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The Impact of Taxes and Transfers on Skill Premium

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Abstract

The level of wage inequality has varied across advanced industrial countries. One of the main reasons has been a significant difference in the skill wage premium. This paper analyzes the impact of taxes and transfers on skill premium and social welfare in a heterogeneous-agents incomplete-markets model, extended to allow for capital-skill complementarity. Our analysis shows that a significant fraction of the difference in the skill wage premium between the United States and Japan can be attributed to the difference in the tax rate on capital income.

KEYWORDS: Skill premium; capital-skill complementarity; incomplete markets; capital income taxation; composition effect.

JEL CLASSIFICATION: E13, E24, E62, H24, J31.

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1 Introduction

The level of wage inequality has varied widely across advanced industrial countries (Krueger, Perri, Pistaferri, and Violante, 2010). One of the main reasons for this has been a significant difference in the skill wage premium, defined as the ratio of the average wage of college graduate workers to that of non-college graduate workers. When comparing two of the largest economies in the world in the year 2000, the variance of the log hourly wage was 47 percent higher in the United States than in Japan, while the skill wage premium was 26 percent higher in the United States than in Japan (Heathcote, Perri, and Violante, 2010; Lise, Sudo, Suzuki, Yamada, and Yamada, 2014).

Despite the large difference in the skill wage premium between the United States and Japan, there was not much difference in the level of technology or the share of the skilled population. In fact, the shares of population with tertiary education were 36.5 percent in the United States and 33.6 percent in Japan in the year 2000 (OECD, 2015). Although the two countries were similar in those demand and supply factors, there was a notable difference in the tax system between the two countries. The difference in the tax system lies in the rate of tax on capital income. The tax rate on capital income was 37 percent higher in Japan than in the United States in the year 2000, while the tax rates on labor income and consumption were similar between the two countries.

In this paper, we show quantitatively that a significant fraction of the difference in the skill wage premium between the United States and Japan can be attributed to the difference in the tax system. In light of the difference in the tax rate on capital income, we develop a general equilibrium model, in which capital income taxation influences the labor market equilibrium through a shift in the supply of and demand for physical capital. Two features of our model are important in accounting for the difference in the skill wage premium between the United States and Japan. First, the production technology exhibits capital-skill complementarity. Second, employment changes in response to idiosyncratic shocks to worker productivity. We further show that a change in policy that raises the U.S. tax rate on capital income to the Japanese tax rate not only reduces the skill wage premium but also can improve social welfare.

This paper builds upon the work of Prescott (2004) and Alonso-Ortiz and Rogerson (2010), who

show that cross-country differences in labor supply and labor productivity can be attributed to the difference in the tax and transfer system. Our analysis is related to the quantitative macroeconomic literature, which considers the role of taxes and transfers in the heterogeneous-agents incomplete-markets model of Huggett (1993) and Aiyagari (1994), extended to allow for endogenous labor supply. Among others, Flodén and Lindé (2001) and Alonso-Ortiz and Rogerson (2010) analyze the impact of labor income taxes and transfers, Nakajima and Takahashi (2016) analyze the impact of consumption taxes and transfers, and Aiyagari and McGrattan (1998) and Flodén (2001) analyze the impact of government debt and transfers. We extend their models to allow for capital-skill complementarity, and analyze the impact of capital income taxes and transfers on the skill wage premium. In addition, we compare the impact of capital income taxes and transfers between the representative-agent model and the heterogeneous-agents incomplete-markets model to understand the mechanism of changes in the skill wage premium.

Our analysis is also related to the quantitative public finance literature, which revisits the well-known result of Chamley (1986) and Judd (1985) that the optimal tax rate on capital income is zero in the steady state. Among others, Aiyagari (1995) and İmrohoroğlu (1998) show that, in incomplete markets, the optimal tax rate on capital income may be strictly positive in the steady state. Conesa, Kitao, and Krueger (2009) demonstrate that the optimal tax rate on capital income is 36 percent in the steady state, when the tax rate on labor income is optimally progressive, in their heterogeneous-agents incomplete-markets model. In light of their results, it is not necessarily welfare-improving to reduce the tax rate on capital income. In addition, the impact of capital income taxes and transfers on social welfare may differ in the presence and absence of capital-skill complementarity. We, thus, consider the welfare consequences of a change in policy that raises the U.S. tax rate on capital income to the Japanese tax rate.

The rest of the paper proceeds as follows. Section 2 compares the skill wage premium and the tax system across countries. Section 3 presents the model and describes the measurement of the impact of taxes and transfers on the skill wage premium. Section 4 describes the calibration procedure and shows quantitative results. The final section provides a summary and conclusion.

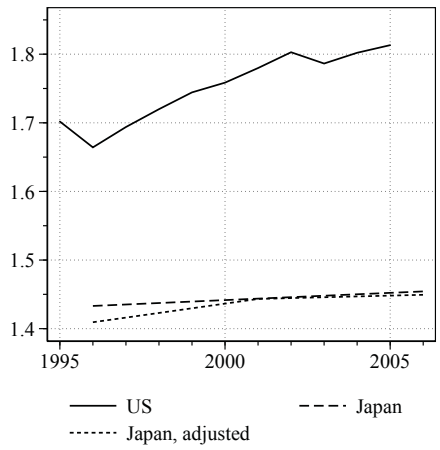
2 International Comparison

We first compare the United States to Japan and then to European countries in terms of the skill wage premium and the tax system.

2.1 The United States and Japan

Skill premium Figure 1 illustrates the skill wage premium in the United States for the years 1995 to 2005 and in Japan for the years 1996 to 2006. The data used are from the Current Population Survey (CPS) for the United States and the Employment Status Survey (ESS) for Japan. The ESS is the most comparable household survey to the CPS for the purpose of our analysis, although it has been conducted only every five years. Following Heathcote, Perri, and Violante (2010), we calculate the skill wage premium for men and women aged 25 to 60 for both countries. Four-year college graduates are classified as skilled, and the rest are classified as unskilled. During the period, the skill wage premium was on average 1.75 in the United States and 1.44 in Japan.

Figure 1: Skill premium in the United States and Japan



The difference in the skill wage premium cannot be attributed to the difference in the composition of the workforce between the two countries. The United States and Japan were similar in the share of skilled population among the OECD countries. If anything, the share of skilled population was greater in the United States than in Japan during the period. Even when we reweight the

Japanese sample such that it has the same distribution of age, sex, and education as the U.S. sample using the DiNardo, Fortin, and Lemieux (1996) method, the skill wage premium, which is the ratio of the averages, remains almost unchanged (Figure 1).[1]

The difference in the skill wage premium cannot be attributed to the difference in the quality of education. Existing studies conclude that the quality of education is higher in Japan than in the United States, regardless of methodologies (Schoellman, 2012; Kaarsen, 2014). Kaarsen (2014) shows that students in Japan acquire 23 percent more knowledge than those in the United States for each year of schooling. If two-year college graduates in Japan are classified as skilled on the basis of his result, the skill wage premium becomes even lower, ranging from 1.25 to 1.29.

