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"The Impact of Taxes and Transfers on Skill Premium"

Shuhei Takahashi and Ken Yamada

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The Impact of Taxes and Transfers on Skill Premium*

Shuhei Takahashi† Ken Yamada‡

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Abstract

We analyze the impact of the size of the tax and transfer system on inequality and welfare in a heterogeneous agent/incomplete markets model, extended to allow for capital–skill complementarity. The skill wage premium can decrease significantly with an increase in the size of the tax and transfer system due to a rise in the capital income tax rate when idiosyncratic shocks to labor productivity are not insurable. The differences in the steady-state skill wage premium under different capital income tax rates are consistent with those observed across countries. The welfare of the unskilled improves with a rise in the capital income tax rate, while that of the skilled deteriorates.

KEYWORDS: Wage inequality; capital–skill complementarity; incomplete markets; capital income taxes; composition effect.
JEL CLASSIFICATION: E13, E24, E62, H24, J31.

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†Kyoto University. Email: takahashi@kier.kyoto-u.ac.jp
‡Kyoto University. Email: yamada@econ.kyoto-u.ac.jp

1 Introduction

The level of wage inequality has varied widely across advanced industrial countries (Freeman and Katz, 1995; Krueger et al., 2010). One of the main reasons for this is a significant difference in the skill wage premium, defined as the ratio of the average wages of college graduate workers to those of non-college graduate workers. When the level of wage inequality is compared between two of the largest economies in the year 2000, the skill wage premium was 26 percent higher in the United States than Japan, and the variance of the log hourly wages was 47 percent higher in the United States than Japan (Heathcote et al., 2010; Lise et al., 2014). In fact, the skill wage premium is positively and significantly correlated with the variance of log hourly wages at a correlation coefficient of 0.70 and a p-value of 0.05 in the year 2000 among the eight OECD countries (Canada, Germany, Italy, Japan, Spain, Sweden, the United Kingdom, and the United States).[1]

Cross-country differences in wage inequality have been attributed to several factors in the literature, such as labor market institutions (Blau and Kahn, 1996; Nickell and Layard, 1999), the supply of and demand for skills (Leuven et al., 2004), technological change and labor market institutions (Acemoglu, 2003), technological change and international trade (Parro, 2013), and the progressivity of labor income taxes (Guvenen et al., 2014). Nonetheless, differences in the skill wage premium across countries at a given point in time have been less well understood than changes in the skill wage premium over time for a given country. This study aims to provide a new explanation for significant and persistent differences in the skill wage premium across countries.

Building upon the analyses of hours worked and labor productivity in Prescott (2004) and Alonso-Ortiz and Rogerson (2010), we focus on the tax and transfer system as a source of differences in labor market outcomes across countries. When the tax system is compared between the United States and Japan, the main difference lies in the capital income tax rate. As detailed in the next section, the capital income tax rate was higher in Japan than in the United States from the 1990s to the 2000s, while the skill wage premium was higher than the United States than Japan. At the same time, the labor income tax rate and the consumption tax rate were similar between the two countries. Motivated by these facts, we examine the extent to which cross-country differences in the skill wage premium can be attributed to the capital income tax rate.

In this study, we first document persistent differences in wage inequality and tax rates between the United States and Japan. We then use a heterogeneous agent/incomplete markets model to examine the extent to which the size of the tax and transfer system can account for cross-country differences in the skill wage premium. Our model has two key features in the analysis. First, labor supply is indivisible in a way that accounts for cross-country differences in employment rates, as in Chang and Kim (2006) and Alonso-Ortiz and Rogerson (2010). Second, the production technology exhibits capital–skill

[1] The correlation coefficient is calculated based on the results of Brzozowski et al. (2010) in Canada, Fuchs-Schündeln et al. (2010) in Germany, Jappelli and Pistaferri (2010) in Italy, Lise et al. (2014) in Japan, Pijoan-Mas and Sánchez-Marcos (2010) in Spain, and Domeij and Flodén (2010) in Sweden, Blundell and Etheridge (2010) in the United Kingdom, and Heathcote et al. (2010) in the United States.

complementarity in a way that allows for the influence of capital equipment on the skill wage premium, as in Griliches (1969) and Krusell et al. (2000). In this context, the heterogeneous agent model has a wider range of implications than the representative agent model from four points of view. First, we can evaluate the impact of capital income taxes on the wage distribution, as well as the skill wage premium. Second, we can consider precautionary savings and labor supply against idiosyncratic shocks, and thus, rationalize the role of capital income taxes for improving social welfare. Third, we can allow for the possibility that the relative demand for and the relative supply of skilled to unskilled labor may change according to the size of the tax and transfer system. Finally, related to the last point, we can take into account differences in changes in the average productivity of skilled and unskilled workers associated with changes in employment due to a change in the size of the tax and transfer system. We demonstrate how important these points are to understanding inequality and welfare by comparing the results obtained from the representative agent and heterogeneous agent models and by quantifying the sources of changes in the skill wage premium.

We calibrate the heterogeneous agent model to the U.S. economy and evaluate the impact of tax reforms on wage inequality and social welfare. We mainly consider the tax reform that raises the U.S. capital income tax rate and adjusts lump-sum transfers to balance the government budget. Our results indicate that such reform can result in a significant decrease in wage inequality and a moderate increase in social welfare. The magnitude of the decrease in the skill wage premium (the variance of log wages) due to the tax reform corresponds to a significant (large) fraction of the difference in the skill wage premium (the variance of log wages) between the United States and Japan. The welfare effects of tax reform differ starkly between the skilled and the unskilled. Consequently, the premium to skills declines with a rise in the capital income tax rate not only in terms of hourly wages but also in terms of lifetime utility. We decompose the difference in the skill wage premium under different capital income tax rates to understand the mechanism through which the tax and transfer system affects the skill wage premium in incomplete markets. Our results show that the difference in the skill wage premium are attributable not only to a difference in the relative market wages of skilled to unskilled labor but also to a difference in the composition of the workforce. Furthermore, the difference in the relative market wages arises from shifts in the relative supply of, as well as the relative demand for, skilled to unskilled labor. We finally confirm that changes in the skill wage premium in European countries compared to the United States are also in line with the predictions of our model.

This study is related to three strands of the literature. First, this study is related to the literature that considers the role of the tax and transfer system in the heterogeneous agent/incomplete markets model of Huggett (1993) and Aiyagari (1994), extended to allow for endogenous labor supply. Flodén and Lindé (2001) and Alonso-Ortiz and Rogerson (2010) analyze the impact of labor income taxes and transfers, Yum (2018) analyzes the impact of capital income taxes and transfers, Nakajima and Takahashi (2019) analyze the impact of consumption taxes and transfers, and Aiyagari and McGrattan (1998) and Flodén (2001) analyze the impact of government debt and transfers.

Second, this study is related to the literature that reexamines the well-known result of Chamley (1986) and Judd (1985) that the optimal tax rate on capital income is zero in the steady state. Aiyagari (1995) and İmrohoroğlu (1998) show that the optimal tax rate on capital income may be strictly positive in the steady state when markets are incomplete. Conesa et al. (2009) show 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 incomplete markets.

Finally, this study is related to the literature that examines changes in the skill wage premium using general equilibrium models with capital–skill complementarity. He and Liu (2008) evaluate the impact of tax reform that eliminates capital income taxes using a representative agent model, in which labor supply is exogenous but skill is endogenous. They find that the skill wage premium increases only modestly even if the capital income tax rate is reduced to zero in the United States. Angelopoulos et al. (2014) evaluate the impact of tax reforms that lower the labor and capital income tax rates on the skill wage premium using a general equilibrium model, in which a representative capitalist and representative skilled and unskilled workers choose consumption, savings, and labor supply. They find that the skill wage premium can increase significantly if the capital income tax rate is lowered in the United Kingdom. Slavík and Yazici (2020) evaluate the impact of a rise in the wage risk from the years 1967 to 2010 in the United States on the skill wage premium using a heterogeneous agent/incomplete markets model with divisible labor.

The rest of the paper proceeds as follows. Section 2 describes differences in wage inequality and tax rates across countries. Section 3 presents the structure of the model, the decomposition of differences in the skill wage premium, and the measurement of welfare effects. Section 4 provides a quantitative analysis of capital income taxes and transfers on the premium to skills and social welfare. The final section summarizes and concludes.

2 International Comparison

We start our analysis by describing persistent differences (and similarities) in wage inequality and tax rates between the United States and Japan. We then compare the skill wage premium and the capital income tax rate between the United States and European countries.

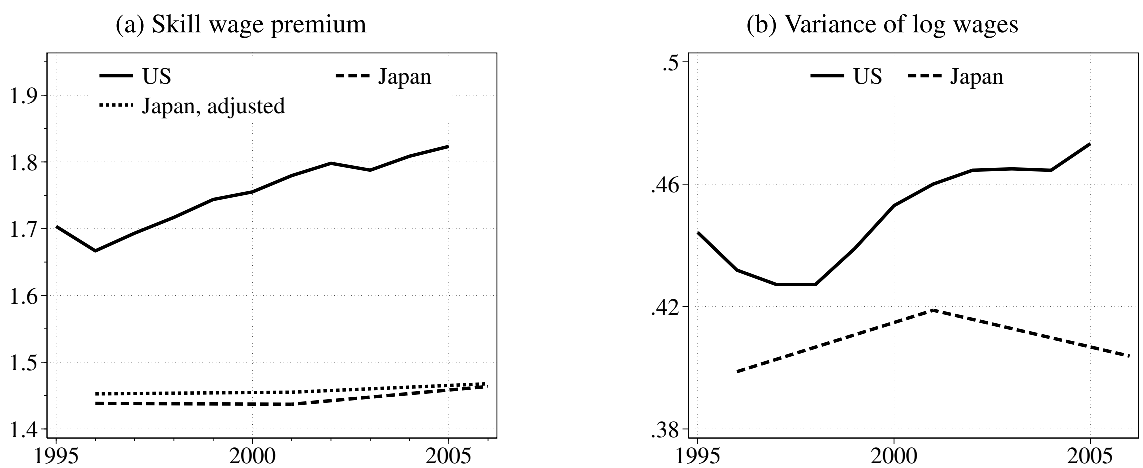
2.1 The United States and Japan

2.1.1 Wage inequality

Throughout this study, the skill wage premium is defined as the ratio of the average hourly wages of college graduate workers to those of non-college graduate workers, and hourly wages are calculated as the ratio of annual earnings to annual hours worked, as is standard in the literature (Heathcote et al., 2010; Krueger et al., 2010). Four-year college graduates are classified as skilled, while the rest are classified as unskilled, as is also the standard in the literature. When we calculate the average wages, we adjust for changes in the composition of the workforce by holding the employment share by age, sex, and education fixed over time in a manner similar to that in Autor et al. (2008).[2] For cross-country comparison, we additionally adjust for differences in changes in the composition of the workforce across countries by holding the employment share by age, sex, and education fixed at the U.S. level.

Figure 1 displays the skill wage premium and the variance of log hourly wages in the United States for the years 1995 to 2005 and in Japan for the years 1996 to 2006. The data are taken 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. The sample used is the same as in Heathcote et al. (2010) for the United States and constructed in the same way as in Heathcote et al. (2010) for Japan. The sample comprises men and women aged 25 to 60, who mainly work (at least 260 hours) and earn at least half of the minimum wage during the year. During this period, the skill wage premium was consistently higher in the United States than Japan (see the bold and dashed lines in Figure 1a). The average values over this period were 1.75 in the United States and 1.44 in Japan. Similarly, the variance of log wages was consistently higher in the United States than Japan (Figure 1b). The average values over this period were 0.450 in the United States and 0.407 in Japan.

