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Abstract

Japan's aging population and shrinking workforce are straining the public pension system. This study extends a Bewley-type overlapping generations model with heterogeneous households, more precisely accounting for Japan's tax system and two-tier pension structure, to analyze the effects of Japan's public pension reform proposals on individual households, the aggregate economy, and social welfare. The model calibrated to the 2022 Japanese economy suggests that cutting pension benefits by 20%, raising the eligibility age by five years, and removing the pension adjustments and suspensions under the statutory system would all increase private wealth, thus capital stock, labor supply, and total output in the long run if the pension tax rate and the consumption tax rate were adjusted to balance the government budget. With regard to the welfare impact, current and near-future households would experience net losses on average, whereas future households would benefit overall.

JEL Classification Numbers: E62, H55, J26.

Keywords: Pension reform; Retirement age; Overlapping generations; Heterogeneous agents; Social welfare.

1 Introduction

Low birth rates and aging populations are becoming a major problem for many countries. Of particular concern is the decline in the working-age population due to these demographic changes. Furthermore, current public pension systems are greatly affected by these demographic changes. Many countries have

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adopted pay-as-you-go public pension systems, in which the contributions collected from the working-age population are used to pay pension benefits to the elderly generation. However, due to the declining birth rates, the number of households in the younger generation is decreasing, and the total amount of contributions that can be collected is decreasing. At the same time, the total amount of pension benefits paid is increasing due to increasing numbers of older-generation households. This has led to an imbalance in pension finances, and if no corrective measures are taken, there is a risk that it will lead to the eventual collapse of the public pension system. Maintaining balance within the current framework would require raising the insurance contribution rate for the younger generation, placing a heavy financial burden on them.

Japan is one of the countries facing the challenge. According to the Ministry of Health, Labour and Welfare, Japan's total fertility rate in 2023 was 1.20, the lowest ever recorded. Data from the Statistics Bureau of Japan shows that in the same year, the proportion of people aged 65 and older reached a historic high of 29.1% of the total population. In response to these pressing demographic shifts and to enhance the sustainability of the pension system, the Japanese government gradually increased public pension insurance contribution rates from 2004 to 2017 and is currently in the process of raising the pension eligibility age from 60 to 65. Further reforms are under consideration, including potentially extending the eligibility age beyond 65 and expanding the scope of coverage for employees' pensions.

The present study extends the Bewley-type incomplete market overlapping generations model with heterogeneous households by incorporating Japan's detailed progressive tax system and public pension system. It analyzes the potential impact of Japan's public pension reform proposals on individual households, the aggregate economy, and social welfare. Three pension reform policies are analyzed in this study: a 20% proportional reduction in public pension benefits, a five-year increase in the pension eligibility age, and the removal of pension adjustments and suspensions in the Old-Age Pension System for Working Retirees. In reality, pension reforms typically maintain benefit levels while increasing contribution rates. However, since the financial burden on younger households cannot continue to increase indefinitely, this study adopts the opposite experimental approach in the first policy experiment by reducing public pension benefits by 20% to alleviate the financial strain on younger households. In the model economy, pension benefits are adjusted to balance the pension budget, and the consumption tax rate is adjusted to balance the rest of the government budget, with the aim of balancing the government budget for each policy change.

One of the main contributions of the present study is that the Japanese income tax system and public pension system are carefully incorporated into the model. A key feature of the Japanese system is that public pension contributions are deductible when calculating income tax. This means that reforms affecting the pension contribution rate directly alter the marginal income tax rate paid by individuals, thereby influencing their optimization decisions. Another contribution of the present study is that it incorporates the two-tier public pension system, the National Pension System, the Employees' Pension Insurance System, and the Old-Age Pension System for Working Retirees. In the Japanese system, like those in some other countries, public pension benefits are partially income taxable, depending on the household's pension income and other sources of income. Furthermore, some elderly workers aged 65 and older are subject to additional reductions in their pension benefits if they continue working. Incorporating these mechanisms allows the model to analyze the possible effects of public pension reform on household saving and labor supply decisions more accurately.

The main findings of the present study are as follows. The first policy reform, a 20% reduction in public pension benefits, would increase capital stock by 7.4%, labor supply by 0.9%, and total output by 3.6% in the long run. As a result, the pension contribution rate would fall by 20.2% and the consumption tax rate would fall by 1.6 percentage points in the long run. Households (modeled as single individuals) aged between 18 and 59 at the time of policy change would be worse off on average, but future households would be better off on average by 5.9% in the consumption equivalence measure.

The second reform, a five-year increase in the pension eligibility age, has a similar but smaller effect. The reform would increase capital stock by 3.8%, labor supply by 0.9%, and total output by 2.1% in the long run, and it would reduce the pension contribution rate by 16.0% and the consumption tax rate by 1.2 percentage points. In the second reform, the reduction in pension contribution would be smaller than that in the first reform, partly because the national pension benefits would increase due to the additional five years of contribution-paid in the model economy. Households aged between 31 and 59 at the time of policy change would be worse off on average, but future households would be better off on average by 2.4% in the consumption equivalence measure.

The third policy change, the removal of pension adjustments and suspensions in the Old-Age Pension System for Working Retirees, which will be explained in more detail later, would increase capital stock by 0.3%, labor supply by 0.7%, and total output by 0.5% in the long run, and it would reduce the pension contribution rate by 0.2% and the consumption tax rate by 0.3 percentage points. Though the third reform generates a sizable impact to the savings and labor supply of elderly households aged between 65 and 70, the overall effect on the economy is relatively small. Households would be better off in this pension reform, and future households would be better off on average by 0.4% in the consumption equivalence measure.

The results of the policy experiments show that cutting public pension benefits proportionately by 20% is desirable from the perspectives of efficiency and welfare. These findings suggest that if the pension reforms implemented between 2004 and 2017 had set a lower target contribution rate while adjusting benefit levels accordingly, the economy might have been more prosperous today. Under the current public pension system, the lower bound of benefit levels is set at a 50% replacement rate. However, if future pension reforms are considered, instead of maintaining the replacement rate by increasing contribution burdens, lowering the replacement rate itself should also be regarded as a viable option. Raising the pension eligibility age by five years stimulates both savings and labor supply, while also leading to an increase in the annual pension benefits received by households. From the perspective of enhancing social welfare, this policy reform is desirable. Removing pension adjustments and suspensions under the Old-Age Pension System for Working Retirees is advisable based on the calculations presented in this study.

A large number of previous studies have quantitatively analyzed the potential impact of pension reform proposals. Some of these studies use a large-scale but deterministic overlapping generations model with representative households. Auerbach and Kotlikoff (1987) examine the effects of cuts in social security benefits and increases in the retirement age in the US economy. Their study is widely regarded as the pioneering work in applying a large-scale OLG model to analyze the effects of policy reforms. Fehr (2000) accounts for rising life expectancy and declining fertility in Germany to examine the impacts of pension reforms, such as an increase in the retirement age and a gradual decline in pension level. de la Croix, Pierrard, and Sneessens (2013) analyze the impact of eliminating early retirement benefits on elderly workers' labor supply and pension costs in the European nations. Vogel, Ludwig, and Börsch-Supan (2017) construct an open-economy model of three European nations: France, Germany and Italy, and they evaluate the effectiveness of several policy adjustments, such as raising the retirement age, in mitigating the economic and welfare impacts of population aging. Heer, Polito, and Wickens (2020) identify the threshold dependency ratios of the US and 14 European countries at which tax revenues can no longer sustain the planned level of transfers to retirees.

Other studies use a large-scale Bewley-type OLG model with heterogeneous households. De Nardi and İmrohoroğlu (1999) evaluate the impacts on the macroeconomy and welfare of fiscal reforms, including an increase in the retirement age. Nishiyama and Smetters (2007) examine the effects of partial social security privatization on efficiency over the transition path, using a notion of lump-sum redistribution authority. Nishiyama (2015) incorporates the population projection by the US Social Security Administration and analyzes the effects of an aging population. Díaz-Giménez and Díaz-Saavedra (2009) examine the impact of delaying both the first and normal retirement ages by three years on pension costs and welfare in the Spanish economy. İmrohoroğlu and Kitao (2009) explore the role of the intertemporal elasticity of substitution (IES) in shaping the quantitative results of social security reform. İmrohoroğlu and Kitao (2012) incorporate health and medical expenditure risks into their model and analyze the behavior of claiming social security benefit before the normal retirement age. Kitao (2014) examine the effects of various policy options on the macroeconomy and welfare under demographic transitions. Kitao (2015) incorporates Japan's two-tier public pension system and the integrated government budget to the model, and analyzes several pension reform scenarios that include reducing benefits by 20% and raising the retirement age to 70. Kitao (2017) analyzes a 20% reduction in the replacement rate and a three-year increase in the retirement age to examine the different outcomes of reform timing. Hagiwara (2021) analyzes the impact of revising the Old-Age Pension System for Working Retirees on elderly employment, the macroeconomy, pension finance, and welfare.

The rest of this paper is structured as follows. Section 2 introduces the large-scale heterogeneous-agent OLG model employed in this study and defines the recursive competitive equilibrium of the model economy. Section 3 describes the model calibration and outlines the baseline economy. Section 4 presents the results of three policy experiments and analyzes their effects on the model economy. Finally, Section 5 concludes the paper.

2 The Model

The model used in this paper is a standard Bewley-type incomplete market overlapping-generations (OLG) model (e.g., Nishiyama and Smetters, 2014), extended with the Japanese tax system and public pension system. The model economy consists of a large number of heterogeneous and OLG households, a representative firm operating in a perfectly competitive market, and a government with commitment technology. The economy is on a balanced-growth path with a productivity growth rate μ and a population growth rate ν.

2.1 The Households

Households are heterogeneous with respect to their wealth, $a \in A = [0, a_{max}]$, average historical earnings, $b \in B = [0, b_{max}]$, working ability, $e \in E = [0, e_{max}]$, and age, $i = 1, ..., I$. Households enter the economy and begin working at $i = 1$, which corresponds to age 20 in the real world. Households start receiving old-age pension benefits at age $I_1 = 46$ (corresponds to a real age of 65), and may live up to age $I = 80$ (corresponds to a real age of 99).

This model incorporates the Old-Age Pension System for Working Retirees, which allows households aged 65 and older to continue working while receiving pension benefits. The Japanese public pension system consists of two components: the National Pension (NP) and Employees' Pension Insurance (EPI). The NP is a universal public pension insurance program, with contributions typically starting at age 20 and covering up to 480 months. The EPI, on the other hand, is designed for eligible employees and requires enrollment for those who meet its criteria. In the Japanese economy, enrollment in the EPI entitles individual to receive benefits from both the NP and EPI in retirement. In this model, all working-age households are assumed to be enrolled in the EPI, which means that they pay only EPI contributions and are eligible for benefits from both. EPI benefits may be adjusted or suspended under the Old-Age Pension System for Working Retirees, depending on the total combined amount of employment income and EPI benefits received by each household.

Households aged 65 and older who continue working and meet the eligibility requirements for the EPI system are required to remain enrolled and continue paying pension contributions until the age of 70. During this period, their contribution-paid periods and average historical earnings are updated annually. Upon reaching age 70 ($I_2 = 51$), households are assumed to cease participation in the EPI system. They are no longer required to pay pension contributions, and their contribution-paid periods and average historical earnings stop being updated. However, under the Old-Age Pension System for Working Retirees, their EPI benefits remain subject to adjustments beyond age 70.

The individual state of a household is represented by $\mathbf{s} = (i, e, a, b)$, while the aggregate state of the economy in period t is represented by $\mathbf{S}_t = (x(\mathbf{s}), W_{G,t})$. Here, $x(\mathbf{s})$ is the population density function of households, and $W_{G,t}$ is the government's net worth at the beginning of period t.

The government's policy schedule at the beginning of period t is

$$\mathbf{\Psi_t} = \{C_{G,s}, tr_{LS,s}, \tau_{c,s}, \tau_{P,s}(\cdot), \tau_{H,s}(\cdot), tr_{SS,s}(\cdot), \tau_{I,s}(\cdot), q_s, W_{G,s+1}\}_{s=t}^{\infty},$$

where $C_{G,t}$ is the government's general expenditure, $tr_{LS,t}$ is lump-sum transfers to each household, and $\tau_{c,t}$ is a flat tax on consumption. $\tau_{P,t}(\cdot)$ and $\tau_{H,t}(\cdot)$ are functions that calculate contributions to EPI and Health Insurance (HI), respectively. $tr_{SS,t}(\cdot)$ is the function that calculates pension benefits households receive after reaching pension eligibility age. $\tau_{I,t}(\cdot)$ is the function that calculates income tax collected from households. q_t is the uniform transfer received by working-age households, which in this model is accidental bequests collected and distributed by the government. $W_{G,t+1}$ is the government's net worth at the beginning of period $t+1$.

