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A Structural Estimation of the CES Preferences and Linear Labor Supply: The Case of Prime-Age Males in Japan

by

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Abstract

The tax simulation studies in Japan have necessarily relied on arbitrary sets of preference parameters due to the paucity of the empirical estimates. Motivated by this state of the art, we estimate the labor supply function and preference parameters for Japanese prime-age males, allowing for the complex Japanese income tax system and taking advantage of a large microdata set we obtained for this study. We employ two versions of the method of maximum likelihood. One is the celebrated Hausman method which assumes a linear labor supply function (Hausman 1979). The other is the method proposed by Zabalza (1983), which takes advantage of an explicit specification of the CES preferences. We have examined several estimation patterns and calculated elasticities over the whole or sub-samples of observations. While the sample averages of uncompensated elasticities are estimated between $0.06-0.21$, those of compensated counterparts result in higher ranges ($0.08-1.39$) due to rather large negative estimates for the income effects. It may be interesting to point out that the compensated elasticities tend to be higher in the CES case ($0.41-1.39$) than the Hausman case ($0.08-1.12$) despite the fact that the former is immune from the MaCurdy critique (MaCurdy et al. 1990).

Key words: personal income taxes, pice-wise linear budget constraint, labor supply

JEL codes: H21, H24, H31, J22

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1 Introduction

Evaluating market response to taxation has profound implications for assessing public policy. Since taxes distort an economy to the extent that consumer choices are affected by taxation, designing optimal tax structure requires parameters that describe how individuals response to tax changes. In addition, if taxes are distortionary, the marginal cost of public funds (MCPF) may be more than unity, blowing up the effective cost of an expenditure program more than its nominal value. Given the fact that labor taxes constitute a majority of tax revenues in most developed countries, therefore, the estimation of labor supply response to taxation has been a primal focus of the empirical literature (Pencavel 1986, Blundell and MaCurdy 1999).

In contrast to the rich stock of empirical studies for North America and Europe, however, few analogous attempts have been made in Japan.[1] First, very few of the Japanese studies properly allow for the effect of tax system on the budget constraint of consumers.[2] With a progressive taxation system, marginal tax rates on personal labor income depend on the number of hours worked, which means that after-tax wage rates are influenced by the hours of worked. This makes an individual budget constraint piece-wise linear where each of its segments is identified with a linear line defined by the after-tax wage rate – the slope – and the 'virtual income' – the intercept of the linear line extended from that segment. As labor hours vary, both the after-tax wage rate and the virtual income also vary, which gives rise to the endogeneity problems in estimating labor supply responses. While this is the standard argument in the literature, however, typical Japanese studies have not allowed for the issues that the piece-wise linear budget constraint may raise.[3] In addition, a majority of the Japanese studies employ before-tax, rather than after-tax, wage rate as an explanatory variable. Since the *gross* wage elasticity of labor supply makes sense *only when the tax structure does not vary* (Blomquist 1988), tax policy evaluation based on the gross elasticity will be problematic.

Second, little interest has been shown in the labor supply of prime age male workers in Japan, although they contribute to a substantive part of income tax revenues.[4] Given the institutional constraints in the Japanese labor markets, many Japanese economists tend to question the limitation and unreality of the standard

[1] Except our own studies, we have found only 21 published studies that estimate the wage effects on labour supply. Among them nine studies employed micro-data, while the others utilized data aggregated either at national or prefectural level. See Bessho and Hayashi (2005) for more.

[2] Possible exceptions may include Akabayashi (2002) which focuses on female labor supply, not on that of the prime-age males.

[3] The argument is well summarized in, for example, Blundell and MaCurdy (1999).

[4] Okamoto (1984), Asano (1997), and Yamada et al. (1999) estimated the labor supply of prime-age males. But their data sets are, however, aggregate and they did not properly consider the effects of the tax system. There are very few microdata-based studies with a possible exception of Shimada and Sakai (1980) who estimate for males under 30 living with their parents. Naito (2003) is another exception but his sample is also limited.

leisure-goods choice model.[5] They often assume that workers, unable to respond to wage rate changes by adjusting their labor supply, only either accept or reject the set of wage and working hours proposed by prospective employers. As such, when they decide to work, the elasticity of the labor supply along the intensive margin is zero with the fixed working hours.[6] This type of modeling is deemed to be even more suited to prime-age male workers in this country. We know, however, that the standard labor supply model does *not* necessarily require workers to freely choose their working hours for a given value of wage rate (Blundell and MaCurdy 1999). The model can be predicated on an environment where workers pick one pair of wage rate and labor hours from among those that several possible employers offer. We then interpret selected pairs as labor supply functions that represent workers' preferences over the set of wage rates and working hours.

Third, despite the paucity of the empirical estimates for the Japanese economy, a series of tax reform simulation has been conducted (Honma et al. 1985, Honma et al. 1987, Hashimoto et al. 1989, Honma 1991, Yamada 1991, Konishi 1997, Hashimoto 1998, Uemura 2001). An applied general-equilibrium (AGE) model is set up to examine the effects of tax changes by simulating how an exogenous change in a tax system would disturb an existing equilibrium and yield a new one. Of course, AGE models need parameters that characterize consumer preferences, which in turn condition labor responses to the tax change. However, since there seem to be no reliable estimates for consumer preferences or labor responses, the tax simulation studies have necessarily relied on arbitrary sets of preference parameters.

Motivated by this state of the art, and taking advantage of the data set obtained for this study, we estimate the labor supply function and preference parameters for Japanese prime-age males (age 25 to 55), allowing for the issues discussed above. In this exercise, we employ the two estimation methods proposed respectively by Hausman (1979) and Zabalza (1983). Both are what is called 'structural' and take advantage of the method of maximum likelihood. But they differ in the specification of consumer preferences and in the way how the log-likelihood functions are derived. Note that the structure of our data set precludes other popular methods, including the IV estimation (e.g., MaCurdy 1981) and the difference-in-difference (D-in-D) method (e.g., Saez 2003). The current study draws on *Syugyo Kozo Kihon Chosa* [Employment Status Survey] conducted in 1997 and 2002. While the survey is arguably the most comprehensive survey on labor supply with a large number of observations, labor hours in the survey are coded with intervals for which no point data are available. Furthermore, the structure of the data is not that of panel data,

[5] In fact, constraints in labor markets are pointed out in other countries too. For example, Kimball and Shapiro (2003) discuss the constraints on labor hours imposed by the employers, and the difference between the observed wage and the shadow wage implicit in a long-term relationship between firms and workers.

[6] For this type of reasoning, see Higuchi and Hayami (1984).

with different samples surveyed over time. These limitations make the applications of the IV and D-in-D methods less straightforward, and leave us the two methods that utilizes the ML estimation which readily allows for the data set with interval data, as we shall show in this study.

While the two methods share a common basis in that they utilize the ML method and explicitly take account of both the consumer preferences and the tax system in place, Zabalza's method seems to have been less popular than Hausman's. However, the method, which specifies consumers' preferences as a CES form, may have several advantages. First, it is less 'computationally demanding' since the CES specification yields a much simpler ML function. Second, the method well conforms to the existing tax simulation studies, since such simulations frequently specify consumer preference as a CES form. With the method by Zabalza, therefore, we could lend an empirical basis to the tax simulations which was once based upon the arbitrary choice of the decisive parameters.

We examine several estimation patterns and calculate the wage elasticities of labor over the whole or sub-samples of observations. To anticipate the results, we will show that the uncompensated (Marshallian) elasticities are estimated to range between $0.06 - 0.21$ on average. Along with a rather large income effects, the compensated (Hicksian) counterparts resulted in higher ranges ($0.08 - 1.39$), which tend to be higher in the CES case ($0.41 - 1.39$) than the Hausman case ($0.08 - 1.12$). This result may be interesting since the former case is immune from the MaCurdy critique (MaCurdy 1990).