Figure 1: Wage inequality in the United States and Japan



Notes: The bold and dashed lines in Figure 1a indicate the skill wage premium in the United States and Japan, respectively, after adjusting for changes in the composition of the workforce. The dotted line in Figure 1a indicates the skill wage premium in Japan after additionally adjusting for differences in changes in the composition of the workforce across countries.

The skill wage premium in Japan remains almost unchanged even when the U.S. employment share by age, sex, and education group is used as a weight to calculate the skill wage premium (see the dotted line in Figure 1a). This result implies that the difference in the skill wage premium between the two countries cannot be attributed to the age, sex, and education composition of the workforce. Furthermore,

[2]The adjustment proceeds as follows. We first group workers according to their age, sex, and education, and average the wages for each group. We then average the wages across groups using the time-averaged employment share of each group as a weight.

the difference in the skill wage premium between the two countries does not seem to be attributed to the quality of education because the literature consistently finds that the quality of education is higher in Japan than the United States (Schoellman, 2012; Kaarsen, 2014). Specifically, Kaarsen (2014) shows that students in Japan acquire 23 percent more knowledge than those in the United States for each year of schooling. The difference in the skill premium would not decrease but rather increase if we adjust for the difference in the quality of education between the two countries.

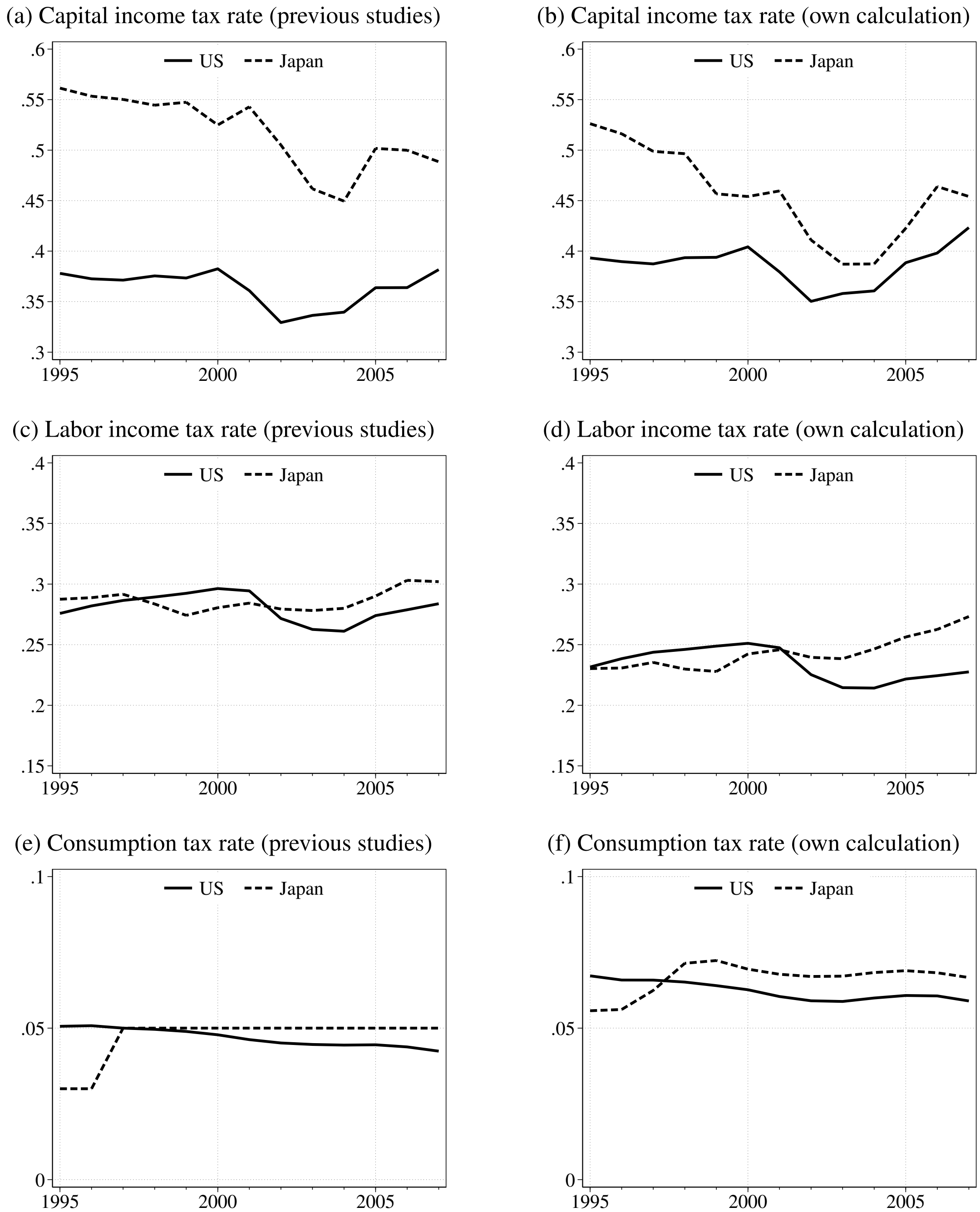
There has been a significant difference in the skill premium between the United States and Japan over past decades, although it is perhaps not widely known. Educational wage differentials were consistently greater in the United States than Japan from the late 1960s to the 1980s (Katz et al., 1995). Since the 1980s, the skill wage premium has substantially increased in the United States (Autor et al., 2008). Nonetheless, the magnitude of the difference in the skill wage premium between the two countries is more noticeable than that of the change in the United States (Figure 1a).

2.1.2 Tax rates

For the purpose of international comparison, tax rates on capital income, labor income, and consumption are typically calculated as the ratios of revenues from taxes on capital income, labor income, and consumption to capital income, labor income, and consumption expenditure, respectively, (Mendoza et al., 1994; Carey and Rabesona, 2002; Trabandt and Uhlig, 2011). We compare these tax rates between the United States and Japan based on the results of previous studies as well as those of our own calculation. Figure 2 displays the capital income tax rate, the labor income tax rate, and the consumption tax rate in the United States and Japan for the years 1995 to 2007. The U.S. tax rates in the left figures are based on the results of Trabandt and Uhlig (2011), who calculate the average tax rates in the United States and 14 European countries for the years 1995 to 2007 using the Mendoza et al. (1994) approach. The U.S. tax rate on capital income is close to the average among these countries. The Japanese tax rates in the left figures are based on the results of Nutahara (2015), who refines the results of Gunji and Miyazaki (2011). Gunji and Miyazaki (2011) calculate the average marginal tax rates in Japan for the years 1963 to 2007 using the Joines (1981) approach. Their results are consistent with those of Mendoza et al. (1994) on the Japanese tax rates for the years 1965 to 1996. The U.S. and Japanese tax rates in the right figures are based on our own calculation. We adopt the approach of Carey and Rabesona (2002), who relax some of the assumptions made in Mendoza et al. (1994), in calculating the U.S. and Japanese tax rates. We use data available from the OECD National Accounts and Revenue Statistics for this purpose.

Looking at the results of previous studies, the capital income tax rate was on average 52 percent in Japan as opposed to 36 percent in the United States, while the labor income and consumption tax rates were on average 28 percent and 5 percent, respectively, in both countries (Figures 2a, 2c, and 2e). Looking at the results of our own calculation, the capital income tax rate was on average 46 percent in Japan as opposed to 39 percent in the United States, while the labor income and consumption tax rates were on average 23 to 24 percent and 6 to 7 percent, respectively, in both countries (Figures 2b, 2d, and 2f). Therefore, both results indicate that the capital income tax rate was consistently higher in Japan than the United States, while the labor income and consumption tax rates were consistently similar between the two countries. The magnitude of the difference in the capital income tax rate between the two countries is conservative in our calculation.

Figure 2: Tax rates in the United States and Japan



Notes: The average tax rates in Figures 2a, 2c, and 2e are based on the results of Trabandt and Uhlig (2011) and Nutahara (2015), while those in Figures 2b, 2d, and 2f are based on the results of our own calculation.

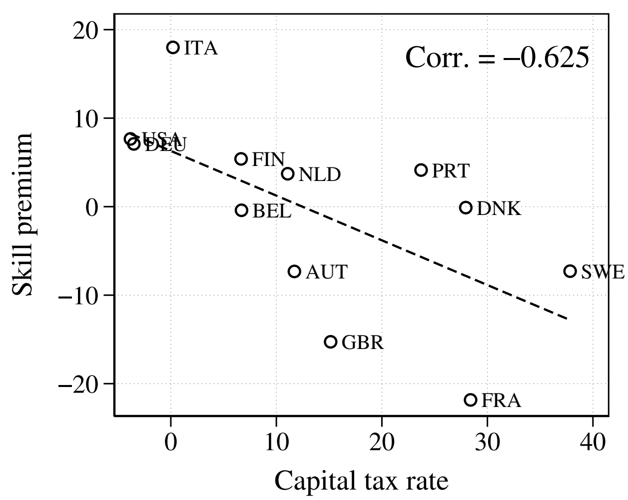
The higher rate of capital income taxes in Japan is due in large part to the higher rate of corporate tax. Devereux et al. (2002) calculate the average effective tax rates on corporate income in 19 OECD countries for the years 1982 to 2001. According to their updated results,[3] the effective corporate tax rate was highest in Japan among those countries from the 1990s to the 2000s.

It may be worth mentioning that tax progressivity did not differ much between the United States and Japan during this period. According to the OECD Tax Database, in the year 2000, the national marginal tax rates on labor income were progressive from 15, 28, 31, 36, to 39.6 percent in the United States and from 10, 20, 30, to 37 percent in Japan.

2.2 The United States and Europe

The differences in the skill wage premium and the capital income tax rate between the United States and Japan were largely stable over time. As the two countries were similar in other characteristics such as the consumption and labor income tax rates and the share of skilled population, the U.S.–Japan comparison deserves special attention to uncover the extent to which persistent differences in wage inequality across countries can be attributed to the capital income tax rate. However, at the same time, we are also interested in differences in wage inequality between the United States and European countries and its relationship with the capital income tax rate. When we compare the United States and European countries, we correlate changes in the skill wage premium with changes in the capital income tax rate to control for the influence of other factors.

Figure 3: Changes in the skill wage premium, 1995–2005



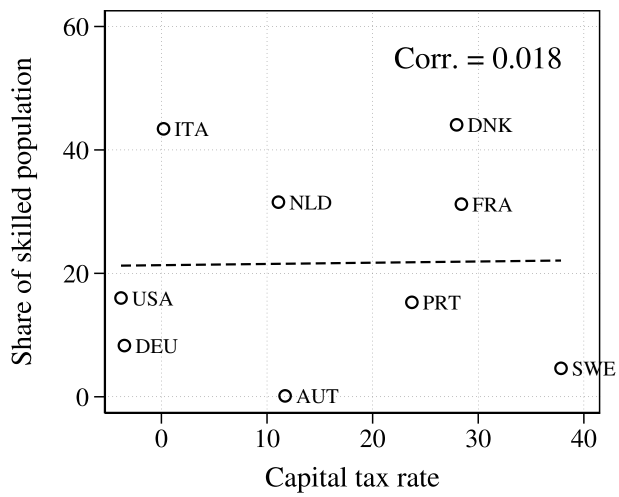
Notes: The vertical and horizontal axes indicate the log point changes in the skill wage premium and the capital income tax rate between the years 1995 and 2005. The dashed line indicates the regression line. Country names are abbreviated as follows: AUT, Austria; BEL, Belgium; DEU, Germany; DNK, Denmark; FIN, Finland; FRA, France; GBR, the United Kingdom; ITA, Italy; NLD, the Netherlands; PRT, Portugal; SWE, Sweden; and USA, the United States.