2.1.1 The Optimization Problem

Let $v(\mathbf{s}, \mathbf{S}_t; \boldsymbol{\Psi}_t)$ be the household's value function at the beginning of period t. The optimization problem is then:

$$v(\mathbf{s}, \mathbf{S}_t; \boldsymbol{\Psi}_t) = \max_{c,h,a'} \left\{ u(c,h) + \tilde{\beta}\phi_i E\big[v(\mathbf{s}', \mathbf{S}_{t+1}; \boldsymbol{\Psi}_{t+1}) \,|\mathbf{s} \big] \right\} \tag{1}$$

subject to the constraints for the decision variables,

$$c > 0, \qquad 0 \leq h < 1, \qquad a' \geq 0,$$

and the laws of motion of the individual state variables,

$$\mathbf{s}' = \left(i+1, e', a', b'\right), \tag{2}$$

$$\begin{aligned} a' = \frac{1}{1+\mu}\big[& (1+r_t)a + w_t eh + tr_{SS,t}(i,b) - \tau_{P,t}(i, w_t eh) - \tau_{H,t}(w_t eh, tr_{SS,t}(\cdot)) \\ & -\tau_{I,t}(r_t a, w_t eh, tr_{SS,t}(\cdot)) + tr_{LS,t} + q_t - (1+\tau_{c,t})c \big], \end{aligned} \tag{3}$$

$$b' = \mathbf{1}_{\{i \geq I_2\}} b + \mathbf{1}_{\{i < I_2\}} \frac{1}{i}\left[(i-1)b + \min\left\{ w_t eh - \frac{1}{2}\left[\tau_{P,t}(\cdot) + \tau_{H,t}(\cdot)\right], \vartheta_{1max} \right\} \right], \tag{4}$$

where $u(\cdot)$ is the household's period utility function, and

$$u(c,h) = \frac{\left[c^{\theta}(1-h)^{1-\theta} \right]^{1-\gamma}}{1-\gamma}, \tag{5}$$

where $\tilde{\beta}$ is a growth-adjusted discount factor defined as $\tilde{\beta} = \beta(1-\mu)^{\theta(1-\gamma)}$. c is household consumption, and h is household working hours. μ is the productivity growth rate, ϕ_i is the conditional survival probability of a household at the end of age i given that the household is alive at the beginning of age i. $\tau_{c,t}$ is the consumption tax rate.

In this model, household income is categorized into labor income, interest income, and pension income. Income tax $\tau_{I,t}(\cdot)$ is calculated separately for each category, based on real-world policies. Interest income is taxed separately using a flat tax rate, while pension income is taxed using a combination of progressive deductions and a flat tax rate, and labor income is taxed progressively. The calculations also account for employment income deduction, basic exemption, and the inhabitant tax.

In equation (4), I_2 is used because average historical earnings are updated until age 70 ($i = I_2$). ϑ_{1max} is the upper limit of the standard remuneration used to calculate benefits under the EPI system. In the real economy, social insurance contributions are typically shared between employers and employees. Therefore, in this model, employer-paid insurance contributions are considered part of employees' labor income, effectively making households bear the full cost of these contributions.

In reality, the average historical earnings used to calculate EPI benefits are based on actual salaries, which do not include the employer's share of social insurance contributions. To reflect this, in equation (4), labor income w_teh is adjusted by subtracting half of the total social insurance contributions, ensuring consistency with the real-world calculation of b. The details of the social security system and tax system are explained in Section 3.5 and 3.6.

2.1.2 The Household's Decision Rules

To solve the household's optimization problem for all possible states $\mathbf{s}$, this study first computes the household's decision rules $c(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t)$ and $h(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t)$ numerically. The remaining decision rules a' and b' are then calculated using the obtained values of c and h,

$$\begin{aligned} a'(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) = \frac{1}{1+\mu} \{ & (1+r_t) a + w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) + tr_{SS,t}(i, b) \\ & - \tau_{P,t}(i, w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t)) - \tau_{H,t}(w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t), tr_{SS,t}(\cdot)) \\ & - \tau_{I,t}(r_t a, w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t), tr_{SS,t}(\cdot)) + tr_{LS,t} + q_t \\ & - (1+\tau_{c,t}) c(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) \}, \end{aligned} \tag{6}$$

$$\begin{aligned} b'(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) = \mathbf{1}_{\{i \geq I_2\}} b + \mathbf{1}_{\{i < I_2\}} \frac{1}{i} \Bigg[(i-1) b + \min \Bigg\{ & w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) \\ - \frac{1}{2} \left[\tau_{P,t}(i, w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t)) + \tau_{H,t}(w_t eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t), tr_{SS,t}(\cdot)) \right], & \vartheta_{1max} \Bigg\} \Bigg]. \end{aligned} \tag{7}$$

2.1.3 The Distribution of Households

Let $x_t(\mathbf{s})$ be the population density function of households at period t, and $X_t(\mathbf{s})$ be the cumulative distribution function. Households enter the economy at age 20 with no assets or earning history, thus $a = b = 0$. However, each household has different earning ability e. The total population of 20-year-old households is normalized to unity,

$$\int_{E\times A\times B} dX_t\left(1,e,a,b\right) = \int_E dX_t\left(1,e,0,0\right) = 1. \tag{8}$$

Given the population growth rate ν and the conditional survival probability ϕ_i, the law of motion for the growth-adjusted population distribution is

$$x_{t+1}\left(\mathbf{s}'\right) = \frac{\phi_i}{1+\nu}\int_{E\times A\times B} \mathbf{1}_{\{a'=a'(\mathbf{s},\mathbf{S}_t;\mathbf{\Psi}_t),b'=b'(\mathbf{s},\mathbf{S}_t;\mathbf{\Psi}_t)\}}\pi\left(e'|e\right) dX_t\left(\mathbf{s}\right), \tag{9}$$

where $\pi\left(e'|e\right)$ is the transition probability density function of earning ability e from age i to age $i+1$.

2.1.4 The Measure of Welfare

This study employs the veil of ignorance welfare measure to assess the impact of policies on household welfare. This measure represents the welfare effects of a policy as the percentage change in baseline consumption path that would generate the same change in household utility as the policy itself. By translating utility changes into equivalent consumption changes, this measure provides an intuitive way to understand the welfare impact of policies.

Let $\lambda_{i,1}$ and $\lambda_{1,t}$ be the percentage change in baseline consumption path that would generate the same expected lifetime utility change as the policy itself. $\lambda_{i,1}$ applies to households of each age when the policy is implemented, while $\lambda_{1,t}$ applies to newborn households ($i = 1$) entering the economy during the transition. Their functional forms are

$$\lambda_{i,1} = \left[\left(\frac{Ev\left(\mathbf{s}_i,\mathbf{S}_1;\mathbf{\Psi}_1\right)}{Ev\left(\mathbf{s}_i,\mathbf{S}_0;\mathbf{\Psi}_0\right)}\right)^{\frac{1}{\theta(1-\gamma)}} - 1\right]\times 100, \tag{10}$$

$$\lambda_{1,t} = \left[\left(\frac{Ev\left(\mathbf{s}_1,\mathbf{S}_t;\mathbf{\Psi}_t\right)}{Ev\left(\mathbf{s}_1,\mathbf{S}_0;\mathbf{\Psi}_0\right)}\right)^{\frac{1}{\theta(1-\gamma)}} - 1\right]\times 100, \tag{11}$$

where $\mathbf{s}_1 = (1,e,a,b)$ is the state of a newborn household (age $i = 1$) in the economy, $v\left(\mathbf{s}_1,\mathbf{S}_t;\mathbf{\Psi}_t\right)$ is the lifetime utility of a specific $i = 1$ household at period t after the policy change. $Ev\left(\mathbf{s}_1,\mathbf{S}_t;\mathbf{\Psi}_t\right)$ is the expected lifetime utility of an $i = 1$ household in period t, and it is defined as

$$Ev\left(\mathbf{s}_1,\mathbf{S}_t;\mathbf{\Psi}_t\right) = \int_{E\times A\times B} v\left(\mathbf{s}_1,\mathbf{S}_t;\mathbf{\Psi}_t\right) dX_t\left(\mathbf{s}_1\right). \tag{12}$$

2.1.5 The Supply of Capital and Labor

This study assumes a closed economy, where the capital stock K_t is the sum of total private wealth $W_{P,t}$ and the government's net worth $W_{G,t}$. The total labor supply is the aggregate efficient labor provided by all households. Their functional forms are

$$W_{P,t} = \sum_{i=1}^{I} \int_{E\times A\times B} a dX_t(\mathbf{s}), \qquad K_t = W_{P,t} + W_{G,t}, \tag{13}$$

$$L_t = \sum_{i=1}^{I} \int_{E\times A\times B} eh(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) dX_t(\mathbf{s}). \tag{14}$$

2.2 The Representative Firm

The representative firm employs capital and labor as production factors and operates according to a Cobb-Douglas production function

$$Y_t = A\tilde{K}_t^{\alpha}\tilde{L}_t^{1-\alpha}, \tag{15}$$

where A is the total factor productivity, and $\tilde{K}$ and $\tilde{L}$ are the capital input and labor input in efficiency units chosen by the firm. Letting δ be the depreciation rate, the firm's profit maximizing conditions are

$$\alpha A \left(\frac{\tilde{K}_t}{\tilde{L}_t}\right)^{\alpha-1} - (r_t + \delta) = 0, \tag{16}$$

$$(1-\alpha) A \left(\frac{\tilde{K}_t}{\tilde{L}_t}\right)^{\alpha} - w_t = 0. \tag{17}$$

Given the assumption of a closed economy, the factor markets clear such that $\tilde{K}_t = K_t$ and $\tilde{L}_t = L_t$. Gross domestic product, which is here identical to gross national product Y_t, is

$$Y_t = F(K_t, L_t) = (r_t + \delta)(W_{P,t} + W_{G,t}) + w_t L_t. \tag{18}$$

2.3 The Government

2.3.1 Government General Budget

This section defines the government revenue and expenditure in this model. The Public Pension System contribution revenue $T_{P,t}$ is

$$T_{P,t}\left(\bar{\tau}_{p,t}\right)=\sum_{i=1}^{I}\int_{E\times A\times B}\tau_{P,t}\left(i,w_{t}eh\left(\mathbf{s},\mathbf{S}_{t};\mathbf{\Psi}_{t}\right);\bar{\tau}_{p,t}\right)dX_{t}\left(\mathbf{s}\right), \tag{19}$$

where $\bar{\tau}_{p,t}$ is the contribution rate of Employees' Pension Insurance. The Public Pension System benefit expenditure $TR_{SS,t}$ is

$$TR_{SS,t}\left(\psi_{t}\right)=\sum_{i=I_{1}}^{I}\int_{E\times A\times B}tr_{SS,t}\left(i,b;\psi_{t}\right)dX_{t}\left(\mathbf{s}\right), \tag{20}$$

where ψ_t is the pension sector balance factor, adjusted to ensure that the pension sector budget is always balanced.

The Healthcare Insurance contribution revenue $T_{H,t}$ is

$$T_{H,t}\left(\bar{\tau}_{h,t}\right)=\sum_{i=1}^{I}\int_{E\times A\times B}\tau_{H,t}\left(w_{t}eh\left(\mathbf{s},\mathbf{S}_{t};\mathbf{\Psi}_{t}\right),tr_{SS,t}\left(\cdot\right);\bar{\tau}_{h,t}\right)dX_{t}\left(\mathbf{s}\right), \tag{21}$$

where $\bar{\tau}_{h,t}$ is the contribution rate of Health Insurance. The government's income tax revenue $T_{I,t}$ is

$$\begin{aligned}T_{I,t}\left(\varphi_{t},\bar{\tau}_{k,t},\bar{\tau}_{ss,t},\bar{\tau}_{r1,t},\bar{\tau}_{r2,t}\right)=\sum_{i=1}^{I}\int_{E\times A\times B}&\tau_{I,t}\left(r_{t}a,w_{t}eh\left(\mathbf{s},\mathbf{S}_{t};\mathbf{\Psi}_{t}\right),tr_{SS,t}\left(\cdot\right);\right.\\&\left.\varphi_{t},\bar{\tau}_{k,t},\bar{\tau}_{ss,t},\bar{\tau}_{r1,t},\bar{\tau}_{r2,t}\right)dX_{t}\left(\mathbf{s}\right),\end{aligned} \tag{22}$$

where φ_t is a parameter of labor income tax function, representing the highest progressive tax rate faced by households. $\bar{\tau}_{k,t}$ is the interest income tax rate, $\bar{\tau}_{ss,t}$ is the pension income tax rate, $\bar{\tau}_{r1,t}$ and $\bar{\tau}_{r2,t}$ are the inhabitant tax rates. The consumption tax revenue $T_{C,t}$ is

$$T_{C,t}\left(\tau_{c,t}\right)=\tau_{c,t}\sum_{i=1}^{I}\int_{E\times A\times B}c\left(\mathbf{s},\mathbf{S}_{t};\mathbf{\Psi}_{t}\right)dX_{t}\left(\mathbf{s}\right), \tag{23}$$

and the lump-sum transfer spending $TR_{LS,t}$ is

$$TR_{LS,t}\left(tr_{LS,t}\right)=\sum_{i=1}^{I}\int_{E\times A\times B}tr_{LS,t}dX_{t}\left(\mathbf{s}\right). \tag{24}$$

The law of motion of the government's net worth $W_{G,t+1}$ is

$$W_{G,t+1} = \frac{1}{(1+\mu)(1+\nu)} \big[(1+r_t) W_{G,t} + T_{I,t} + T_{C,t}(\tau_{c,t}) - TR_{LS,t}(tr_{LS,t}) \\ + T_{P,t} - TR_{SS,t} + T_{H,t} - C_{G,t} \big], \tag{25}$$

where ν is the population growth rate.