Our exercise, of course, has several caveats. First, our model is static. While the literature has also examined intertemporal models of labor supply, however, such an intertemporal study demands more information than that is available for the current study. For example, the model based on the two-stage budgeting requires information on individual assets or on individual consumption (MaCurdy 1983). In addition, the estimation of Frisch labor supply function requires us to allow for individual fixed effects, which typically presumes a panel structure of the data (MaCurdy 1981). We are thus limited to examining the *intra*temporal elasticity based on a static model. Second, our intent is to estimate a base-line model that may conveniently be used for tax simulation studies. Of course, workers may not have a perfect knowledge of tax structure and do not maximize their utility without evading or avoiding taxes. A household is not a unitary actor, and there may be important interactions among family members. While allowing for these *realistic* assumptions is important,[7] but doing so should constitute a topic for another paper. Third, while there are several dimensions of workers' response to wage changes, we only consider intensive margins. Workers decide whether to enter the labor force (extensive margin), and change their

[7] See Gemmell et al. (2004) for the fiscal illusion and Brett (1988) for the intrafamily resource allocation.

hours worked and/or the intensity of their work (intensive margin).[8] While we are aware that distinguishing between these two margins is important,[9] we focus on the intensive margin for this paper.

This paper is organized as follows. The next section (Section 2) extends the two models originally invented by Hausman and Zabalza and derives the two types of log-likelihood functions that are adjusted for our data structure. In Section 3, we explain our sample, data set and the construction of the key variables. Section 4 provides the estimates and discusses implications. Section 5 then concludes.

2 Method

2.1 Linear Labor Supply

Since the Hausman method is explained elsewhere, we simply provides its basic assumptions and the modifications our data necessitates. The Hausman method starts with a linear labor supply function in level:

$$h_i = \alpha w_i + \beta y_i + \boldsymbol{Z}_i \gamma + u_i \tag{1}$$

where h_i is hours worked, w_i is net wage rate, y_i is the virtual income, $\boldsymbol{Z}_i$ is a vector of observable individual characteristics, and u_i is error term. Note that, due to different marginal tax rates under the progressive tax system, the price of leisure (i.e., net-of-tax wage rate) changes discontinuously, depending on individual consumption of leisure ($L - h_i$ where L is the time endowment). This makes the budget line kinked and piece-wise linear. For a given segment of the budget line, the constraint is linearly expressed as

$$x_i = w_i \cdot h_i + y_i \tag{2}$$

where $w_i = w(Y_i, \boldsymbol{M}_i, W_i) = (1 - m(Y_i, \boldsymbol{M}_i))W_i$ and $y_i = y(Y_i, \boldsymbol{M}_i)$. W_i is gross wage rate and $Y_i \equiv W_i h_i$ is earned income. Expressions $m(Y_i, \boldsymbol{M}_i)$ and $y(Y_i, \boldsymbol{M}_i)$ associates marginal tax rate m and virtual income y of individual i with his income $Y_i = W_i h_i$ and his household characteristics $\boldsymbol{M}_i$ that affect tax deductions and credits (and may be different from $\boldsymbol{Z}_i$). As such, w_i and y_i are constructed with wage and no-labor income data combined with a detailed examination of the tax codes.

The error term is decomposed as $u_i = \zeta_i + \varepsilon_i$ where ζ_i is unobserved difference in preferences that is not explained by $\boldsymbol{Z}_i$, and ε_i is other unspecified type of error that include optimization errors by consumers as well as measurement errors by

[8] There are additional dimensions of consumer responses if the wage change is caused by changes in taxes. Tax avoidance and evasion are prime examples. Several studies therefore focus on estimating the elasticity of taxable income, rather than labor supply. See, for example, Auten and Carroll (1999) and Gruber and Saez (2002).

[9] See, for example, Saez (2002) and Bhattarai and Whalley (2003).

observers. These two components are independently distributed with $\zeta_i \sim N(0, \sigma_\zeta^2)$ and $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$. With the definition $v_i \equiv \varepsilon_i + \zeta_i \sim N(0, \sigma_v^2)$, the correlation coefficient between v_i and ζ_i is given as $\rho(v_i,\, \zeta_i) = \sigma_\zeta / \sigma_v$ with $E(v_i \varepsilon_i) = \sigma_\varepsilon^2$ and $E(v_i \zeta_i) = \sigma_\zeta^2$.

The progressive labor income taxation makes consumer's budget constraint piecewise linear. Let $h_1^*, ..., h_{J-1}^*$ be labor supply on which the budget kinks. Segment j defines a linear line with a set of net wage rate and virtual income (w_j, y_j) for $j = 1, 2, ..., J$. With $g_j \equiv \alpha w_j + \beta y_j + \boldsymbol{Z}\gamma$, labor supply h is characterized as

$$h = \begin{cases} g_1 + \zeta + \varepsilon & \text{if } g_1 + \zeta < h_1^* \\ h_1^* + \varepsilon & \text{if } g_2 + \zeta < h_1^* < g_1 + \zeta \\ g_2 + \eta + \varepsilon & \text{if } h_1^* < g_2 + \zeta < h_2^* \\ \vdots & \\ h_{J-1}^* + \varepsilon & \text{if } g_J + \zeta < h_{J-1}^* < g_{J-1} + \zeta \\ g_J + \eta + \varepsilon & \text{if } h_{J-1}^* < g_J + \zeta. \end{cases} .$$

where index i is suppressed.

We can then assign the probability for each of the events. Recall that our data do not contain a point value h but an interval $[h_L, h_H]$: we only observe whether or not $h \in [h_L, h_H]$. This requires us to depart from the standard Hausman method and to derive the probability of h falling in a given interval:

$$\begin{aligned} & \Pr[h_L < g_j + \zeta + \varepsilon < h_H, h_{j-1}^* < g_j + \zeta < h_j^*] \\ = \; & \Psi\left(\frac{h_H - g_j}{\sigma_v}, \frac{h_j^* - g_j}{\sigma_\zeta}, \rho\right) - \Psi\left(\frac{h_L - g_j}{\sigma_v}, \frac{h_j^* - g_j}{\sigma_\zeta}, \rho\right) \\ & -\Psi\left(\frac{h_H - g_j}{\sigma_v}, \frac{h_{j-1}^* - g_j}{\sigma_\zeta}, \rho\right) + \Psi\left(\frac{h_L - g_j}{\sigma_v}, \frac{h_{j-1}^* - g_j}{\sigma_\zeta}, \rho\right) \end{aligned}$$

where $\Psi(x_1, x_2, \rho)$ is a joint cumulative distribution of two random variables x_1 and x_2 that are drawn from the standard normal distribution with correlation coefficient ρ. The probability that the observed value of h with its optimal part (h^*) on a kink point $(h^* = h_L)$ falls between $[h_L,\, h_H]$ is:

$$\begin{aligned} & \Pr[h_L < h_j^* + \varepsilon < h_H, g_{j+1} + \zeta < h_j^* < g_j + \zeta] \\ = \; & \Pr[h_L - h_j^* < \varepsilon < h_H - h_j^*, h_j^* - g_j < \zeta < h_j^* - g_{j+1}] \\ = \; & \left[\Phi\left(\frac{h_H - h_j^*}{\sqrt{\sigma_\varepsilon^2}}\right) - \Phi\left(\frac{h_L - h_j^*}{\sqrt{\sigma_\varepsilon^2}}\right)\right] \cdot \left[\Phi\left(\frac{h_j^* - g_{j+1}}{\sqrt{\sigma_\zeta^2}}\right) - \Phi\left(\frac{h_j^* - g_j}{\sqrt{\sigma_\zeta^2}}\right)\right]. \end{aligned}$$

where $\Phi(\cdot)$ is the cumulative standard normal distribution. With these two types of probability defined over the observations, we can construct the ML function of our sample to estimate parameters α, β, γ, ρ, σ_v, and σ_ζ.

2.2 CES Utility Function

The method proposed by Zabalza (1983) starts by assuming that the preferences of individual i are represented by the following CES utility function:

$$u(x_i, h_i) = \left(x_i^{-\mu} + \kappa_i \cdot (T - h_i)^{-\mu} \right)^{-\frac{1}{\mu}}, \tag{3}$$

where x_i is the composite good as numeraire, h_i is labor supply, and $\mu > -1$ is the parameter that represents the elasticity of substitution. The weight κ_i is determined by personal characteristics $\mathbf{Z}_i$ (vector) and a random component ξ_i as:

$$\kappa_i \equiv \exp\left(\boldsymbol{Z}_i \boldsymbol{\theta} - \xi_i\right), \tag{4}$$

where e is the base of the natural logarithm, and $\boldsymbol{\theta}$ is a corresponding coefficient vector. Note that $\kappa_i > 0$ by construction. With the linearly approximated piece-wise linear budget constraint (2) and the specification for κ_i (4), the labor supply function is given as

$$h_i^* = \frac{T \cdot \left[w(W_i h_i, \boldsymbol{M}_i) / \exp\left(\boldsymbol{Z}_i \boldsymbol{\theta} - \xi_i\right)\right]^{\frac{1}{1+\mu}} - y(W_i h_i, \boldsymbol{M}_i)}{w(W_i h_i, \boldsymbol{M}_i) + \left[w(W_i h_i, \boldsymbol{M}_i) / \exp\left(\boldsymbol{Z}_i \boldsymbol{\theta} - \xi_i\right)\right]^{\frac{1}{1+\mu}}} \tag{5}$$

which is a fairly complex function to estimate.