Figure 3 plots the log point changes (i.e., approximately the percentage changes) in the skill wage premium against those in the capital income tax rate in the United States and European countries between

[3]The updated results are available at https://www.ifs.org.uk/publications/3210.

the years 1995 and 2005. The skill wage premium is defined in the same way as described above, and the average wages of college and non-college graduate workers are calculated as the ratio of total labor compensation to total hours worked using data from the EU KLEMS database. The capital income tax rate is based on the results of Trabandt and Uhlig (2011). During this period, both information is available in the United States and 11 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Sweden, and the United Kingdom). The skill wage premium tends to increase in countries such as the United States, where the capital income tax rate did not increase, and tends to decrease in countries such as France, where the capital income tax rate increased. Overall, changes in the capital income tax rate are negatively associated with changes in the skill wage premium at a correlation coefficient of –0.625 and a p-value of 0.030.

Figure 4: Changes in the share of skilled population, 1995–2005



Notes: The vertical and horizontal axes indicate the log point changes in the share of skilled population and the capital income tax rate between the years 1995 and 2005. The dashed line indicates the regression line. Country names are abbreviated as follows: AUT, Austria; DEU, Germany; DNK, Denmark; FRA, France; GBR, the United Kingdom; ITA, Italy; NLD, the Netherlands; SWE, Sweden; and USA, the United States.

The difference in the skill wage premium across countries may reflect the difference in the share of skilled population. The shares of skilled population did not differ much between the United States and Japan, as they were 36.5 percent in the United States and 33.6 percent in Japan in the year 2000. In contrast, the shares of skilled population differ between the United States and European countries in terms of both levels and growth rates. We are concerned about the possibility that the association between changes in the skill wage premium and changes in the capital income tax rate may be driven by changes in the share of skilled population. Figure 4 plots the log point changes in the share of skilled population against those in the capital income tax rate in the United States and European countries between the years 1995 and 2005. During this period, the data on the share of skilled population aged 25 to 64 are available in the United States and eight European countries (Austria, Denmark, France, Germany, Italy, the Netherlands, Sweden, and the United Kingdom) from OECD.Stat. Changes in the capital income tax rate are not associated with changes in the share of skilled population at a correlation coefficient of

0.018 and a p-value of 0.963. The negative association between changes in the skill wage premium and changes in the capital income tax rate does not seem to be attributed to the share of skilled population.

3 Economic Model

We describe the representative agent/complete markets model and the heterogeneous agent/incomplete markets model. In the analysis, we use the former as a benchmark and focus mainly on the latter. The heterogeneous agent model builds upon the model of indivisible labor developed by Chang and Kim (2007) and Alonso-Ortiz and Rogerson (2010). We extend their model by incorporating capital–skill complementarity and capital income taxes.

3.1 Households

We first describe the problem of a representative household, and then, that of heterogeneous households.

3.1.1 Representative household

The economy is populated by a continuum of identical 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 $U_j(C_{jt},H_{jt})$, where C_{jt} is consumption, and H_{jt} is hours worked in period t. Let φ denote the share of household members who are skilled. Preferences are given by

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

where $\beta \in (0,1)$ is the discount factor. The instantaneous utility function is specified as:

$$U_j\left(C_{jt},H_{jt}\right) = \ln C_{jt} - \frac{\psi}{1+\theta} H_{jt}^{1+\theta} \qquad \text{for } j \in \{S,U\}, \tag{2}$$

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

We assume that markets are complete. The budget constraint is given by:

$$(1+\tau_c)\left[\varphi C_{St} + (1-\varphi) C_{Ut}\right] = (1-\tau_n)\left[\varphi w_{St} H_{St} + (1-\varphi) w_{Ut} H_{Ut}\right] + \left[1+(1-\tau_k) r_t\right] A_t - A_{t+1} + F_t, \tag{3}$$

where w_{jt} is the wage rate, r_t the rental price of capital, A_t assets, τ_c the consumption tax rate, τ_n the labor income tax rate, τ_k the capital income tax rate, and F_t lump-sum transfers from the government to households. Assets consist of physical capital and government debt. We use uppercase letters to denote aggregate variables.

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

$$C_{St} = C_{Ut} \equiv C_t, \tag{4}$$

$$\frac{w_{St}}{w_{Ut}} = \left(\frac{H_{St}}{H_{Ut}}\right)^{\theta}, \tag{5}$$

$$1 + (1 - \tau_k) r_t = \frac{1}{\beta}\left(\frac{C_t}{C_{t-1}}\right). \tag{6}$$

Equations (4) and (5) imply that none of the tax rates influence the relative consumption or the relative labor supply of the skilled to the unskilled, while equation (6) implies that the capital income tax rate influences asset holdings.

3.1.2 Heterogeneous households

The economy is populated by a continuum of infinitely-lived agents, each of whom is either skilled or unskilled, and experiences idiosyncratic shocks to labor productivity. Let $\mathbb{E}_t$ denote the expectation operator conditional on information at period t. Preferences are given by:

$$\mathbb{E}_\tau \sum_{t=\tau}^{\infty} \beta^{t-\tau} U_j(c_t, h_t), \tag{7}$$

where c_t consumption, and h_t hours worked in period t. We assume that labor is indivisible. The model of indivisible labor, pioneered by Hansen (1985) and Rogerson (1988), has the advantages that it can allow for the lack of flexibility in hours worked and the presence of fixed costs of work. This model is suitable in contexts that focus on cross-sectional heterogeneity (Alonso-Ortiz and Rogerson, 2010). Following Alonso-Ortiz and Rogerson (2010), the instantaneous utility function is specified as:

$$U_j(c_t, h_t) = \ln c_t - \psi_j h_t \qquad \text{for } j \in \{S, U\}, \tag{8}$$

where $c_t \geq 0$, and $h_t \in \{0, \bar{h}_j\}$. Given that labor supply is indivisible, the utility function can be specified to be linear in hours without loss of generality. We allow for a difference in the disutility of work between skilled and unskilled workers (i.e., $\psi_S \neq \psi_U$) to account for a difference in employment rates between skilled and unskilled workers. We also allow for a difference in hours worked between skilled and unskilled workers (i.e., $\bar{h}_S \neq \bar{h}_U$), although we focus on the employment decision.

Each agent 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 labor productivity (x_t), the 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), the productivity process is specified as the first-order autoregressive process:

$$\ln x_t = \varrho \ln x_{t-1} + \epsilon_t, \tag{9}$$

where ϵ is normally and independently distributed across individuals and time with a mean of zero and a standard deviation of ς. We assume that the persistence (ϱ) and volatility (ς) of idiosyncratic productivity do not differ between the skilled and the unskilled. However, we relax this assumption and confirm the robustness of quantitative results in the appendix.

We assume that insurance markets are absent. Each agent accumulates assets (a_t) to self-insure against idiosyncratic shocks. The budget constraint can be written as:

$$(1+\tau_c)\,c_t = (1-\tau_n)\,x_t w_{jt} h_t + [1+(1-\tau_k)\,r_t]\,a_t - a_{t+1} + f_t, \tag{10}$$
$$c_t \geq 0,\;\; a_{t+1} \geq 0,\;\; h_t \in \left\{0, \overline{h}_j\right\},$$

where r_t is the interest rate on assets that consist of physical capital and government debt. Consumption and assets must be non-negative in all periods.

We formulate the household problem recursively. We remove time subscripts and use the prime to denote the next period value. We use the squiggle to denote normalization by output (Y); for example, $\tilde{a} = a/Y$. After normalization, the aggregate variables are constant in a stationary equilibrium. We include only individual-level variables (i.e., assets, productivity, and skill type) in a set of state variables.

The value function when employed can be expressed as:

$$V^e(\widetilde{a}, x, j) = \max_{\widetilde{c}, \widetilde{a}'} \left\{\ln \widetilde{c} - \psi_j \overline{h}_j + \beta \mathbb{E}[V(\widetilde{a}', x', j)|\, x]\right\} \tag{11}$$

subject to

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

where g is the rate of growth in output. The value function when not employed can be expressed as:

$$V^n(\widetilde{a}, x, j) = \max_{\widetilde{c}, \widetilde{a}'} \{\ln \widetilde{c} + \beta \mathbb{E}[V(\widetilde{a}', x', j)|\, x]\} \tag{12}$$

subject to

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

The labor supply decision can then be described by:

$$V(\widetilde{a}, x, j) = \max\{V^e(\widetilde{a}, x, j), V^n(\widetilde{a}, x, j)\}. \tag{13}$$

A set of decision rules for consumption, hours worked, and asset holdings can be derived as the solution to this problem.

3.2 Firms

Production in the economy is summarized by an aggregate production function: $Y_t = \mathcal{F}(N_{St}, N_{Ut}, K_{Et}, K_{Ot})$, where N_{St} is skilled labor, N_{Ut} unskilled labor, K_{Et} capital equipment, and K_{Ot} capital structures in period t. Following Krusell et al. (2000), the constant returns-to-scale technology production function is specified as:

$$\mathcal{F}(N_{St}, N_{Ut}, K_{Et}, K_{Ot}; z_t) = K_{Ot}^{\alpha}\left\{\mu(z_t N_{Ut})^{\sigma} + (1-\mu)\left[\lambda K_{Et}^{\rho} + (1-\lambda)(z_t N_{St})^{\rho}\right]^{\frac{\sigma}{\rho}}\right\}^{\frac{1-\alpha}{\sigma}}. \tag{14}$$

Labor-augmenting technology exhibits a deterministic trend; that is, $z_{t+1} = (1+g)z_t$, where $g > 0$. The share parameters are $0 \leq \mu \leq 1$ and $0 \leq \lambda \leq 1$, whereas the substitution parameters are $\rho < 1$ and $\sigma < 1$. Unless $\sigma = \rho$, the degree of substitution between skilled labor and capital equipment differs from that between unskilled labor and capital equipment. The production technology exhibits capital–skill complementarity if capital equipment is more complementary to skilled labor than unskilled labor (i.e., $\sigma > \rho$).

Under the assumption of competitive markets, profit maximization is achieved by equating factor prices with the values of the marginal products of inputs:

$$\widetilde{w}_{St} = (1-\alpha)(1-\mu)(1-\lambda)\widetilde{K}_{Ot}^{\frac{\alpha\sigma}{1-\alpha}}\left(\lambda\widetilde{K}_{Et}^{\rho} + (1-\lambda)(\widetilde{z}_t N_{St})^{\rho}\right)^{\frac{\sigma-\rho}{\rho}}\widetilde{z}_t^{\rho} N_{St}^{\rho-1}, \tag{15}$$

$$\widetilde{w}_{Ut} = \widetilde{K}_{Ot}^{\frac{\alpha\sigma}{1-\alpha}}(1-\alpha)\mu\widetilde{z}_t^{\sigma} N_{Ut}^{\sigma-1}, \tag{16}$$

$$r_{Et} = (1-\alpha)(1-\mu)\widetilde{K}_{Ot}^{\frac{\alpha\sigma}{1-\alpha}}\left[\lambda\widetilde{K}_{Et}^{\rho} + (1-\lambda)(\widetilde{z}_t N_{St})^{\rho}\right]^{\frac{\sigma-\rho}{\rho}}\lambda\widetilde{K}_{Et}^{\rho-1} - \delta_E, \tag{17}$$

$$r_{Ot} = \alpha\widetilde{K}_{Ot}^{-1} - \delta_O, \tag{18}$$

where δ_E and δ_O are the depreciation rates of equipment and structures, respectively. Capital equipment and structures are equivalent for households; thus, $r_E = r_O = r$ in the equilibrium.

As none of the tax rates appear in the profit-maximizing conditions (15)–(18), taxation does not influence the determination of factor prices from a partial equilibrium perspective. From a general equilibrium perspective, however, capital income taxation affects the stock of capital, and in turn, affects the relative marginal product of skilled labor, thereby influencing the skill wage premium.