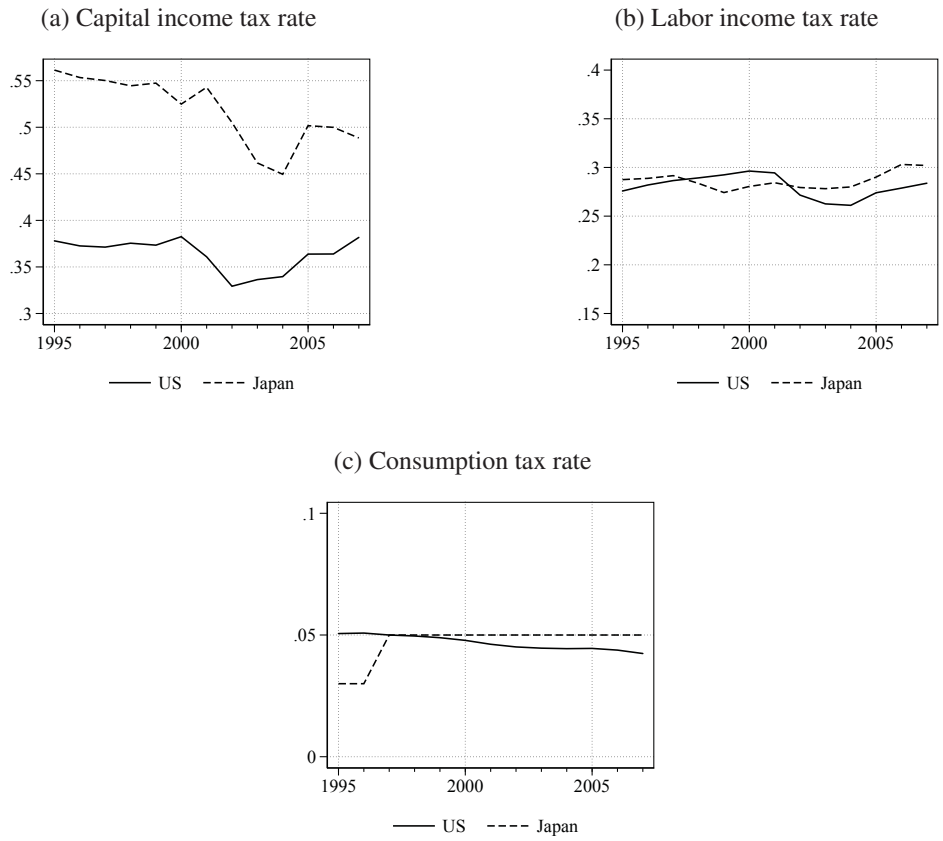
The difference in the skill wage premium has been present for several decades, though perhaps not widely known. Educational wage differentials were consistently greater in the United States than in Japan from the late 1960s to the 1980s (Katz, Loveman, and Blanchflower, 1995). The skill wage premium has substantially increased in the United States for recent years, as is well known. Nonetheless, the magnitude of the difference in the skill wage premium between the two countries is much greater than the magnitude of the change in the United States (Figure 1).

Tax rates Figure 2 illustrates the average marginal tax rates on capital income, labor income, and consumption in the United States and Japan for the years 1995 to 2007. The U.S. tax rates are based on the results of Trabandt and Uhlig (2011), and the Japanese tax rates are based on the results of Gunji and Miyazaki (2011) and Nutahara (2015). During the period, the capital income tax rate was on average 52 percent in Japan as opposed to 36 percent in the United States, while the consumption and labor income tax rates were on average 5 percent and 28 percent, respectively, in both countries. Differences in the tax rates between the two countries are not due to methodological differences across studies, as Gunji and Miyazaki (2011) confirm the robustness of their results. Among the countries analyzed in Trabandt and Uhlig (2011), the capital income tax rate was near the average in the United States and highest in Japan. The higher rate of capital income taxes in Japan is due

[1] Alternatively, even when we adjust for differences in the age, sex, and education composition of the workforce across countries in a way similar to Krusell, Ohanian, Rios-Rull, and Violante (2000), who adjust for changes in the workforce composition over time, the difference in the skill wage premium mostly still remains.

in large part to the higher rate of corporate tax. Importantly, there was not much difference in the progressivity of labor income taxes between the two countries during the period (See the OECD tax database for details).

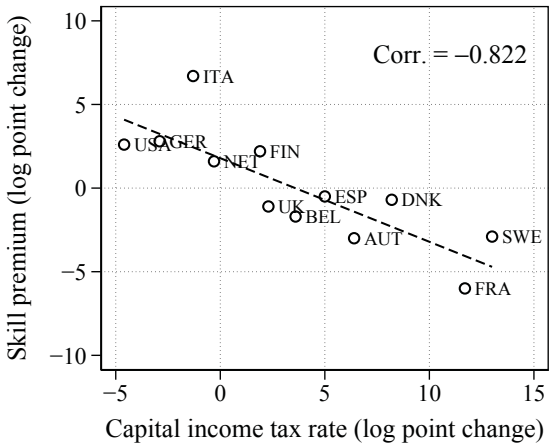
Figure 2: Tax rates in the United States and Japan



2.2 The United States and Europe

Skill premium and capital income tax rate Figure 3 plots the log point change in the skill wage premium against the log point change in the capital income tax rate in the United States and European countries for the years 1995 to 2004. The skill wage premium is calculated using data from the EU KLEMS database. The capital income tax rate is based on the results of Trabandt and Uhlig (2011). There is clearly a strong negative association between the skill wage premium and the capital income tax rate. The subsequent analysis is relevant to the cross-country difference in

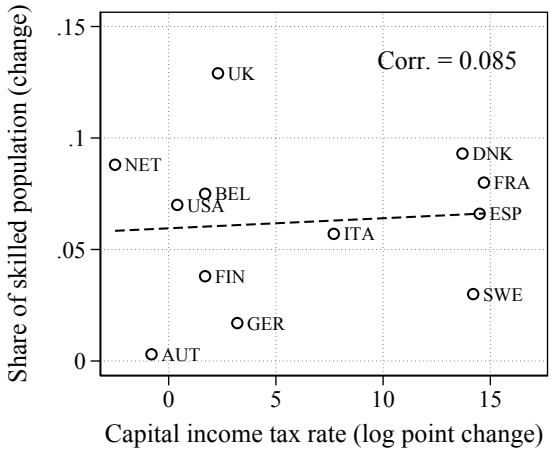
Figure 3: Skill premium, 1995–2004



Notes: The sample comprises Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Italy (ITA), Netherlands (NET), Spain (ESP), Sweden (SWE), United Kingdom (UK), and United States (USA). The same applies to Figure 4

the skill wage premium in many countries, although we focus on the United States and Japan, for which there were greater differences in the skill wage premium and the capital income tax rate and greater similarities in the share of skilled population and other tax rates.

Figure 4: Share of skilled population, 1995–2007



Share of skilled population Figure 4 plots the log point change in the share of skilled population against the log point change in the capital income tax rate in the United States and European countries for the years 1995 to 2004. The share of skilled population is calculated using data from

the OECD database. There is no clear association between the share of skilled population and the capital income tax rate. The correlation coefficient is, indeed, close to zero. This implies that the change in the share of skilled population is unlikely to be the main mechanism to account for the negative association between the skill wage premium and the capital income tax rate. Therefore, we maintain an assumption that the share of skilled population is invariant to a change in the capital income tax rate in the subsequent analysis.

3 The Model

We consider the heterogeneous-agents incomplete-markets model, which builds upon the model of Chang and Kim (2007) and Alonso-Ortiz and Rogerson (2010). We extend their model to allow for capital-skill complementarity. Slavík and Yazici (2016) develop a similar model in which labor is divisible. We present a representative-agent version of the model in Appendix A.1.

3.1 Households

The economy is populated by a continuum of infinitely-lived agents of unit mass who are either skilled or unskilled indexed by $j \in \{S, U\}$. Preferences are described by:

$$\mathbb{E}_t \sum_{t=\tau}^{\infty} \beta^{t-\tau} U_j(c_t, h_t), \tag{1}$$

where β is the discount factor, c_t consumption, and h_t hours worked in period t. Following Alonso-Ortiz and Rogerson (2010), we specify the instantaneous utility function to be:

$$U_j(c_t, h_t) = \ln c - \psi_j h_t \qquad \text{for } j \in \{S, U\}. \tag{2}$$

As in Hansen (1985) and Rogerson (1988), we assume indivisible labor, i.e. $h_t \in \left\{0, \overline{h}_j\right\}$. We focus on the employment decision, which is important in accounting for cross-country differences in productivity, as shown by Alonso-Ortiz and Rogerson (2010).