Zabalza (1983) skips the direct estimation of (5) for estimating parameters in (3), taking advantage of the CES form of (3). In addition, we can extend his method to forego directly observing h_i^* to obtain the parameters with interval-coded labor hour data as follows.

The labor supply function (4) can be transformed into

$$\left(\frac{w(W_i h_i^*, \boldsymbol{M}_i)}{\kappa_i} \right)^{\frac{1}{1+\mu}} = \frac{w(W_i h_i^*, \boldsymbol{M}_i) h_i^* + y(W_i h_i^*, \boldsymbol{M}_i)}{T - h_i^*} = \frac{x_i^*}{l_i^*},$$

where $l_i^*$and x_i^* are the optimal leisure and numeraire good consumptions. For an arbitrary level of hours worked h, we obtain the marginal tax rate $m(W_i h_i, \boldsymbol{M}_i)$ and the virtual income $y(W_i h_i, \boldsymbol{M}_i)$, and corresponding levels of consumption $x \equiv (1 - m(W_i h_i, \boldsymbol{M}_i))Y + y(W_i h_i, \boldsymbol{M}_i)$ and leisure $l_i \equiv T - Y/W_i$. Then, for a given interval of labor hours $[h_{iL}, h_{iH}]$ with subscripts iH and iL respectively denoting the upper and the lower ends assigned to individual i, a close examination of Figure 1 shows that

$$\frac{x_{iL}}{l_{iL}} \leq \frac{x_i^*}{l_i^*} \leq \frac{x_{iH}}{l_{iH}} \tag{6}$$

where $x_{ij} \equiv (1 - m(W_i h_{ij}, \boldsymbol{M}_i)) W_j h_{ij} + y(W_i h_{ij}, \boldsymbol{M}_i)$ and $l_{ij} \equiv T - h_{ij}$ for $j = L, H$. With $1 + \mu > 0$ and the convex budget set, the right-hand side of (6) then implies that

$$\frac{x_{iH}}{l_{iH}} \geq \frac{x_i^*}{l_i^*} = \left(\frac{w_i^*}{\kappa_i}\right)^{\frac{1}{1+\mu}} \geq \left(\frac{w_{iH}}{\kappa_i}\right)^{\frac{1}{1+\mu}} \text{ or } \frac{x_{iH}}{l_{iH}} \geq \left(\frac{w_{iH}}{\kappa_i}\right)^{\frac{1}{1+\mu}}$$

where $w_{iH} \equiv (1 - m(W_i h_{iH}, \boldsymbol{M}_i))W_i$. Similarly, the left-hand side of (6) implies

$$\frac{x_{iL}}{l_{iL}} \leq \frac{x_i^*}{l_i^*} = \left(\frac{w_i^*}{\kappa_i}\right)^{\frac{1}{1+\mu}} \leq \left(\frac{w_{iL}}{\kappa_i}\right)^{\frac{1}{1+\mu}} \text{ or } \frac{x_{iL}}{l_{iL}} \leq \left(\frac{w_{iL}}{\kappa_i}\right)^{\frac{1}{1+\mu}}$$

where $w_{iL} \equiv (1 - m(W_i h_{iL}, \boldsymbol{M}_i))W_i$. With (4), we show that the probability of observing the labor income of individual i between $[h_{iL}, h_{iH}]$ is

$$\begin{aligned}
& \Pr\left\{\frac{x_{iH}}{l_{iH}} \geq \left(\frac{w_{iH}}{\exp(\boldsymbol{Z}_i\boldsymbol{\theta} - \xi_i)}\right)^{\frac{1}{1+\mu}} \text{ and } \left(\frac{w_{iL}}{\exp(\boldsymbol{Z}_i\boldsymbol{\theta} - \xi_i)}\right)^{\frac{1}{1+\mu}} \geq \frac{x_{iL}}{l_{iL}}\right\} \\
= \; & \Pr\left\{\xi_i \leq \boldsymbol{Z}_i\boldsymbol{\theta} - \ln w_{iH} + (1+\mu)\cdot\ln\left(\frac{x_{iH}}{l_{iH}}\right)\right. \\
& \left. \text{and } \boldsymbol{Z}_i\boldsymbol{\theta} - \ln w_{iL} + (1+\mu)\cdot\ln\left(\frac{x_{iL}}{l_{iL}}\right) \leq \xi_i\right\}
\end{aligned}$$

which is a contribution to the likelihood function we use to estimate parameters $\{\mu, \boldsymbol{\theta}\}$. In particular, if we assume that $\xi \sim N(0, \sigma_\xi^2)$, the log-likelihood function will be

$$\begin{aligned}
\ln L(\mu, \boldsymbol{\theta}, \sigma_\xi) = & \sum_i \ln\left\{\Phi\left(\frac{\boldsymbol{Z}_i\boldsymbol{\theta} - \ln w_{iH} + (1+\mu)\cdot\ln(x_{iH}/l_{iH})}{\sigma_\xi}\right)\right. \\
& \left. -\Phi\left(\frac{\boldsymbol{Z}_i\boldsymbol{\theta} - \ln w_{iL} + (1+\mu)\cdot\ln(x_{iL}/l_{iL})}{\sigma_\xi}\right)\right\} \qquad (7)
\end{aligned}$$

where $L(\cdot)$ is the likelihood function and $\Phi(\cdot)$ is the cumulative distribution function of normally distributed random variable ξ. Since $x_{ij} \equiv (1 - m(W_i h_{ij}, \boldsymbol{M}_i))W_i h_{ij} + y(W_i h_{ij}, \boldsymbol{M}_i)$, $l_j \equiv T - h_{ij}$ and $w_{ij} \equiv (1 - m(W_i h_{ij}, \boldsymbol{M}_i))W_i$ for $j = L, H$, we use the above log-likelihood to obtain ML estimates of preference parameters $\{\mu, \boldsymbol{\theta}\}$ with interval coded labor hours $[h_{iL}, h_{iH}]$. More specifically, for a given values of μ and $\boldsymbol{\theta}$, we can quantify (6) with data for wage rate W_i, personal characteristics $\boldsymbol{Z}_i$, marginal tax rate m_{ij}, and virtual income y_{ij}. The latter two are calculated for a given interval $[h_{iL}, h_{iH}]$, with reference to the tax schedule and the relevant household information $\boldsymbol{M}_i$.

3 Data sets

3.1 Data and variables

The data used in our samples are obtained from *Syugyo Kozo Kihon Chosa* [Employment Status Survey] by the Statistical Bureau of the Japanese Government in

1997 and 2002. This survey is conducted every five years and arguably the most comprehensive labor survey in Japan, which contains about 11 million individual observations with a variety of household characteristics. Our focus is on the labor supply of prime age (25-55) males who are also classified as the head with non-working spouse. We further excluded observations with the following characteristics: (a) self-employed workers, (b) board's members of private companies or non-profit organizations, (c) family workers for SMEs, (d) the unemployed due to illness, (e) those who had changed residence or job within one year, and (f) those who had children within one year. We also excluded those with non-labor income since the survey does not provide the point value for that variable (therefore the sample consists of those only with labor income). These omissions reduce the sample size down to 73,713 in 1997 and 63,703 in 2002.