3.3 Government

The government levies proportional taxes on capital income, labor income, and consumption at rates τ_k, τ_n, and τ_c, respectively, and spends the tax revenue on government consumption (G), lump-sum transfers

(F), and interest payments on government debt (B). The government budget constraint can be written as:

$$\widetilde{G}+\widetilde{F}+r\widetilde{B}=(1+g)\widetilde{B}'-\widetilde{B}+\tau_c\widetilde{C}+\tau_n(\widetilde{w}_S N_S+\widetilde{w}_U N_U)+\tau_k r\left(\widetilde{K}_E+\widetilde{K}_O+\widetilde{B}\right), \tag{19}$$

where the ratio of government consumption to output ($\tilde{G}$) and the ratio of government debt to output ($\tilde{B}$) are exogenously given. Following Prescott (2004) and Alonso-Ortiz and Rogerson (2010), we assume that when the government raises tax rates, it raises lump-sum transfers to households by an amount equal to the increased tax revenue.

Under a tax and transfer system with progressive tax rates and/or means-tested transfers, the government can redistribute more from the skilled to the unskilled. In such a case, the tax and transfer system would have a greater impact on the skill wage premium. In this study, we aim to assess the impact of the tax and transfer system on the skill wage premium conservatively under the tax and transfer system with proportional tax rates and lump-sum transfers.

3.4 Equilibrium

3.4.1 Heterogeneous agent model

The equilibrium of the heterogeneous agent economy is characterized as follows. Given policies $\{\tilde{G}, \tilde{B}, \tau_c, \tau_n, \tau_k, \tilde{F}\}$ and initial conditions $\{K_{E0}, K_{O0}, z_0, \xi_0\}$, a stationary competitive equilibrium consists of a set of value functions $\{V^e(\tilde{a},x,j), V^n(\tilde{a},x,j), V(\tilde{a},x,j)\}$, a set of decision rules for consumption, hours worked, and asset holdings $\{\tilde{c}(\tilde{a},x,j), h(\tilde{a},x,j), \tilde{a}'(\tilde{a},x,j)\}$, aggregate labor and capital inputs $\{N_S, N_U, \tilde{K}_E, \tilde{K}_O\}$, price system $\{\tilde{w}_S, \tilde{w}_U, r\}$, 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 asset market clears, that is, $\tilde{K}_E + \tilde{K}_O + \tilde{B} = \tilde{A}$, where $\tilde{A} = \int \tilde{a}(\tilde{a},x,j)d\xi$; the labor markets clear, that is, $N_S = \int_{\{j=S\}} xh(\tilde{a},x,j)d\xi$ and $N_U = \int_{\{j=U\}} xh(\tilde{a},x,j)d\xi$; the final goods market clears, that is, $\tilde{C} + \tilde{G} + (g+\delta_E)\tilde{K}_E + (g+\delta_O)\tilde{K}_O = 1$, where $\tilde{C} = \int \tilde{c}(\tilde{a},x,j)d\xi$; and individual and aggregate behaviors are consistent for all $A^0 \subset \mathcal{A}$ and $X^0 \subset \mathcal{X}$, that is, $\xi'(A^0,X^0,j) = \int_{A^0,X^0}\{\int_{\mathcal{A},\mathcal{X}} \mathbb{1}_{a'=a(\tilde{a},x,j)} d\pi(x'|x)d\xi\}d\tilde{a}'dx'$.

3.4.2 Representative agent model

The equilibrium of the representative agent economy is characterized as follows. Given policies $\{\tilde{G}, \tilde{B}, \tau_c, \tau_n, \tau_k, \tilde{F}\}$ and initial conditions $\{K_{E0}, K_{O0}, z_0\}$ a stationary equilibrium consists of an allocation $\{\tilde{C}_S, \tilde{C}_U, H_S, H_U, N_S, N_U, \tilde{K}_E, \tilde{K}_O\}$ and price system $\{\tilde{w}_S, \tilde{w}_U, r\}$ such that given prices, the allocation solves the household's problem and the firm's problem; the government budget is balanced; the asset market clears, that is, $\tilde{K}_E + \tilde{K}_O + \tilde{B} = \tilde{A}$; the labor markets clear, that is, $N_S = \varphi H_S$ and $N_U = (1-\varphi)H_U$; and the final goods market clears, that is, $\tilde{C} + \tilde{G} + (g+\delta_E)\tilde{K}_E + (g+\delta_O)\tilde{K}_O = 1$.

3.5 Skill wage premium

The skill wage premium is defined as the ratio of the average hourly wages of skilled labor to those of unskilled labor in the steady state of the heterogeneous agent model. Let H_j denote the aggregate labor supply for each skill group j; that is, $H_j = \int_j h(\tilde{a}, x, j) d\xi$ for $j \in \{S, U\}$. The average hourly wages of group j can be calculated as $w_j N_j / H_j$ for $j \in \{S, U\}$. The skill wage premium can be written as:

$$\omega_{\text{ha}}^{w} \equiv \frac{w_S N_S / H_S}{w_U N_U / H_U}. \tag{20}$$

When the skill wage premium is compared between two countries with different tax rates, the difference can be decomposed as:

$$\Delta \ln \omega_{\text{ha}}^{w} = \underbrace{\Delta \ln \left(\frac{w_S N_S}{H_S} \right)}_{\text{effect on skilled}} \underbrace{- \Delta \ln \left(\frac{w_U N_U}{H_U} \right)}_{\text{effect on unskilled}}. \tag{21}$$

The first term is the difference in the average wages of skilled labor, while the second term is the difference in the average wages of unskilled labor. We refer to the former as the effect on skilled wages and the latter as the effect on unskilled wages. When capital equipment is more complementary to skilled than unskilled labor, a reduction in the capital stock resulting from a rise in the capital income tax rate affects the average wages of skilled labor and those of unskilled labor differently. Equation (21) implies that the higher skill wage premium is attributable to the higher average wages of skilled labor, the lower average wages of unskilled labor, or both.

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

$$\Delta \ln \omega_{\text{ha}}^{w} = \underbrace{\Delta \ln \left(\frac{w_S}{w_U} \right)}_{\text{price effect}} \underbrace{+ \Delta \ln \left(\frac{N_S / H_S}{N_U / H_U} \right)}_{\text{composition effect}}. \tag{22}$$

The first term represents the difference in the relative market wages of skilled to unskilled labor, while the second term represents the difference in the relative average productivity of skilled to unskilled labor. The skill wage premium can change not only due to a change in the equilibrium wages in the labor market but also due to a change in the composition of the workforce. We refer to the former as the price effect and the latter as the composition effect. Alonso-Ortiz and Rogerson (2010) point to the importance of the composition effect (also known as the selection effect) in accounting for the fact that the observed labor productivity is sometimes higher in continental Europe than in the United States, while the employment rate is significantly higher in the United States than in continental Europe. Equation (22) implies that the difference in the skill wage premium is proportional to that in the relative market wages of skilled labor and that in the relative average productivity of skilled labor.

The relative market wages of skilled labor equals the relative marginal product of skilled labor (i.e., the ratio of equation (15) to equation (16)). The price effect in equation (22) can be decomposed as:

$$\Delta \ln\left(\frac{w_S}{w_U}\right) = \underbrace{\frac{\sigma-\rho}{\rho}\Delta \ln\left[\lambda\left(\frac{K_E}{zN_S}\right)^{\rho}+(1-\lambda)\right]}_{\text{capital-skill complementarity effect}} \underbrace{-(1-\sigma)\Delta \ln\left(\frac{N_S}{N_U}\right)}_{\text{relative labor quantity effect}}. \tag{23}$$

The first term reflects the difference in the relative quantity of capital equipment to skilled labor, while the second term reflects the difference in the relative quantity of skilled to unskilled labor. We refer to the former as the capital–skill complementarity effect and the latter as the relative labor quantity effect. The equilibrium price of skills is determined by the forces of the supply of and the demand for skills. In the presence of capital–skill complementarity ($\sigma > \rho$), the relative market wages of skilled labor not only decrease with a rise in skilled labor relative to unskilled labor but also increase with a rise in capital equipment relative to skilled labor. Equation (23) implies that the difference in the skill premium is proportional to that in the relative quantity of capital equipment and inversely proportional to that in the relative quantity of skilled labor.

In contrast, the skill wage premium in the steady state of the representative agent model can be derived as:

$$\omega_{\text{ra}}^{w} \equiv \frac{w_S}{w_U} = \left(\frac{1-\varphi}{\varphi}\frac{N_S}{N_U}\right)^{\theta}. \tag{24}$$

When the skill wage premium is compared between two countries with the same share of the skilled population but different tax rates, the difference can be written as:

$$\Delta \ln \omega_{\text{ra}}^{w} = \theta \Delta \ln\left(\frac{N_S}{N_U}\right). \tag{25}$$

Equation (25) implies that the difference in the skill wage premium depends only on that in the relative demand for skilled labor.

3.6 Welfare

We describe how we measure the welfare premium to skills and the impact of tax reform on social welfare.

3.6.1 Welfare premium

We evaluate the premium to skills not only in terms of hourly wages but also in terms of lifetime utility in the steady state of the heterogeneous agent model. Suppose that the economy is initially at the steady state. The difference in welfare between the skilled and the unskilled can be expressed as the percentage difference in consumption, denoted by ϖ_{sp}, which equalizes the lifetime utility between the skilled and the unskilled as follows:

$$\frac{1}{\varphi_U}\int_{\{j=U\}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\ln\left((1+\varpi_{\text{sp}})\,\widetilde{c}_{Ut}\right)-\psi_U h_{Ut}\right]d\xi=\frac{1}{\varphi_U}\int_{\{j=S\}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\ln\widetilde{c}_{St}-\psi_S h_{St}\right)d\xi, \tag{26}$$

where $\varphi_S = \varphi$ and $\varphi_U = 1-\varphi$. The skill welfare premium can then be measured as $\omega_{\text{ha}}^{v} \equiv 1+\varpi_{\text{sp}} = \exp\left[(1-\beta)(\Upsilon_S-\Upsilon_U)\right]$, where $\Upsilon_j = (1/\varphi_j)\int_j \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\ln\widetilde{c}_{jt}-\psi_j h_{jt}\right)d\xi$.

3.6.2 Welfare effect of tax reform

When we evaluate the impact of tax reform on social welfare, we define social welfare as the weighted sum of the lifetime utility of all agents in the steady state of the heterogeneous agent model:

$$\Upsilon^m \equiv \int_{\{j=S,U\}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\ln\widehat{c}^m-\psi_j h^m\right)d\xi^m \qquad \text{for } m\in\{0,1\}, \tag{27}$$

where $\hat{c}^m \equiv \tilde{c}^m Y_0^m$, and Y_0^m is the benchmark output. The superscript m represents either the pre-reform steady state ($m=0$) or the post-reform steady state ($m=1$). The welfare effect of tax reform can be expressed as the percentage change in consumption, denoted by ϖ, which equalizes social welfare in the two steady-state equilibrium allocations:

$$\int_{\{j=S,U\}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left[\ln\left((1+\varpi)\,\widehat{c}^0\right)-\psi_j h^0\right]d\xi^0=\int_{\{j=S,U\}}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\ln\widehat{c}^1-\psi_j h^1\right)d\xi^1. \tag{28}$$

The welfare effect of tax reform can then be measured as $\varpi = \exp\left[(1-\beta)\left(\Upsilon^1-\Upsilon^0\right)\right]-1$.

