company, 30% of these new employees will move to another company.

(b) After the age of 25, the wage rate elasticity is stable between －0.15 and －0.20.(10)

(c) Adj. R^2 increases with age. This reflects the fact that employment relationships stabilize with an increase in workers' age.

(d) The three WH contract curves for workers over the age of 40 appear to be very similar.

Figure 8 WH contract curve of male college graduate, 2015



4－2 Female college graduates (Table 5, Figure 9)

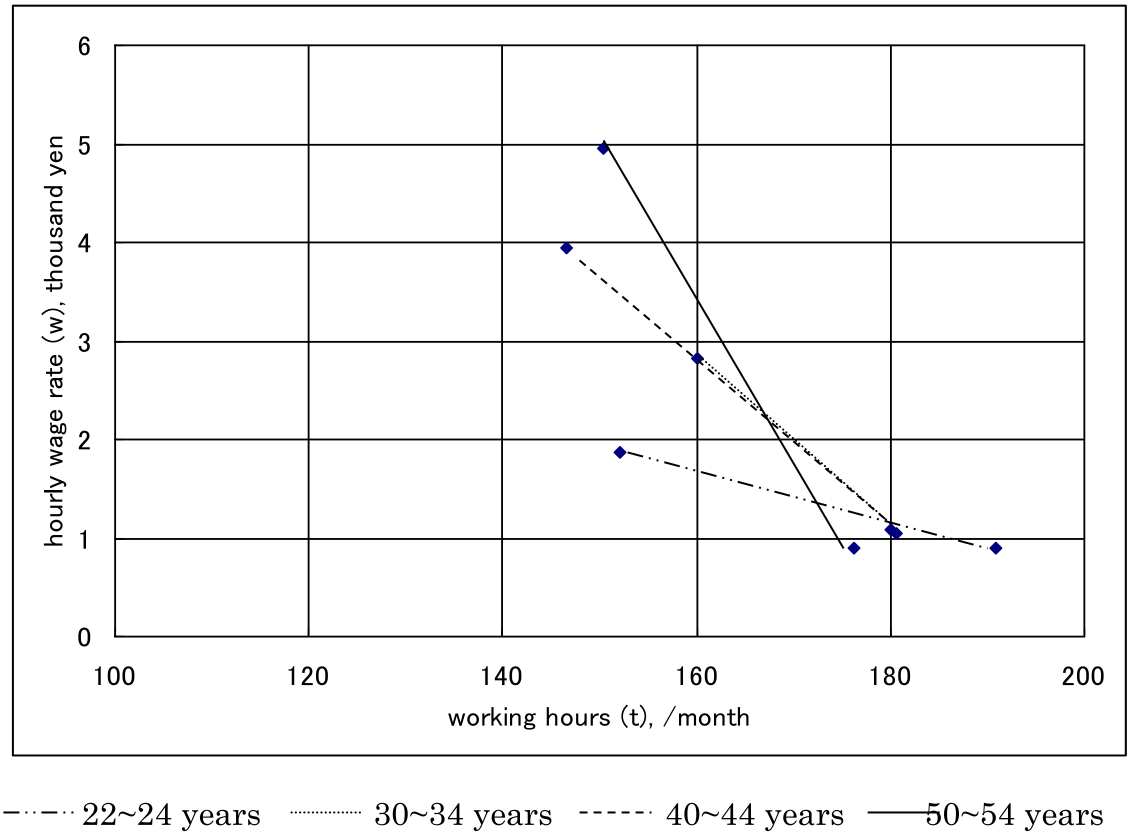
The results for female college graduates are summarized as follows.

(a) The wage rate elasticity is the highest (−0.305) in the 22~24 age group when they are new employees, which is the same situation as that of the male college graduates. Similar to the male college graduates, 30% of these new employees move to another company within three years after entering a company.

(b) After the age of 30, wage rate elasticity stabilizes to lie between −0.08 and −0.15.

(c) The wage rate elasticity of female college graduates is a little lower than that of the male college graduates.

Figure 9 WH contract curve of female college graduate, 2015



4－3 Male high school graduates (Table 6, Figure 10)