Tables 1a and 1b show the summary statistics for 1997 and 2002. The labor supply (dependent variable) is measured as annual hours worked for a given year. The independent variables are standard and consist of after-tax (net) wage, virtual income, age, age squared, the number of children below 15 years old, and the number of dependents other than said children. The net wage is calculated as a product of gross wage and one minus marginal tax rate. Recall that hours worked is coded with intervals in the survey, which make it impossible to obtain gross wage as a ratio of income to hours worked as in the standard studies. Therefore, we followed Shimada and Sakai (1980) to construct gross wage data from *Chingin Kozo Kihon Tokei Chosa* [Basic Survey on Wage Structure] and match them with the observations used in our sample. Specifically, we constructed a tabulation of average gross wages sorted by (a) sex, (b) educational background, (c) age, and (d) place of living (47 prefectures), and assign them with the observations that share the same combination of the four types of characterizations. The marginal tax rate and virtual income are calculated with a close examination of the Japanese tax codes in 1997 and 2002 as we see below. Recall that we excluded observations with non-labor income. Therefore, variations in virtual income only come from those in gross wages (W_i) as well as household characteristics ($\boldsymbol{M}_i$) that affect exemptions and credits for personal income and payroll taxes. Other dependent variables (age, the number of children below 15 years old, and the number of other dependents) are obtained from the survey.

3.2 The tax system

Three types of taxes are imposed on personal income in Japan: (i) 'Income Tax' by the national government (national income tax), (ii) 'Inhabitants Taxes' by preferctures and municipalities[10] (local income taxes), and (iii) social security contributions to

[10] The amounts of inhabitants taxes are calculated based on the income in the previous year in practice. However, we assume away complications this entails.

social security funds (payroll taxes)[11]. The details of the tax system for 1997 and 2002 are described in Table 2.

The tax rates apply to 'taxable income.' Taxable income is obtained by substracting from annual gross wages a series of deductions and allowances, which include 'employment income deduction,' social security deductions, basic allowance and other allowances for spouse and dependents. The amount of employment income deduction regressively deducts certain percentages of gross wages as seen in Table 2. The social security contributions (pay roll taxes) are all deducted too. The basic allowance applies to all households. The allowances for spouse are applicable if the taxpayer's spouse earns income under a certain level. Allowances are also made for dependents. Such dependends, for example, include children aged between 16 and 23 that do not work. The summary of those deductions and allowances is provided in the table. The deductions and allowances differ as individual characteristics differ. In other words, deductions and allowances have to be defined on individual basis. We only consider the household characteristics we can obtain from the survey. The data from individual observation allow us to calculate basic allowance, allowances for spouse, allowance for dependents, employment income deduction and deduction for social insurance premiums.

Tax rates are progressive[12]. The determinants of the effective marginal tax rates consist of statutory tax rates of the national and local income taxes, employment income deduction rates and social insurance premium rates. For example, the possible pairs of statutory rates of the two income taxes yeild nine combined rates in 1997: 0%, 5%, 15%, 20%, 30%, 35%, 45%, 55%, and 64%. In addition to these, there are proprotional payroll tax rates that depend on the type of employers for social security contributions. Thus there are 8 kinks in the piece-wise linear budget constraint in 1997. With the introduction of the system of proportional tax credit and the changes in the tax system, the analogous number of the kink points nine in 2002. Since the system of employment income deduction generates additional five kink points, the number of kink points in the budget constraint is 13 in 1997 and 14 in 2002, although the upper kinks may not be realized if gross wage rates are too low.

[11] We assume public pension insurance, public health insurance and public unemployment insurance as social insurance. The premiums of social insurance differ as places of work differs. The data does not contain, however, such information needed to calculate social insurance premium. We assume that the social insurance premium is 13.325% if the firm where the individual works employs less than 1000 people, 14.306% if more than 1000 people, 12.9395% if the individual is a public servant, in 1997 (as of 2002, the rates are 11.29, 12.568 and 11.09, respectively). In addition, special payroll tax are applied for bonus in 1997. We ignore the upper limit of the social insurance premium.

[12] The tax rates of inhabitants tax shown in Table are based on "standard tax rates". Prefectures and municipalities are able to change these tax rates in principle, but in practice, almost all local governments employ the standard tax rates for inhabitants tax.

3.3 Elasticities

We evaluate labor supply responses in elasticity form. The uncompensated wage elasticity of labor supply η_i, income effect ϕ_i, and compensated wage elasticity of labor supply η_i^c are given as, for the linear labor supply function case,

$$\begin{aligned} \eta_i &= \alpha w_i / h_i \\ \phi_i &= \beta w_i \\ \eta_i^c &= \eta_i - \phi_i \end{aligned}$$

and, for the CES case,

$$\begin{aligned} \eta_i &= \frac{w_i}{h_i} \frac{y_i + \frac{1}{1+\mu}(w_i/\kappa_i)^{\frac{1}{1+\mu}}(-\mu T + y_i/w_i)}{(w_i + (w_i/\kappa_i)^{\frac{1}{1+\mu}})^2}, \\ \phi_i &= -\frac{w_i}{w_i + (w_i/\kappa_i)^{\frac{1}{1+\mu}}}, \\ \eta_i^c &= \eta_i - \phi_i. \end{aligned}$$

Two problems arise in calculating the elasticities. First, we do not have point data for h_i since our data for the hours worked are coded as intervals. In addition, the fitted values for h_i are not readily available as in the standard case of the interval regression, since w_i and y_i depends on h_i. We cope with this problem through picking up the largest value of consumer utility. Since each segment of the piece-wise linear budget constraint for individual i is associated with a pair of after-tax wage rate w_i and virtual income y_i, we can see how individual indirect utility varies depending on the choice of the pair[13]. By construction, the optimal consumption-labor choice is given by the pair (or segment) that yields the highest value of the utility function. With the pair (w_i, y_i) thus identified, we obtain a point estimate for h_i, which allows us to calculate elasticities. We also allow for the preference heterogeneity by drawing ζ or ξ from a random number generator for normal distribution with zero mean and estimated standard error, and adding those values to the above point estimates for the labor hours.[14]

[13]For the linear labor supply case, the indirect utility is obtained as

$$v(w_i, y_i) = \exp[\beta w_i] \cdot \left(y_i + \frac{\alpha}{\beta} w_i - \frac{\alpha}{\beta^2} + \frac{\mathbf{Z_i}\gamma}{\beta} \right)$$

with the labor supply functions $h_i = \alpha w_i + \beta y_i + \mathbf{Z}_i \gamma + \theta_i$. For the CES case, with labor supply $h_i = (T(w_i/\kappa_i)^{\frac{1}{1+\mu}} - y_i)/w_i + (w_i/\kappa_i)^{\frac{1}{1+\mu}}$, the indirect utility function is

$$v(w_i, y_i) = \frac{(w_i T + y_i)[(w_i/\kappa_i)^{-\frac{\mu}{1+\mu}} + \kappa_i]^{-\frac{1}{\mu}}}{w_i + (w_i/\kappa_i)^{\frac{1}{1+\mu}}}.$$

[14]Note that the assumption about measurement error make variance of estimated working hours

Second, it is not straightforward to define the wage elasticities of labor supply at the kink points.[15] Common wage rates cannot be defined, nor can elasticities, at the kink points. To circumvent the problem, we take advantage of the fact that elasticities are mechanically defined once net-wage rates, quantities of labor supply and numeraire good are available. We then artificially define a psuedo-elasticity that utilizes a pair of labor supply and the numeraire along with the net wage rate of the 'next' segment.[16]

4 Results

4.1 Linear Labor Supply

Table 3 lists the main estimation results. The coefficients on after-tax wage rate and virtual income have expected signs and are all statistically significant at the standard levels of significance. The absolute values of the coefficients are are larger in 2002 than those in 1997. Including educational backgrounds as additional explanatory variables increases the absolute values and the changes are more conspicuous for for the after-tax wage rate. The number of young kids affects positively and the number of specific dependent children have negative effects on hours worked. The standard deviations of preference heterogeneity (σ_ζ) and observation error (σ_v) are also statistically significant. Given the standard error for the 'fitted values' we will see in Table 4, these two values suggest that there are larger variations that are unexplained by the structural component.

The elasticities based on Table 3 are listed in Table 4. The average values of the uncompensated elasticities range from .059 to .178. Along with the range for the income effects between $-.321$ and $-.637$, the average values of the compensated elasticities range from .379 to .815. The compensated labor supply elasticities are estimated larger, by more than .1, with the specification that includes educational backgrounds as explanatroy variables. In each case, the magnitude of substitution and income effects are both large, but they are cancelled out to yeild rather reasonable values for the Marshallian elasticities. For example, the uncompensated elasticity of .1 means that working hours of a worker, who works $2,500$ hours per year and receive $3,000$ yen per hour (that is, her annual earnings is 7.5 million yen), increase only 2.5 hours per year when her hourly wage increase by 1% (her annual earnings increase $7,500$ yen). While we are focusing on the intensive margin, these small values are consistent with previous studies.