We decompose the welfare effect (ϖ) into the portion attributable to a change in consumption (ϖ_c) and the portion attributable to a change in leisure (ϖ_ℓ) to understand the sources of changes in social welfare. Leisure is defined as $\ell = 1-h$. We further decompose each of the two effects into the portions attributable to changes in the levels of consumption (ϖ_c^{level}) and of leisure ($\varpi_\ell^{\text{level}}$) and the portions attributable to changes in the distributions of consumption (ϖ_c^{dist}) and of leisure ($\varpi_\ell^{\text{dist}}$). The welfare effect can be approximated as $\varpi \simeq \varpi_c^{\text{level}}+\varpi_c^{\text{dist}}+\varpi_\ell^{\text{level}}+\varpi_\ell^{\text{dist}}$. Appendix A.3 describes the details of the welfare decomposition.

4 Quantitative Analysis

We calibrate the model to the U.S. economy and evaluate the impact of a change in the size of the tax and transfer system on inequality and welfare.

Table 1: Summary of parameters

Parameters	Description (targets)	Values
Parameters calibrated internally		
λ	Share parameter, skilled (capital share of output, 36%; Alonso-Ortiz and Rogerson, 2010)	0.543
μ	Share parameter, unskilled (skill wage premium, 1.75; CPS)	0.3525
β	Discount factor (after-tax interest rate, 4%; Alonso-Ortiz and Rogerson, 2010)	0.9636
ψ_S	Disutility of work for the skilled (employment rate of the skilled, 83.5%; CPS)	2.168
ψ_U	Disutility of work for the unskilled (employment rate of the unskilled, 72.6%; CPS)	2.508
Parameters set externally		
τ_k, τ_n, τ_c	Capital income, labor income, and consumption tax rates (see section 2.1.2)	0.386, 0.234, 0.062
$\tilde{G}$	Ratio of government consumption to output (Trabandt and Uhlig, 2011)	0.178
$\tilde{B}$	Ratio of government debt to output (Trabandt and Uhlig, 2011)	0.628
g	Growth rate (Trabandt and Uhlig, 2011)	0.02
α	Share parameter, capital structures (Krusell et al., 2000)	0.117
σ	Substitution elasticity, unskilled vs. skilled (Krusell et al., 2000)	0.401
ρ	Substitution elasticity, skilled vs. equipment (Krusell et al., 2000)	–0.495
δ_E	Depreciation rate of capital equipment (Krusell et al., 2000)	0.125
δ_O	Depreciation rate of capital structures (Krusell et al., 2000)	0.05
ϱ	Persistence of idiosyncratic productivity (Alonso-Ortiz and Rogerson, 2010)	0.94
ς	Standard deviation of idiosyncratic productivity (Alonso-Ortiz and Rogerson, 2010)	0.205
φ	Share of the skilled population (CPS)	0.288
$\bar{h}_S$	Hours worked of skilled workers (CPS)	0.366
$\bar{h}_U$	Hours worked of unskilled workers (CPS)	0.342

4.1 Calibration

We set several key parameters to match specific aggregate targets inside the model and set the remaining parameters outside the model. Appendix A.1 describes how we compute the equilibrium in the model economy.

4.1.1 Parameters calibrated internally

We calibrate two parameters in the production function and three parameters in preferences in the heterogeneous agent model. We set the share parameters for skilled and unskilled labor in the production function (λ and μ), the discount factor (β), and the disutility of work for the skilled and the unskilled (ψ_S and ψ_U) to match the skill wage premium of 1.75, the capital share of output of 36 percent, the after-tax interest rate of 4 percent, the employment rate of 83.5 percent for the skilled, and the employment rate of 72.6 percent for the unskilled, respectively. The first and third target values are standard and obtained from Alonso-Ortiz and Rogerson (2010). The second and last two target values are calculated using the sample of those aged 25 to 60 in the CPS for the years 1995 to 2005. We use the time-averaged values to avoid yearly fluctuations. Consequently, we set the parameters as listed in Table 1.

In the representative agent model, we calibrate two parameters in the production function and two parameters in preferences. We set the share parameters for skilled and unskilled labor in the production function (λ and μ) and the discount factor (β) to match the same targets as in the heterogeneous agent model. When we set the disutility of work (ψ), we follow Trabandt and Uhlig (2011), who assume a Frisch elasticity of one and calibrate ψ to match the average hours worked of 0.25. Consequently, we set the parameters at $(\mu,\lambda,\beta,\psi) = (0.322, 0.545, 0.994, 12.6)$.

4.1.2 Parameters set externally

We choose the rest of the parameters, including those in the government budget constraint, the stochastic productivity process, the production function, and the utility function, in a way consistent with the U.S. data (Table 1). First, we set the capital income tax rate (τ_k), the labor income tax rate (τ_n), and consumption tax rate (τ_c) based on the results of our own calculation. We set the government consumption to output ratio ($\tilde{G}$) and the government debt to output ratio ($\tilde{B}$) based on the results of Trabandt and Uhlig (2011). We use the time-averaged values for the reason mentioned above. The tax system is characterized by these five parameters. In addition, we follow Trabandt and Uhlig (2011) in setting the growth rate (g).

When we set the share parameter for capital structures (α), the parameters governing the degree of substitution among capital equipment, skilled labor, and unskilled labor (σ and ρ), and the depreciation rates of capital equipment and structures (δ_E and δ_O), we follow Krusell et al. (2000) who estimate the aggregate production function in the United States.

When we set the parameters for the persistence (ϱ) and volatility (ς) of idiosyncratic productivity, we follow Alonso-Ortiz and Rogerson (2010) who set these parameters based on the estimates of the wage process for male workers in the United States. The magnitude of the bias due to selection into employment is considered to be empirically negligible for male workers (Low et al., 2010).

Finally, we set the share of the skilled population (φ) as equal to the share of people who graduated from four-year colleges and hours worked ($\bar{h}_j$) as equal to the mean annual hours worked of group j normalized by annual discretionary time (365×16). For both parameters, the time-averaged values are calculated using the sample of those aged 25 to 60 in the CPS for the years 1995 to 2005.

4.1.3 Fit of the model

The actual skill wage premium, the capital share of output, and the after-tax interest rate in the United States are precisely replicated in the steady states of both the representative agent and heterogeneous agent models under the U.S. tax system (column 5 of Table 2). The actual employment rates of the skilled and the unskilled in the United States are also precisely replicated in the steady state of the heterogeneous agent model under the U.S. tax system.

Table 2: Capital tax rates, capital accumulation, and relative employment

τ_k	0.0	0.1	0.2	0.3	0.386	0.4	0.457	0.457	0.5	0.6	0.7
τ_n, τ_c, $\tilde{G}$, $\tilde{B}$	US	US	US	US	US	US	JP	US	US	US	US
	Panel A: Representative agent model										
Capital–output ratio	2.72	2.64	2.53	2.42	2.30	2.28	2.19	2.19	2.11	1.91	1.65
After-tax interest rate	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	Panel B: Heterogeneous agent model										
Capital–output ratio	2.67	2.58	2.49	2.39	2.29	2.28	2.20	2.20	2.14	1.97	1.75
After-tax interest rate	4.17	4.15	4.11	4.06	4.00	3.98	3.95	3.95	3.90	3.79	3.63
Relative employment rate	1.05	1.06	1.07	1.10	1.15	1.16	1.22	1.20	1.22	1.29	1.33

Notes: Panels A and B report the capital–output ratio and the after-tax interest rate in the steady states of the representative agent and heterogeneous agent models, respectively. Panel B also reports the employment rate of the skilled relative to the unskilled in the steady state of the heterogeneous agent model. The first to fourth, sixth, and ninth to eleventh columns report their values under different capital income tax rates. The fifth and seventh columns report their values under the U.S. and Japanese tax systems, respectively.

Table 2 shows how the capital–output ratio, the after-tax interest rate, and the employment of the skilled relative to the unskilled can change in response to tax reforms that alter the capital income tax rate or replace the U.S. tax system with the Japanese tax system. The capital–output ratio declines with a rise in the capital income tax rate in the steady states of the representative agent and heterogeneous agent models. The direction of the prediction is consistent with the data. The capital–output ratio is typically considered to be above 2.5 in the United States (see Conesa et al., 2009; Alonso-Ortiz and Rogerson, 2010, for examples), while it is estimated to range from 2.1 to 2.3 between the years 1995 and 2005 in Japan (Hansen and İmrohoroğlu, 2016). The after-tax interest rate is unchanged in the steady state of the representative agent model so that equation (6) holds, while it changes modestly in the steady state of the heterogeneous agent model. There is no significant difference in the capital–output ratio and the after-tax interest rate between the representative agent and heterogeneous agent models if the U.S. tax rate on capital income is replaced with the Japanese tax rate. This result implies that such reform has only a small effect on precautionary savings.[4] The relative employment rate of the skilled to the unskilled increases with a rise in the capital income tax rate in the steady state of the heterogeneous agent model. The direction of the prediction is again consistent with the data. The relative employment rate is 1.33 in the Japanese ESS data as opposed to 1.15 in the U.S. CPS data. We elaborate on changes in the relative employment in the subsequent subsection.

The actual distributions of annual earnings and net wealth in the United States are broadly replicated in the steady state of the heterogeneous agent model (Table 3). The quintile shares of earnings and wealth in the United States are the time-averaged values calculated from the Survey of Consumer Finances (SCF) for the years 1995 to 2007. The SCF is conducted every three years. We select households in which household heads are aged 25 to 60 in the sample and trim the top one percent of wealthy households. Admittedly, the model understates the top quintile share of earnings and wealth. However, the predictions of our model are broadly similar to those of Alonso-Ortiz and Rogerson (2010).

Table 3: Quintile shares of earnings and wealth (%)

	Annual earnings			Net wealth		
	Model	AO–R	Data	Model	AO–R	Data
First	13.1	1.6	7.7	0.1	0.02	–0.3
Second	13.8	16.7	12.2	1.4	0.8	1.5
Third	18.5	20.3	17.4	7.1	6.7	5.6
Fourth	22.3	24.2	23.0	20.3	21.1	14.0
Fifth	32.1	37.3	39.7	71.0	71.3	79.2

Notes: The first and fourth columns report the quintile shares of annual earnings and net wealth in percentage terms, respectively, in the steady state of the heterogeneous agent model. The second and fifth columns report the results of Alonso-Ortiz and Rogerson (2010). The third and sixth columns report the actual quintile shares of earnings and wealth, respectively, in the United States.

4.2 Labor market implications

We mainly analyze the impact of tax reforms that raise the U.S. tax rate on capital income to the Japanese tax rate or replace the U.S. tax system with the Japanese tax system. These tax reforms result in an increase in the size of the tax and transfer system.

4.2.1 Differences in wage inequality

In both the representative agent and heterogeneous agent models, the steady-state skill wage premium matches the actual skill wage premium in the United States (column 5 of Panel A of Table 4). The skill wage premium declines with a rise in the capital income tax rate in both models. However, the rate

[4] Nakajima and Takahashi (2019) discuss in detail the impact of consumption taxes and transfers on precautionary savings. The same discussion applies to the impact of capital income taxes and transfers.

of decline is significantly greater in the heterogeneous agent model than the representative agent model (Panel A of Table 4). If the U.S. tax system is replaced with the Japanese tax system, the skill wage premium declines from 1.75 to 1.63 in the steady state of the heterogeneous agent model. The magnitude of this decline corresponds to 39 percent of the actual difference between the two countries. If only the U.S. tax rate on capital income is replaced with the Japanese tax rate, the skill wage premium declines from 1.75 to 1.66. The magnitude of this decline corresponds to 29 percent of the actual difference between the two countries.