2.3.2 Accidental Bequests

To simplify the analysis, it is assumed that when a household with assets deceases, those assets are collected by the government and distributed as a lump sum transfer to all households within the same period. Let Q_t be the total accidental bequests collected by the government in period t, then

$$Q_t = \sum_{i=1}^{I} \int_{E \times A \times B} (1-\phi_i)(1+\mu) a'(\mathbf{s}, \mathbf{S}_t; \mathbf{\Psi}_t) \, dX_t(\mathbf{s}). \tag{26}$$

The uniform bequest q_t each household receives is

$$q_t = \left(\sum_{i=1}^{I} \int_{E \times A \times B} dX_t(\mathbf{s}) \right)^{-1} Q_t. \tag{27}$$

2.4 Recursive Competitive Equilibrium

The recursive competitive equilibrium in this economy is defined as follows.

Definition: Recursive Competitive Equilibrium. Let $\mathbf{s} = (i, e, a, b)$ be the individual state of households, $\mathbf{S}_t = (x(s), W_{G,t})$ be the aggregate state of the economy, and $\mathbf{\Psi}_t$ be the government policy schedule at the beginning of period t,

$$\mathbf{\Psi}_t = \{C_{G,s}, tr_{LS,s}, \tau_{c,s}, \tau_{P,s}(\cdot), \tau_{H,s}(\cdot), tr_{SS,s}(\cdot), \tau_{I,s}(\cdot), q_s, W_{G,s+1}\}_{s=t}^{\infty}.$$

A time series of the factor prices and government policy variables,

$$\mathbf{\Omega}_t = \{r_s, w_s, \varphi_s, \tau_{c,s}, \bar{\tau}_{k,s}, \bar{\tau}_{ss,s}, \bar{\tau}_{r1,t}, \bar{\tau}_{r2,t}, \bar{\tau}_{p,s}, \bar{\tau}_{h,s}, tr_{LS,s}, \psi_s, q_s, C_{G,s}, W_{G,s+1}\}_{s=t}^{\infty},$$

the value functions of households, $\{v(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s)\}_{s=t}^{\infty}$, the distribution of households, $\{x_s(\mathbf{s})\}_{s=t}^{\infty}$, and the decision rules of households

$$d(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s) = \left\{c(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s), h(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s), a'(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s), b'(\mathbf{s}, \mathbf{S}_s; \mathbf{\Psi}_s)\right\}_{s=t}^{\infty},$$

are in a recursive competitive equilibrium if, for all $s = t, ..., \infty$,

1. each household chooses $d(\mathbf{t}, \mathbf{S}_t; \mathbf{\Psi}_t)$ to maximize her lifetime utility, taking factor prices and the government policy as given;
2. each firm chooses its factor inputs ($\tilde{K}_t$, $\tilde{L}_t$) and maximizes its own profit;
3. factor markets clear under the factor prices (r_t, w_t).

The economy is in a steady-state equilibrium, thus on the balanced-growth path, if $\mathbf{S}_s = \mathbf{S}_{s+1}$ and $\mathbf{\Psi}_s = \mathbf{\Psi}_{s+1}$ for all $s = t, ..., \infty$.

3 Calibration

This study uses statistical data from the Japanese economy in 2022 to construct the baseline economy for policy experiments. In reality, Japan is still in the process of raising the pension eligibility age from 60 to 65. According to the plan, the pension eligibility age for men will rise to 65 by 2025, and for women by 2030. However, since the analysis includes steady-state equilibrium, the baseline economy assumes that the pension eligibility age has already been raised to 65. Based on the baseline, the policy experiment on raising the eligibility age examines the impact of raising the pension eligibility age from 65 to 70 on the macroeconomy and household welfare. Other settings are based on Japan's current system. The main parameters are summarized in Table 1.

3.1 Demographics

In Japan, individuals are required to join the public pension system upon turning 20. Accordingly, in this study, the age at which households enter the model ($i = 1$) corresponds to 20 years old in real life. Households are assumed to survive for a maximum of 80 periods ($I_{max} = 80$), which means that all survivors exit the model economy at the end of their 99th year. In the baseline economy, two key ages are considered: I_1 and I_2. Households begin receiving pension benefits at $I_1 = 46$ (age 65), and stop paying pension contribution at $I_2 = 51$ (age 70).

Table 1: Parameters and Values

Parameter		Value	Comment
Maximum Possible Age	I	80	Corresponds to a real-life age of 99
Pension Eligibility Age	I_1	46	
Contribution Free Age	I_2	51	The age at which pension contribution are no longer required
Productivity Growth Rate	μ	0.0070	Average change rate in real GDP per capita in 2003-2022
Population Growth Rate	ν	-0.0011	Average change rate in 2003-2022
Household Survival Rates	ϕ_i		Based on the 23rd Life Tables 2020
Share Parameter of Capital Stock	α	0.4124	SNA data
Discount Factor	β	1.0099	$K/Y = 3.5$ in the baseline
Coefficient of Relative Risk Aversion	γ	3.0000	
Depreciation Rate of Capital Stock	δ	0.0628	SNA data $r = 0.0550$ in the baseline
Share Parameter of Consumption	θ	0.6540	Frisch elasticity 0.5
Benefit Multiplier of the EPI	κ	0.0055	
Autocorrelation Parameter of Log Income	ρ	0.9500	Income variance by 10-year age groups
Standard Deviation of Log Income Shocks	σ	0.2200	in 2022
Average Earning Ability	$\bar{e}_i$		Estimated by OLS with 2022 wage data
Full Amount of NP Benefit	np	0.0841	¥777,800 in 2022[a]
Upper Limit of the Standard Remuneration y_P	ϑ_{1max}	1.3293	12× ¥65,000 + 3×¥1,500,000 = ¥12,300,000 in 2022[a]
Converted ϑ_{1max}	ϑ_{2max}	1.5178	
Annual Adjustment Amount for the Suspension of EPI Benefit	ϑ_{3max}	0.6485	¥6,000,000 in 2024[a]
Converted Upper Limit of the Standard Remuneration of the HI	ϑ_{4max}	2.6647[b]	12× ¥1,390,000 + ¥5,730,000 = ¥22,410,000 in 2022[a]
Income Tax Parameters: Tax Rate Limit	φ_t	0.4500	Maximum individual income tax rate
: Curvature	φ_1	1.0628	} Estimated by OLS
: Scale	φ_2	0.6671	
Consumption Tax Rate	$\tau_{c,t}$	0.1000	
Interest Income Tax Rate	$\bar{\tau}_{k,t}$	0.2020	$T_I/Y = 7.2\%$ in the Baseline
Pension Income Tax Rate	$\bar{\tau}_{ss,t}$	0.0500	
Inhabitant Tax Rate 1	$\bar{\tau}_{r1,t}$	0.0500	Apply for interest income
Inhabitant Tax Rate 2	$\bar{\tau}_{r2,t}$	0.1000	Apply for labor and pension income
Converted EPI Contribution Rate	$\bar{\tau}_{p,t}$	0.1603	18.3% in reality
Converted HI Contribution Rate	$\bar{\tau}_{h,t}$	0.0876[b]	10% average contribution rate
Government Consumption	$C_{G,t}$	12.2133	$C_G = T_C + T_I + T_H - TR_{LS}$ in the baseline
Lump-sum Transfers	$tr_{LS,t}$	0.0000	
Pension Sector Balance Factor	ψ_t	1.0098	
Total Factor Productivity	A	0.8153	$w = 1.0$ in the baseline
Accidental Bequests per Households	q_t	0.0273	

[a] One unit of income in the model economy equals to 9,252,820 Japanese Yen.
[b] Varies depending on the household's age and labor income.

Considering the impact of COVID-19 on GDP growth, the model sets the productivity growth rate as follows. Using real GDP data (at 2015 constant prices) from the Cabinet Office, Government of Japan's National Accounts, and population data from the Statistics Bureau of Japan, for 2000, 2003, 2019, and 2022, Japan's average annual growth rate of real GDP per capita is calculated over two periods: 2000 to 2019 and 2003 to 2022. The 2000 population figure is the confirmed number from the census, while data for 2003, 2019, and 2022 are Population Estimates as of October 1st. The calculations, based on a compound interest method, yield growth rates of 0.68% for the period 2000 to 2019, and 0.73% for the period 2003 to 2022. To mitigate the concentrated impact of COVID-19 on GDP, a productivity growth rate of 0.70% is chosen for the model. The population growth rate ν is estimated at -0.11%, based on population data from 2003 to 2022. This negative value for ν indicates Japan's population decline over the past two decades.

The conditional survival probability ϕ_i, which is the probability that a household aged i will reach age $i+1$, is calculated using data from the 23rd Life Tables (2020) published by the Ministry of Health, Labour and Welfare of Japan. The Ministry provides two types of life tables: Complete Life Tables based on the Annual Vital Statistics and the Population Census, and Abridged Life Tables based on the Provisional Annual Vital Statistics and the Population Estimates. Complete Life Tables are published every five years, while Abridged Life Tables are estimated annually. According to the 2020 Abridged Life Tables, COVID-19 reduced the average life expectancy in Japan by 0.03 years for men and 0.02 years for women. However, the average life expectancy for both men and women in the 2020 Complete Life Tables exceeds that of the 2019 Abridged Life Tables. To ensure statistical accuracy, this study uses the 2020 Complete Life Tables. The gender ratio at age 20 is set at 105:100, and a weighted average is applied to calculate survival probabilities for each age, which are then used as ϕ_i.

3.2 Preferences

In this study, the coefficient of relative risk aversion is set to $\gamma = 3.0$. The Frisch elasticity, which measures the responsiveness of labor supply to wage changes for an average worker, is given by the formula

$$\frac{1-\bar{h}}{\bar{h}} \frac{1-\theta\left(1-\gamma\right)}{\gamma} = 0.5. \tag{28}$$

By setting the consumption share parameter in the Cobb-Douglas utility function to $\theta = 0.6540$, the Frisch elasticity approaches 0.5. Here, $\bar{h}$ is the average labor hours of the working-age population. However, defining the working-age population is not straightforward, as this model allows households aged 65 and older to continue working. To ensure consistency, $\bar{h}$ is defined here as the average labor hours of households aged 64 and younger. In the baseline, the average labor hours is 0.6070.

3.3 Production Technology

This study calibrates the capital share α using statistical data from the Generation of Income Account in the National Accounts of Japan for 2022 (calendar year). In these accounts, operating surplus and mixed income are recorded as separate items, which makes them easier to use in analysis.

However, mixed income corresponds to proprietors' income, which combines the labor and capital contributions of sole proprietors, making it challenging to separate these components. To address this, compensation of employees is first added to the net operating surplus, and the ratio of compensation of employees to the total value is calculated. This ratio is then applied to net mixed income (excluding consumption of fixed capital) to estimate the labor contribution of sole proprietors to production. As a result, the labor income ratio to GDP for 2022 is calculated to be 0.5876. This value is the labor share, $1 - \alpha$, and the capital share α is consequently set to 0.4124.

The average value of the capital coefficient (fixed capital stock/GDP) for Japan was calculated as 3.5194 for the period 2003 to 2022, and as 3.4355 for the period 2000 to 2019. Based on these calculations, the discount factor β is set to 1.0099 in the baseline model to ensure that the capital-to-output ratio (K/Y) equals 3.5. When $\theta = 0.6540$ and $\gamma = 3.0$, the growth-adjusted discount factor is

$$\tilde{\beta} = \beta \left(1 + \mu\right)^{\theta(1-\gamma)} = 1.0007. \tag{29}$$

The ratio of consumption of fixed capital to fixed capital stock for 2022 was calculated as 0.0629. To ensure that the interest rate r equals 0.0550 in the baseline, the depreciation rate δ is finely adjusted to 0.0628,

$$r = \alpha A \left(\frac{K_t}{L_t}\right)^{\alpha-1} - \delta = \alpha \frac{Y}{K} - \delta = 0.0549, \tag{30}$$

$$\delta = \alpha \frac{Y_t}{K_t} - 0.0550 = \frac{0.4124}{3.5} - 0.0550 = 0.0628. \tag{31}$$

To ensure that the wage rate w in the baseline economy equals 1.0 in the baseline, the total factor productivity (TFP) scalar is set to 0.8153,

$$w = (1-\alpha)\, A \left(\frac{K_t}{L_t}\right)^{\alpha} = (1-\alpha)^{1-\alpha} A \left(\frac{K_t}{Y_t}\right)^{\alpha} = 1, \tag{32}$$

$$A = \left[(1 - 0.4124)^{(1-0.4124)}(3.5)^{0.4124}\right]^{-1} = 0.8153. \tag{33}$$

3.4 Working Ability

Working ability calibration is based on data from Table 1 of the 2022 Basic Survey on Wage Structure, published by the Ministry of Health, Labour and Welfare of Japan. This dataset provides information on contractual cash earnings, actual number of scheduled hours worked, actual number of overtime worked, and annual special cash earnings by five-year age groups, covering public and private establishments across all industries. The data include all enterprise sizes with over 10 employees, total employees (male and female), and total educational backgrounds.