In addition, we estimated the labor supply function with subsamples categorized

smaller than that of actual hours.

[15] As noted above, our data for the hours worked are coded intervals. This make it impossible to verify actual labor supply is near kink points.

[16] We are thus considering the case where labor supply increases a little bit from a given kink point.

by employment status. Table 5 shows the results. For the permanent workers, the uncompensated elasticities are less than .100. And both the compensated elasticity and the income effect are smaller than those obtained from the whole sample in Table 4. For supply workers, the sample-average elasticities are much larger than those for permanent workers, which may naturally be expected. The sample variance of the uncompensated elasticities are also larger, which may be due to the fact that the virtual income is statistically insignificant with the large standard error. For daily-workers, the coefficient on the virtual income is negative on average. Given the average value for the uncompensated elasticity, this means that the Slutsky condition is not satisfied on average with the negative value of the average uncompensated elasticity. Noting that the coefficient on virtual income is not statistically significant, this results may be due to the small sample size and/or specification errors.

We also examined the subsamples categorized by educational backgrounds. Table 6a shows the results for the 1997 data. While the coefficients on after-tax wage rate are all statistically significant with expected signs, those on virtual income are statistically insignificant for the subsamples other than 4-year college graduates, and has an unexpected sign for 2-year college graduates. On the other hand, in Table 6b which lists the results from the 2002 data, we see expected signs on after-tax wage and virtual income which are all statistically significant. Comparing high school graduates with 4-year college graduates, both of which have larger sample sizes (more than $20,000$), we see that the compensated and uncompensated elasticities of college graduates are larger than those of high school graduates. In particular, the compensated elasticity of college graduates in 2002 is more than 1.[17]

4.2 CES Utility Function

For the CES case, we do not directly estimate the labor supply function. Instead, paramters of the utility function in a CES form as (3) and (4) are estimated to be utilized to obtain the elasticities. Table 7 lists the estimation results. Columns 1 and 4 do not allow for individual characteristics as controls (i.e., κ is constant over observations). The other columns do allow for different combinations of the controls, which all exhibit statistical significance. The number of children under 14 years of age has a negative effect on the leisure weight, while the number of 'specific' dependents has a positive effect. The effects of junior high school graduation are estimated to be negative. These results are consistent with the case of the linear labor supply function.

The parameter μ represents the elasticity of substitution and falls within the range of $-.148$ to $.011$. Note that the CES utility function approaches the linear utility

[17] This may be counterintuitive since college graduates in Japan may tend to be thought as being employed in large established companies where labor hours are rather inelastic to wages. These small elasticities may be due to relatively small variations of the wage rate of college graduates.

function if $\mu \to -1$, and the Cobb-Douglas form if if $\mu \to 0$.

Table 8 shows the average elasticities based on the results in Table 7. The average uncompensated elasticities range from .138 to .211 along with the average income effects of around $-.79$, which together yeilds the average compensated elasticities which range from .9 to 1.0. These compensated electicities are higher than analogous values for the linear labor supply function case. However, the uncompensated values are still rather small.

We also conducted subsample estimation that is analogous to the linear function case. Table 9 shows the results by the employment status. The compensated elasticities are quite large being in the vicinity of unity. Still, the values are relatively smaller for permanent workers, an analogous result we obtained for the linear labor supply function case. Tables 10a and 10b show the results for the subsamples categorized by the educational backgrounds. The substitution and income effects do not vary very much among the different education backgrounds. The values of the uncompensated elasticities, ranging from .15 to .25, are similar to or somewhat larger than those obtained in the other case.

4.3 Comparison

We have found that the elasticities differ depending on the specification[18]. We consider the difference more closely, examining the case of 2002. The results are compared in Table 11. Note that we assume away the preference heterogeneity in the linear labor supply so that the results of the two types of estimation comparable. As such, the figures are slightly different from those in Table 4 and 8 that allow for random variables (ζ and ξ) in calculating the elasticities.

The CES specification yeilds more elastic response, but the predictions two models replicate are quite similar. We calculated the 'fitted' values for the average tax rates, the marginal tax rates, the hours worked and net wage rates. As the table shows, the average values of these are quite similar. The standard deviations are also similar except that the variations of the predicted hours worked are larger for the CES case than those for the linear case. In addition, the correlation of the pair of predicted values is high.

Since different values for labor supply are used for the pair of elasticities, this may have caused the CES specification to yield more elastic response. However, the difference in the preference specifications may be more important. Figure 2 shows the indifference curves of the two specifications based on the parameters in Table 3 and 7. The parameter values are such that the two indifference curves 'single-cross' at a given bundle, with the curve for the CES case being steeper. Therefore, for a given bundle, one unit of leisure is evaluated higher in the CES case than in the linear case,

[18] As is pointed out in the literature (Pencavel 1986, MaCurdy et. al 1990, Eklöf and Sacklen 2000), the Hausman method in general has produced larger uncompensated wage effects.

suggesting that the substitution effects for the CES case are larger. The difference might be due to the restrictions that the two specifications *a priori* impose.

In both cases, while the uncompensated elasticites are estimated relatively low, high negative values of the income effects make the compensated elasticites rather large. The celebrated MaCurdy critique (MaCurdy et al. 1990) may then apply here. The criticism argues that since the ML function for the Hausman method allows for the kink points in the budget constraint, restrictions are built in the estimation so that larger labor responses are obtained. However, it may be interesting to note that the CES case, which yeilded even larger responses, does not have to allow for such kink points.

5 Concluding remarks

In this paper, we have estimated the labor supply function of prime age males in Japan. Our contributions may be summarized as follows. First, our attempt should be the first attempt to estimate the labor responses of Japanese prime age males that allows for the consumer budget that allows for the details of the Japanese progressive income tax system. Second, we have utilized the method by Zabalza (1983) that takes advantage of the CES specification of consumer preferences, in addition to the standard Hausman method. The parameters estimated for the CES preferences may be utilized for tax simulation studies. Third, given that our dependent variable is coded as interval, we have extended the existing two methods to specify the two maximum likelihood functions that allow for the interval data. Fourth, based on the estimates and the data, we have calculated wage elasticities of labor supply for the two specifications, i.e., a linear labor supply of the Hausman method and the CES specification of the Zabalza method. In the base-line model, the sample averages for uncompensated elasticites range from 0.06 to 0.18 with the linear specification, and from 0.14 to 0.21 with the CES specification. However, with high negative values of the income effects, the compensated elasticites turns out to be rather large, ranging from 0.38 to 0.82 with the linear specification and from 0.93 to 1.00 with the CES specification. The celebrated MaCurdy crisism attributes larger labor responses to the ML function that allows for the kink points in the consumer's budget constraint. It then may be interesting to note that the CES case, which yeilded larger responses, does not have to allow for the kink points to obtain its ML estimates.

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Figure 1. Piecewise-linear budget constraint