Table 4: Capital tax rates and wage inequality

τ_k	0.0	0.1	0.2	0.3	0.386	0.4	0.457	0.457	0.5	0.6	0.7
τ_n, τ_c, $\tilde{G}$, $\tilde{B}$	US	US	US	US	US	US	JP	US	US	US	US
	Panel A: Skill wage premium										
Representative	1.82	1.81	1.79	1.77	1.75	1.75	1.73	1.73	1.71	1.67	1.60
Heterogeneous	2.03	1.99	1.94	1.85	1.75	1.74	1.63	1.66	1.60	1.46	1.34
Data					1.75		1.44				
	Panel B: Variance of log wages										
Heterogeneous	0.540	0.539	0.533	0.510	0.478	0.474	0.440	0.451	0.436	0.394	0.351
Data					0.450		0.407				

Notes: Panel A reports the skill wage premium in the steady states of the representative agent and heterogeneous agent models. Panel B reports the variance of log wages in the steady state of the heterogeneous agent model. The first to fourth, sixth, and ninth to eleventh columns report their values under different capital income tax rates. The fifth and eighth columns report their values under the U.S. and Japanese tax systems along with the actual values in the United States and Japan, respectively.

The level of wage inequality can be successfully replicated not only in terms of the skill wage premium but also in terms of the variance of log wages. In the heterogeneous agent model, the steady-state variance of log wages approximately matches the actual variance of log wages in the United States, although no parameter is calibrated to match the variance of log wages (column 5 of Panel B of Table 4). The variance of log wages decreases significantly with a rise in the capital income tax rate in the steady state of the heterogeneous agent model (Panel B of Table 4). If the U.S. tax system is replaced with the Japanese tax system, the variance of log wages declines from 0.478 to 0.440 in the steady state of the heterogeneous agent model. The magnitude of this decline corresponds to 85 percent of the actual difference between the two countries. If only the U.S. tax rate on capital income is replaced with the Japanese tax rate, the variance of log wages declines from 0.478 to 0.451. The magnitude of this decline corresponds to 63 percent of the actual difference between the two countries.

These results seem to suggest that some features and implications of the heterogeneous agent model are important in accounting for differences in wage inequality under different capital income tax rates. We subsequently quantify the sources of differences in the skill wage premium to understand the mechanism through which the tax and transfer system affects the level of wage inequality in incomplete markets.

4.2.2 Decomposition of differences in the skill wage premium

Panel A of Table 5 presents the log point changes in the skill wage premium in the steady state of the heterogeneous agent model in response to tax reforms that alter the U.S. capital income tax rate or replace the U.S. tax system with the Japanese tax system. We decompose the changes in the skill wage premium to deepen understanding of the impact of the tax and transfer system on wage inequality.

Effects on skilled and unskilled wages Panel B of Table 5 presents the log point changes in the skill wage premium attributable to the effect on skilled wages and the effect on unskilled wages. A reduction in the capital stock resulting from a rise in the capital income tax rate increases the average wages of unskilled labor who are relatively substitutable with capital equipment but decreases the average wages of skilled labor who are relatively complementary to capital equipment. Consequently, the decline in the skill wage premium resulting from a rise in the capital income tax rate is attributed to an increase in unskilled wages and a decrease in skilled wages. The effect on skilled wages and the effect on unskilled wages account for 62 and 38 percent, respectively, of the decline in the skill wage premium when the U.S. tax system is replaced with the Japanese tax system. The two effects account for 82 and 18 percent, respectively, of the decline in the skill wage premium when the U.S tax rate on capital income is replaced with the Japanese tax rate. The effect on skilled wages is greater in magnitude than that on unskilled wages, but the effect on unskilled wages is not negligible.

Price and composition effects Panel C of Table 5 presents the log point changes in the skill wage premium attributable to the price effect and the composition effect. An increase in the capital income tax rate reduces capital accumulation, while it raises government revenues, and thus, lump-sum transfers to households. These changes cause shifts in the demand for and supply of skills. On the one hand, the reduction in the capital stock would result in a decrease in the relative demand for skilled to unskilled labor. On the other hand, increased transfers to households cause an income effect that reduces labor supply. Unskilled workers with the lowest productivity are most susceptible to this effect. Therefore, the income effect would raise the relative labor supply of skilled to unskilled labor and lower the relative average productivity of skilled to unskilled labor. Consequently, the relative market wages of skilled to unskilled labor would decrease due to lower demand for and higher supply of skilled labor relative to unskilled labor, while the relative average productivity of skilled to unskilled labor would decrease due to compositional changes of the workforce. In fact, the decline in the skill wage premium is attributed not only to the former price effect but also to the latter composition effect. The price effect and the composition effect account for 58 and 42 percent, respectively, of the decline in the skill wage premium when the U.S. tax system is replaced with the Japanese tax system. The two effects account for 63 and 37 percent, respectively, of the decline in the skill wage premium when the U.S tax rate on capital income is replaced with the Japanese tax rate. Both effects account for a significant fraction of the decline in the skill wage premium.

Table 5: Decomposition of differences in the skill wage premium

τ_k	0.0	0.1	0.2	0.3	0.4	0.457	0.457	0.5	0.6	0.7
τ_n, τ_c, $\tilde{G}$, $\tilde{B}$	US	US	US	US	US	JP	US	US	US	US
	Panel A: Left-hand side of equation (21) or (22)									
Total effect	14.95	12.82	10.50	5.85	–0.77	–7.25	–5.44	–8.76	–17.82	–26.95
	Panel B: Right-hand side of equation (21)									
Effect on skilled	14.49	11.78	8.68	4.53	–0.69	–4.49	–4.45	–7.22	–15.38	–24.63
	[96.9]	[91.9]	[82.6]	[77.5]	[90.1]	[61.9]	[81.8]	[82.4]	[86.3]	[91.4]
Effect on unskilled	0.46	1.04	1.82	1.32	–0.08	–2.76	–0.99	–1.54	–2.44	–2.32
	[3.1]	[8.1]	[17.4]	[22.5]	[9.9]	[38.1]	[18.2]	[17.6]	[13.7]	[8.6]
	Panel C: Right-hand side of equation (22)									
Price effect	9.76	8.43	6.03	3.47	–0.68	–4.21	–3.43	–5.44	–11.95	–19.61
	[65.3]	[65.7]	[57.5]	[59.4]	[88.5]	[58.1]	[63.1]	[62.1]	[67.0]	[72.8]
Composition effect	5.19	4.39	4.47	2.37	–0.09	–3.04	–2.00	–3.32	–5.88	–7.34
	[34.7]	[34.2]	[42.5]	[40.6]	[11.6]	[41.9]	[36.9]	[37.9]	[33.0]	[27.2]
	Panel D: Right-hand side of equation (23)									
Complementarity effect	7.14	5.83	4.19	2.21	–0.39	–2.52	–2.38	–3.83	–8.67	–15.32
	[73.2]	[69.2]	[69.5]	[63.6]	[57.0]	[59.8]	[69.5]	[70.3]	[72.6]	[78.1]
Quantity effect	2.62	2.60	1.84	1.27	–0.29	–1.69	–1.05	–1.62	–3.28	–4.29
	[26.8]	[30.8]	[30.5]	[36.4]	[43.0]	[40.2]	[30.5]	[29.7]	[27.4]	[21.9]

Notes: Panels A, B, C, and D report the log point changes in the skill wage premium, those attributable to the effect on skilled wages and the effect on unskilled wages, those attributable to the price effect and the composition effect, and those attributable to the capital–skill complementarity effect and the relative labor quantity effect, respectively. Panels B, C, and D also report the contribution rate of each effect in square brackets. The first to fifth and seventh to tenth columns report their values if the U.S. tax rate on capital income is raised or lowered from 38.6 percent. The sixth column reports their values if the U.S. tax system is replaced with the Japanese tax system.

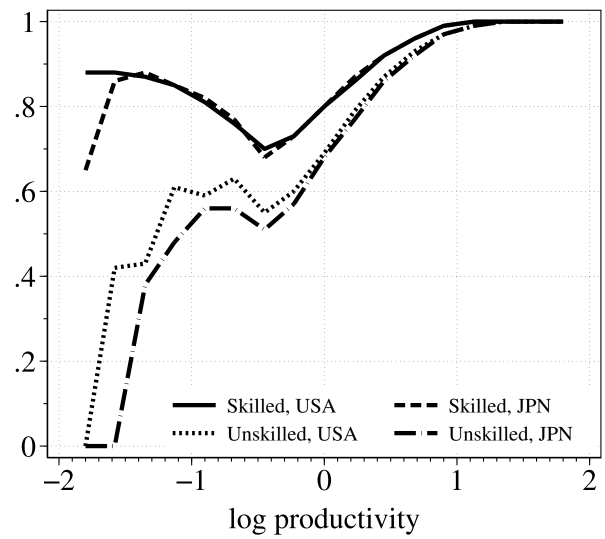
Complementarity and quantity effects Panel D of Table 5 presents the log point changes in the relative market wages of skilled to unskilled labor attributable to the capital–skill complementarity effect and the relative labor quantity effect. As mentioned above, if the capital income tax rate is raised, the relative market wages would decrease due to lower demand for and higher supply of skilled labor relative to unskilled labor. The shift in the relative demand for skilled labor is represented by the capital–skill complementarity effect, while the shift in the relative supply of skilled labor is represented by the relative labor quantity effect. The decline in the relative market wages results from both the capital–skill complementarity effect and the relative labor quantity effect. The capital–skill complementarity effect and the relative labor quantity effect account for 60 and 40 percent, respectively, of the decline in the skill wage premium when the U.S. tax system is replaced with the Japanese tax system. The two effects account for 70 and 30 percent, respectively, of the decline in the skill wage premium when the U.S tax rate on capital income is replaced with the Japanese tax rate. Both effects account for a significant fraction of the price effect.

4.2.3 Employment

One of the important sources of changes in the skill wage premium is the compositional changes in employment, as shown above. We thus elaborate on changes in employment in response to the tax reform that replaces the U.S. tax rate on capital income with the Japanese tax rate. Figure 5 illustrates how the employment rates of the skilled and the unskilled vary according to their productivity under the U.S. and Japanese capital income tax rates. For each level of productivity, the employment rate of the skilled is higher than that of the unskilled, reflecting differences in their preferences and market wages. When the productivity of workers increases, the employment rate may increase due to a substitution effect or decrease due to an income effect. The substitution effect tends to dominate the income effect for the unskilled who are less likely to be wealthy. However, the income effect can dominate the substitution effect for the skilled who are more likely to be wealthy. Under the U.S. tax system, the employment rate of the skilled increases with a rise in their productivity if their productivity is not far below the average but decreases with a rise in their productivity if their productivity is considerably low. The employment rate of the unskilled almost monotonically increases with a rise in their productivity, and the rate of increase is largest when their productivity is lowest.

Both the employment rates of the skilled and the unskilled can decrease with an increase in the size of the tax and transfer system. The employment rate of the skilled can decrease if the disincentive effects of increased transfers and decreased wages are sufficiently large, while the employment rate of the unskilled can decrease if the income effect associated with increased transfers sufficiently exceeds the substitution effect associated with increased wages. If the U.S. tax rate on capital income is replaced with the Japanese tax rate, most of the workers who exit the labor market are unskilled workers with low productivity. The employment rate of the skilled decreases only among those with the lowest productivity, while the employment rate of the unskilled decreases among those with lower-than-average productivity. The rate of decrease in the employment rate is greater among those with lower productivity. These changes underlie a decrease in the relative labor supply of the skilled to the unskilled and an increase in the relative average productivity of skilled to unskilled labor that explain part of the changes in the skill wage premium.

Figure 5: Employment rate



Notes: This figure illustrates how the employment rates of the skilled and the unskilled vary according to their productivity in the steady state of the heterogeneous agent model.