First, the average annual labor income by age group is calculated using contractual cash earnings and annual special cash earnings provided in the table. Employer-paid insurance contributions are considered part of employees' labor income in this study, and these contributions are added to the average amounts. Next, average annual labor hours are approximated using actual number of scheduled hours worked and overtime worked. Based on these calculations, the hourly labor income by age group is derived.

Using the hourly labor income data by age group, an OLS regression with a cubic function of age is performed to estimate the average hourly labor income by age. One important point to note is that the actual pension eligibility age in 2022 fell between 60 and 64 years old. As a result, the average hourly labor income in the data may underestimate the working ability of individuals aged 60 to 64, as well as those aged 65 to 69. This is because post-retirement re-employment often comes with lower wage levels than pre-retirement employment. Given that the policy experiment raises the pension eligibility age to 70, interpolation is used to estimate the average hourly labor income for individuals aged 60 to 69 to reflect the potential working ability, instead of relying on the actual data. Additionally, in the dataset, employees aged 70 and older are grouped together. Here, this study uses the actual data for this group as a proxy for individuals aged 70 to 74. Figure 1 shows the data and the estimation results. According to the estimation, the average hourly labor income for households reaches its peak at age 53 and declines to 0 by age 82.

Then, using the original data from the 2022 Basic Survey on Wage Structure, this study calculates the average hourly labor income for workers aged 20 to 64, and uses it to standardize the OLS estimates. The result is this model's average working ability by age, with an average value of 1.0 for ages 20 to 64.

Household labor productivity can fluctuate due to various events and external shocks. Therefore, the

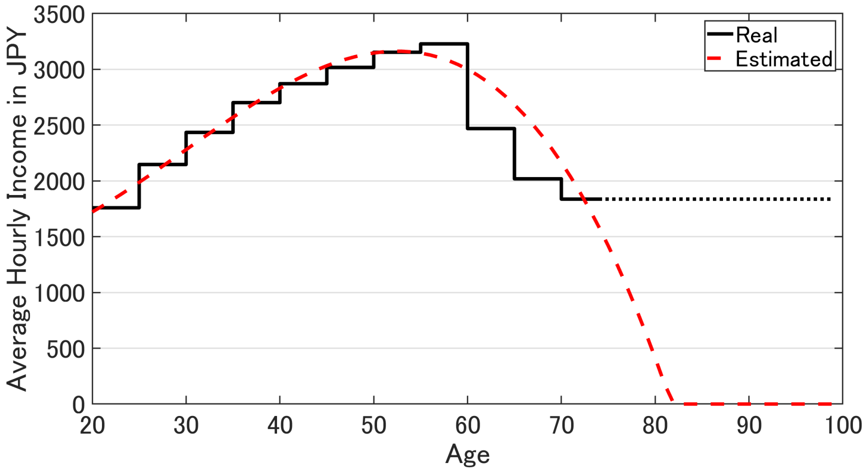

Figure 1: Average Hourly Income

working ability of an age i household in this model is assumed to satisfy:

$$\ln e_i = \ln \bar{e}_i + \ln z_i, \tag{34}$$

where i ranges from 1 to 62 as households' working ability becomes zero after $i = 62$ (age 81). Here, $\bar{e}_i$ is the previously estimated average working ability, and z_i is a persistent shock assumed to follow an AR(1) process. Specifically,

$$\ln z_i = \rho \ln z_{i-1} + \epsilon_i, \quad \epsilon_i \sim N\left(0, \sigma^2\right), \tag{35}$$

where the autocorrelation parameter ρ is set to 0.95, and the standard deviation σ is 0.22. This study uses data from the 2022 Comprehensive Survey of Living Conditions, published by the Ministry of Health, Labour and Welfare of Japan, to calibrate the AR(1) process. The data includes non-executive employees aged 15 and above, categorized into 10-year age groups, with those under 29 grouped together and those 60 and above grouped together. The variance of logarithmic income is calculated for employees aged 20 to 59. These variances are then compared with the model's calculated variances of logarithmic labor income to adjust ρ and σ, ensuring that the model replicates the observed variance patterns. As shown in Figure 2, the variance of the model's logarithmic labor income matches the variance of the data.

The AR(1) process is approximated using a Markov chain. In this approach, $\ln z_i$ is discretized into five nodes, and the Markov transition matrix is constructed using Rouwenhorst's method. The unconditional probability distribution is given by $\pi_i = (0.0625, 0.2500, 0.3750, 0.2500, 0.0625)$ for $i =$

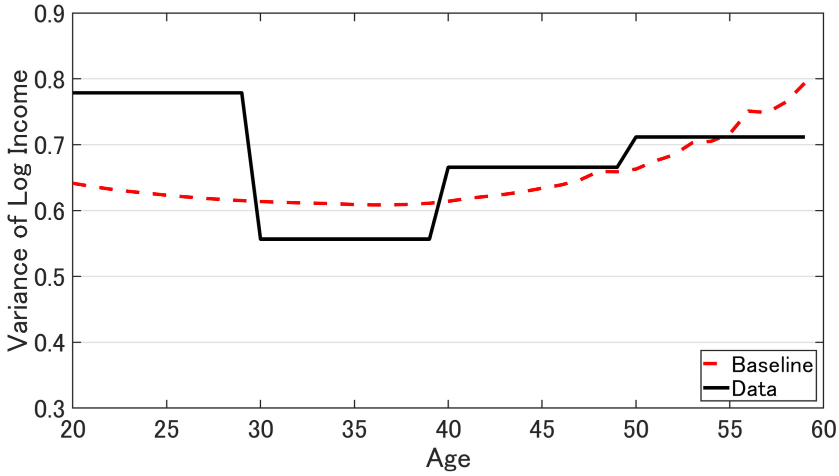

Figure 2: The Variance of Log Labor Income by Age

$1, \ldots, 62$. The Markov transition matrix is

$$\Pi_i = \begin{pmatrix} 0.90369 & 0.02317 & 0.00059 & 0.00002 & 0.00000 \\ 0.09269 & 0.90547 & 0.04637 & 0.00178 & 0.00006 \\ 0.00357 & 0.06956 & 0.90607 & 0.06956 & 0.00357 \\ 0.00006 & 0.00178 & 0.04637 & 0.90547 & 0.09269 \\ 0.00000 & 0.00002 & 0.00059 & 0.02317 & 0.90369 \end{pmatrix}.$$

3.5 Taxation

In this model, income is divided into three categories: labor, interest, and pension income. A flat tax rate is applied to interest income, a combination of progressive deductions and a flat tax rate is used for pension income, and labor income tax follows the function proposed by Gouveia and Strauss (1994). In summary, the income tax function is

$$\begin{aligned} \tau_{I,t}\left(r_t a, w_t e h, tr_{SS,t}(\cdot)\right) &= \tilde{\tau}_{I,t}\left(r_t a, \tilde{y}, tr_{SS,t}(\cdot)\right) \\ &= \tau_{K,t}\left(r_t a\right) + \varphi_t \left[\tilde{y} - \left(\tilde{y}^{-\varphi_1} + \varphi_2\right)^{-\frac{1}{\varphi_1}}\right] + \tau_{SS,t}(i, b) \\ &\quad + \tau_{R,t}\left(r_t a, \tilde{y}, tr_{SS,t}(\cdot)\right), \end{aligned} \tag{36}$$

where

$$\tau_{K,t}\left(r_t a\right) = \bar{\tau}_{k,t}\, r_t a, \tag{37}$$

$$\tilde{y} = \max\left\{w_t eh - d_1\left(w_t eh\right) - \tau_{H,t}\left(\cdot\right) - \tau_{P,t}\left(\cdot\right), 0\right\}, \tag{38}$$

$$\tau_{SS,t}\left(i, b\right) = \tilde{\tau}_{SS,t}\left(tr_{SS,t}\left(\cdot\right)\right) = \bar{\tau}_{ss,t}\left[\, tr_{SS,t}\left(\cdot\right) - d_2\left(tr_{SS,t}\left(\cdot\right), \psi_t\right)\right], \tag{39}$$

$$\tau_{R,t}\left(r_t a, \tilde{y}, tr_{SS,t}\left(\cdot\right)\right) = \bar{\tau}_{r1,t}\, r_t a + \bar{\tau}_{r2,t}\left[\, tr_{SS,t}\left(\cdot\right) - d_2\left(\cdot\right) + \tilde{y}\right]. \tag{40}$$

The interest income tax rate is denoted by $\bar{\tau}_{k,t}$, $\tilde{y}$ is the taxable labor income, $d_1\left(\cdot\right)$ is the basic exemption and the employment income deduction, $\bar{\tau}_{ss,t}$ is the pension income tax rate, and $d_2\left(\cdot\right)$ is the progressive deduction used to calculate the pension income tax. In this model, the basic exemption is first applied to labor income, and if any amount remains, it is applied to pension income.

In addition to income tax, this model incorporates a simplified inhabitant tax $\tau_{R,t}\left(\cdot\right)$, applying different inhabitant tax rates based on income categories. In the real Japanese economy, inhabitant tax consists of two components: a prefectural tax and a municipal tax. The tax payment also consists of two parts: a per capita portion and an income-proportional portion. However, since the model does not include local governments, the tax rates for prefectural and municipal taxes are unified. Additionally, for simplicity, the per capita portion is omitted in the model. It is also assumed that the same taxable income base is used as each income tax. The inhabitant tax rates are set at $\bar{\tau}_{r1,t} = 5\%$ for interest income and $\bar{\tau}_{r2,t} = 10\%$ for labor income and pension income. The revenue from inhabitant taxes is allocated to government expenditures as this model assumes the absence of local governments.

Given the complexity of Japan's intertwined income tax and social security systems, this study calibrates the labor income tax function using the following method. Salary nodes are set in 10,000 yen increments, ranging from a monthly employment salary of 50,000 yen to 3,880,000 yen. Annual salary for each node is then calculated by aggregating monthly salary, and this value is treated as a household's gross employment salary. Based on these annual salary levels, basic exemption, employment income deduction, and full pension and health insurance contributions are determined. In reality, social insurance contributions are shared equally between employees and employers. This study considers employer-paid insurance contributions as part of employees' labor income. Accordingly, adjustments are made so that the modeled labor income, based on the model's wage rate, working ability, and working hours, corresponds to the total of actual salaries and employer-paid insurance contributions.

Taxable labor income is calculated by subtracting employment income deduction, half of the social insurance contributions, and basic exemption from annual salary levels. Using the income tax rate tables

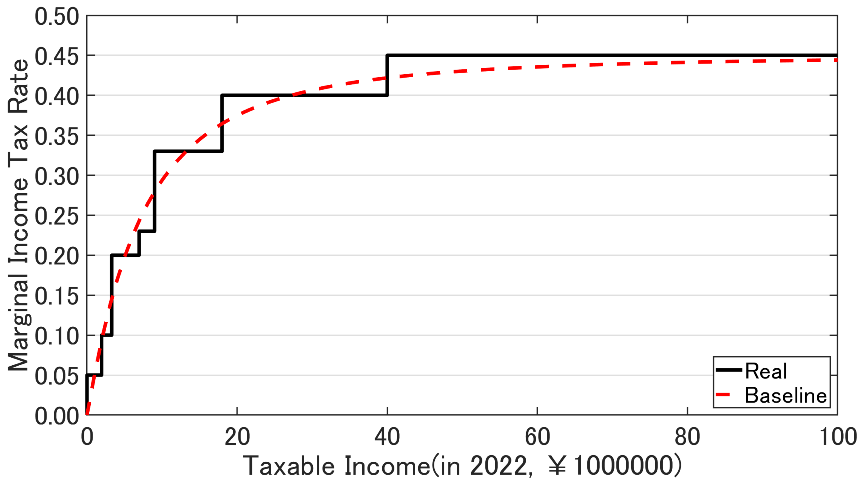

Figure 3: Marginal Income Tax Rates

on the National Tax Agency Japan's website, the income tax amount is calculated for each taxable income level. The parameter $\varphi_t = 0.45$ is set to match the maximum marginal tax rate of 45% in Japan's current system.