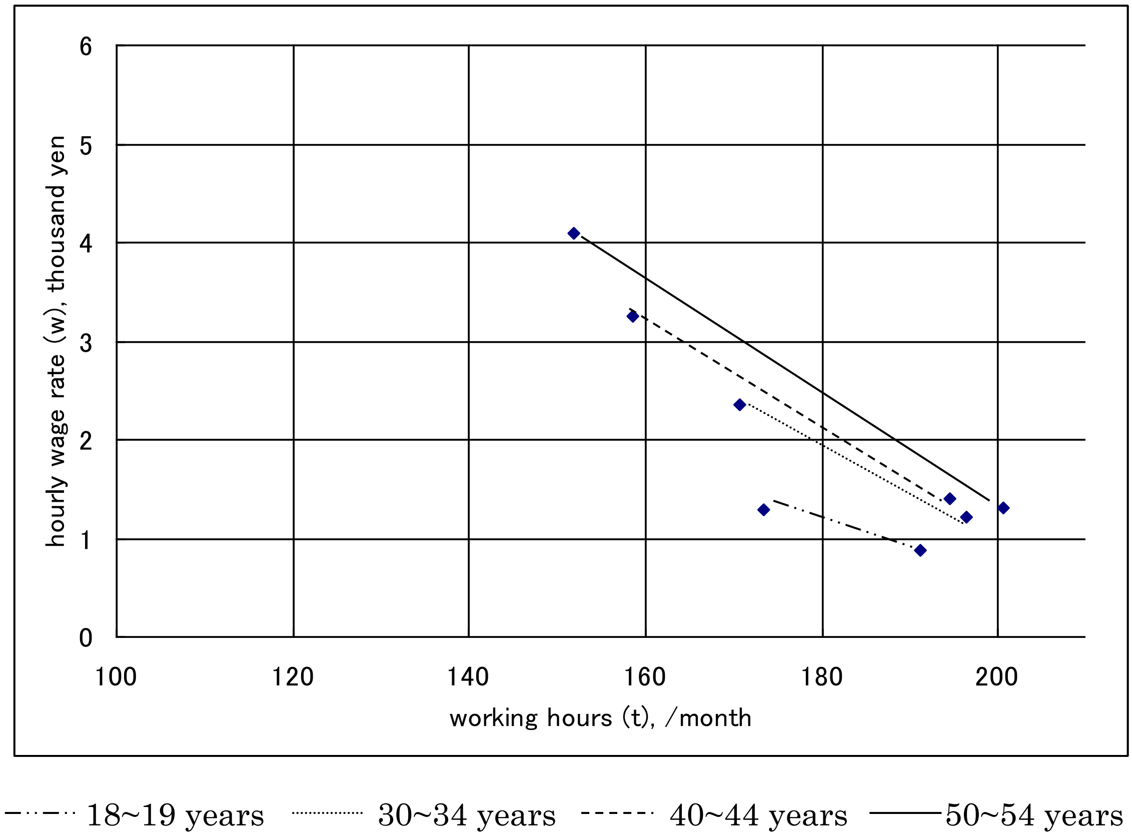
The results for male high school graduates are similar to those of the male college graduates.

(a) The wage rate elasticity is the highest (－0.258) in the 18~19 age group when they are new employees. They graduate from high school at the age of 17. After entering a company, 50% of these new employees move to another company within three years.

(b) After the age of 30, the wage rate elasticity stabilizes to －0.20~－0.27. Their elasticity is somewhat higher than that of the male college graduates.

(c) Adj. R^2 increases with age, which is the same situation as that of the male college graduates.

Figure 10 WH contract curve of male high school graduate, 2015



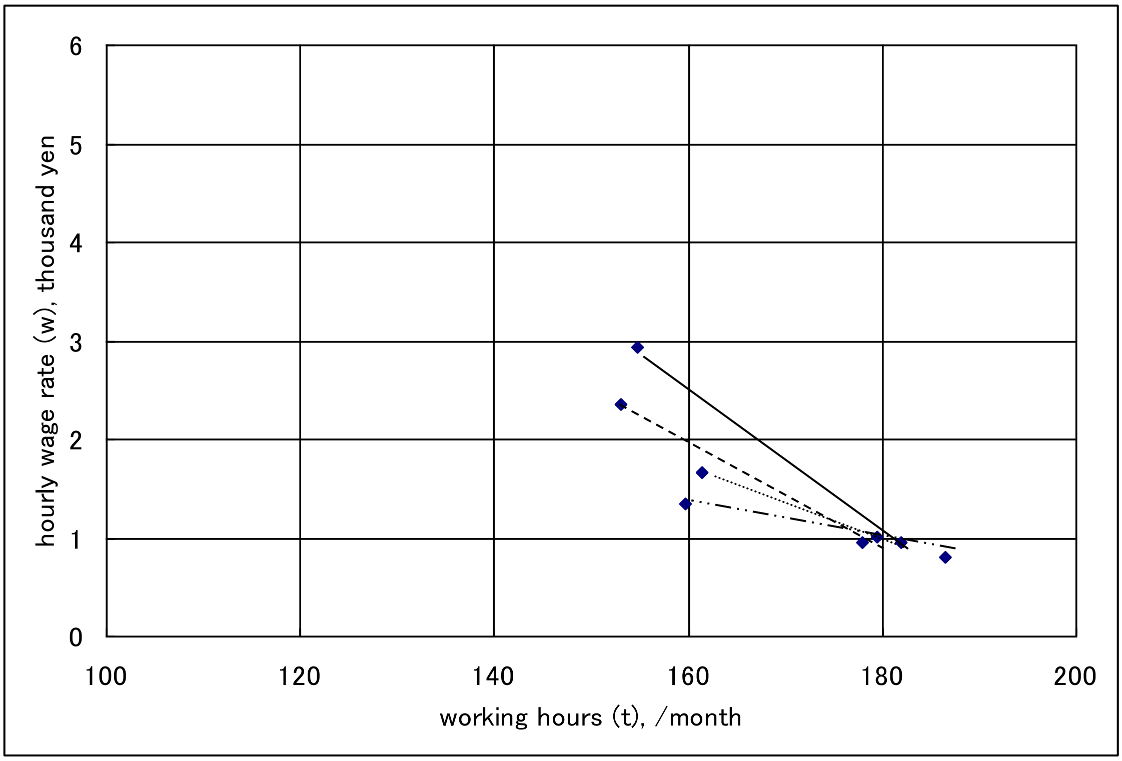
4－4　Female high school graduates (Table 7, Figure 11)

Table 7 presents the estimated results for female high school graduates. We have results similar to those of the female college graduates.

(a) The wage rate elasticity is the highest (−0.301) in the 18~19 age group when they are new employees. Similar to the case of male high school graduates, 50% of these new employees move to another company within three years after entering a company.

(b) After the age of 30 years, the wage rate elasticity stabilizes to −0.12~−0.22, which is a little lower than that of the male high school graduates.