Each household receives labor earnings, $x_t w_{jt} h_t$, and lump-sum transfers from the government, f_t. Labor earnings vary according to idiosyncratic shocks to productivity, x_t, the market wage rate, w_{jt}, and hours worked, h_t. Productivity evolves stochastically according to the transition probability function: $\pi(x'|x) = \Pr(x_{t+1} \leq x_t | x_t = x)$. Following Alonso-Ortiz and Rogerson (2010), we specify the idiosyncratic productivity process to be the first-order autoregressive process:

$$\ln x_t = \varrho \ln x_{t-1} + \epsilon_t, \tag{3}$$

where ϵ is normally distributed with standard deviation ς. We adjust ν to normalize the average idiosyncratic productivity to unity, i.e., $\mathbb{E}(x_t) = 1$, as in the analysis of Aiyagari and McGrattan (1998). We also consider the extension of the productivity process, in which the persistence, ϱ, and volatility, ς, differ between skilled workers and unskilled workers, in order to assess the robustness of quantitative results. Each household is subject to a borrowing constraint: $a_{t+1} \geq 0$, where assets a_t consist of physical capital and government debt. The budget constraint can be written as:

$$\begin{gathered}(1+\tau_c) c_t = (1-\tau_n) x_t w_{jt} h_t + [1 + (1-\tau_k) r_t] a_t - a_{t+1} + f_t, \\ c_t \geq 0, \;\; a_{t+1} \geq 0, \;\; h_t \in \left\{0, \overline{h}_j\right\},\end{gathered} \tag{4}$$

where r_t is the interest rate. A key feature of the heterogeneous-agents incomplete-markets model is that households adjust their savings and labor supply to self-insure against idiosyncratic shocks to their productivity under the borrowing constraint.

We now consider a recursive equilibrium. We denote by V^E the present value of household utility when being employed, V^N the present value of household utility when not being employed, and $\xi(\widetilde{a}, x, j)$ is the distribution of households. As in Aiyagari and McGrattan (1998), Flodén (2001), and others, the squiggles denote normalization by Y for detrending throughout the paper. The value of employment can be expressed as:

$$V^E(\widetilde{a}, x, j) = \max_{\widetilde{c}, \widetilde{a}'} \left\{ \ln \widetilde{c} - \psi_j \overline{h}_j + \beta \mathbb{E}[V(\widetilde{a}', x', j) | x] \right\} \tag{5}$$

subject to:

$$(1+\tau_c)\widetilde{c}+(1+g)\widetilde{a}' = (1-\tau_n)xw_j\overline{h}_j+[1+(1-\tau_k)r]\widetilde{a}+\widetilde{f}, \qquad \widetilde{c}\geq 0,\ \widetilde{a}'\geq 0,$$

and $\xi' = \mathcal{T}(\xi)$, where $\mathcal{T}$ denote a transition operator for ξ. The value of non-employment can be expressed as:

$$V^N(\widetilde{a},x,j) = \max_{c,a'}\{\ln\widetilde{c}+\beta\mathbb{E}[V(\widetilde{a}',x',j)|\,x]\} \tag{6}$$

subject to:

$$(1+\tau_c)\widetilde{c}+(1+g)\widetilde{a}' = [1+(1-\tau_k)r]\widetilde{a}+\widetilde{f}, \qquad \widetilde{c}\geq 0,\ \widetilde{a}'\geq 0,$$

and $\xi' = \mathcal{T}(\xi)$. The labor supply decision can then be described by:

$$V(\widetilde{a},x,j) = \max\left\{V^E(\widetilde{a},x,j),V^N(\widetilde{a},x,j)\right\}. \tag{7}$$

We derive a set of decision rules for consumption, hours worked, and asset holdings as the solution to this problem. We denote by $\widetilde{c}(\widetilde{a},x,j)$, $h(\widetilde{a},x,j)$, and $\widetilde{a}'(\widetilde{a},x,j)$ the decision rules for consumption, hours worked, and asset holdings, respectively.

3.2 Firms

Production in the economy is summarized by an aggregate function $Y_t = F(N_{St},N_{Ut},K_{Et},K_{St};z_t)$, where N_{St} is skilled labor input, N_{Ut} unskilled labor input, K_{Et} equipment capital input, K_{St} structures capital input, and z_t a measure of labor-augmenting technology in period t. We assume that final goods are produced by perfectly competitive firms.

We consider a constant returns-to-scale technology and specify the production function to be:

$$\mathcal{F}(N_{St},N_{Ut},K_{Et},K_{St};z_t) = K_{St}^{\alpha}\left\{\mu(z_tN_{Ut})^{\sigma}+(1-\mu)\left[\lambda K_{Et}^{\rho}+(1-\lambda)(z_tN_{St})^{\rho}\right]^{\frac{\sigma}{\rho}}\right\}^{\frac{1-\alpha}{\sigma}}. \tag{8}$$

Labor-augmenting technology exhibits a deterministic trend: $z_{t+1} = (1+g)z_t$, where $g>0$ is the

growth rate of technology. The share parameters are $0 \leq \mu \leq 1$ and $0 \leq \lambda \leq 1$. The substitution parameters are $\rho < 1$ and $\sigma < 1$. The elasticity of substitution between skilled labor and capital is given by $1/(1-\rho)$, while the elasticity of substitution between unskilled labor and the skilled labor-capital composite is $1/(1-\sigma)$. The degree of diminishing marginal product differs between skilled labor and unskilled labor whenever $\sigma \neq \rho$. Production technology exhibits capital-skill complementarity if $\sigma > \rho$ (Krusell, Ohanian, Rios-Rull, and Violante, 2000). In the presence of capital-skill complementarity, the relative marginal product of skilled labor increases with a rise in capital equipment.

Profit maximization is achieved by equating factor prices with the values of the marginal products of inputs:

$$\widetilde{w}_{St} = (1-\alpha)(1-\mu)(1-\lambda)\widetilde{K}_{St}^{\frac{\alpha\sigma}{1-\alpha}}\left(\lambda\widetilde{K}_{Et}^{\rho}+(1-\lambda)(\widetilde{z}_t N_{St})^{\rho}\right)^{\frac{\sigma-\rho}{\rho}}\widetilde{z}_t^{\rho}N_{St}^{\rho-1}, \tag{9}$$

$$\widetilde{w}_{Ut} = \widetilde{K}_{St}^{\frac{\alpha\sigma}{1-\alpha}}(1-\alpha)\mu\widetilde{z}_t^{\sigma}N_{Ut}^{\alpha-1}, \tag{10}$$

$$r_{Et} = (1-\alpha)(1-\mu)\widetilde{K}_{St}^{\frac{\alpha\sigma}{1-\alpha}}\left[\lambda\widetilde{K}_{Et}^{\rho}+(1-\lambda)(\widetilde{z}_t N_{St})^{\rho}\right]^{\frac{\sigma-\rho}{\rho}}\lambda\widetilde{K}_{Et}^{\rho-1}-\delta_S, \tag{11}$$

$$r_{St} = \alpha\widetilde{K}_{St}^{-1}-\delta_U, \tag{12}$$

where δ_E and δ_S are the depreciation rates of equipment and structures, respectively. Capital equipment and structures are equivalent for households; thus, $r_E = r_S = r$ at the equilibrium. It is worth noting that none of the tax rates appears in the profit-maximizing conditions (9)–(12). Basically, taxation on consumption, labor income, and capital income does not play a significant role for the determination of factor prices in a partial equilibrium model. In a general equilibrium model, however, capital income taxation reduces the stock of capital and thus reduces the relative marginal product of skilled labor, thereby reducing the skill wage premium.

3.3 Government

We assume that the government levies proportional taxes and spends part of the tax revenue on lump-sum transfers to households, as in many previous studies (e.g., Flodén and Lindé, 2001;

Prescott, 2004; Alonso-Ortiz and Rogerson, 2010). When the government levies proportional taxes on consumption, labor income, and capital income at rates τ_c, τ_n, and τ_k, respectively, and spends the tax revenue on government consumption G_t, lump-sum transfers F_t, and interest payments on government debt B_t, the government budget constraint can be written as:

$$G_t + F_t + r_t B_t = B_{t+1} - B_t + \tau_c C_t + \tau_n (w_{St} N_{St} + w_{Ut} N_{Ut}) + \tau_k r_t (K_{Et} + K_{St} + B_t),$$

where C_t is aggregate household consumption. The government budget constraint can be rewritten as:

$$\widetilde{G} + \widetilde{F} + r\widetilde{B} = \widetilde{B}' - (1+g)\widetilde{B} + \tau_c \widetilde{C} + \tau_n (\widetilde{w}_S N_S + \widetilde{w}_U N_U) + \tau_k r \left(\widetilde{K}_E + \widetilde{K}_S + \widetilde{B}\right), \tag{13}$$

where $\widetilde{G}$ and $\widetilde{B}$ are assumed to be exogenously given.