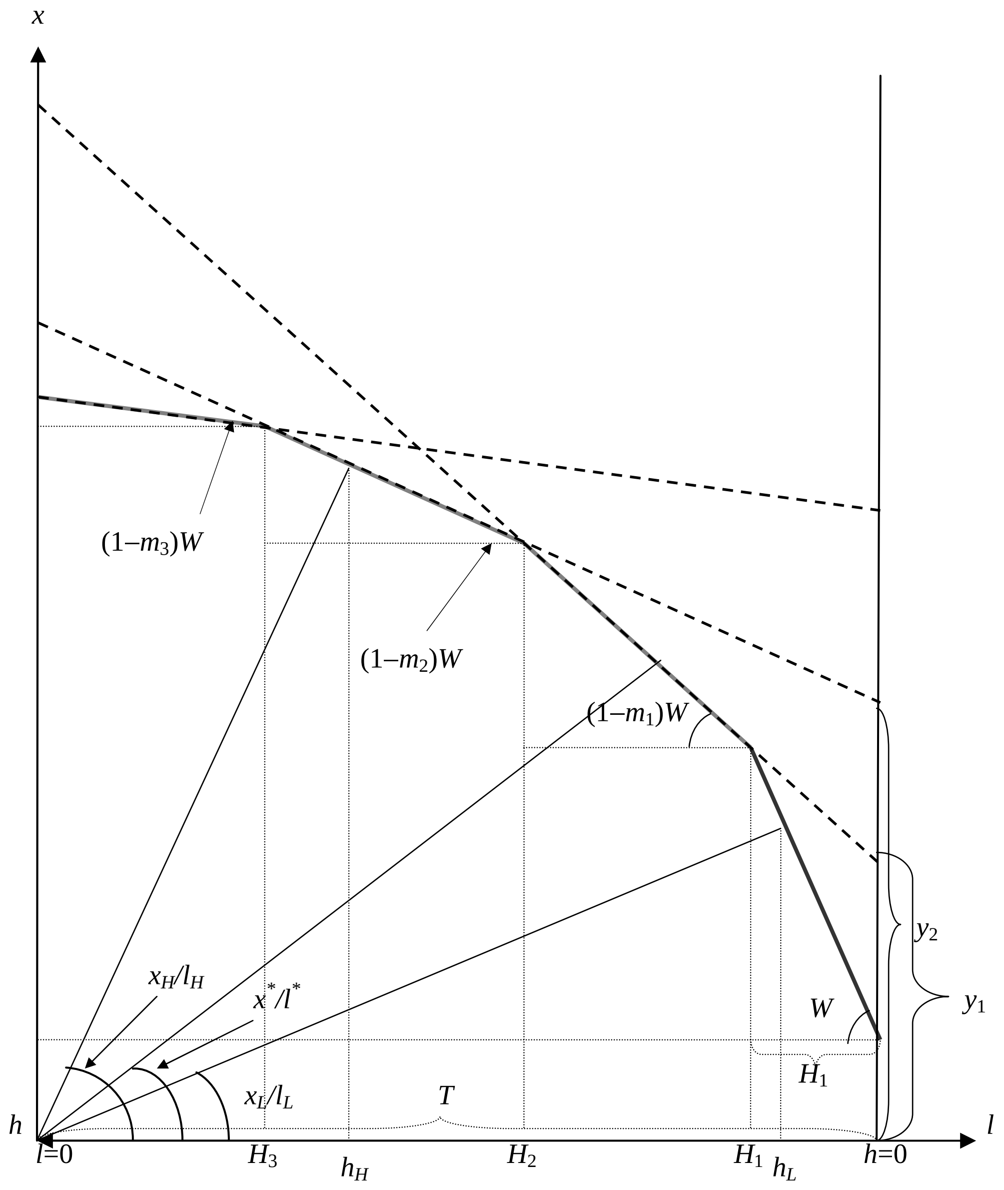

Table 1a: Sample statistics, 1997

	Average	S. D.	max	min
Before-tax wage rate	0.281	0.087	0.087	0.613
Hours worked (lower end)	1387.3	376.2	0	2142.9
Hours worked (upper end)	2460.8	1256.9	107.1	5840
Age	42.470	8.029	25	55
# of kids younger than 15	0.879	1.005	0	7
# of Specific dependent children	0.275	0.554	0	4
Junior high school	0.139	0.346	0	1
High school	0.489	0.500	0	1
2-year college	0.062	0.240	0	1
4-year college, graduate school	0.310	0.463	0	1

(Note) Sample size is 73,697

Table 1b: Sample statistics, 2002

	Average	S. D.	max	min
Before-tax wage rate	0.266	0.090	0.072	0.591
Hours worked (lower end)	1450.9	401.8	0	2142.9
Hours worked (upper end)	2659.7	1427.4	107.1	5840
Age	42.794	8.191	25	55
# of kids younger than 15	0.949	1.002	0	6
# of Specific dependent children	0.270	0.557	0	4
Junior high school	0.105	0.307	0	1
High school	0.473	0.499	0	1
2-year college	0.080	0.271	0	1
4-year college, graduate school	0.342	0.474	0	1

(Note) Sample size is 63,703.

Table 2: Outline of income taxation system

(Thousand yen)

	1997		2002	
	Income tax	Inhabitants tax	Income tax	Inhabitants tax
Basic allowance	380	330	380	330
Allowance for spouses	380	330	380	330
Special allowance for spouses	380	330	380	330
Allowance for dependents	380	330	380	330
Allowance for specific dependents	530	410	630	450
Employment income deduction	Not over 1,800, 40% Not over 3,600, 30% Not over 6,600, 20% Not over 10,000, 10% Over 10,000, 5%	Not over 1,800, 40% Not over 3,600, 30% Not over 6,600, 20% Not over 10,000, 10% Over 10,000, 5%	Not over 1,800, 40% Not over 3,600, 30% Not over 6,600, 20% Not over 10,000, 10% Over 10,000, 5%	Not over 1,800, 40% Not over 3,600, 30% Not over 6,600, 20% Not over 10,000, 10% Over 10,000, 5%
Lower limit	650	650	650	650
Tax rate	Not over 3,300, 10% Over 3,300, 20% Over 9,000, 30% Over 18,000, 40% Over 30,000, 50%	Not over 2,000, 5% Over 2,000, 10% Over 7,000, 15%	Not over 3,300, 10% Over 3,300, 20% Over 9,000, 30% Over 18,000, 37%	Not over 2,000, 5% Over 2,000, 10% Over 7,000, 13%
Payroll tax rate (small firm)	13.325%	-	11.29%	-
Payroll tax rate (large firm)	14.306%	-	12.568%	-
Payroll tax rate (public servant)	12.9395%	-	11.09%	-
Proportional tax credit			20% Upper limit: 250	15% Upper limit: 40

(Note) Special payroll tax rates for bonus are applied in 1997 for employees of private companies.

<u>Table 3: Estimation Results: Linear Labor Supply Function</u>

	1997		1997		2002		2002	
After-tax wage rate	400.901	***	1070.525	***	952.910	***	1342.749	***
	(75.08)		(104.15)		(96.71)		(110.45)	
Virtual income	-1.344	***	-1.488	***	-2.518	***	-2.806	***
	(0.18)		(0.21)		(0.30)		(0.31)	
Age	3.024		0.693		13.329	***	13.205	***
	(2.60)		(2.66)		(3.25)		(3.30)	
Age^2	-0.127	***	-0.142	***	-0.257	***	-0.278	***
	(0.03)		(0.03)		(0.04)		(0.04)	
# of kids younger than 15	9.099	***	8.228	***	10.119	***	9.659	***
	(2.12)		(2.16)		(2.67)		(2.71)	
# of Specific dependent children	-16.294	***	-18.298	***	-11.087	**	-10.114	**
	(3.52)		(3.63)		(4.34)		(4.41)	
Junior high school			124.420	***			123.192	***
			(6.33)				(8.03)	
2-year college			-0.628				0.903	
			(7.85)				(8.62)	
4-year college			-27.138	***			-5.539	
			(6.51)				(7.52)	
Constant	1767.852	***	1748.732	***	1560.738	***	1521.834	***
	(50.28)		(51.19)		(63.25)		(64.18)	
σ_θ	330.835	***	330.845	***	343.862	***	336.471	***
	(16.12)		(14.78)		(16.28)		(14.98)	
σ_v	250.229	***	255.041	***	325.658	***	334.372	***
	(20.01)		(18.04)		(15.47)		(13.18)	
# of observation	73712		73697		63717		63703	
Log Likelihood	-73666.7		-73447.5		-68266.2		-68126.0	

(Note) Figures in parentheses shows standard error.