The extent to which employment decreases due to a rise in the capital income tax rate depends on the size of income effect associated with increased transfers, which depends on the extent to which tax revenue increases due to a rise in the capital income tax rate. As the slope of capital tax Laffer curve is flatter than that of labor tax Laffer curve (Trabandt and Uhlig, 2011; Nutahara, 2015), employment decisions are less likely to change in response to a rise in the capital income tax rate than a rise in the labor income tax rate. However, the impact of income effect differs significantly between the skilled and the unskilled. Unskilled workers with low productivity are more likely to leave their employment as a result of increased transfers than skilled workers with low productivity. This difference between the skilled and the unskilled results in a change in the relative labor supply and the relative average productivity of skilled to unskilled labor.

4.3 Welfare implications

We have shown that the skill wage premium can decrease significantly with a rise in the capital income tax rate. We now evaluate the impact of tax reform that alters the capital income tax rate on social welfare.

4.3.1 Differences in the welfare premium

The premium to skills is typically measured in terms of wage differentials between skilled and unskilled workers. The skill wage premium is a useful measure to understand the level of wage inequality and the workings of the labor market. However, it is not a metric to determine the difference in lifetime utility between the skilled and the unskilled. When we aim to evaluate the impact of tax reform, we are ultimately concerned with its impact on welfare. Although it is more difficult to measure the premium to skills in terms of lifetime utility than hourly wages, it is possible to measure a difference in consumption-equivalent welfare between the skilled and the unskilled, as described in section 3.6.1.

Table 6: Capital tax rates and welfare premium

τ_k	0.0	0.1	0.2	0.3	0.386	0.4	0.457	0.5	0.6	0.7
Skill welfare premium	2.30	2.22	2.12	2.01	1.90	1.88	1.81	1.76	1.62	1.48
Skill wage premium	2.03	1.99	1.94	1.85	1.75	1.74	1.63	1.66	1.60	1.46

Notes: This table reports the welfare premium to skills, along with the wage premium to skills, under different capital income tax rates in the steady state of the heterogeneous agent model.

Table 6 reports the premium to skills measured in terms of welfare along with that measured in terms of wages. The welfare premium to skills is slightly higher than the wage premium to skills when it is evaluated using the quantitative macroeconomic model calibrated to the U.S. economy. Under the U.S. tax system, the welfare premium to skills is 1.90, while the wage premium to skills is 1.75. At the same time, not only the skill wage premium but also the skill welfare premium decline with a rise in the capital income tax rate. The rate of decline in the skill welfare premium is similar to that in the skill wage premium if the U.S. tax rate on capital income is replaced with the Japanese tax rate, although it can be greater than that in the skill wage premium if the capital income tax rate is raised further. These results confirm that the wage premium to skills is a metric indicative of the welfare premium to skills.

4.3.2 Differences in welfare

Social welfare always decreases with a rise in the capital income tax rate in the steady state of the representative agent model (Panel A of Table 7). However, it can increase with a rise in the capital income tax rate in the steady state of the heterogeneous agent model (Panel B of Table 7). Social welfare reaches its maximum when the capital income tax rate is zero in the representative agent model, while it does so when the capital income tax rate is around 60 percent in the heterogeneous agent model. The consequential inequality can differ starkly between the two models. When social welfare reaches its maximum, the skill wage premium is around 1.46 in the heterogeneous agent model as opposed to 1.82 in the representative agent model. In this context, there is not necessarily a tradeoff between equality and efficiency in the heterogeneous agent model, while there is in the representative agent model. If the U.S. tax rate on capital income is replaced with the Japanese tax rate, social welfare decreases by 0.88 percent in the representative agent model but increases by 0.62 percent in the heterogeneous agent model. This reform can reduce inequality and improve welfare in the heterogeneous agent model.

Table 7: Capital tax rates and welfare

τ_k	0.0	0.1	0.2	0.3	0.4	0.457	0.5	0.6	0.7
	Panel A: Representative agent model								
Welfare	1.62	1.49	1.21	0.71	–0.15	–0.88	–1.60	–4.06	–8.40
	Panel B: Heterogeneous agent model								
Welfare	–4.51	–3.44	–2.02	–0.97	0.30	0.62	0.89	0.92	–0.57
Skilled	9.27	7.92	5.89	3.14	–0.47	–2.91	–4.59	–10.15	–16.76
Unskilled	–9.57	–7.68	–5.05	–2.59	0.61	2.08	3.20	5.78	6.85

Notes: Panels A and B report the percentage changes in welfare in the steady states of the representative agent and heterogeneous agent models, respectively, if the U.S. tax rate on is raised or lowered from 38.6 percent. Panel B also reports the percentage changes in welfare separately for the skilled and the unskilled.

Tax reform improves social welfare when it improves the efficiency of equilibrium allocations. When markets are incomplete, workers are less likely to leave their employment due to adverse productivity shocks and more likely to accumulate assets to smooth consumption over time. After they accumulate sufficient assets, they may decide not to work even if their productivity is near the highest. Consequently, the employment rate of those with low (high) productivity is higher (lower) in incomplete markets than complete markets (Alonso-Ortiz and Rogerson, 2010). Under such circumstances, the equilibrium allocations may become more efficient with an increase in the size of the tax and transfer system because the employment rate of those with considerably low productivity decreases as a result (Figure 5).

The welfare effects of tax reform differ starkly between the skilled and the unskilled in the heterogeneous agent model. The last two rows of Table 7 report the welfare effects separately for the skilled and the unskilled. A rise in the capital income tax rate leads to a welfare gain for the unskilled but a welfare loss for the skilled. Both effects are not small when they are measured separately, although the total welfare effect might appear to be small because the two effects are largely canceled out. If the U.S. tax rate on capital income is replaced with the Japanese tax rate, the welfare of the unskilled increases by 2.1 percent, while that of the skilled decreases by 2.9. There are three reasons for such differences between the skilled and the unskilled. First, the employment response to tax reform differs in magnitude between the skilled and the unskilled (Figure 5). Second, the wage response to tax reform differs in direction between the skilled and the unskilled. The average wages of skilled (unskilled) workers decrease (increase) with a rise in the capital income tax rate (Table 5). Finally, the wealthy skilled bear a greater tax burden than the poor unskilled, while the poor unskilled benefit more from government transfers than the wealthy skilled. The difference in the welfare effects between the skilled and the unskilled may make it difficult for the government to raise the tax rate on capital income in reality.

4.3.3 Decomposition of differences in welfare

Differences in social welfare can be decomposed into portions attributable to changes in the level and distribution of consumption and leisure, as described in section 3.6.2. A rise in the capital income tax rate depresses the level of consumption but improves the inequality of consumption and the level and inequality of leisure (Table 8). If the U.S. tax rate on capital income is replaced with the Japanese tax rate, the welfare loss from a decrease in the level of consumption is greater than the welfare gain from a decrease in the inequality of consumption. The welfare gain from an increase in the level of leisure is greater than that from a decrease in the inequality of leisure. Overall, the welfare gain from a rise in the capital income tax rate is a consequence that the welfare gain from an increase in leisure exceeds the welfare loss from a decrease in consumption.

Table 8: Decomposition of the welfare effect

τ_k	0.0	0.1	0.2	0.3	0.4	0.457	0.5	0.6	0.7
Welfare	–4.51	–3.42	–1.97	–0.96	0.30	1.15	0.95	1.21	0.42
Consumption									
level	3.87	3.28	2.69	1.50	–0.14	–1.61	–2.72	–6.21	–11.63
distribution	–3.93	–2.81	–1.30	–0.54	0.24	0.43	0.73	1.35	1.82
Leisure									
level	–4.29	–3.75	–3.24	–1.85	0.18	1.76	2.85	5.91	10.05
distribution	–0.16	–0.15	–0.13	–0.08	0.01	0.06	0.09	0.16	0.17

Notes: This table reports the approximate percentage changes in welfare attributable to changes in the level and distribution of consumption and leisure in the steady state of the heterogeneous agent model if the U.S. tax rate on capital income is raised or lowered from 38.6 percent.

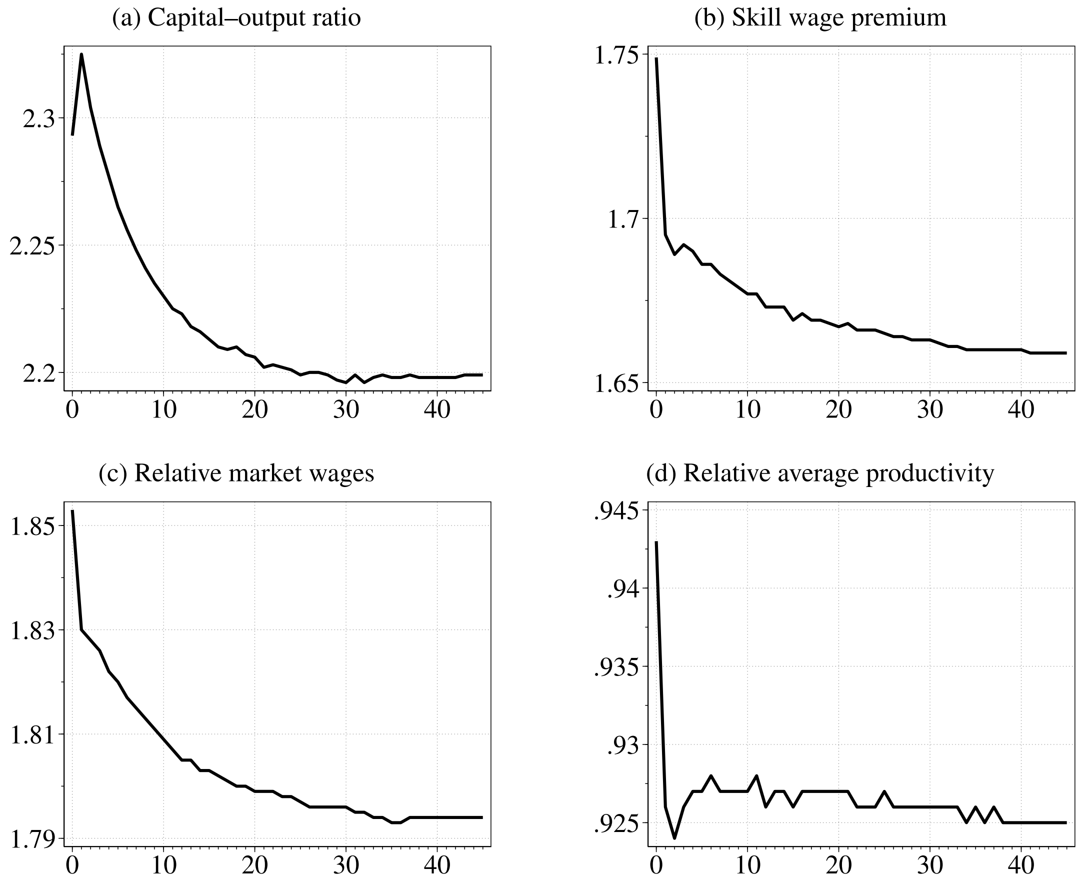
4.3.4 Welfare along the transition

We have so far measured the welfare effect by comparing the equilibrium allocations between steady states under different tax rates. We have not considered changes in welfare during the transition to the new steady state. In such a case, the welfare loss (gain) for the skilled (unskilled) may be overstated because it results from a sudden fall (rise) in the skilled (unskilled) wages associated with a sudden drop in the capital stock. During the transition from the initial to the new steady state, however, the capital stock and the relative wages decline gradually, and part of the decline in the capital stock is accompanied by an increase in consumption. If the welfare effect is measured after transitional welfare changes are taken into account, its magnitude may change considerably.

We thus consider an unexpected once-and-for-all tax reform that replaces the U.S tax rate on capital income with the Japanese tax rate, and measure the welfare effect of tax reform after taking into account transitional welfare changes. Although the total welfare gain from the tax reform changes only marginally from 0.62 percent to 0.64 percent, the welfare loss for the skilled decreases from 2.91 percent to 0.61 percent, and the welfare gain for the unskilled decreases from to 2.08 to 1.15 percent. Therefore, the tax reform that raises the capital income tax rate may not eventually entail a large welfare loss for the skilled.