If tax rates are progressive or transfers are means-tested, the government will redistribute more from skilled workers to unskilled workers. As more distribution takes place, the impact of taxes and transfers on skill premium will be greater, as detailed in the next section. This means that we conservatively assess the impact of taxes and transfers on skill premium in the system of proportional taxes and lump-sum transfers.

3.4 Equilibrium

The equilibrium of the economy is characterized as follows. Given policies $\left\{\widetilde{G}, \widetilde{B}, \tau_c, \tau_n, \tau_k, \widetilde{F}\right\}$ and initial conditions $\{z_0, \xi_0\}$, a stationary competitive equilibrium consists of a set of value functions $\left\{V^E(\widetilde{a}, x, j), V^N(\widetilde{a}, x, j), V(\widetilde{a}, x, j)\right\}$, a set of decision rules for consumption, hours worked, and asset holdings $\{\widetilde{c}(\widetilde{a}, x, j), h(\widetilde{a}, x, j), \widetilde{a}'(\widetilde{a}, x, j)\}$, aggregate inputs $\left\{N_S, N_U, \widetilde{K}_E, \widetilde{K}_S\right\}$, price system $\{\widetilde{w}_S, \widetilde{w}_U, r\}$, and a law of motion for the distribution $\xi' = \mathcal{T}(\xi)$ such that: the decision rules and the value functions solve the household's problem; aggregate inputs solve the firm's problem; the government budget is balanced; the capital market clears, i.e., $\widetilde{K}'_E + \widetilde{K}'_S + \widetilde{B}' = \int \widetilde{a}'(\widetilde{a}, x, j)\, d\xi$; labor markets clear, i.e., $N_S = \int_{\{j=S\}} x h(\widetilde{a}, x, j)\, d\xi$ and $N_U = \int_{\{j=U\}} x h(\widetilde{a}, x, j)\, d\xi$; the final goods market clears, i.e., $\int \{\widetilde{c}(\widetilde{a}, x, j) + \widetilde{a}'(\widetilde{a}, x, j)\}\, d\xi = F\left(N_S, N_U, \widetilde{K}_E, \widetilde{K}_S; \widetilde{z}\right) + (1-\delta_E)\widetilde{K}_E + (1-\delta_S)\widetilde{K}_S$; and in-

dividual and aggregate behaviors are consistent for all $A^0 \subset \mathcal{A}$ and $X^0 \subset \mathcal{X}$, i.e., $\xi'\left(A^0, X^0, j\right) = \int_{A^0,X^0} \left\{ \int_{\mathcal{A},\mathcal{X}} \mathbb{1}_{a'=a(\widetilde{a},x,j)} d\pi\left(x' \mid x\right) d\xi \right\} d\widetilde{a}' dx'$.

3.5 Skill Premium

The equilibrium skill wage premium is defined as:

$$\omega_{\text{ha}} \equiv \frac{w_S N_S / H_S}{w_U N_U / H_U} = \left(\frac{w_S}{w_U}\right)\left(\frac{N_S / H_S}{N_U / H_U}\right), \tag{14}$$

where H_j is the aggregate labor supply of a group j, i.e., $H_j = \int_j h(\widetilde{a}, x, j)\, d\xi$ for $j \in \{S, U\}$. The ratio of the market wage for skilled labor to the market wage for unskilled labor, w_S / w_U, equals the relative marginal product. The ratio of the aggregate labor input to the aggregate labor supply, N_j / H_j, represents the average idiosyncratic productivity of a group j, and thus, the ratio of N_j / H_j between the two groups represents the relative average productivity. The skill wage premium, thus, increases with a rise in the relative marginal product of skilled labor and the relative average productivity of skilled labor.

When we compare two countries with different tax rates, the difference in the skill wage premium can be decomposed as:

$$\Delta \ln \omega_{\text{ha}} = \underbrace{\Delta \ln\left(\frac{w_S N_S}{H_S}\right)}_{\text{effect on skilled}} - \underbrace{\Delta \ln\left(\frac{w_U N_U}{H_U}\right)}_{\text{effect on unskilled}}. \tag{15}$$

The first term is the difference in the average wage of skilled workers, while the second term is the difference in the average wage of unskilled workers. We refer to the former as the effect on skilled workers and the latter as the effect on unskilled workers. Naturally, the difference in the skill wage premium is proportional to the difference in the average wage of skilled workers, and inversely proportional to the difference in the average wage of unskilled workers. The higher skill wage premium is attributable to the higher average wage of skilled workers, the lower average wage of unskilled workers, or both.

Alternatively, the difference in the skill wage premium can be decomposed as:

$$\Delta \ln \omega_{\text{ha}} = \underbrace{\Delta \ln \left(\frac{w_S}{w_U} \right)}_{\text{price effect}} + \underbrace{\Delta \ln \left(\frac{N_S / H_S}{N_U / H_U} \right)}_{\text{composition effect}}. \tag{16}$$

The difference in the skill wage premium depends not only on the difference in the relative marginal product of skilled labor but also on the difference in the relative average productivity of skilled labor resulting from the difference in the tax system. The first term represents the equilibrium effect with respect to a difference in the relative marginal product, while the second term represents the mechanical effect with respect to a difference in the relative average productivity. We refer to the former as the price effect and the latter as the composition effect.

4 Quantitative Assessment

We calibrate the model to the U.S. economy and quantitatively assess the impact of taxes and transfers on the skill wage premium and social welfare. We quantitatively analyze the impact of a change in policy that replaces the U.S. tax system with the Japanese tax system. We outline methods for computing the equilibrium in the model economy in Appendix A.2.

4.1 Parameterization

Table 1 summarizes parameterization for the analysis of the heterogeneous-agents incomplete-markets model. We choose several key parameters to match specific aggregate targets inside the model and set the rest of parameters outside the model.

Parameters set externally We follow Trabandt and Uhlig (2011) in setting the consumption tax rate τ_c, the labor income tax rate τ_n, the capital income tax rate τ_k, the ratio of government consumption to output $\widetilde{G}$, the ratio of government debt to output $\widetilde{B}$, and the growth rate g. These fiscal parameters are set at their average values over the years 1995 to 2007. We follow Krusell, Oha-

Table 1: Summary of parameterization

Parameters	Moments (targets)	Values
Parameters set externally		
τ_c, τ_n, τ_k	Consumption, labor income, and capital income tax rates (Trabandt and Uhlig, 2011)	0.05, 0.28, 0.36
$\widetilde{G}$	Ratio of government consumption to output (Trabandt and Uhlig, 2011)	0.18
$\widetilde{B}$	Ratio of government debt to output (Trabandt and Uhlig, 2011)	0.63
g	Growth rate (Trabandt and Uhlig, 2011)	0.02
δ_E	Depreciation rate of capital equipment (Krusell, Ohanian, Rios-Rull, and Violante, 2000)	0.05
δ_S	Depreciation rate of capital structures (Krusell, Ohanian, Rios-Rull, and Violante, 2000)	0.125
α	Share parameter, capital structures (Krusell, Ohanian, Rios-Rull, and Violante, 2000)	0.117
ρ	Substitution elasticity, skilled labor vs capital (Krusell, Ohanian, Rios-Rull, and Violante, 2000)	–0.495
σ	Substitution elasticity, unskilled vs skilled/capital (Krusell, Ohanian, Rios-Rull, and Violante, 2000)	0.401
ϱ	Persistence in productivity (Alonso-Ortiz and Rogerson, 2010)	0.94
ς	Standard deviation of idiosyncratic shocks to productivity (Alonso-Ortiz and Rogerson, 2010)	0.205
$\overline{h}_S$	Hours worked of skilled workers (Heathcote, Perri, and Violante, 2010)	0.366
$\overline{h}_U$	Hours worked of unskilled workers (Heathcote, Perri, and Violante, 2010)	0.342
s	Share of the skilled population (CPS)	0.288
Parameters calibrated internally		
β	Discount factor (capital-output ratio, 2.87; Trabandt and Uhlig, 2011)	0.9815
λ	Share parameter, capital equipment (capital share of output, 38%; Trabandt and Uhlig, 2011)	0.620
μ	Share parameter, unskilled labor (skill wage premium, 1.75; Heathcote, Perri, and Violante, 2010)	0.365
ψ_S	Disutility of work for skilled (employment rate of skilled, 83.5%; CPS)	2.05
ψ_U	Disutility of work for unskilled (employment rate of unskilled, 72.6%; CPS)	2.37