Figure 11 WH contract curve of female high school graduate, 2015



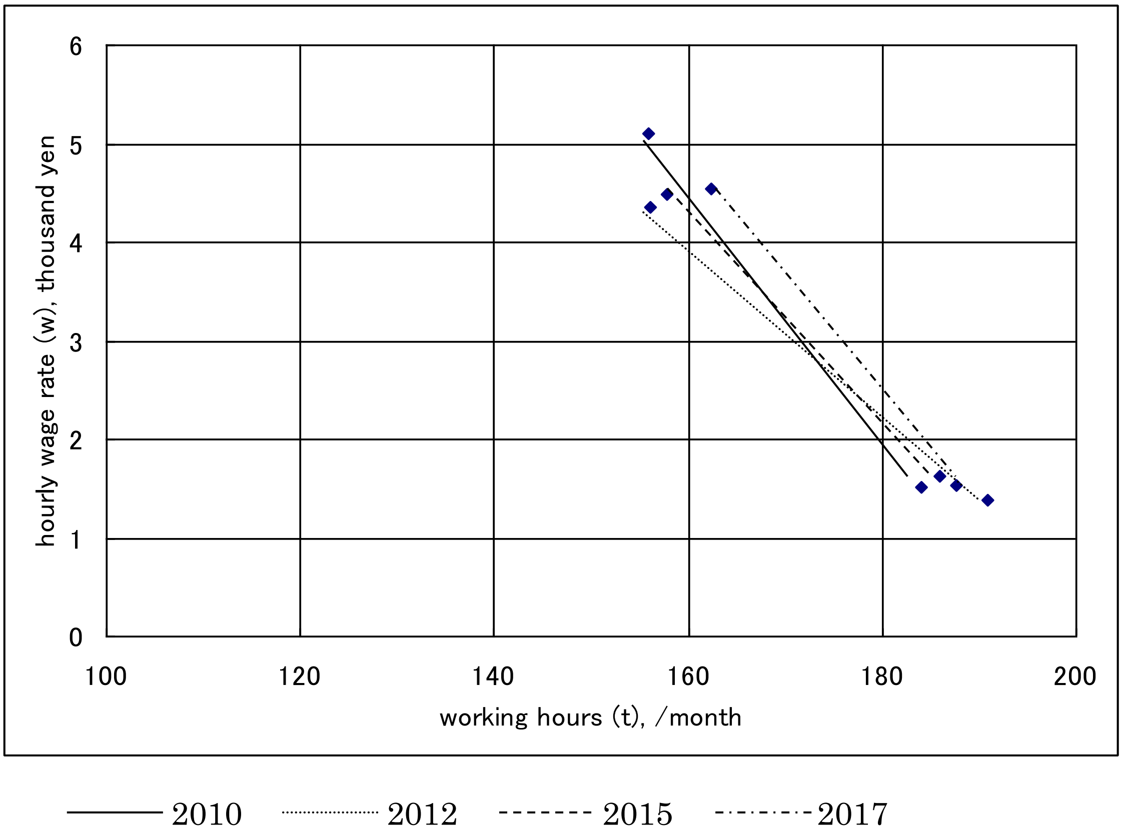
－··－·· 18~19 years　　··········· 30~34 years　　- - - - - 40~44 years　　——— 50~54 years

4－5 Time series of WH contract curve (Table 8, Figure 12)

(college male graduates in the 40~44 age group)

Table 8 presents the estimates for college male graduates in the 40~44 age group for the eight years between 2010 and 2017. The estimated WH contract curves remain very stable in this period. In particular, the three WH contract curves of 2010, 2011 and 2014 are very similar, and the two WH contract curves of 2012 and 2013 are very similar. Wage rate elasticity is quite stable during these eight years and lies between −0.12 and −0.20.

Figure 12 Time series of WH contract curve
(male college graduate 40~44 age group, from 2010 to 2017).



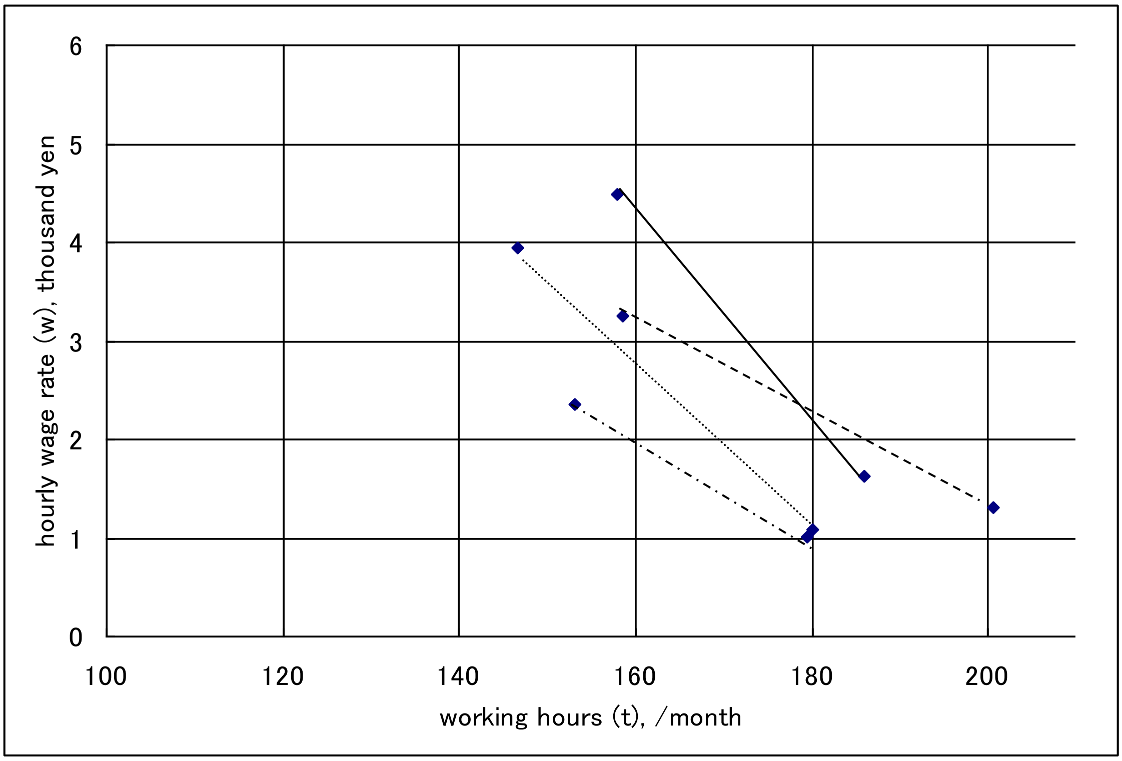
4−6 Comparison of WH contract curves by academic career and gender