Before estimating the labor income tax function used in the model, all values are standardized. This study standardizes the model using the average annual labor income of households aged 20 to 64, which in the model is 0.6236. Using data from Table 1 of the 2022 Basic Survey on Wage Structure, including the social insurance contributions paid by employers, the average annual labor income of households aged 20 to 64 is calculated as 5,769,873 yen. Dividing this by the average labor income in the model, one unit of labor income in the model corresponds to 9,252,820 yen in reality, which is used for standardization. After standardizing the tax amounts and taxable income, the OLS method is applied to estimate the remaining two parameters in the Gouveia and Strauss income tax formula, yielding $\varphi_1 = 1.0628$ and $\varphi_2 = 0.6671$. Here, φ_1 is the curvature of the income tax function, and φ_2 is the scale. Figure 3 compares the estimated marginal tax rates from the model with the actual marginal tax rates.

Calculating income tax, corporate tax, and inheritance tax revenues as a percentage of GDP in 2022 yields 7.2%. In this model, φ_t is set to 0.45, and $\bar{\tau}_{k,t}$ is set to 0.202, which results in an income tax (without inhabitant tax) -to-GDP ratio of 7.2% in the baseline economy's steady-state equilibrium.

The basic exemption in the model is simplified to a uniform amount of $480,000$ yen, while in the real economy, this exemption applies to individuals with a total income of 24 million yen or less. For higher income levels, the basic exemption is reduced in three steps and becomes zero for individuals with total income exceeding 25 million yen. The actual employment income deduction is a piecewise linear function of annual earnings, ranging from $550,000$ yen to $1,950,000$ yen. In this study, this deduction is approximated as a quadratic function of labor income. The lower limit of 550,000 yen is ignored for simplicity, which may result in an overestimation of taxes for low-income taxpayers. However, the effect is partially offset because the Gouveia and Strauss formula tends to underestimate taxes for low-income taxpayers.

For pension income, a deduction $d_2(\cdot)$ is applied based on pension income levels. In the actual system, for households aged 65 or above, the calculation of this deduction depends on total income excluding pension income, with three different schemes available. To simplify the analysis, this study assumes that all eligible households qualify for the scheme offering the highest deduction amount, which ranges from 1,100,000 yen to 1,950,000 yen. Since pension benefits are adjusted using the benefit adjustment factor ψ_t, the deductions are scaled accordingly to align with the adjusted benefits. A pension income tax rate of $\bar{\tau}_{ss,t} = 5\%$ is then applied to calculate the pension income tax.

3.6 Social Security System

This model includes a social insurance system with two components: a pay-as-you-go public pension system, consisting of the NP and EPI, and the simplified HI system. The public pension system employs a detailed structure with an actual contribution rate of 18.3%. Since the model does not analyze the impact of health insurance on household behavior, the healthcare insurance system is simplified, using a contribution rate of 10%, based on the average rate set by the Japan Health Insurance Association.

In the real economy, social insurance contributions are calculated using actual salaries, which is $w_t eh - \frac{1}{2}(\tau_{P,t}(\cdot) + \tau_{H,t}(\cdot))$ in this model. For computational feasibility, this study addresses the nesting problem by converting the contribution rates instead of labor income. The EPI contribution function is

$$\tau_{P,t}(i, w_t eh) = \mathbf{1}_{\{i<I_2\}} \bar{\tau}_{p,t} \min(w_t eh, \vartheta_{2max}), \tag{41}$$

where $\bar{\tau}_{p,t} = 0.1603$ is the converted EPI contribution rate. Working households must enroll in the EPI system until they reach $I_2 = 51$ (age 70), where ϑ_{2max} is the converted upper limit of the standard remuneration of the EPI system. In the actual system, the standard remuneration of the EPI system is predetermined based on the previous year's salaries and divided into 32 levels. In this model, however, the standard remuneration is simplified to depend on the current period's salaries, and only the upper limit is retained.

The converted upper limit of the standard remuneration used in calculating EPI contributions is set as $\vartheta_{2max} = 1.5178$. The upper limit $\vartheta_{1max} = 1.3293$ used in calculating average historical earnings b is the unconverted version of ϑ_{2max}, corresponding to the actual amount of 12,300,000 yen in 2022. In the actual system, the upper limit of the standard remuneration does not include bonuses. However, bonuses are subject to the same EPI contribution rate as standard remuneration, with a separate upper limit of 1,500,000 yen per occurrence, applicable up to three times a year. In this model, since bonuses are not explicitly considered, they are treated as part of labor income when setting the upper limit of standard remuneration.

The calculation of pension benefits differs between the NP and EPI systems. The NP provides a fixed pension benefit based on the contribution-paid periods, while EPI benefits depend on both the contribution-paid periods and average historical earnings. In this model, it is not feasible to precisely measure the number of years each household has paid pension contributions. For the EPI, this issue is addressed by updating the formula each period. For the NP, it is assumed that all households receive the full amount uniformly (777,800 yen per year in 2022, the amount a household with 480 months of contribution-paid periods would receive).

The EPI benefit function is

$$tr_{EP,t}\left(i,b\right) = \mathbf{1}_{\{i\geq I_1\}}\, \kappa\, b\, I_P\, \left(1+\mu\right)^{I_1-i}, \tag{42}$$

where $\kappa = 0.005481$, the benefit multiplier, reflects the actual multiplier in the Japanese EPI system, and is used to calculate EPI benefits based on average historical earnings b and the contribution-paid period I_P.

The NP benefit function is

$$tr_{NP,t}\left(i\right) = \mathbf{1}_{\{i\geq I_1\}}\, np\, \left(1+\mu\right)^{I_1-i}, \tag{43}$$

where $np = 0.0841$ is the full amount of NP benefit received annually by households. In the actual Japanese economy, this amount is determined annually by the pension sector.

This model incorporates the Old-Age Pension System for Working Retirees. Therefore, the total public pension benefits function is

$$\begin{aligned} tr_{SS,t}\left(i,b\right) = \mathbf{1}_{\{i\geq I_1\}}\psi_t \Bigg[\, tr_{NP,t}\left(\cdot\right) + \max\Bigg(0, tr_{EP,t}\left(\cdot\right) \\ - \max\left\{0, \frac{1}{2}\left[\, tr_{EP,t}\left(\cdot\right) + y_P - \vartheta_{3max}\,\right]\right\}\Bigg)\Bigg], \end{aligned} \tag{44}$$

which accounts for the adjustments to EPI benefits under the Old-Age Pension System for Working Retirees. Here, $y_P = \min\left\{w_t eh - \frac{1}{2}\left[\,\tau_{H,t}\left(\cdot\right) + \tau_{P,t}\left(\cdot\right)\right], \vartheta_{1max}\right\}$ is a simplified function to calculate the household's standard remuneration used in the EPI. $\vartheta_{3max} = 0.6485$ is the annual threshold for the adjustment and suspension of EPI benefits under the Old-Age Pension System for Working Retirees. Due to a revision in the Old-Age Pension System for Working Retirees, the 2024 threshold of 500,000 yen per month is used instead of the 2022 threshold of 470,000 yen per month.

Under this system, if the sum of $tr_{EP,t}(\cdot)$ and y_P exceeds ϑ_{3max}, 50% of the excess amount is suspended from the EPI benefit. If the sum is sufficiently large, the EPI benefit would be fully withheld temporarily. For simplicity, this study assumes that the pension sector maintains a balanced budget in each period. Since the EPI contribution rate and the calculation method for pension benefits are fixed according to actual policies, a balance factor ψ_t is used to proportionately adjust the pension benefits to match the collected contributions, with $\psi_t = 1.0098$ in the baseline economy. ψ_t is fixed at the baseline level in the policy experiments.

The ratio of total pension benefits to GDP is 8.4% in the baseline economy. According to the Ministry of Health, Labour, and Welfare's Overview of the Employees' Pension Insurance and National Pension Programs, total pension benefits paid to public pension recipients at the end of 2022 amounted to 55.7 trillion yen (including mutual aid pensions). Since survivor and disability pensions are not included in the model framework, this study excludes these components when calculating the actual pension benefits-to-GDP ratio. The adjusted amount is 47.9 trillion yen, which corresponds to a pension benefits-to-GDP ratio of 8.5%. Due to the lack of data on survivor and disability mutual aid pensions, their exact amount could not be subtracted. Nevertheless, the model's pension benefits-to-GDP ratio remains quite close to the actual figure.

For health insurance, this study assumes that HI contributions are made from both labor income and pension income. The function of the healthcare insurance contribution is

$$\tau_{H,t}\left(w_t eh, tr_{SS,t}\left(\cdot\right)\right) = \bar{\tau}_{h,t}\, \min\left(w_t eh,\, \vartheta_{4max}\right) + 0.1\, tr_{SS,t}\left(\cdot\right), \tag{45}$$

where $\bar{\tau}_{h,t} = 0.0876$ is the converted HI contribution rate. As in the pension system, $\vartheta_{4max} = 2.6647$ is the converted upper limit of the standard remuneration of the HI system, reflecting the actual upper limit of 22,410,000 yen in 2022. For simplicity, only the upper limit is retained. Similar to the EPI, under the actual system, the upper limit for standard remuneration for the HI in this model includes not only an individual's annual income but also an annual bonus of up to 5,730,000 yen.

For households whose labor income exceeds ϑ_{2max} in the EPI system, their marginal EPI contribution rate becomes 0; therefore, $\bar{\tau}_{h,t}$ is adjusted to 0.0952 accordingly. For working households aged 70 or older, since they are no longer required to pay EPI contributions, $\bar{\tau}_{h,t}$ is adjusted to 0.0952, and ϑ_{4max} is adjusted to 2.5431 accordingly. Pension income is not subject to EPI contributions, nor does it involve employer co-contribution. Therefore, the HI contribution rate applied to pension income does not need to be converted in this model. In reality, individuals aged 75 or older are covered under the Elderly Person's Medical Program, and health insurance contributions are paid on an individual basis, without employer co-contribution. However, for simplicity, the model assumes that even for households aged 75 or older, HI contributions arising from labor income continue to follow the employer co-contribution structure.

Since this study does not consider state variables representing the health status of households, it assumes that the government collects HI contributions to fund general government expenditures. In the baseline scenario, the government's net worth $W_{G,t}$ is set to zero, meaning that $C_{G,t} = T_{C,t} + T_{I,t} + T_{H,t} - TR_{LS,t}$. In the policy experiments, government consumption $C_{G,t}$ is fixed at the baseline level, and the government adjusts the consumption tax rate $\tau_{c,t}$ to achieve budget balance, where $W_{G,t} = W_{G,t+1}$.

4 Policy Experiments

This study analyzes the effects of three pension reform proposals, focusing on their impacts on the macroeconomy, long-run economic growth, and welfare. Particular attention is given to how these policies alleviate the contribution burden on younger generations. The first policy involves cutting public pension benefits proportionately by 20% while reducing pension contribution levels for working households to maintain the financial balance of the pension system. The second policy proposes gradually raising the pension eligibility age from 65 to 70, which reduces total pension payments for elderly households, and lowers pension contribution levels for working households to keep the system balanced. Considering that the Old-Age Pension System for Working Retirees may reduce work incentives for elderly households, the third policy experiment examines the effects of removing pension payment adjustments and suspensions in this system.

The economy is at a baseline steady-state equilibrium in period $t = 0$. At the beginning of period $t = 1$, the government announces a permanent new policy, triggering adjustments in the economy that ultimately lead to a new steady-state equilibrium.

4.1 Cutting Public Pension Benefits Proportionately by 20%

Section 4.1 analyzes the effects of a policy that cuts public pension benefits proportionately by 20%. Considering both the sustainability of the pension system and the financial burden on households, this study assumes a reform approach that controls pension benefit levels rather than relying on the traditional method of increasing the contribution burden on younger households. In the policy experiment outlined in this section, the pensionable age remains unchanged, meaning that the NP benefit is treated as a fixed amount. To implement the 20% reduction in the model, the NP benefit is multiplied by an adjustment factor of 80%. For the EPI, the policy is applied by adjusting the benefit multiplier κ in the pension calculation formula with the same factor of 80%. Since the pension system in this model operates with an independent budget, reduced expenditures allow the government to lower the public pension contribution rate. This, in turn, affects macroeconomic indicators, requiring the government to adjust tax rates to maintain a balanced general budget.

The policy is scheduled to be implemented in period $t = 1$. However, an immediate 20% reduction in public pension benefits would be too unfair to households that are already elderly in period $t = 1$. Therefore, households aged 60 and older ($i \geq 41$) in period $t = 1$ are not affected by the policy. Adjustment for future elderly households are applied gradually over 40 years, ultimately achieving a 20% reduction across all generations.

To implement the policy in the model, two parameters, $\psi_{tr,t}$ and $\psi_{p,t}$, are introduced. $\psi_{tr,t}$ is the adjustment factor for reducing pension benefit amounts, while $\psi_{p,t}$ is the adjustment factor for reducing the pension contribution rate. Households are assumed to pay pension contributions equal to $\psi_{p,t}$ times the contributions calculated based on their labor income to ensure the pension sector's budget remains balanced.