nian, Rios-Rull, and Violante (2000) in setting the depreciation rates of equipment and structures δ_E and δ_S, the share parameter on capital structures α, and the parameters ρ and σ governing the elasticity of substitution between skilled labor and capital and the elasticity of substitution between unskilled labor and the skilled labor-capital composite, respectively. When we set the parameters for persistence in productivity ϱ and the standard deviation of idiosyncratic shocks to productivity ς, we follow Chang and Kim (2007) and Alonso-Ortiz and Rogerson (2010), who set these parameters based on the estimates of the wage process for male workers. The magnitude of the bias due to selection into employment is considered to be empirically negligible for male workers (Low, Meghir, and Pistaferri, 2010). We set the share of the skilled population s as equal to the share of people who have a four-year college degree, and hours worked $\overline{h}_j$ as equal to the mean annual hours worked of a group j divided by annual discretionary time (365×16), both of which are calculated from the sample of those aged 25 to 60 in the CPS for the years 1995 to 2005. We describe parameters and results when we use the alternative productivity process in Appendix A.3.

Parameters calibrated internally We calibrate the discount factor β, the share parameters on capital equipment and unskilled labor λ and μ in the production function, and the parameters ψ_S and ψ_U governing the disutility of work to match the capital-output ratio of 2.87, the capital share of output of 38 percent, the skill wage premium of 1.75, the employment rate of 83.5 percent for the skilled, and the employment rate of 72.6 percent for the unskilled, respectively. The first two target values are from Trabandt and Uhlig (2011), and the last three target values are from the sample of those aged 25 to 60 in the CPS for the years 1995 to 2005.

Model fit By virtue of the calibration procedure, the model replicates the target values exactly. Although we do not calibrate any parameters to match the variance of log wages, the model can also replicate the variance of log wages. The predicted value of 0.453 is close to the average value of 0.450 in the CPS for the years 1995 to 2005. In addition, the model can broadly predict the distributions of earnings and wealth in the United States, although it cannot exactly replicate the top quintile share of wealth. We provide the details of data and model predictions on the distributions

of wages, earnings, and wealth in Appendix A.4.

4.2 Labor market implications

We analyze the impact of a change in policy that replaces the U.S. tax system with the Japanese tax system. The tax system is characterized by five fiscal parameters $\left(\tau_c, \tau_n, \tau_k, \widetilde{G}, \widetilde{B}\right)$ in the model economy. We set the fiscal parameters in Japan based on the results of Gunji and Miyazaki (2011) and Nutahara (2015). Their average values over the years 1995 to 2007 are $\tau_c = 0.047$, $\tau_n = 0.288$, $\tau_k = 0.519$, $\widetilde{G} = 0.198$, and $\widetilde{B} = 0.604$ for Japan, as opposed to $\tau_c = 0.05$, $\tau_n = 0.28$, $\tau_k = 0.36$, $\widetilde{G} = 0.18$, and $\widetilde{B} = 0.63$ for the United States. The government consumption-output ratio and the government debt-output ratio are not notably different between the two countries. The key difference in the tax system lies in the capital income tax rate.

Changes in skill premium Table 2 shows how the skill wage premium would change if the U.S. tax system was replaced with the Japanese tax system. The capital income tax rate is higher in Japan than in the United States. Replacing the U.S. tax system with the Japanese tax system means increasing the size of the tax and transfer system. The first row of Table 2 reports the actual skill wage premium in the United States and Japan, while the second and third rows report the predicted skill wage premium under the U.S. tax system, the Japanese tax system, and the Japanese capital income tax rate in the heterogeneous-agents incomplete-markets model and the representative-agent model, respectively. In the heterogeneous-agents incomplete-markets model, the skill wage premium would decline from 1.75 to 1.62. The magnitude of this decline corresponds to 42 percent of the actual difference between the United States and Japan. If only the U.S. tax rate on capital income was replaced with the Japanese tax rate, the skill wage premium would decline even more from 1.75 to 1.58. The magnitude of this decline corresponds to 55 percent of the actual difference between the United States and Japan.

The predicted skill wage premium differs substantially between the representative-agent model and the heterogeneous-agents incomplete-markets model. In the representative-agent model, the

Table 2: Tax system and skill premium

$\tau_c, \tau_n, \widetilde{G}, \widetilde{B}$	US	JPN	US
τ_k	US	JPN	JPN
Data	1.75	1.44	–
Heterogeneous agents	1.75	1.62	1.58
Representative agent	1.75	1.71	1.71

skill wage premium would decline by only 4 percentage points if the U.S. tax system was replaced with the Japanese tax system.[2] Before we discuss the mechanism to explain the difference between the two models, we describe the results concerning the decomposition of changes in the skill wage premium.

Effects on skilled and unskilled workers We decompose changes in the skill wage premium into the effect on skilled workers and the effect on unskilled workers (see equation 15) and into the price effect and the composition effect (see equation 16). The first and second rows of Table 3 report the log point changes, relative to the U.S. tax system, in the average wage of skilled workers and the average wage of unskilled workers, respectively. Raising the tax rate on capital income causes a reduction in the capital stock, which results in a decrease in the average wage of skilled workers who are more complementary to capital, but possibly an increase in the average wage of unskilled workers who are more substitutable with capital. The decline in the skill wage premium resulting from replacing the U.S. tax system with the Japanese tax system is attributed completely to a decrease in the average wage of skilled workers; on the other hand, the decline in the skill wage premium resulting from raising the U.S. tax rate on capital income to the Japanese tax rate is attributed to an increase in the average wage of unskilled workers, as well as a decrease in the average wage of skilled workers. While 79 percent of the decline in the skill wage premium is attributable to a decrease in the average wage of skilled workers, the remaining 21 percent is attributable to an increase in the average wage of unskilled workers.

[2] He and Liu (2008) analyze the impact of capital income taxes and transfers on the skill wage premium in a representative-agent model, in which the production technology exhibits capital-skill complementarity, the share of skilled population is endogenous, and labor supply is exogenous. They show quantitatively that, if capital income taxes were eliminated, the skill wage premium would increase only modestly in the United States.

Table 3: Decomposition of the impact of taxes and transfers

$\tau_c, \tau_n, \widetilde{G}, \widetilde{B}$	US → JPN	US
τ_k	US → JPN	US → JPN
Effect on skilled	–8.20 (110.0%)	–8.06 (79.0%)
Effect on unskilled	–0.75 (–10.0%)	2.14 (21.0%)
Price effect	–5.33 (71.5%)	–6.28 (61.7%)
Composition effect	–2.12 (28.5%)	–3.91 (38.3%)

Price and composition effects The third and fourth rows report the log point changes, relative to the U.S. tax system, in the skill wage premium attributable to the price effect and the composition effect, respectively. The reduction in the capital stock resulting from raising the capital income tax rate decreases the relative demand for skilled labor which is more complementary to capital than unskilled labor. In addition, increased government transfers financed from increased tax revenue causes an income effect reducing labor supply. In the heterogeneous-agents incomplete-markets model, workers who consequently decide not to work are more likely to be unskilled workers who have lower productivity. Therefore, redistribution in the form of taxes and transfers results in an increase in the relative supply of skilled labor and a reduction in the relative average productivity of skilled labor. It is worth mentioning that these redistribution effects will be greater if unskilled workers pay proportionally less taxes or receive more transfers than skilled workers in the system of progressive taxes and means-tested transfers. This means that we conservatively assess the impact of taxes and transfers in the system of proportional taxes and lump-sum transfers. In sum, the price effect is caused by a reduction in the relative demand for skilled labor and an increase in the relative supply of skilled labor, while the composition effect is caused by a reduction in the relative average productivity of skilled labor. Both effects work in the same direction to reduce the skill wage premium. The price effect and the composition effect, respectively, account for 72 and 28 percent of the decline in the skill wage premium when replacing the U.S. tax system with the Japanese tax system and 62 and 38 percent of the decline in the skill wage premium when replacing only the U.S. tax rate on capital income with the Japanese tax rate.