Figure 13 compares WH contract curve by academic career and gender for the 40~44 age group. We have the following findings:

(a) Male college graduates work about 20 hours more per month than female college graduates at a given wage rate. Similarly, male high school graduates work about 20 hours more per month than female high school graduates at a given wage rate.

(b) The wage rate elasticity of college graduates is a little smaller than that of the high school graduates.

Figure 13 Comparison of WH contract curve by academic career and gender (40~44 age group, 2015).



—— male college graduate ·········· female college graduate

- - - - - male high school graduate -·-·-·- female high school graduate

4－7 Summary of Section 4

A summary of estimated elasticity is provided in Table 9.

Table 9 Summary of wage rate elasticity

	New employee	After age 30
Male college graduate	－0.358	－0.15 ~－0.20
Female college graduate	－0.305	－0.08 ~－0.15
Male high school graduate	－0.258	－0.20 ~－0.27
Female high school graduate	－0.301	－0.12 ~－0.22

As summarized in Table 9, we obtained very stable estimates of wage rate elasticity of the supply of working hours. This implies that the structure of the supply of working hours is very stable. We can conclude that the wage rate elasticity is the highest among new employees and stabilizes after the age of 30. The wage rate elasticity of females is a little lower than that of males. (11)

Regarding the WH-contract curve (Figure 8, 9, 10, 11), these four figures have the following common characteristics.

(a)As employees get older, WH contract curves shift upward or rotate slightly clockwise. The cause of the upward shift may be that the productivity of workers rises with human capital accumulation.(12)

(b)The right ends of all WH contract curves are almost in the same area and at the lowest wage rate level. For this group, productivity does not increase with age. In other words, human capital accumulation does not appear to occur in this group.

(c) After the age of 40, WH contract curves are very similar. This shows that workers' productivity does not increase after that time, or that their rate of human capital accumulation slows down.

5. Income tax and its effect on working hours

In this section, we conducted a comparative static analysis to see whether income tax decreases the supply of working hours. As stated above, in the hedonic wage model, the budget constraint for a laborer is the HW curve.

5－1　Model

In the hedonic wage model, the slope of the HW curve (the budget constraint for a laborer) can be higher or lower than the hourly wage rate. Let the ratio of the slope and its hourly wage rate (w) be α. Subsequently, the budget constraint, which is linearly approximated, is described as follows.

$$E = \alpha wt + \beta \qquad (\alpha > 0) \qquad (1)$$

As E = wt, we have

$$\beta = (1 - \alpha) wt. \qquad (2)$$

In the conventional model, $\alpha = 1$ and $\beta = 0$.

Now, the utility maximizing behavior is expressed as follows.

$$\text{Max } U(E, t) \qquad \text{st. } E = \alpha wt + \beta.$$

We define the following Lagrangian function where λ is the Lagrangian multiplier.

$$\Gamma(E, t, \lambda) = U(E, t) - \lambda \{ E - \alpha wt - \beta \} \qquad (3)$$

With partial differentiation, we have the following first order conditions.

$$\begin{aligned} U_E - \lambda &= 0 \\ U_t + \alpha w \lambda &= 0 \\ -E + \alpha wt + \beta &= 0 \end{aligned} \qquad (4)$$

From the total differentiation of Equation (4), we have the following equations.

$$\begin{aligned} U_{EE}\, dE + U_{Et}\, dt - d\lambda &= 0 \\ U_{tE}\, dE + U_{tt}\, dt + \alpha w\, d\lambda &= -\alpha \lambda\, dw \\ -dE/dw + \alpha w\, dt &= -\alpha t dw - d\beta \end{aligned} \qquad (5)$$

By solving Equation (5) and using the first order conditions Equation (4), we have the following Slutsky equation and an equation of income effect. (13)

$$dt/dw = \alpha / \Delta \{ U_E + t\,[U_{tE} - (U_t/U_E)U_{EE}\,]\,\} \tag{6}$$

$$dt/d\beta = (1/\Delta)\{ U_{tE} - (U_t/U_E)U_{EE}\,\} \tag{7}$$

In Equation (6), if $\alpha = 1$, then it is the case of the standard model. Therefore, in the hedonic wage model, the Slutsky equation is just multiplied by α to that of the standard model. The first term in the bracket (U_E/Δ) is the substitution effect and the second term is the income effect, which is shown in Equation (7).