Because the 20% reduction is phased in over 40 years, $\psi_{tr,t}$ is not a fixed value during this adjustment period. In the baseline economy, $\psi_{tr,0} = 1$, but from period $t = 1$ onward, it is adjusted based on the entry time of households into the model. Similarly, $\psi_{p,t}$ is adjusted dynamically to reflect the pension sector's budgetary condition. To maintain a balanced general budget, the consumption tax rate $\tau_{c,t}$ is adjusted as necessary. The adjustment factor $\psi_{tr,t}$ during this process is determined by the following equation:

$$\psi_{tr,t}\left(i\right) = \mathbf{1}_{\{i<t\}}0.8 + \mathbf{1}_{\{t\leq i<40+t\}} \times \left\{0.8 + (i-t)\frac{0.2}{40}\right\} + \mathbf{1}_{\{i\geq 40+t\}}1. \tag{46}$$

The adjustment of the pension contribution reduction parameter $\psi_{p,t}$ is determined by the following equation:

$$\psi_{p,t} = \frac{TR_{SS,t}\left(\psi_t, \psi_{tr,t}\right)}{T_{P,t}}, \tag{47}$$

where $TR_{SS,t}(\cdot)$ is the total public pension benefits distributed to all elderly generations in each period, which has already been adjusted by ψ_t and $\psi_{tr,t}$. $T_{P,t}$ is the total pension contributions that can originally be collected from working households before any adjustments, serving as the financial resource for the pension system.

The adjustment of the consumption tax rate is determined by the following equation:

$$\tau_{c,t} = \frac{1}{C_{P,t}} \left(C_{G,t} - T_{I,t} + TR_{LS,t} - T_{H,t} \right), \tag{48}$$

where $C_{P,t}$ is the private consumption. In this model, the effects of health status and health insurance on household utility are disregarded; therefore, it is assumed that the health insurance contributions are fully spent by the government within the same period they are collected.

4.1.1 Life-Cycle Effects in the Long Run

Figure 4 shows the long-run effects of cutting public pension benefits proportionately by 20% over the life cycle of households, displayed as age-specific averages. The solid black line represents the baseline equilibrium in period 0, while the dashed red line represents the new steady-state equilibrium after the policy change. The noticeable dip in the working hours, EPI contributions, and labor income tax curves between age 65 and 69 is attributed to the Old-Age Pension System for Working Retirees. Under this system, pension recipients adjust their working hours downward to reduce their labor income and thereby avoid reductions in their pension benefits. After reaching age 70, households no longer need to pay EPI contributions, causing the EPI contributions curve to drop to 0. Meanwhile, the working hours and labor income tax curves rebound.

Private wealth, particularly that of households aged 40 and older, would increase significantly after the policy change. This is because households anticipate reduced future pension benefits and adjust their behavior by increasing savings to compensate. To facilitate greater savings, working hours of households aged 40 and older would also increase slightly. The increase in private wealth is larger than the increase in labor supply, leading to a higher wage rate and lower interest rate after the policy change.

As a result, labor income and labor income tax payments would increase across working households. The EPI contributions paid by households would decrease by approximately 20% until they reach pensionable age ($i = 46$). In Japan's policy framework, social insurance contributions are deductible when calculating labor income taxes. After the policy change, the reduction in pension contributions would lead to higher labor income tax payments for households up to age 70, explaining the significant increase

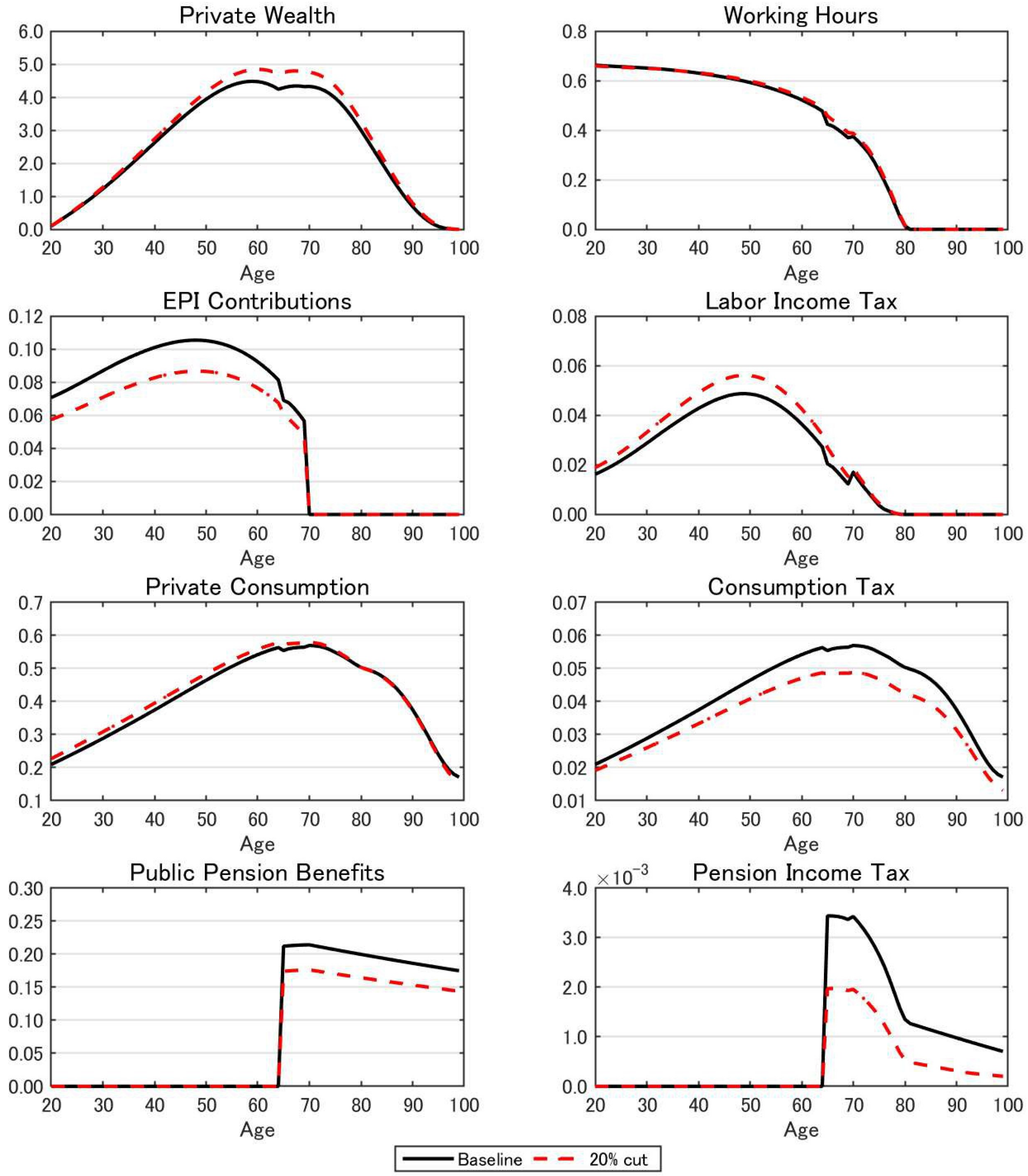

Figure 4: Life-Cycle Effects of Cutting Public Pension Benefits by 20%

in their labor income tax payments relative to the change in working hours.

Higher income tax payments would boost government revenue. To maintain a balanced budget, the government would lower the consumption tax rate, leading to reduced consumption tax payments across all generations. Private consumption among working households would increase slightly, while consumption among households in their 90s would decrease slightly after the policy change. This difference arises from the reduction in EPI contributions, which decreases the disposable income of older

Table 2: Transition Effects of Cutting Pension Benefits by 20% (%ch. from the baseline economy)

Year	1	6	11	21	51	101	151	Long run
Capital Stock	0.0	0.1	0.3	0.9	4.4	7.4	7.4	7.4
Labor Supply	0.0	0.0	0.1	0.3	1.0	0.9	0.9	0.9
Gross Domestic Product	0.0	0.1	0.2	0.6	2.4	3.6	3.6	3.6
Private Consumption	-0.1	-0.1	-0.1	0.1	1.7	3.3	3.3	3.3
Interest Rate[a]	0.0	-0.0	-0.0	-0.0	-0.2	-0.4	-0.4	-0.4
Wage Rate	-0.0	0.0	0.1	0.3	1.4	2.6	2.6	2.6
Consumption Tax Rate[a]	-0.0	-0.0	-0.1	-0.2	-1.1	-1.6	-1.6	-1.6
EPI Contribution Adjustment Factor	-0.0	-0.1	-0.5	-3.0	-17.2	-20.4	-20.2	-20.2
Welfare of Age 20 Households	-0.2	0.2	0.7	1.8	5.1	5.9	5.9	5.9

[a] Changes in percentage points from the baseline economy.

households while boosting the disposable income of households up to age 70. With higher disposable income and a lower consumption tax rate, these households would allocate more of their income to current consumption.

Pension income tax payments would decrease among eligible households due to the 20% reduction in pension benefits. Additionally, pension income tax payments would decrease with age, with the rate of decrease slowing around age 80. In this model, when households earn both pension and labor income, the basic exemption is applied to labor income first, with any remaining portion allocated to pension income. As households age and earn less labor income, a larger portion of the basic exemption would be allocated to pension income, resulting in a further reduction in pension income taxes.

4.1.2 Macroeconomic Effects in the Transition Path

In this study, a sufficiently long period of 200 years is used to capture the adjustment process as the economy transitions towards a new steady-state equilibrium following the policy change. The results of this transition process are summarized in Table 2 and Figure 5. Year $t = 0$ is the baseline economy before the policy change, while year $t = 201$ is the new steady-state equilibrium. As shown in Table 2 and Figure 5, by year $t = 151$, all variables have effectively converged to their new steady-state equilibrium values.

Cutting public pension benefits by 20% prompts households to increase their savings in preparation for retirement, resulting in an increase in capital stock compared to the baseline level. Capital stock would increase by 0.3% in year $t = 11$ and by 7.4% in the long run.

Labor supply would increase by 0.1% in year $t = 11$ and by 0.9% in the long run. GDP would increase by 0.2% in year $t = 11$ and by 3.6% in the long run. Initially, consumption would decrease by 0.1% in year $t = 11$, as households, anticipating reduced future public pension benefits, would prioritize

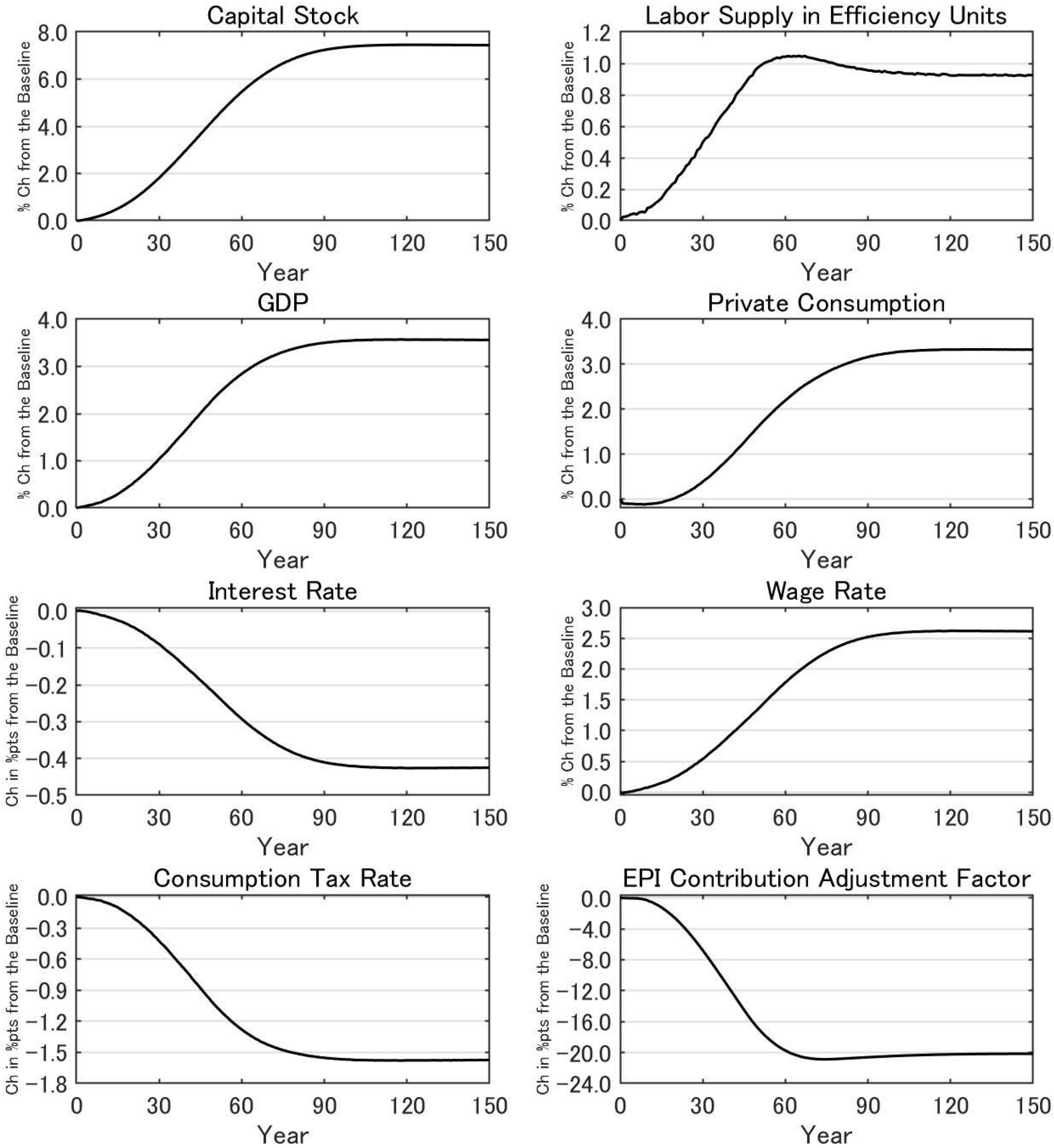

Figure 5: Transition Effects of Cutting Pension Benefits by 20% ($\%$ch. from the baseline economy)

savings over immediate consumption to prepare for retirement. However, in the long run, consumption would increase by 3.3%.