Representative vs. heterogeneous agents Given the discussion above, there are two reasons to explain why the impact of taxes and transfers on skill premium is greater in the heterogeneous-agents incomplete-markets model than in the representative-agent model. First, the price effect is greater in the heterogeneous-agents incomplete-markets model than in the representative-agent model, because the relative supply of skilled labor does not change in the representative-agent model. Second, the composition effect is absent in the representative-agent model.

Relative employment The model predicts that the relative employment rate of skilled workers is 1.15 under the US tax system, 1.19 under the Japanese tax system, and 1.23 under the Japanese capital income tax rate. The direction of the predicted change in the relative employment rate is consistent with the data. The relative employment rate in Japan was higher on average at 1.33 in the ESS than in the United States for the years 1996 to 2006.

Capital-output ratio The model predicts that the capital-output ratio is 2.87 under the US tax system, 2.64 under the Japanese tax system, and 2.65 under the Japanese capital income tax rate. The direction of the predicted change in the capital-output ratio is consistent with the data. The capital-output ratio was consistently lower at 2.5 or below in Japan than in the United States for the years 1995 to 2005 (Hansen and İmrohoroğlu, 2016).

4.3 Welfare implications

We have shown that the skill wage premium would significantly decline if the U.S. tax system was replaced with the Japanese tax system. We then evaluate the impact of such a change in tax policy on social welfare. To do so, we measure social welfare by the weighted sum of lifetime utility of all agents. We describe the details of the measurement and decomposition of the welfare effect in Appendix A.5.

Social welfare We consider the impact on social welfare of a change in policy that raises the U.S. tax rate on capital income to the Japanese tax rate. When we measure the welfare effect, we hold

government consumption and debt relative to output constant. Table 4 reports the consumption-equivalent welfare changes. The distortion caused by raising the capital income tax rate will reduce welfare in the representative-agent complete-markets model, but may improve welfare in the heterogeneous-agents incomplete-markets model, in which agents tend to work longer and save more than their efficient levels. While it is desirable to reduce the capital income tax rate to zero in the representative-agent model, it is desirable to impose some level of taxes on capital income in the heterogeneous-agents model. In incomplete markets, increased government transfers financed from increased tax revenue serve as additional insurance against idiosyncratic shocks to productivity, as well as redistribution to reduce inequality. In the presence of capital-skill complementarity, redistribution works more effectively, because in that case wage differentials persistently exist between skilled workers and unskilled workers. The first row of Table 4 indicates that a change in policy that raises the U.S. tax rate on capital income to the Japanese tax rate entails a welfare gain of 1.7 percent in the heterogeneous-agents model, while the fourth row indicates that it entails a welfare loss of 0.8 percent in the representative-agents model.

Table 4: Capital income taxation and social welfare

$\tau_c, \tau_n, \widetilde{G}, \widetilde{B}$	US
τ_k	US $\rightarrow$ JPN
	Heterogeneous agents
Welfare	1.73%
Skilled	–4.90%
Unskilled	4.54%
	Representative agent
Welfare	–0.82%
	Heterogeneous agents, transition
Welfare	2.74%
Skilled	–2.84%
Unskilled	5.08%

The second and third rows of Table 4 report the welfare effect when measured separately for skilled workers and unskilled workers. Raising the tax rate on capital income entails a welfare loss of 4.9 percent for skilled workers but a welfare gain of 4.5 percent for unskilled workers. The main reason for this is that, as we have seen in Table 2, the average wage of unskilled workers increases

by 2.1 log points, while the average wage of skilled workers decreases by 8.1 log points. Another reason is redistribution from skilled workers to unskilled workers. Unskilled and poor workers benefit more from transfers, while skilled and wealthy workers pay a higher amount of taxes.

Decomposition of the welfare effect We decompose the welfare effect into welfare effects attributable to changes in the level and distribution of consumption and leisure. Table 5 shows the extent to which the welfare effect is attributed to changes in the level and distribution of consumption and leisure. Raising the tax rate on capital income reduces the level of consumption but improves the inequality of consumption and the level and inequality of leisure. The welfare loss from a reduction in the level of consumption is greater than the welfare gain from a reduction in the inequality of consumption. The welfare gain from an increase in the level of leisure is substantially greater than the welfare gain from the inequality of leisure due in large part to the linearity of leisure in preferences. In total, the welfare gain from an increase in leisure exceeds the welfare loss from a decline in consumption.

Table 5: Decomposition of the welfare effect

$\tau_c, \tau_n, \widetilde{G}, \widetilde{B}$	US
τ_k	US $\rightarrow$ JPN
Welfare	0.73%
Consumption	
level	–2.71%
distribution	0.44%
Leisure	
level	2.97%
distribution	0.09%

Welfare along the transition We have so far measured the welfare effect by comparing the two steady states under different tax rates. The welfare gain or cost in the transition to the new steady state has been ignored in the measurement. When the two steady states are compared before and after raising the tax rate on capital income, the welfare gain may be understated because the welfare difference between the two steady states reflects a substantial reduction in the capital stock and the

average wage of skilled workers. Along the transition from the initial steady state to the new steady state, however, the capital stock declines gradually, and part of the decline in the capital stock results from an increase in consumption. If the welfare effect is measured after transitional welfare changes are taken into account, the results may change considerably. The last three rows of Table 4 report the welfare effect when transitional welfare changes are taken into account for all workers, skilled workers, and unskilled workers, respectively. We consider a once-and-for-all unexpected change in the tax rate on capital income. The total welfare gain resulting from raising the capital income tax rate increases from 1.7 percent to 2.7 percent.

5 Conclusion

We have analyzed the impact of taxes and transfers on skill premium and social welfare in a heterogeneous-agents incomplete-markets model, extended to allow for capital-skill complementarity. We have quantified the extent to which the skill wage premium declines as a result of raising the tax rate on capital income in the United States. Our analysis shows that the skill wage premium would decline from 1.75 to 1.62 if the U.S tax rate on capital income was replaced with the Japanese tax rate. The magnitude of this decline corresponds to 55 percent of the actual difference in the skill wage premium between the United States and Japan. Such a change in tax policy, which reduces persistent wage differentials between skilled workers and unskilled workers, can result in an increase in social welfare.

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A Appendix

A.1 Representative-agent model

We describe the representative-agent model, which we use as a benchmark in the analysis.

A.1.1 Households

The economy is populated by a continuum of infinitely-lived households. Each household is composed of a unit mass of household members who are either skilled or unskilled indexed by $j \in \{S,U\}$, and whose preferences are described by $U_j\left(C_{jt},H_{jt}\right)$, where C_{jt} is consumption and H_{jt} is hours worked in period t. We denote s as the share of household members who are skilled.

We consider a problem in which the representative household maximizes the discounted weighted sum of utility:

$$\sum_{t=\tau}^{\infty}\beta^{t-\tau}\left[sU_S\left(C_{St},H_{St}\right)+(1-s)\,U_U\left(C_{Ut},H_{Ut}\right)\right] \tag{17}$$

subject to the budget constraint:

$$\begin{aligned}(1+\tau_c)\left[sC_{St}+(1-s)\,C_{Ut}\right] &= (1-\tau_n)\left[sw_{St}H_{St}+(1-s)\,w_{Ut}H_{Ut}\right] \\ &\quad +\left[1+(1-\tau_k)\,r_t\right]A_t-A_{t+1}+F_t. \end{aligned} \tag{18}$$

Assets A_t consist of physical capital and government debt. We specify the instantaneous utility function to be:

$$U_j\left(C_{jt},H_{jt}\right)=\ln C_{jt}-\psi\frac{H_{jt}^{1+\theta}}{1+\theta} \qquad \text{for } j\in\{S,U\}, \tag{19}$$

where the parameter ψ represents the disutility of work, and the parameter $\theta \geq 0$ represents the Frisch labor supply elasticity.