Equation (6) is described as follows:

$$dt/dw = \alpha \{ s + t(dt/d\beta) \}$$

where $s = U_E/\Delta$ is the substitution effect. This is rewritten in the elasticity form as follows:

$$\begin{aligned} \eta\,(t, w) &= (w/t)\ dt/dw \\ &= \alpha \{ (w/t)s + (w)\ dt/d\beta \} \\ &= \alpha \{ S^* + mpe \} \qquad (8) \end{aligned}$$

where η (t, w) is “the uncompensated elasticity of hours of work with respect to wages,” S* is “the income-compensated elasticity of hours of work with respect to wages,” and mpe (=$wdt/d\beta$) is “the marginal propensity to earn out of the non-wage income.”(14)

5－2 Tax effect on working hours (15)

Does income tax decrease the supply of working hours? Using the same model as the last subsection, we analyze the tax effect. Let tax rate be τ, then the laborer’s utility maximizing behavior is expressed as follows

$$\text{Max } U(E, t) \qquad \text{st. } E = (1-\tau)\,(\alpha wt + \beta). \tag{9}$$

Let us define the following Lagrangian function where λ is the Lagrangian multiplier.

$$\pi(E, t, \lambda) = U(E, t) - \lambda\{E - (1-\tau)(\alpha wt + \beta)\} \tag{10}$$

Subsequently, we have the following first order conditions:

$$\begin{aligned} &U_E - \lambda = 0 \\ &U_t + (1-\tau)\alpha w\lambda = 0 \\ &-E + (1-\tau)(\alpha wt + \beta) = 0 \end{aligned} \tag{11}$$

From the total differentiation of Equation (11) and by solving the obtained equations, we have the following Slutsky equation:(16)

$$dt/d\tau = -w/\Delta\{\alpha U_E + t\,[U_{tE} - (U_t/U_E)U_{EE}]\} \tag{12}$$

When α=1, it is the case of the standard model. In the elasticity form, Equation (12) is rewritten as follows:

$$\begin{aligned} \eta(t, \tau) &= (\tau/t)dt/d\tau \\ &= (\tau/t)\times(-)w/\Delta\{\alpha U_E + t\,[U_{tE} - (U_t/U_E)U_{EE}]\} \\ &= (-)\tau\times\{\alpha S^* + mpe\} \end{aligned} \tag{13}$$

Eliminating S* with Equation (8), we have

$$\eta(t, \tau) = (-\tau)\times\{\eta(t, w) + (1-\alpha)mpe\}. \tag{14}$$

In Equation (14), we estimate that it is very likely that $\eta(t, \tau) > 0$ from the combination of $\eta(t, w)$, α, and mpe. From our empirical results $\eta(t, w) = -0.1 \sim -0.3$ and $\alpha = 0.7 \sim 1.3$. We also assume that mpe will lie between -0.01 and -0.5.(17)

We examine the following two cases $\alpha \leq 1$ and $\alpha > 1$.

(1) $\alpha \leq 1$

$\eta(t, \tau)$ is positive from Equation (14), because $\eta(t, w)$ and mpe are negative. Therefore, income tax will increase the supply of working hours.

The case of the standard model (α=1) is included here.

(2) α>1

It is possible that η(t, τ) is negative. If η(t, w)=−0.1, α=1.3, and mpe=−0.5, then η(t, w) +(1−α)mpe = (−0.1 + −0.3×−0.5) = +0.05>0. Therefore, η(t, τ) will become negative and income tax will decrease the working hours. However, for this case to occur it will need that the negative η(t, w) is larger than −0.1 and sufficiently close to 0, α is sufficiently large (more than 1.3), and mpe is sufficiently small (less than −0.5 and near to −1.0). These combinations will rarely occur. Therefore, it is very unlikely that η(t, τ) is negative.

6. Conclusion

In this study, we estimate the wage rate elasticity of the supply of working hours. Our estimation is based on the hedonic wage model wherein the notion of the supply curve of working hours is not used. In the hedonic wage model, working hours and wage rates are determined bilaterally by the contract between laborers and employers. The locus of the contract is called the wage-hour contract curve (the WH contract curve). Thus, our estimation of the wage rate elasticity of the supply of working hours is with respect to the WH contract curve. However, it is possible to reinterpret our estimation results from the viewpoint of the standard model. This allows the WH contract curve to be reinterpreted as the supply curve of working hours in the standard model, and its wage rate elasticity of working hours as Marshallian elasticity.

We obtain very stable estimates, implying the existence of a stable structure of the supply of working hours. Particularly, the estimated wage rate elasticity is stable after the age of 30. The wage rate elasticities are −0.12~−0.20, −0.08~−0.15, −0.20~−0.27, and −0.12~−0.22 for male college graduates, female college graduates, male high school graduates, and female high school graduates respectively. We can say that the wage rate elasticity of females is a little lower than that of males. An interesting finding here is that the elasticity of new employees is a little higher at −0.36, −0.31, −0.26, and −0.30 for male college graduates, female college graduate, male high school graduates, and female high school graduates, respectively.

Concerning the effect of wage income tax on working hours, we conduct a comparative static analysis. With the estimated results of wage rate elasticity of the supply of working hours, we conclude that the tax on wage income is not likely to decrease the supply of working hours. In other words, the efficiency loss of the wage income tax will not occur in the Japanese context.

Notes

(1) The idea of hedonic price model originates from Lewis (1969) and Tinbergen(1951, 1956). Rosen (1974) followed its idea and established the hedonic price theory.

(2) There are many survey articles on the SMSC. For example, refer to Killingsworth (1983), Pencavel (1986), Killingsworth and Heckman(1986), Blundell and MaCurdy (1999), Keane (2011), and Bargain and Peich (2013).

(3) Kinoshita (2017) argues that the demand curve of working hours has the following theoretical problems. If it is combined with the SMSC, then the hourly wage rate must have two roles to equilibrate demand and supply of both working hours and laborers. Eventually, the system of equations will become over determined.

(4) Quasi-fixed costs of employment play a very important role in employers' decision. Refer to Oi (1962), Becker (1964) and Lewis (1969).