Except for the first few years, the growth in capital stock would consistently exceed the growth in labor supply throughout the transition process. As a result, the interest rate would decrease slightly in the short run, and by 0.4 percentage points in the long run. The decrease in the interest rate would lead to lower returns on household savings, which would, in turn, increase current consumption. Additionally, the wage rate would increase by 0.1% in year $t = 11$, and by 2.6% in the long run, which would, in turn, increase labor supply.

The policy change would result in enhanced economic activity, leading to a 0.1 percentage points decrease in the consumption tax rate in year $t = 11$ and a 1.6 percentage points decrease in the long run. The EPI contribution adjustment factor ψ_p, initially set to 1.0 in the baseline, would decrease by 20.2% after the policy change. This reduction indicates that, in the model economy, the policy would successfully alleviate the burden of public pension contributions on working households. The results of this policy experiment, which take the opposite adjustment approach to the actual policy changes that increased pension contribution rates, suggest that in the context of a declining birth rate and aging population, maintaining contribution rates while reducing pension benefits may be a more desirable approach than raising contribution rates to sustain benefit levels. This is because lower contribution rates and lower benefit levels could provide a more positive stimulus to the economy. Furthermore, this implies that if the pension reforms implemented between 2004 and 2017 had set the target contribution rate below 18.3% and adopted a lower replacement rate, the economy might have been more prosperous today.

4.1.3 The Impact on Welfare

In this study, the veil of ignorance measure is used to calculate consumption equivalence. As shown in Table 2, the welfare of newborn households would decline by the equivalent of a 0.2% decrease in the baseline consumption path in year $t = 1$, but improve by the equivalent of a 5.9% increase in the long run.

Figure 6 shows the consumption equivalence of welfare changes by age, capturing the changes in households' lifetime expected utility. The vertical axis is the consumption equivalence rate, while the horizontal axis is the age of households at the time of policy change ($t = 1$). The vertical line marks households aged 20 in year $t = 1$. The area to the left of the line corresponds to households existing in the economy at year $t = 1$, while the area to the right corresponds to newborn households entering the economy after the policy is implemented. Consequently, the right part of the horizontal axis contains negative values, corresponding to the current age of these future newborn households in period $t = 1$.

The policy applies to households aged 59 and below in year $t = 1$. Older households would benefit slightly from higher wage rates and lower consumption tax rates, while households aged 60 to 69 would also see their financial situation improve due to reduced pension contributions. As a result, welfare changes for households aged 60 and above would be negligible, ranging from 0.01% to 0.16%, as shown in Figure 6.

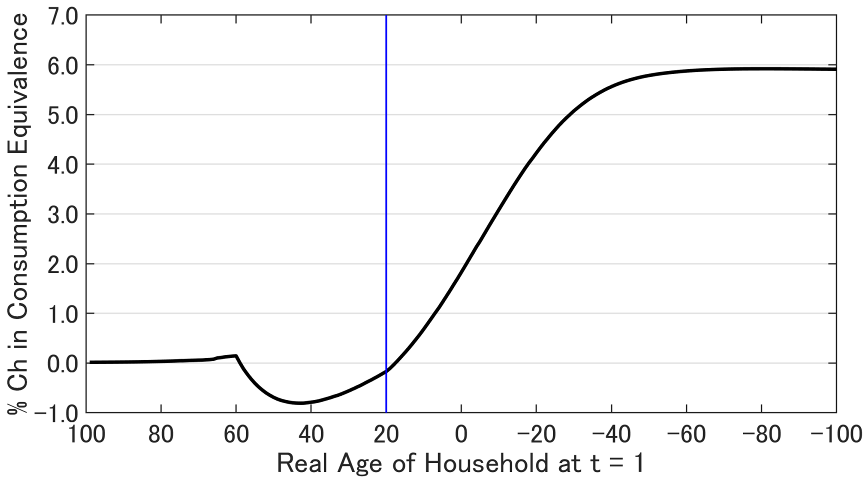

Figure 6: Welfare Effects of Cutting Pension Benefits by 20% ($\%$ch. in consumption equivalence)

Households aged 18 to 58 in year $t = 1$ would bear the negative impact of the policy change. These households face reduced future benefits despite having paid more into the system with a relatively high EPI contribution rate, resulting in a decline in their lifetime expected utility. Future households born into the economy after the policy change, however, would experience welfare gains. In the long run, newborn households would be better off by 5.9%, as measured by consumption equivalence. In summary, while the policy negatively impacts the welfare of current households in the short run, it yields significant long-run benefits. From a welfare perspective, the results suggest that an economy with both lower contribution rates and lower pension benefits may achieve a higher level of social welfare than an economy with higher contribution rates and higher benefits. In other words, an economy that maintains contribution rates while reducing benefit levels may attain a higher welfare level than one that sustains benefit levels by increasing contribution rates.

4.2 Raising the Pension Eligibility Age by Five Years

As Japan's birthrate continues to decline, labor shortages and imbalances in the public pension system are expected to intensify, posing a threat to the sustainability of social security. Raising the pension eligibility age offers a direct policy solution to these challenges. In fact, the Japanese government has already begun taking steps in this direction, including initiatives to promote employment for individuals up to age 70.

Currently, Japan is transitioning the pension eligibility age from 60 to 65, with the age set to reach 65 for men by 2025 and for women by 2030. In the baseline economy, this study assumes age 65 as the pension eligibility age. This section examines the potential economic impacts of gradually raising the eligibility age to 70, focusing on labor supply, economic growth, and social welfare.

This model incorporates the Old-Age Pension System for Working Retirees, which introduces two key age thresholds. The first is the pension eligibility age, which is set at $I_1 = 46$ in the baseline, corresponding to age 65 in reality. The second is $I_2 = 51$, equivalent to age 70, when elderly households who continue working are no longer required to pay public pension contributions. Based on these assumptions, the policy experiment explores a gradual increase in the public pension eligibility age by age cohort. To maintain consistency with the first policy experiment, the eligibility age for households aged 60 and above in year $t = 1$ remains unchanged. For households aged 57–59, the eligibility age is set at $i = 47$ (corresponding to age 66 in reality). For households aged 54–56, the eligibility age is set at $i = 48$ (corresponding to age 67 in reality). For households aged 51–53, the eligibility age is set at $i = 49$ (corresponding to age 68 in reality). For households aged 48–50, the eligibility age is set at $i = 50$ (corresponding to age 69 in reality). For households aged 47 and younger, along with future generations, the eligibility age is set at $i = 51$ (corresponding to age 70 in reality).

The second threshold $I_2 = 51$ remains fixed throughout the policy adjustment. Once the pension eligibility age adjustments are fully implemented, the Old-Age Pension System for Working Retirees will naturally phase out for households aged 65 to 69. However, for households aged 70 and above, the system will still apply in cases where the combined total of pension and labor income exceeds ϑ_{3max}.

During the adjustment process, the pension eligibility age I_1, which varies across different age cohorts, is defined as follow:

$$\begin{aligned} I_1 = \mathbf{1}_{\{i \le t+27\}} 51 + \mathbf{1}_{\{t+28 \le i \le t+30\}} 50 + \mathbf{1}_{\{t+31 \le i \le t+33\}} 49 + \mathbf{1}_{\{t+34 \le i \le t+36\}} 48 \\ + \mathbf{1}_{\{t+37 \le i \le t+39\}} 47 + \mathbf{1}_{\{i \ge t+40\}} 46. \end{aligned} \tag{49}$$

In the baseline economy, the NP benefit is assumed to reflect the full amount for a contribution-paid period of 40 years. However, as the pension eligibility age is raised under the policy experiment, the contribution-paid period should also be extended. To simplify the analysis, this policy experiment assumes that the NP contribution-paid period is lengthened proportionally as the eligibility age increases, leading to a corresponding rise in the NP benefit. The updated formula for calculating the NP benefit is

$$tr_{NP,t}(i) = np \frac{I_1 - 6}{40} (1 + \mu)^{I_1 - i}, \tag{50}$$

where np is the full amount of NP benefit in the baseline economy.

As in the previous policy experiment, the fiscal balance of the pension sector is maintained by adjusting the scaling factor $\psi_{p,t}$ applied to public pension contributions, ensuring the pension system's

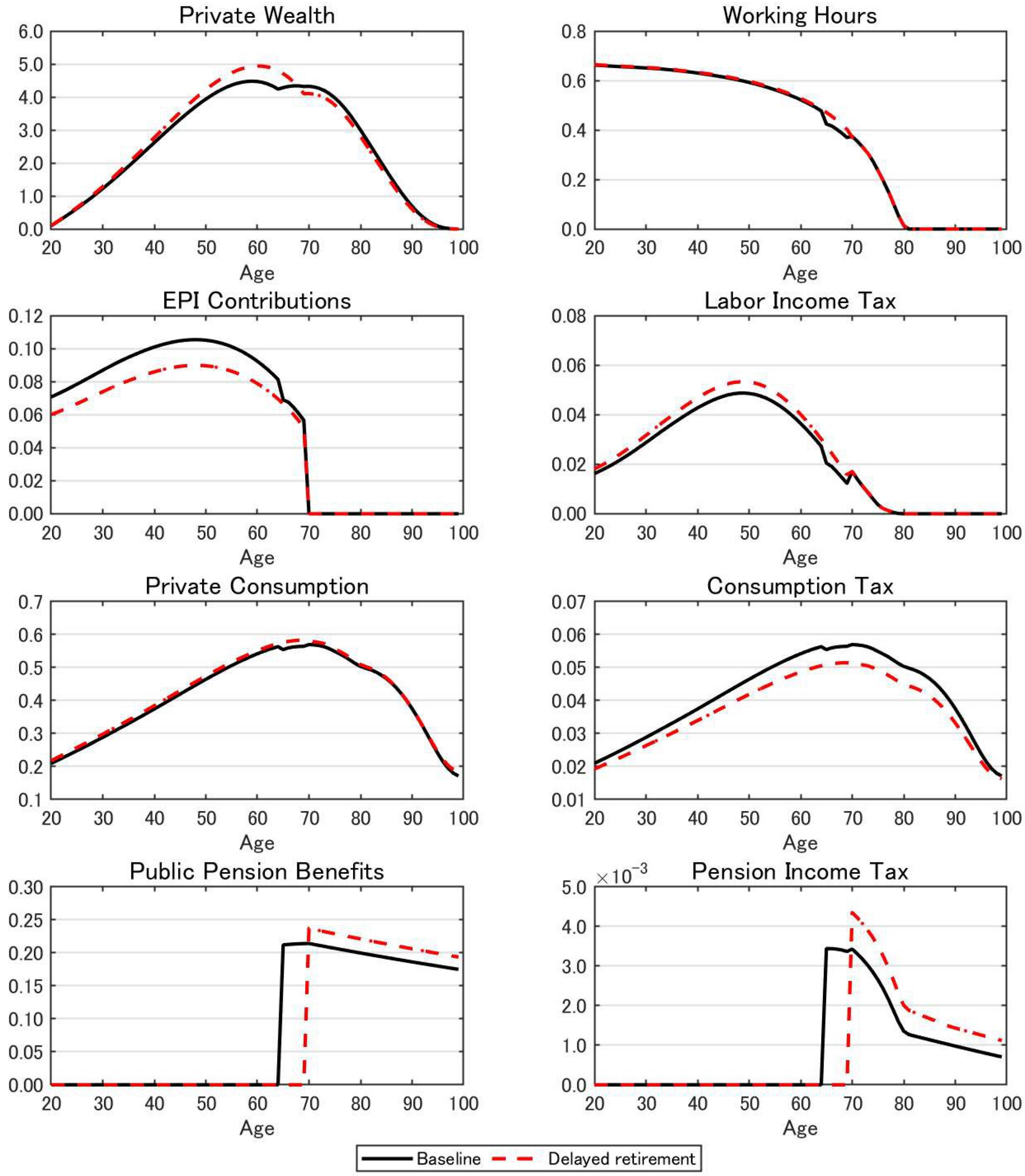

Figure 7: Life-Cycle Effects of Raising Public Pension Eligibility Age by Five Years

financial stability during the transition process. The general government budget is balanced by adjusting the consumption tax rate $\tau_{c,t}$.