Table 4: Estimated Elasticity: Linear Labor Supply Function

	Average	S. D.	max	min
1997, without education variables				
η	0.059	0.024	0.013	0.396
ϕ	-0.321	0.104	-0.824	-0.090
η_c	0.379	0.125	0.105	1.039
1997, with education variables				
η	0.157	0.064	0.035	0.811
ϕ	-0.355	0.115	-0.912	-0.100
η_c	0.512	0.172	0.142	1.548
2002, without education variables				
η	0.126	0.052	0.025	0.692
ϕ	-0.572	0.199	-1.445	-0.140
η_c	0.698	0.244	0.168	1.817
2002, with education variables				
η	0.178	0.072	0.033	0.900
ϕ	-0.637	0.221	-1.610	-0.157
η_c	0.815	0.285	0.195	2.136

<u>Table 5a: Estimation Results: Linear Labor Supply Function, 1997</u>

	Permanent work		Supply work		Daily-workers	
After-tax wage rate	242.554	***	3215.131	**	1914.118	*
	(72.06)		(1510.64)		(1082.24)	
Virtual income	-1.075	***	-6.828		5.775	*
	(0.17)		(5.18)		(3.47)	
Age	3.932		-8.316		-71.276	*
	(2.57)		(73.22)		(38.24)	
Age^2	-0.134	***	0.121		0.710	
	(0.03)		(0.89)		(0.46)	
# of kids younger than 15	8.726	***	96.520		48.717	
	(2.09)		(60.66)		(32.79)	
# of Specific dependent children	-16.681	***	82.045		120.132	*
	(3.47)		(119.68)		(63.07)	
Constant	1768.856	***	1151.652		2776.447	
	(49.72)		(1413.27)		(749.28)	
σ_θ	318.847	***	695.042	***	153.310	
	(19.13)		(57.52)		(129.89)	
σ_ν	256.939	***	57.260		424.613	***
	(22.38)		(87.23)		(60.26)	
# of observation	73290		170		252	
Log Likelihood	-73000.5		-242.1		-310.6	
η	0.036		0.447		0.133	
	(0.01)		(1.01)		(0.33)	
ϕ	-0.257		-0.901		0.859	
	(0.08)		(0.36)		(0.26)	
η_c	0.292		1.348		-0.726	
	(0.10)		(1.12)		(0.26)	

(Note) Figures in parentheses show standard error.

Table 5b: Estimation Results: Linear Labor Supply Function, 2002

	Permanent work	Supply work	Daily-workers
After-tax wage rate	604.384 ***	3168.541 **	357.449
	(92.69)	(1324.17)	(872.02)
Virtual income	-1.711 ***	-7.938	2.508
	(0.28)	(5.56)	(5.79)
Age	15.363 ***	-24.279	4.051
	(3.18)	(45.37)	(33.03)
Age^2	-0.275 ***	0.238	-0.110
	(0.04)	(0.54)	(0.40)
# of kids younger than 15	9.884 ***	45.971	28.647
	(2.61)	(40.32)	(31.25)
# of Specific dependent children	-10.622 **	-38.552	65.424
	(4.21)	(77.69)	(49.22)
Constant	1559.633 ***	1789.322 **	1551.618 **
	(62.06)	(904.69)	(667.31)
σ_θ	337.345 ***	675.224 ***	190.410
	(21.26)	(43.43)	(248.44)
σ_v	320.199 ***	137.091	430.521 ***
	(20.96)	(135.23)	(114.77)
# of observation	62897	406	414
Log Likelihood	-67030.0	-609.8	-517.7
η	0.081	0.321	0.004
	(0.03)	(0.58)	(0.00)
ϕ	-0.391	-0.801	0.263
	(0.13)	(0.34)	(0.09)
η_c	0.472	1.122	-0.259
	(0.16)	(0.70)	(0.09)

(Note) Figures in parentheses show standard error.

Table 6a: Estimation Results: Linear Labor Supply Function 1997

	Junior high school	High school	2-year college	4-year college, graduate school
After-tax wage rate	1029.197 ***	602.610 ***	800.038 ***	1436.949 ***
	(267.77)	(107.71)	(288.11)	(200.67)
Virtual income	-0.173	-0.002	0.571	-2.363 ***
	(0.68)	(0.19)	(0.46)	(0.35)
Age	-10.860	-1.344	-5.677	9.794
	(6.92)	(3.46)	(10.09)	(6.00)
Age^2	-0.025	-0.102 **	-0.101	-0.247 ***
	(0.08)	(0.04)	(0.12)	(0.07)
# of kids younger than 15	9.275	6.374 **	2.866	8.767 **
	(6.48)	(2.92)	(7.85)	(4.09)
# of Specific dependent children	-1.319	-25.032 ***	-22.363	-16.391 **
	(9.17)	(4.73)	(15.10)	(7.69)
Constant	2129.439 ***	1818.147 ***	1933.178 ***	1481.696 ***
	(142.63)	(66.40)	(183.54)	(112.05)
σ_θ	386.580 ***	405.218 ***	402.566 ***	323.883 ***
	(44.58)	(3.13)	(9.46)	(15.31)
σ_v	178.000 *	3.597	16.579	274.213
	(94.24)	(4.89)	(44.86)	(13.96)
# of observation	10221	36061	4538	22877
Log Likelihood	-10198.0	-36379.4	-4490.1	-22332.8
η	0.115	0.082	0.039	0.270
	(0.04)	(0.04)	(0.04)	(0.10)
ϕ	-0.032	0.000	0.127	-0.728
	(0.01)	(0.00)	(0.03)	(0.20)
η_c	0.146	0.082	-0.088	0.998
	(0.04)	(0.04)	(0.05)	(0.29)

(Note) Figures in parentheses shows standard error.

Table 6b: Estimation Results: Linear Labor Supply Function 2002

	Junior high school		High school		2-year college		4-year college, graduate school	
After-tax wage rate	2320.557	***	757.585	***	1054.992	***	1524.666	***
	(376.22)		(135.08)		(273.37)		(200.84)	
Virtual income	-3.605	*	-1.345	**	-1.184	*	-2.677	***
	(1.85)		(0.52)		(0.65)		(0.47)	
Age	0.869		12.697	***	22.059	**	16.456	**
	(10.27)		(4.38)		(11.03)		(6.73)	
Age^2	-0.161		-0.245	***	-0.415	***	-0.349	***
	(0.12)		(0.05)		(0.13)		(0.08)	
# of kids younger than 15	15.229		9.051	**	3.472		11.131	**
	(10.74)		(3.74)		(8.90)		(4.81)	
# of Specific dependent children	-6.225		-16.267	***	-5.533		3.222	
	(13.63)		(5.87)		(17.34)		(8.17)	
Constant	1814.591	***	1561.668	***	1426.252	***	1448.140	***
	(211.59)		(85.34)		(204.97)		(129.15)	
σ_θ	111.101		453.224	***	491.774	***	309.608	***
	(237.38)		(17.68)		(10.08)		(20.13)	
σ_v	462.336	***	127.825	*	1.392		348.073	***
	(50.22)		(66.47)		(4.15)		(13.21)	
# of observation	6716		30152		5073		21762	
Log Likelihood	-7212.8		-32929.8		-5472.8		-22465.2	
η	0.209		0.091		0.135		0.262	
	(0.05)		(0.06)		(0.08)		(0.08)	
ϕ	-0.583		-0.258		-0.245		-0.804	
	(0.13)		(0.06)		(0.06)		(0.21)	
η_c	0.792		0.349		0.380		1.066	
	(0.17)		(0.09)		(0.12)		(0.28)	

(Note) Figures in parentheses shows standard error.

<u>Table 7a. Estimation Results: CES Utility Function, 1997</u>

Age			-0.0032		-0.0003	
			(0.002)		(0.002)	
Age^2			0.0001	***	0.0001	***
			(0.000)		(0.000)	
# of kids younger than 15			-0.0051	***	-0.0044	***
			(0.002)		(0.001)	
# of Specific dependent children			0.0115	***	0.0108	***
			(0.003)		(0.002)	
Junior high school					-0.0770	***
					(0.004)	
2-year college					-0.0031	
					(0.005)	
4-year college, graduate school					0.0081	**
					(0.004)	
Constant	1.3943	***	1.0711	***	0.7901	***
	(0.017)		(0.047)		(0.054)	
μ	0.0108	*	-0.0793	***	-0.1460	***
	(0.006)		(0.006)		(0.009)	
σ	0.3463	***	0.3160	***	0.2951	***
	(0.002)		(0.002)		(0.003)	
# of observation	73697		73697		73697	
Log Likelihood	-74308.6		-73762.4		-73597.4	

(Note) Figures in parentheses show standard error.

<u>Table 7b. Estimation Results: CES Utility Function, 2002</u>

Age			-0.0084	***	-0.0074	***
			(0.002)		(0.002)	
Age^2			0.0002	***	0.0002	***
			(0.000)		(0.000)	
# of kids younger than 15			-0.0057	***	-0.0053	***
			(0.002)		(0.002)	
# of Specific dependent children			0.0072	**	0.0059	**
			(0.003)		(0.003)	
Junior high school					-0.0782	***
					(0.005)	
2-year college					-0.0006	
					(0.006)	
4-year college, graduate school					0.0031	
					(0.004)	
Constant	1.1461	***	1.0343	***	0.9012	***
	(0.015)		(0.052)		(0.055)	
μ	-0.0622	***	-0.1143	***	-0.1482	***
	(0.005)		(0.005)		(0.007)	
σ	0.3625	***	0.3409	***	0.3285	***
	(0.002)		(0.002)		(0.003)	
# of observation	63703		63703		63703	
Log Likelihood	-69727.9		-69184.1		-69074.8	

(Note) Figures in parentheses show standard error.