We show changes in the capital stock and the relative wages that underlie welfare changes during the transition from the initial to the new steady state. Figures 6a and 6b illustrate how the capital–output

Figure 6: Changes in the skill wage premium along the transition



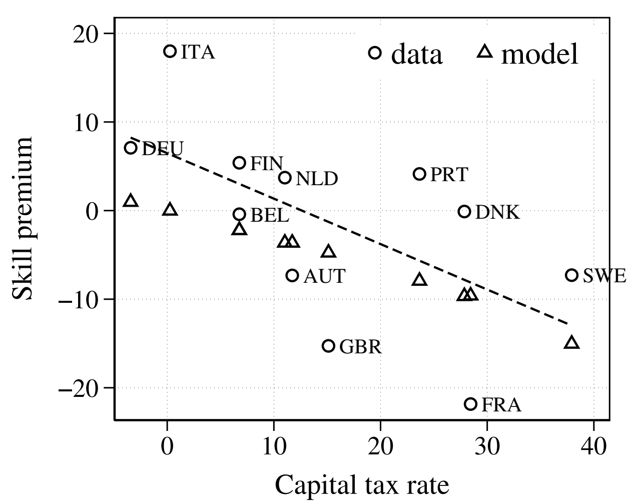
ratio and the skill wage premium change in the transition after the capital income tax rate is raised from 38.6 to 45.7 percent. The capital–output ratio declines gradually after an initial jump owing to a fall in output. The skill wage premium falls sharply at first, and then declines gradually. The rates of decline in the capital–output ratio and the skill wage premium decrease over time. The initial drop in the skill wage premium results mainly from a fall in the relative average productivity, and the subsequent gradual decline results mostly from a decline in the relative marginal product. To understand the mechanisms of the change in the skill wage premium, the skill wage premium is decomposed into the relative market wages and the relative average productivity of skilled to unskilled labor (Figures 6c and 6d). The initial fall in the relative average productivity is attributable to the exit of unskilled workers with low productivity from the labor market. As this is followed by the exit of skilled workers with low productivity workers from the labor market, the relative average productivity returns slightly towards the initial level. Changes in the relative average productivity are non-smooth owing to the discrete nature of employment. The gradual decline in the relative market wages reflects the gradual decline in the capital–output ratio. The decline in the skill wage premium are attributed to decreases in both the relative market wages and the relative average productivity.

4.4 Changes in the skill wage premium

We end our analysis by discussing the implications of our results for changes in the skill premium in European countries. As shown in Figure 3, changes in the capital income tax rate are negatively and significantly associated with changes in the skill wage premium between the years 1995 and 2005 in the United States and European countries. The regression line indicates that one percent increase in the capital income tax rate is associated with a 0.51 percent decrease in the skill wage premium.

We examine whether the pattern of data in European countries can be replicated in the heterogeneous agent model. To this end, we compute the extent to which the skill wage premium would change in the steady state of the heterogeneous agent model if the U.S. tax rate on capital income would be changed at the same rate as European tax rates. Figure 7 plots the relationship of changes in the capital income tax rate with changes in the steady-state skill wage premium, as well as changes in the actual skill wage premium, in 11 European countries. Changes in the capital income tax rate are also negatively associated with changes in the steady-state skill wage premium. In fact, the relationship of changes in the capital income tax rate with changes in the skill premium predicted from the model is in line with the regression line that summarizes the relationship of changes in the capital income tax rate with changes in the actual skill wage premium in European countries. Therefore, the negative association between changes in the capital income tax rate and changes in the skill wage premium observed in European countries can be explained in terms of our model.

Figure 7: Actual and predicted changes in the skill wage premium



Notes: This figure plots the log point changes in the skill wage premium in the steady state of the heterogeneous agent model, as well as the actual log point changes in the skill wage premium, against the actual log point changes in capital income tax rate between the years 1995 and 2005 for each European country. The dashed line indicates the regression line, as in Figure 3. Country names are abbreviated as follows: AUT, Austria; BEL, Belgium; DEU, Germany; DNK, Denmark; FIN, Finland; FRA, France; GBR, the United Kingdom; ITA, Italy; NLD, the Netherlands; PRT, Portugal; and SWE, Sweden.

5 Conclusion

We have examined the relationship between the level of wage inequality and the size of the tax and transfer system in a model with uninsurable idiosyncratic shocks and capital–skill complementarity. The skill wage premium can decrease significantly with an increase in the size of the tax and transfer system due to a rise in the capital income tax rate in the heterogeneous agent model unlike in the representative agent model. The differences in the steady-state skill wage premium under different capital income tax rates are consequently much greater and closer to those observed across countries in the heterogeneous agent model than the representative agent model. These results confirm the usefulness of the heterogeneous agent model in the context of evaluating the size of the tax and transfer system and understanding the sources of economic inequality.

In this context, an important implication of the heterogeneous agent model is that the welfare effects differ starkly between the skilled and the unskilled. The welfare of the unskilled improves with an increase in the size of the tax and transfer system due to a rise in the capital income tax rate, while that of the skilled deteriorates. As a result, the premium to skills declines with an increase in the size of the tax and transfer system not only in terms of hourly wages but also in terms of lifetime utility. If the U.S. tax rate on capital income is raised to the Japanese tax rate, the net welfare effect would be positive. At the same time, an important feature of the heterogeneous agent model is that the labor supply responses to an increase in the size of the tax and transfer system differ between the skilled and the unskilled. As a result, the relative average productivity of skilled to unskilled labor decreases with an increase in the size of the tax and transfer system. After this composition effect is taken into account, the differences in wage inequality across countries would be somewhat smaller than the observed differences.

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A Appendix

A.1 Numerical algorithm

We describe how we compute the equilibria in the heterogeneous agent model.

Steady state We compute the steady-state equilibrium allocation in the heterogeneous agent/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 $(\tilde{a}, x, j)$, and compute the transition probability $\pi(x'|x)$ using the Tauchen (1986) method.

2. Set a guess for $\{\tilde{K}_E, N_S, \tilde{z}\}$. Compute $\tilde{K}_O$ from equations (17) and (18).

3. Given $\{\tilde{K}_E, \tilde{K}_O, N_S, \tilde{z}\}$, compute N_U from equation (14), $\tilde{w}_S$ from equation (15), $\tilde{w}_U$ from equation (16), r from equation (17), and aggregate consumption $\tilde{C}$ from the goods market clearing condition. Given $\{\tau_k, \tau_n, \tau_c, \tilde{G}, \tilde{B}\}$, compute $\tilde{F}$ from equation (19).

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

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

   (b) Update the value function using the Bellman equations (11) and (12) until convergence. Given the value function, obtain the decision rules $\{\tilde{c}(\tilde{a}, x, j), h(\tilde{a}, x, j), \tilde{a}'(\tilde{a}, x, j)\}$.

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

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

   (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 $\{\tilde{K}_E, N_S, \tilde{z}\}$. 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 $\{\tilde{K}_{Et}, \tilde{K}_{Ot}, N_{St}, \tilde{z}_t\}_{t=0}^{100}$. Given this path, compute the transition path of $\{\tilde{w}_{St}, \tilde{w}_{Ut}, r_t, N_{Ut}, \tilde{C}_t, \tilde{F}_t\}_{t=0}^{100}$.

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

A.2 Skill-specific productivity process

We consider the heterogeneous agent model, in which the productivity process differs between skilled and unskilled workers. We allow both the persistence (ϱ_j) and volatility (ς_j) of idiosyncratic productivity to differ between the skilled and the unskilled. Following the results of Krueger and Ludwig (2016), we assume that the persistence is 4.4 percent higher for skilled workers than for unskilled workers, and the volatility is 38.6 percent higher for unskilled workers than for skilled workers. We consequently 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 A1 shows the changes in the skill wage premium and social welfare in the steady state if 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 A1: Capital tax rates, skill premium, and welfare when the productivity process is skill-specific

τ_k	US $\rightarrow$ JP
$\tau_n, \tau_c, \widetilde{G}, \widetilde{B}$	US
Skill wage premium	1.75 $\rightarrow$ 1.67
Effect on skilled	–3.52 [76.0 %]
Effect on unskilled	–1.11 [24.0 %]
Price effect	–2.86 [61.8 %]
Composition effect	–1.77 [38.2 %]
Complementarity effect	–2.18 [76.0 %]
Quantity effect	–0.69 [24.0 %]
Skill welfare premium	1.63 $\rightarrow$ 1.56
Welfare	0.54
Skilled	–2.50
Unskilled	1.80

Notes: This table reports changes in skill premium and welfare when the U.S. tax rate on capital income is replaced with the Japanese tax rate. The second to seventh rows report the log point changes in the skill wage premium attributable to each effect with the contribution rate of each effect in square brackets.

A.3 Decomposition of the welfare effect

We decompose the welfare effect (ϖ) into the portion attributable to a change in consumption (ϖ_c) and the portion attributable to a change in leisure (ϖ_ℓ), and further decompose each of the two effects into the portions attributable to changes in the levels of consumption (ϖ_c^{level}) and leisure ($\varpi_\ell^{\text{level}}$) and the portions attributable to changes in the distributions of consumption (ϖ_c^{dist}) and leisure (ϖ_c^{dist}). We show that given the specification of preferences, it is possible to derive a closed-form expression for each welfare effect.

When we write the welfare effect as $1 + \varpi = (1 + \varpi_c)(1 + \varpi_\ell)$, we can rewrite equation (28) as:

$$\int_{\{j=S,U\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \left((1 + \varpi_c)(1 + \varpi_\ell) \widehat{c}^0 \right) - \psi_j h^0 \right] d\xi^0 = \int_{\{j=S,U\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln \widehat{c}^1 - \psi_j h^1 \right) d\xi^1. \qquad (29)$$

Let L_j denote the aggregate leisure of group j. The welfare effect attributable to a change in leisure can be obtained by changing leisure while holding consumption constant.

$$\varpi_\ell = \exp \left[\psi_S \left(L_S^1 - L_S^0 \right) - \psi_U \left(L_U^1 - L_U^0 \right) \right] - 1 \qquad (30)$$

The welfare effect attributable to a change in consumption can then be obtained as $\varpi_c = (1 + \varpi)/(1 + \varpi_\ell) - 1$.

In addition, we write the welfare effects attributable to changes in consumption and leisure as $1 + \varpi_c = (1 + \varpi_c^{\text{level}})(1 + \varpi_c^{\text{dist}})$ and $1 + \varpi_\ell = (1 + \varpi_\ell^{\text{level}})(1 + \varpi_\ell^{\text{dist}})$, respectively. The welfare effect attributable to a change in the level of leisure can be obtained by changing the level of leisure while holding the distribution of leisure and the level and distribution of consumption constant.

$$\varpi_\ell^{\text{level}} = \exp \left[\left(\psi_S L_S^0 + \psi_U L_U^0 \right) \frac{L^1}{L^0} - 1 \right] - 1 \qquad (31)$$

The welfare effect attributable to a change in the distribution of leisure can then be obtained as $\varpi_\ell^{\text{dist}} = (1 + \varpi_\ell)/(1 + \varpi_\ell^{\text{level}}) - 1$. 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 of consumption and the level and distribution of leisure constant.

$$\varpi_c^{\text{level}} = \frac{C^1}{C^o} - 1 \qquad (32)$$

The ratio of C^1 to C^0 is constant because the growth rate is invariant with respect to tax rates. The welfare effect attributable to a change in the distribution of consumption can be obtained as $\varpi_c^{\text{dist}} = (1 + \varpi_c)/(1 + \varpi_c^{\text{level}}) - 1$.