(5) If a firm's quasi-fixed costs are null and its production function is F(Lt) (labor input is measured by man-hours), then its isoprofit curve would become a straight line that passes through the origin. This will be the situation that the standard model assumes. In other words, the standard model implicitly assumes these two conditions. For more details, refer to Kinoshita (1987, p.1269).

(6) Rosen (1986) offers a general theory of compensating wage differences or equalizing wage differences.

(7) This was pointed out by Rosen (1974). The equilibrium hourly wage rate is determined by the equality of demand and supply of laborers (not by the equality of demand and supply of working hours). For more details, refer to Kinoshita (1987, pp.1266~71).

(8) On this point, refer to Kinoshita (1987, p.1275). Here, we assume that firm C and firm D have the same production functions and isoprofit curves.

(9) In the estimation, the hourly wage rate (w) is calculated with the ratio "wage earnings/working hour (E/t)." If there are serious measurement errors in working hour (t), it might cause downward bias for the coefficient β. (Borjas 1980) However, as stated above, it is the employers who answer the questionnaire in the survey, and so we think there should be no serious measurement error.

(10) Our estimation is made with pretax wage data. If the estimation is made with the after tax wage rate, the elasticity will increase slightly. As the Japanese tax system is progressive, the average tax rate for the lowest wage rate worker is 1~2% and that of the highest wage rate worker is 15~17%. As a result, WH-contract curves become a little less steep. Then, the wage rate elasticity of the WH-contract curve becomes a little higher by 0.01~0.03.

(11) Theoretically, the uncompensated wage rate (Marshallian) elasticity can be either positive or negative. Here it will be useful to consider the following interpretation of Marshallian elasticity. Using the following identity d(E) = d(wt) = (dw)t + w(dt), we have:

$$d(E)/(dw)t - w(dt)/(dw)t = 1,$$

which reduces to

$$d(E)/(dw)t + w(dl)/(dw)t = 1,$$

where, l is leisure time and we use d(l+t) = 0.

Here, (dw)t refers to the increase of market value of the total working hours. Therefore, the increase (dw)t is allocated to the increase of wage earnings (dE) and the increase of leisure time (wdl). For example, if Marshallian elasticity is −0.2, it means that 20% of (dw)t is allocated to the increase of leisure time. As leisure time is considered to be a normal good, the negative Marshallian elasticity is a plausible results.

However, if the estimated Marshallian elasticity is positive, (e.g. + 0.2), how this can be consistent with the assumption that leisure is a normal good? Theoretically, there will be two possible interpretations. The first is from the intertemporal substitution model (Heckman and MaCurdy 1980, MaCurdy 1981), and the second is from the home production model (Gronau 1986). The former assumes that future working time is substituted for present working time, and the latter assumes that working time for home production is substituted for market work.

(12) The life time employment system and the seniority wage system are the two characteristics of a typical Japanese firm, and these are considered to be effective for human capital formation. For example, the average length of time for 40~44 year old workers to be in the same company is 13.8 years for male college graduates, 14.4 years for male high school graduates, 10.9 years for female college graduates, and 10.6 years for female high school graduates, respectively.

(13) In Equations (6) and (7), Δ is the following bordered Hessian and positive from the stability condition.

$$\Delta = \begin{vmatrix} U_{EE} & U_{Et} & -1 \\ U_{tE} & U_{tt} & -(U_t/U_E) \\ -1 & -(U_t/U_E) & 0 \end{vmatrix} > 0$$

(14) "Marginal propensity to earn out of non-wage income (wdt/dβ)" can be interpreted as "marginal propensity to spend for leisure out of non-wage income. For more detail of "mpe", refer to Pencavel (1986) pp. 26~31.

(15) The formulation of this section owes to Hausman (1985).

(16) Δ is the same as in note (9).

(17) Refer to Table 19~21 in Pencavel (1986).

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Table 1 Estimates of hedonic wage curve (more than 1000 employees)

	1-tier	2 -tier	3 -tier	4 -tier	5 -tier	6 -tier	7 -tier
(1) a (t value)	78.66 (3.01)	15.65 (0.65)	−48.5 (−2.31)	−39.79 (−2.48)	−29.63 (−1.55)	−121.7 (−2.65)	23.60 (0.19)
(2) B (t value)	0.974 (7.06)	1.425 (10.8)	1.905 (16.8)	1.964 (22.3)	1.981 (18.5)	2.696 (10.3)	2.127 (2.98)
(3) Ad R^2	0.803	0.893	0.953	0.980	0.958	0.938	0.530
(4) Average wage (thousand yen)	1.396	1.512	1.642	1.745	1.814	2.002	2.264
(5) CW ratio (b/average wage)	0.698	0.943	1.160	1.126	1.092	1.346	0.939
(6) Width of wage (thousand yen)	0.212	0.099	0.091	0.063	0.070	0.113	0.304
(7) Working hours (per month)	145~ 239	167~ 204	171~ 205	159~ 199	155~ 190	166~ 186	160~ 191
(8) Total workers (×10)	3,642	3,462	4,759	6,637	6,807	4,779	5,472
(9) No. of samples	13	15	15	11	16	8	8

Note: (1) male college graduates; age group: 25 -29 years, in 2015.