Utility maximization entails equating the relative prices with the marginal rates of substitution across goods and time:

$$C_{St}=C_{Ut}\equiv C_t, \tag{20}$$

$$\frac{w_{St}}{w_{Ut}} = \left(\frac{H_{St}}{H_{Ut}}\right)^{\theta}, \tag{21}$$

$$1 + (1-\tau_k) r_t = \frac{1}{\beta}\left(\frac{C_{t+1}}{C_t}\right). \tag{22}$$

The consumption and labor income tax rates τ_c and τ_n do not appear in the utility-maximizing conditions (20)–(22), while the capital income tax rate τ_k appears in the intertemporal optimality condition (22). Consumption and labor income taxation influences neither the relative consumption nor the relative labor supply of skilled labor, while capital income taxation influences asset holdings.

A.1.2 Firms

Perfectly competitive firms produce output according to the technology (8).

A.1.3 Government

The government levies proportional taxes on consumption, labor income, and capital income, and spends the tax revenue on government consumption, lump-sum transfers, and interest payments on government debt, according to the balanced budget rule (13).

A.1.4 Equilibrium

The equilibrium of the economy is characterized as follows. Given policies $\left\{\widetilde{G}_t, \widetilde{B}_t, \tau_c, \tau_n, \tau_k, \widetilde{F}_t\right\}$ and an initial condition z_0, a competitive equilibrium consists of an allocation $\left\{\widetilde{C}_{St}, \widetilde{C}_{Ut}, H_{St}, H_{Ut}, N_{St}, N_{Ut}, \widetilde{K}_{Et}, \widetilde{K}_{St}\right\}$ and price system $\{\widetilde{w}_{St}, \widetilde{w}_{Ut}, r_t\}$ such that: for all t, given prices, the allocation solves the household's problem and the firm's problem; the government budget is balanced; the capital market clears, i.e., $\widetilde{K}_{Et} + \widetilde{K}_{St} + \widetilde{B}_t = \widetilde{A}_t$; labor markets clear, i.e., $N_{St} = sH_{St}$ and $N_{Ut} = (1-s)H_{Ut}$; and the final goods market clears, i.e., $\widetilde{C}_t + \widetilde{K}_{E,t+1} + \widetilde{K}_{S,t+1} = \mathcal{F}\left(N_{St}, N_{Ut}, \widetilde{K}_{Et}, \widetilde{K}_{St}; z_t\right) + (1-\delta_E)\widetilde{K}_{Et} + (1-\delta_S)\widetilde{K}_{St}$.

A.1.5 Skill premium

The equilibrium skill wage premium is defined as:

$$\omega_{\text{ra}} \equiv \frac{w_S}{w_U} = \left(\frac{1-s}{s}\frac{N_S}{N_U}\right)^{\theta}. \tag{23}$$

The skill wage premium declines with a rise in the share of the skilled population and increases with a rise in the relative demand for skilled labor. When we compare two countries with the same share of the skilled population but different tax rates, the difference in the skill wage premium is:

$$\Delta \ln(\omega_{\text{ra}}) = \theta \Delta \ln\left(\frac{N_S}{N_U}\right). \tag{24}$$

The cross-country difference in the skill wage premium is proportional to the difference in the relative demand for skilled labor resulting from differences in the tax system.

A.1.6 Parameterization

Parameters set externally are chosen to be the same as in Table 1. The Frisch elasticity is set at $\theta = 1$. Following Trabandt and Uhlig (2011), we calibrate ψ to match the average hours worked of 0.25, and consequently set at $\psi = 12.6$. We calibrate a set of parameters (β, λ, μ) to match the same targets as in Table 1, and consequently set at $(\beta, \lambda, \mu) = (0.994, 0.545, 0.322)$. The impact of taxes and transfers on the skill wage premium remain almost unchanged regardless of the value of the Frisch elasticity.

A.2 Numerical algorithm

We describe methods for computing the equilibria in the heterogeneous-agents incomplete-markets model.

Steady state We compute the steady-state equilibrium allocation in the heterogeneous-agents incomplete-markets model by extending the numerical algorithm in Aiyagari and McGrattan (1998)

and Flodén and Lindé (2001), who build upon the algorithm of Huggett (1993) and Aiyagari (1995).

1. Discretize the state space $(\widetilde{a}, x, j)$, and compute the transition probability $\pi(x'|x)$ using the Tauchen (1986) method.

2. Set a guess for $\left\{\widetilde{K}_E, N_S, \widetilde{z}\right\}$. Compute $\widetilde{K}_S$ from (11) and (12).

3. Given $\left\{\widetilde{K}_E, \widetilde{K}_S, N_S, \widetilde{z}\right\}$, compute $\widetilde{w}_S$ from (9), r from (11), N_U from (8), $\widetilde{w}_U$ from (10), and aggregate consumption $\widetilde{C}$ from the goods market clearing condition. Given $\left\{\widetilde{G}, \widetilde{B}, \tau_c, \tau_n, \tau_k\right\}$, compute $\widetilde{F}$ from (13).

4. Solve for the beginning-of-period value function $V(\widetilde{a}, x, j)$.

   (a) Set a guess for $V(\widetilde{a}, x, j)$.

   (b) Update the value function using the Bellman equations (5) and (6) until convergence. Given the value function, obtain the decision rules $\{\widetilde{c}(\widetilde{a}, x, j), h(\widetilde{a}, x, j), \widetilde{a}'(\widetilde{a}, x, j)\}$.

5. Compute the stationary distribution $\xi(\widetilde{a}, x, j)$.

   (a) Set a guess for $\xi(\widetilde{a}, x, j)$.

   (b) Update the distribution by weighting the transition probability according to the distance from the optimal asset holdings to the two adjacent grid points, until convergence.

6. Update $\left\{\widetilde{K}_E, N_S, \widetilde{z}\right\}$. Repeat steps 2 to 5 until convergence.

Transitional dynamics We compute the transition path from the initial steady state to the new steady state as follows:

1. Compute the initial steady state. Assume that the economy converges to the new steady state after 100 periods, and compute the new steady state.

2. Set a guess for the transition path of $\left\{\widetilde{K}_{Et}, \widetilde{K}_{St}, N_{St}, \widetilde{z}_t\right\}_{t=0}^{100}$. Given this path, compute the transition path of $\left\{\widetilde{w}_{St}, \widetilde{w}_{Ut}, r_t, N_{Ut}, \widetilde{C}_t, \widetilde{F}_t\right\}_{t=0}^{100}$.

3. Solve the agent's problem backwards from the last period to the first period, and obtain the decision rules.

4. Given the decision rules, simulate the economy forward from the first period to the last period.

5. Update $\left\{\widetilde{K}_{Et}, \widetilde{K}_{St}, N_{St}, \widetilde{z}_t\right\}_{t=0}^{100}$. Repeat steps 2 to 5 until convergence.

A.3 Alternative productivity process

Following Krueger and Ludwig (2016), we consider the extended version of the productivity process, in which the persistence is 4.4 percent higher for skilled workers than for unskilled workers, while the volatility is 38.6 percent higher for unskilled workers than for skilled workers. We eventually set at $(\varrho_S, \varsigma_S) = (0.9652, 0.1656)$ for skilled workers and $(\varrho_U, \varsigma_U) = (0.9244, 0.2295)$ for unskilled workers such that the weighted averages of the respective parameters remain the same. We then recalibrate a set of parameters $(\beta, \lambda, \mu, \psi_S, \psi_U)$ to match the same targets as in the analysis above. Table 6 shows changes in the skill wage premium and social welfare in the steady state when the U.S. tax rate on capital income is replaced with the Japanese tax rate. We confirm that the main results remain essentially unchanged.

Table 6: Capital income taxation, skill premium, and welfare in the extended model

$\tau_c, \tau_n, \widetilde{G}, \widetilde{B}$	US
τ_k	US → JPN
Wage premium	1.75 → 1.61
Effect on skilled	–6.15 (78.7%)
Effect on unskilled	1.67 (21.3%)
Price effect	–5.57 (71.2%)
Composition effect	–2.25 (28.8%)
Welfare	1.60%
Skilled	–1.99%
Unskilled	3.66%

A.4 Distributions of wages, earnings, and wealth

Table 7 shows the variance of log hourly wages for all workers, skilled workers, and unskilled workers. The first column reports the average values calculated from the Current Population Survey for the years 1995 to 2005. The second and third columns report the predicted values from the model when the productivity process is the same for skilled and unskilled workers and when the productivity process differs between skilled and unskilled workers, respectively. We confirm that the model can account for the wage distribution observed in the data.