Table 8. Elasticities, Income Effects: CES Utility Function

	Average	S. D.	Min	max
1997, without educational variables				
η	0.138	0.034	0.061	0.343
ϕ	-0.790	0.056	-0.944	-0.473
η_c	0.928	0.057	0.609	1.154
κ	3.253	1.071	0.792	11.914
1997, with educational variables				
η	0.211	0.036	0.113	0.426
ϕ	-0.791	0.056	-0.952	-0.492
η_c	1.002	0.062	0.668	1.246
κ	2.666	0.824	0.725	10.469
2002, without educational variables				
η	0.157	0.027	0.100	0.269
ϕ	-0.790	0.010	-0.828	-0.768
η_c	0.947	0.027	0.879	1.066
κ	2.702	0.143	2.464	3.020
2002, with educational variables				
η	0.195	0.028	0.133	0.311
ϕ	-0.790	0.010	-0.838	-0.763
η_c	0.985	0.028	0.899	1.106
κ	2.446	0.146	2.050	2.782

Table 9a. Estimation Results: CES Utility Function, 1997

	Permanent work		Supply work		Daily-workers	
Age	-0.0049	**	0.0263		0.0574	**
	(0.002)		(0.050)		(0.029)	
Age^2	0.0001	***	-0.0004		-0.0006	*
	(0.000)		(0.001)		(0.000)	
# of kids younger than 15	-0.0049	***	-0.0608		-0.0298	
	(0.002)		(0.044)		(0.025)	
# of Specific dependent children	0.0118	***	-0.0562		-0.0800	
	(0.003)		(0.082)		(0.049)	
Constant	1.1650	***	-0.1678		-1.0358	*
	(0.049)		(1.055)		(0.601)	
μ	-0.0603	***	-0.3875	***	-0.3890	***
	(0.006)		(0.085)		(0.050)	
σ	0.3181	***	0.4954	***	0.3304	***
	(0.002)		(0.069)		(0.029)	
# of observation	73275		170		252	
Log Likelihood	-72788.5		-281.6		-355.6	
η	0.119		0.568		0.585	
	(0.03)		(0.07)		(0.06)	
ϕ	-0.791		-0.807		-0.807	
	(0.06)		(0.12)		(0.08)	
η_c	0.910		1.375		1.392	
	(0.06)		(0.17)		(0.12)	

(Note) Figures in parentheses show standard error.

Table 9b. Estimation Results: CES Utility Function, 2002

	Permanent work		Supply work		Daily-workers	
Age	-0.0111	***	0.0387		-0.0021	
	(0.002)		(0.390)		(0.027)	
Age^2	0.0002	***	0.0005		0.0001	
	(0.000)		(-0.330)		(0.000)	
# of kids younger than 15	-0.0058	***	0.0343		-0.0112	
	(0.002)		(-1.270)		(0.024)	
# of Specific dependent children	0.0072	**	0.0653		-0.0473	
	(0.003)		(0.240)		(0.040)	
Constant	1.1647	***	0.8532		1.0722	*
	(0.054)		(0.440)		(0.564)	
μ	-0.0900	***	0.0842	***	-0.1064	**
	(0.006)		(-2.840)		(0.052)	
σ	0.3441	***	0.0673	***	0.3855	***
	(0.002)		(8.900)		(0.027)	
# of observation	62887		405		411	
Log Likelihood	-67599.2		-697.0		-535.3	
η	0.131		0.275		0.119	
	(0.03)		(0.03)		(0.03)	
ϕ	-0.784		-0.805		-0.812	
	(0.06)		(0.11)		(0.07)	
η_c	0.915		1.080		0.931	
	(0.06)		(0.14)		(0.07)	

(Note) Figures in parentheses show standard error.

Table 10a. Estimation Results: CES Utility Function, 1997

	Junior high school		High school		2-year college		4-year college, graduate school	
Age	0.0073		-0.0015		0.0004		-0.0065	*
	(0.005)		(0.003)		(0.008)		(0.004)	
Age^2	0.0000		0.0001	***	0.0001		0.0002	***
	(0.000)		(0.000)		(0.000)		(0.000)	
# of kids younger than 15	-0.0025		-0.0029		-0.0007		-0.0062	**
	(0.004)		(0.002)		(0.006)		(0.003)	
# of Specific dependent children	-0.0005		0.0161	***	0.0114		0.0099	**
	(0.006)		(0.004)		(0.011)		(0.005)	
Constant	0.3536	***	0.9726	***	0.7553	***	0.9170	***
	(0.125)		(0.081)		(0.220)		(0.107)	
μ	-0.1966	***	-0.0982	***	-0.1402	***	-0.1546	***
	(0.021)		(0.014)		(0.035)		(0.016)	
σ	0.2923	***	0.3075	***	0.2907	***	0.2899	***
	(0.007)		(0.005)		(0.011)		(0.005)	
# of observation	10221		36061		4538		22877	
Log Likelihood	-10569.2		-36225.1		-4446.3		-22311.2	
η	0.255		0.148		0.198		0.245	
	(0.03)		(0.03)		(0.03)		(0.04)	
ϕ	-0.787		-0.795		-0.789		-0.786	
	(0.06)		(0.06)		(0.05)		(0.06)	
η_c	1.042		0.943		0.987		1.031	
	(0.07)		(0.06)		(0.06)		(0.06)	

(Note) Figures in parentheses show standard error.

Table 10b. Estimation Results: CES Utility Function, 2002

	Junior high school	High school	2-year college	4-year college, graduate school
Age	0.0003	-0.0076 **	-0.0125	-0.0117 ***
	(0.007)	(0.003)	(0.008)	(0.004)
Age^2	0.0001	0.0002 ***	0.0003 ***	0.0002 ***
	(0.000)	(0.000)	(0.000)	(0.000)
# of kids younger than 15	-0.0069	-0.0048 *	-0.0007	-0.0074 **
	(0.006)	(0.003)	(0.006)	(0.003)
# of Specific dependent children	0.0051	0.0110	0.0033	-0.0048
	(0.009)	(0.004)	(0.012)	(0.005)
Constant	0.4720 ***	1.0253 ***	0.9114 ***	0.9539 ***
	(0.149)	(0.081)	(0.195)	(0.101)
μ	-0.2016 ***	-0.1172 ***	-0.1634 ***	-0.1569 ***
	(0.017)	(0.011)	(0.025)	(0.011)
σ	0.3293 ***	0.3395 ***	0.3358 ***	0.3146 ***
	(0.007)	(0.004)	(0.010)	(0.004)
# of observation	6716	30152	5073	21762
Log Likelihood	-7640.9	-33311.7	-5564.3	-22502.5
η	0.240	0.149	0.205	0.225
	(0.02)	(0.02)	(0.02)	(0.03)
ϕ	-0.781	-0.789	-0.780	-0.778
	(0.07)	(0.06)	(0.07)	(0.06)
η_c	1.021	0.938	0.985	1.003
	(0.08)	(0.06)	(0.07)	(0.06)

(Note) Figures in parentheses show standard error.

<u>Table 11. Linear Labor Supply and CES Utility</u>

	CES	Linear	correlation
η	0.1498	0.1040	0.6912
	(0.026)	(0.032)	
ϕ	-0.7907	-0.5116	-0.3024
	(0.009)	(0.151)	
η_c	0.9405	0.6156	0.5919
	(0.026)	(0.183)	
Predicted average tax rate	0.1764	0.1775	0.9982
	(0.023)	(0.023)	
Predicted marginal tax rate	0.2204	0.2234	0.9624
	(0.037)	(0.037)	
Predicted hours worked	1740.5	1777.0	0.9901
	(84.647)	(75.372)	
Predicted net wage rate	0.2046	0.2038	0.9989
	(0.061)	(0.060)	

(note) The figures based on the estimation results shown in Table 3 and 7, the case without educational backgrounds variables. The data used is of 2002.

Figure 2. Utility Function: Linear Labor Supply and CES Utility