(2) Estimated equation is “E= a + bt” and by OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 2 Estimates of hedonic wage curve (100~999 employees)

	1 -tier	2 -tier	3 -tier	4 -tier	5 -tier	6 -tier	7 -tier
(1) a (t value)	36.08 (0.73)	11.34 (0.36)	−19.47 (−1.36)	17.09 (0.69)	−16.00 (−0.47)	164.1 (1.71)	78.25 (1.27)
(2) b (t value)	1.078 (0.25)	1.307 (7.53)	1.578 (20.7)	1.457 (10.8)	1.739 (9.00)	0.874 (1.59)	1.567 (4.50)
(3) Ad R^2	0.630	0.835	0.964	0.879	0.825	0.276	0.828
(4) Average wage (thousand yen)	1.265	1.370	1.474	1.551	1.648	1.813	2.012
(5) CW ratio (b/average wage)	0.853	0.954	1.071	0.940	1.055	0.482	0.779
(6)Width of wage (thousand yen)	0.074	0.104	0.055	0.066	0.105	0.098	0.173
(7) Working hours (per month)	185~ 207	161~ 204	171~ 200	174~ 199	153~ 187	168~ 182	158~ 197
(8) Total workers (×10)	1,961	2,834	4,901	5,858	8,802	501	2,990
(9) No. of samples	11	12	17	17	18	5	5

Note: (1) male college graduates; age group: 25 -29 years, in 2015.

(2) Estimated equation is “E= a + bt” and by OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 3 Estimates of hedonic wage curve (10~99 employees)

	1 -tier	2 -tier	3 -tier	4 -tier	5 –tier	6 -tier
(1) a (t value)	41.42 (0.97)	−18.92 (−1.02)	4.28 (0.13)	−17.53 (−0.91)	4.68 (0.15)	8.12 (0.34)
(2) b (t value)	0.953 (4.31)	1.378 (13.9)	1.343 (7.43)	1.528 (14.4)	1.474 (8.53)	1.554 (12.3)
(3) Ad R^2	0.688	0.906	0.844	0.919	0.911	0.938
(4) Average wage (thousand yen)	1.176	1.277	1.367	1.431	1.500	1.600
(5) CW ratio (b/average wage)	0.810	1.079	0.983	1.068	0.983	0.972
(6) Width of wage (thousand yen)	0.099	0.077	0.069	0.066	0.049	0.084
(7) Working hours (per month)	177~ 208	169~ 204	173~ 196	160~ 194	174~ 198	169~ 212
(8) Total workers (×10)	945	2,307	2,732	2,862	2,577	422
(9) No. of samples	9	21	11	19	8	11

Note: (1) male college graduate; age group: 25 -29 years, in 2015.

(2) Estimated equation is “E= a + bt” and by OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 4 WH contract curve and its wage rate elasticity

(male college graduates, 2015)

Age	22~24	25~29	30~34	35~39	40~44	45~49	50~54
(1) α (t value)	244.4 (16.4)	215.6 (37.3)	218.4 (35.1)	214.7 (43.5)	201.8 (52.4)	204.78 (53.9)	202.50 (56.7)
(2) β (t value)	−46.4 (−4.25)	−20.3 (−5.86)	−18.54 (−5.73)	−15.59 (−7.11)	−9.79 (−6.74)	−10.45 (−8.31)	−10.05 (−8.89)
(3) Wage rate (thousand yen)	1.081~ 1.790	1.174~ 2.385	1.319~ 2.908	1.436~ 3.430	1.628~ 4.493	1.523~ 4.908	1.593~ 5.437
(4) Ad R^2	0.487	0.613	0.581	0.693	0.631	0.731	0.867
(5) No. of samples	19	22	24	23	27	26	28
(6) δ (t value) {Ad R^2}	−0.358 (−4.72) {0.542}	−0.190 (− 5.96) {0.622}	−0.202 (−6.16) {0.616}	−0.195 (−7.90) {0.736}	−0.155 (−7.31) {0.669}	−0.183 (−10.9) {0.825}	−0.192 (−13.3) {0.867}
(7)Total workers(×10)	30,662	76,022	80,847	83,410	84,961	77,359	65,409

Note: (a) Estimates (1)~(4) are calculated by "$t = \alpha + \beta w$" and OLS, where t is the working hour and w is the hourly wage rate.

(b) Estimates of the wage rate elasticity (6) are calculated by "$\ln(t) = \gamma + \delta \ln(w)$" and OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 5. WH contract curve and its wage rate elasticity (δ)

(female college graduates, 2015)

Age	22~24	25~29	30~34	35~39	40~44	45~49	50~54
(1) α (t value)	226.9 (46.9)	207.1 (57.8)	192.8 (39.7)	189.7 (64.8)	192.7 (53.0)	187.6 (55.5)	181.9 (59.5)
(2) β (t value)	−39.9 (−10.9)	−21.7 (−8.93)	−11.6 (−4.19)	−10.3 (−6.58)	−11.7 (−6.86)	−7.97 (−5.52)	−6.37 (−5.07)
(3) Wage rate (thousand yen)	0.904~ 1.876	0.935~ 2.117	1.051~ 2.826	0.964~ 2.844	1.076~ 3.939	1.047~ 4.337	0.898~ 4.959
(4) Ad R^2	0.831	0.767	0.398	0.610	0.622	0.504	0.469
(5) No. of samples	25	25	26	28	29	30	29
(6) δ (t value) {Ad R^2}	−0.305 (−11.7) {0.850}	−0.180 (−10.2) {0.812}	−0.120 (−4.40) {0.423}	−0.113 (−8.13) {0.707}	−0.151 (−7.32) {0.652}	−0.117 (−6.46) {0.584}	−0.087 (−4.93) {0.454}
(7)Total workers (×10)	28,431	47,857	34,242	25,206	19,609	14,256	9,533

Note: (a) Estimates (1)~(4) are calculated by "$t = \alpha + \beta w$" and OLS, where t is the working hour and w is the hourly wage rate.