Table 7: Variance of log hourly wages

	Data	T-Y1	T-Y2
All	0.450	0.453	0.457
Skilled	0.463	0.395	0.477
Unskilled	0.362	0.358	0.345

Table 8: Quintile shares of earnings and wealth (%)

(a) Annual earnings

	All				Skilled			Unskilled		
	Data	T-Y1	T-Y2	AO-R	Data	T-Y1	T-Y2	Data	T-Y1	T-Y2
First	7.7	10.6	12.4	1.6	9.2	9.9	11.9	9.9	9.6	10.6
Second	12.2	15.3	14.0	16.7	14.5	16.8	12.1	16.1	16.3	16.3
Third	17.4	18.4	17.8	20.3	17.3	19.9	19.5	20.5	19.7	19.3
Fourth	23.0	22.5	21.6	24.2	19.0	23.4	23.4	23.1	23.5	23.8
Fifth	39.7	33.3	34.5	37.3	40.0	30.0	33.2	30.4	30.9	30.0

(b) Net worth

	All				Skilled			Unskilled		
	Data	T-Y1	T-Y2	AO-R	Data	T-Y1	T-Y2	Data	T-Y1	T-Y2
First	–0.3	0.2	0.2	0.02	–0.2	0.0	0.0	–0.2	0.4	0.5
Second	1.5	2.5	2.2	0.8	2.0	1.4	0.5	2.3	3.0	3.7
Third	5.6	9.0	8.3	6.7	6.4	8.3	5.7	6.8	9.6	10.5
Fourth	14.0	21.6	20.4	21.1	15.2	22.3	20.3	16.3	23.0	23.8
Fifth	79.2	66.7	69.0	71.3	76.6	68.0	73.6	74.8	64.1	61.6

Table 8 shows the shares of annual earnings and net worth by quintile for all workers, skilled workers, and unskilled workers. The first column for each group reports the average values calculated from the Survey of Consumer Finances for the years 1995 to 2007. We select households

in which household heads are aged 25 to 60 in the sample and trim the top 1 percent of wealthy households. The second and third columns for each group report the predicted values from the model when the productivity process is the same for skilled and unskilled workers and when the productivity process differs between skilled and unskilled workers, respectively. The fourth column for all workers reports the results of Alonso-Ortiz and Rogerson (2010). We confirm that the predictions of the model are broadly consistent with the earnings and wealth distributions observed in the data. We, however, admit that the model understates the top quintile share of earnings for skilled workers and the top quintile share of wealth for unskilled workers.

A.5 Welfare measurement

We describe the measurement and decomposition of the welfare effect of a change in policy.

Social welfare Social welfare can be defined as the weighted sum of the lifetime utility of all agents, which depends on consumption c_j and leisure, defined as $\ell_j = 1 - h_j$:

$$\begin{aligned} \Upsilon_m &\equiv \int_{\{j=S,U\}} V^m(\widetilde{a},x,j)\,d\xi^m + \frac{\ln Y_0^m}{1-\beta} + \frac{\beta\ln(1+g)}{(1-\beta)^2} \\ &= \int_{\{j=S,U\}} \left\{ \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \widetilde{c}^m - \psi_j (1-\ell^m) \right] \right\} d\xi^m + \frac{\ln Y_0^m}{1-\beta} + \frac{\beta\ln(1+g)}{(1-\beta)^2} \qquad \text{for } m \in \{0,1\}, \end{aligned} \tag{25}$$

where $m = 0$ and $m = 1$ represent the pre-reform steady state and the post-reform steady state, respectively, and Y_0 is the initial output. The welfare consequence of a change in the tax rate can be expressed as the percentage change in consumption, denoted by ϖ, required to leave the agents indifferent between the two equilibrium allocations:

$$\begin{aligned} &\int_{\{j=S,U\}} \left\{ \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln\left((1+\varpi)\widetilde{c}^0\right) - \psi_j \left(1-\ell^0\right) \right] \right\} d\xi^0 + \frac{\ln Y_0^0}{1-\beta} \\ &\qquad = \int_{\{j=S,U\}} \left\{ \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \widetilde{c}^1 - \psi_j \left(1-\ell^1\right) \right] \right\} d\xi^1 + \frac{\ln Y_0^1}{1-\beta}. \end{aligned} \tag{26}$$

The welfare effect of a policy reform can then be measured by:

$$\varpi = \exp\left[(1-\beta)(\Upsilon_1 - \Upsilon_0)\right] - 1. \tag{27}$$

The welfare effect can be decomposed into the portion attributable to a change in consumption and the portion attributable to a change in leisure. Each of the two effects can be further decomposed into the portion attributable to a change in the level of consumption or leisure and the portion attributable to a change in the distribution of consumption or leisure:

$$1 + \varpi = (1+\varpi_c)(1+\varpi_\ell) = \left(1+\varpi_c^{\text{level}}\right)\left(1+\varpi_c^{\text{dist}}\right)\left(1+\varpi_\ell^{\text{level}}\right)\left(1+\varpi_\ell^{\text{dist}}\right) \tag{28}$$

Or approximately, $\varpi \simeq \varpi_c^{\text{level}} + \varpi_c^{\text{dist}} + \varpi_\ell^{\text{level}} + \varpi_\ell^{\text{dist}}$. Below we describe the details of the welfare decomposition.

Decomposition of the welfare effect We decompose the welfare effect into the portion attributable to a change in consumption and the portion attributable to a change in leisure, i.e., $1+\varpi = (1+\varpi_c)(1+\varpi_\ell)$, and further decompose each of the two effects into the portion attributable to a change in the level of consumption or leisure and the portion attributable to a change in the distribution of consumption or leisure, i.e., $1+\varpi_c = \left(1+\varpi_c^{\text{level}}\right)\left(1+\varpi_c^{\text{dist}}\right)$ and $1+\varpi_\ell = \left(1+\varpi_\ell^{\text{level}}\right)\left(1+\varpi_\ell^{\text{dist}}\right)$. Given the specification of preferences, it is possible to derive a closed-form expression for each welfare effect. We first derive $1+\varpi_\ell$ by the linearity of leisure in the utility function, and calculate $1+\varpi_c$ as the residual, i.e., $1+\varpi_c = (1+\varpi)/(1+\varpi_\ell)$. We then derive $1+\varpi_c^{\text{level}}$ and $1+\varpi_\ell^{\text{level}}$, and calculate $1+\varpi_c^{\text{dist}}$ and $1+\varpi_\ell^{\text{dist}}$ as the residuals, i.e., $\varpi_c^{\text{dist}} = (1+\varpi_c)/\left(1+\varpi_c^{\text{level}}\right) - 1$ and $\varpi_\ell^{\text{dist}} = (1+\varpi_\ell)/\left(1+\varpi_\ell^{\text{level}}\right) - 1$. Below we provide the description of ω_ℓ, $\varpi_\ell^{\text{level}}$, and ϖ_c^{level}.

We denote L_j as the aggregate leisure of a group j, and define the aggregate leisure as $L = L_S + L_U$. We denote by the superscripts 0 and 1 the pre-reform steady state and the post-reform steady state, respectively. The welfare effect attributable to a change in leisure can be obtained by

changing leisure while holding consumption constant.

$$\varpi_\ell = \exp\left[\psi_S\left(L_S^1 - L_S^0\right) - \psi_U\left(L_U^1 - L_U^0\right)\right] - 1 \tag{29}$$

The welfare effect attributable to a change in the level of leisure can be described by changing the level of leisure while holding the distribution and consumption constant.

$$\varpi_\ell^{\text{level}} = \exp\left[\left(\psi_S L_S^0 + \psi_U L_U^0\right)\left(\frac{L^1}{L^0} - 1\right)\right] - 1. \tag{30}$$

Similarly, the welfare effect attributable to a change in the level of consumption can be obtained by changing the level of consumption while holding the distribution and leisure constant.

$$\varpi_c^{\text{level}} = \frac{C^1}{C^o} - 1. \tag{31}$$

The ratio of C^1 to C^0 is constant because the growth rate is invariant with respect to tax rates.