(b) Estimates of wage rate elasticity (6) are calculated by "$\ln(t) = \gamma + \delta \ln(w)$" and OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 6. WH contract curve and its wage rate elasticity (δ)
(male high school graduates, 2015)

Age	18~19	20~24	25~29	30~34	35~39	40~44	45~49	50~54
(1) α (t value)	229.9 (18.7)	216.7 (22.7)	222.5 (25.1)	223.3 (30.6)	228.9 (35.3)	228.9 (34.0)	229.2 (37.6)	216.6 (50.4)
(3) β (t value)	−43.7 (−3.81)	−23.2 (−2.92)	−24.4 (−3.89)	−22.3 (−5.01)	−23.4 (−6.85)	−21.7 (−6.73)	−21.3 (−7.85)	−15.8 (−8.94)
(3) Wage rate (thousand yen)	0.885~ 1.292	0.966~ 1.522	1.083~ 1.895	1.206~ 2.362	1.353~ 2.707	1.306~ 3.245	1.460~ 3.423	1.401~ 4.096
(4) Ad R^2	0.404	0.319	0.440	0.522	0.647	0.630	0.708	0.732
(5) No. of samples	21	17	19	23	26	27	26	30
(6) δ (t value) {Ad R^2}	−0.258 (−3.88) {0.413}	−0.147 (−2.85) {0.309}	−0.183 (−3.76) {0.422}	−0.200 (−4.69) {0.489}	−0.243 (−7.16) {0.668}	−0.249 (−7.74) {0.694}	−0.265 (−8.82) {0.754}	−0.221 (−10.6) {0.792}
(7)Total workers (×10)	12,566	40,462	51,523	59,829	79,726	101,476	90,338	79,317

Note: (a) Estimates (1)~(4) are calculated by "$t = \alpha + \beta w$" and OLS, where t is the working hour and w is the hourly wage rate.

(b) Estimate (6) is calculated by "$\ln(t) = \gamma + \delta \ln(w)$" and OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 7. WH contract curve and its wage rate elasticity (δ)

(female high school graduates, 2015)

Age	18~19	20~24	25~29	30~34	35~39	40~44	45~49	50~54
(1) α (t value)	227.1 (36.7)	217.2 (21.3)	209.8 (23.6)	209.5 (30.9)	191.4 (36.0)	199.1 (35.8)	195.4 (42.8)	189.1 (50.4)
(4) β (t value)	−50.1 (−8.35)	−36.2 (−4.09)	−28.5 (−3.82)	−28.8 (−5.51)	−15.6 (−4.19)	−19.5 (−5.30)	−16.5 (−5.65)	−11.7 (−5.13)
(3) Wage rate (thousand yen)	0.809~ 1.346	0.848~ 1.536	0.919~ 1.592	0.958~ 1.671	0.958~ 2.227	1.011~ 2.358	1.011~ 2.507	0.956~ 2.928
(4) Ad R^2	0.783	0.428	0.404	0.583	0.429	0.540	0.553	0.493
(5) No. of samples	20	22	21	22	23	24	26	27
(6) δ (t value) { Ad R^2}	−0.301 (−7.60) {0.749}	−0.246 (−4.29) {0.453}	−0.201 (−3.93) {0.419}	−0.219 (−5.53) {0.584}	−0.146 (−4.71) {0.490}	−0.184 (−5.71) {0.578}	−0.160 (−5.72) {0.560}	−0.121 (−5.48) {0.528}
(7) Total workers (×10)	7,396	23,160	22,680	23,947	28,869	41,534	44,037	40,338

Note: (a) Estimates (1)~(4) are calculated by "$t = \alpha + \beta w$" and OLS, where t is the working hour and w is the hourly wage rate.

(b) Estimate (6) is calculated by "$\ln(t) = \gamma + \delta \ln(w)$" and OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).

Table 8. WH contract curve of male college graduates

(age group: 40~44 years, from 2010 to 2017)

Year	2010	2011	2012	2013	2014	2015	2016	2017
(1) α (tvalue)	196.1 (59.9)	196.3 (55.6	207.1 (41.5)	207.4 (40.8)	196.3 (61.3)	201.8 (52.4)	197.3 (52.9)	200.4 (54.1)
(5) β (tvalue)	−7.88 (−6.86)	−7.54 (−6.04)	−11.69 (−6.30)	−12.09 (−6.73)	−7.87 (−6.81)	−9.79 (−6.74)	−7.56 (−5.38)	−8.39 (−6.03)
(3) Wage rate (thousand yen)	1.523~ 5.099	1.371~ 5.578	1.388~ 4.361	1.546~ 4.869	1.493~ 4.741	1.628~ 4.493	1.488~ 4.510	1.525~ 4.540
(4) Ad R^2	0.590	0.542	0.547	0.604	0.602	0.631	0.466	0.558
(5) No. of samples	33	31	33	30	31	27	33	29
(6) δ (t value) { Ad R^2}	−0.140 (−9.23) {0.725}	−0.133 (−7.74) {0.662}	−0.187 (−8.00) {0.666}	−0.204 (−8.90) {0.730}	−0.132 (−7.83) {0.668}	−0.155 (−7.31) {0.669}	−0.122 (−6.46) {0.560}	−0.137 (−7.55) {0.666}
(7) Total workers (×10)	68,973	69,912	87,510	83,302	82,349	84,961	88,919	82,519

Note: (a) Estimates (1)~(4) are calculated by "$t = \alpha + \beta w$" and OLS, where t is the working hour and w is the hourly wage rate.

(b) Estimate (6) is calculated by "$\ln(t) = \gamma + \delta \ln(w)$" and OLS.

Data source:Basic Survey in Wage Structure, (the Ministry of Health, Labour and Welfare of Japan).