4.2.1 Life-Cycle Effects in the Long Run

Figure 7 shows the long-run effects of raising the pension eligibility age from 65 to 70 over the life cycle of households, displayed as age-specific averages. The shift in pension eligibility age is evident

Table 3: Transition Effects of Raising Eligibility Age by Five Years (%ch. from the baseline economy)

Year	1	6	11	21	51	101	151	Long run
Capital Stock	0.0	0.3	0.7	1.8	3.8	3.8	3.8	3.8
Labor Supply	0.0	-0.0	0.6	1.0	0.9	0.9	0.9	0.9
Gross Domestic Product	0.0	0.1	0.7	1.4	2.1	2.1	2.1	2.1
Private Consumption	-0.4	-0.3	0.2	1.0	2.1	2.2	2.2	2.2
Interest Rate[a]	0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.2	-0.2
Wage Rate	-0.0	0.1	0.0	0.3	1.2	1.2	1.2	1.2
Consumption Tax Rate[a]	0.0	-0.0	-0.4	-0.9	-1.2	-1.2	-1.2	-1.2
EPI Contribution Adjustment Factor	0.0	-0.0	-9.5	-17.2	-16.6	-16.0	-16.0	-16.0
Welfare of Age 20 Households	0.9	1.5	2.0	2.5	2.4	2.4	2.4	2.4

[a] Changes in percentage points from the baseline economy.

from the jump in the public pension benefits curve at age 70. Furthermore, as households stay enrolled in the public pension system for a longer period, their extended contribution-paid periods result in higher average pension benefit amounts.

The private wealth of households up to 70 would increase significantly after the policy change. In this model, households' working ability peaks at age 53 and gradually declines thereafter. Since they cannot receive pension benefits until age 70, households would save during the years when their working ability is relatively high and draw down their assets gradually to maintain their consumption levels.

From the curve of working hours, it can be observed that the distortions caused by the Old-Age Pension System for Working Retirees between ages 65 and 70, which were present in the baseline economy, are no longer evident in the new steady state. With the starting age for pension benefits raised to 70, households aged 65 to 69 would no longer be subject to pension benefit adjustments and suspensions, resulting in their labor supply being unaffected by the system.

The increase in private wealth is larger than the increase in labor supply, leading to a higher wage rate and lower interest rate after the policy change. As a result, labor income and labor income tax payments would increase across working households. Similar to the first policy experiment, raising the pension eligibility age by five years would reduce pension contributions, thereby weakening the deductible effect and leading to higher labor income taxes for households up to age 70.

Higher income tax payments would boost government revenue. To maintain a balanced budget, the government would lower the consumption tax rate, leading to reduced consumption tax payments across all generations. Unlike the first policy experiment, private consumption among households would increase slightly. This is because eligible households receive more pension benefits after this policy change, and thus have less need to save for future consumption. This trend is also evident from the

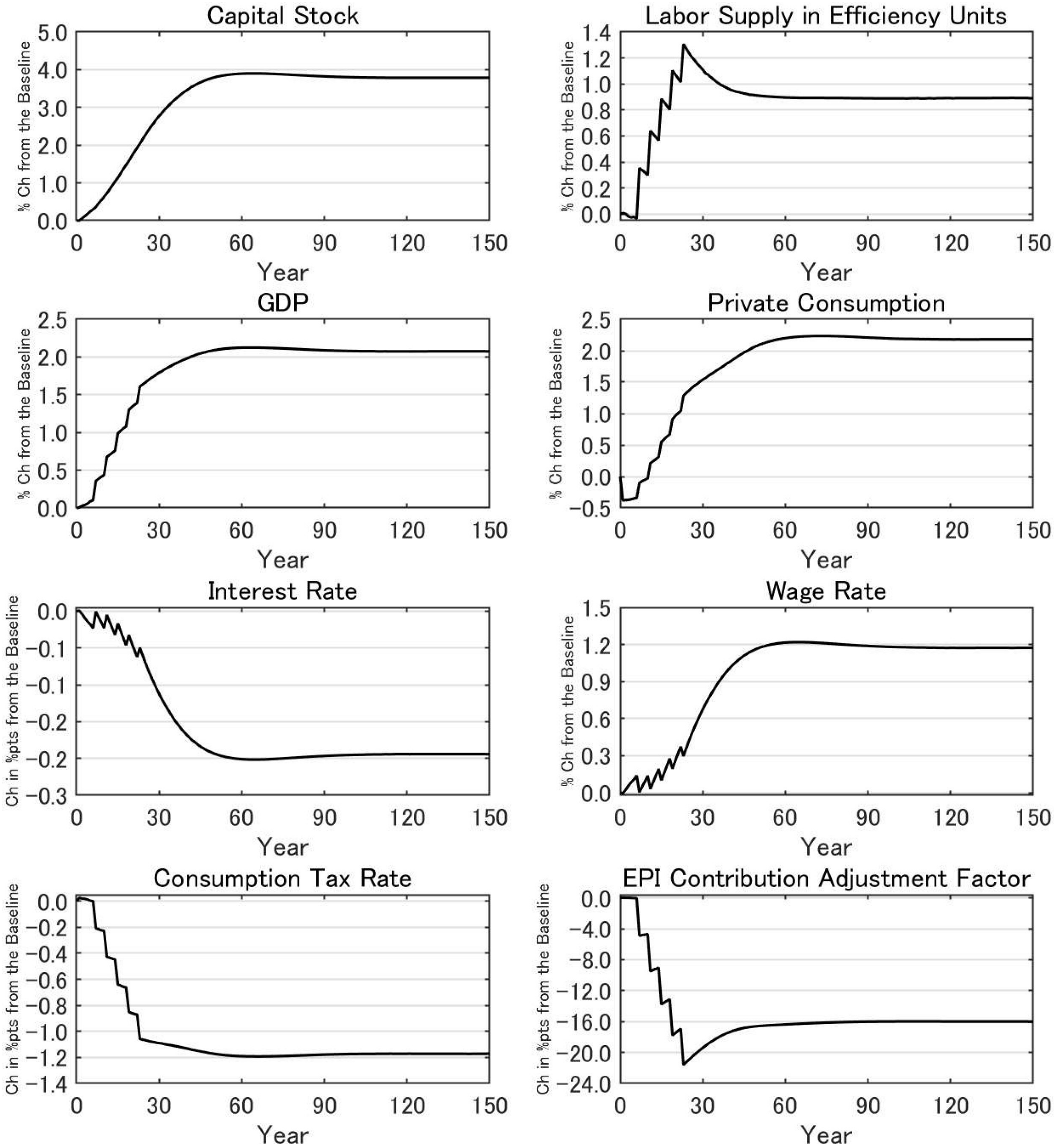

Figure 8: Transition Effects of Raising Eligibility Age by Five Years (%ch. from the baseline economy)

private wealth curve, where the private wealth of households aged 70 and older decreases compared to the baseline. After the policy change, pension income tax payments would be delayed and increase among eligible households, consistent with the policy experiment.

4.2.2 Macroeconomic Effects in the Transition Path

The results are summarized in Figure 8 and Table 3. Since the policy is applied by age cohort, some curves exhibit a step-shaped pattern. The policy of cutting pension benefits proportionately by 20% is

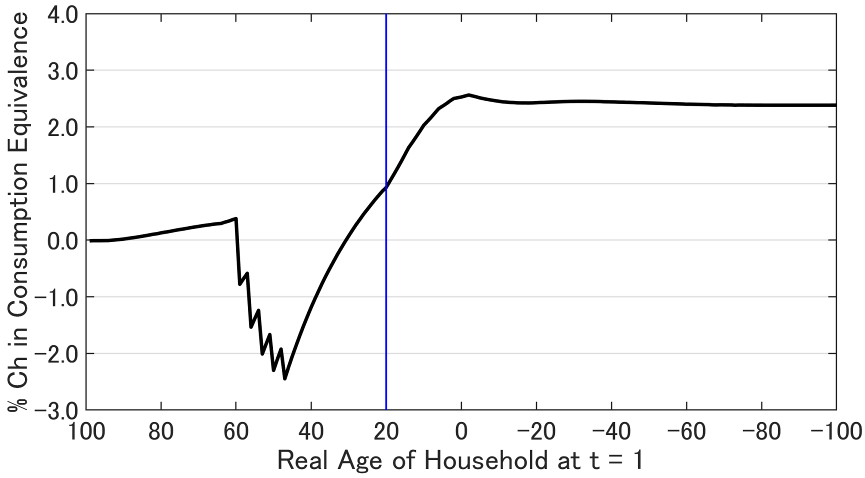

Figure 9: Welfare Effects of Raising Pension Eligibility Age (%ch. in consumption equivalence)

implemented gradually over 40 years. In contrast, the policy experiment raising the eligibility age to 70 follows the same approach as the actual policy in Japan, increasing the age by one year every three years, and completing the transition in approximately 12 years. Therefore, the effects of this policy experiment would appear more quickly than those of the first policy experiment.

Capital stock would increase by 0.7% in year $t = 11$ and by 3.8% in the long run. Labor supply, growing more slowly than capital stock, would increase by 0.6% in year $t = 11$ and by 0.9% in the long run. As the policy takes effect, economic activity would increase, resulting in a GDP increase of 0.7% in year $t = 11$ and 2.1% in the long run.

Immediately after the policy is announced, households would save for the future and reduce their consumption, resulting in private consumption falling below the baseline level. Throughout the transition process, the growth in capital stock would consistently exceed the growth in labor supply. As a result, the interest rate would decrease slightly in year $t = 11$, and decrease by 0.2 percentage points in the long run. The wage rate would increase by 0.1% in year $t = 6$ and by 1.2% in the long run. The consumption tax rate would decrease by 0.4 percentage points in year $t = 11$ and by 1.2 percentage points in the long run. Consumption, which would decrease by 0.3% in year $t = 6$, would increase by 2.2% in the long run.

The EPI contribution adjustment factor would decrease by 9.5% in year $t = 11$, and by 16.0% in the long run. This decrease occurs as the pension eligibility age is raised, resulting in fewer households receiving pensions at the same time, which leads to lower total pension expenditures. The decrease in the adjustment factor would be smaller than in the first policy experiment, partly due to the increase in expenditures on the NP benefit as the contribution-paid period is extended.

4.2.3 The Impact on Welfare

Next, the study examines how raising the pension eligibility age affects welfare. As in the first policy experiment, the veil of ignorance measure is used to calculate consumption equivalence for different age cohorts, and is summarized in Table 3 and Figure 9.

Since this policy experiment does not affect households aged 60 and older in year $t = 1$, Figure 9 clearly shows that the most significant effects are observed in households aged below 60. For households aged 60 and older, the reduction in pension contributions results in a slight improvement in welfare, corresponding to an increase of less than 0.4% in the baseline consumption path. Households in their 90s in year $t = 1$ would be slightly worse off, as they do not live long enough to benefit from the policy's positive effects.

Households aged 31 to 59 in year $t = 1$ would experience the negative effects of the policy. Among them, households aged 47 would experience the greatest decline in welfare, as they are the first cohort to retire at age 70 under the new policy. Future generations, particularly those born later, would show more significant improvements in welfare, with an increase equivalent to a 2.4% rise in the baseline consumption path in the long run. Overall, although the impact is smaller than that of the first policy experiment, this policy can be considered beneficial for enhancing welfare.

4.3 Removing Pension Adjustments and Suspensions

In previous policy experiments, the baseline economy assumes the existence of the Old-Age Pension System for Working Retirees. This unique system allows elderly households to receive pension benefits while continuing to work. However, if the combined total of labor income and pension benefits exceeds a certain threshold, monthly pension benefits may be reduced or even suspended entirely.

When Japan's public pension system was first established, the Old-Age Pension System for Working Retirees did not exist. The public pension system aimed to provide income security for elderly individuals who could no longer work. Therefore, it was considered logical that those who could still earn labor income were not eligible to receive pensions.

However, with the introduction of the system, elderly households gained the option to receive a portion of their pension benefits while continuing to work, providing them with greater flexibility in their labor supply decisions. Today, as more elderly individuals continue to work after reaching the pension eligibility age, concerns have emerged that the system may unintentionally discourage their willingness to supply labor. This study aims to investigate the effects of the Old-Age Pension System for Working Retirees on elderly labor supply, macroeconomic variables, and overall welfare.

Under the current system, elderly households that continue to work while receiving public old-age employee pensions must remain enrolled in the pension system if they are employed at an applicable place of business. Their pension benefits are subject to periodically scheduled updates, meaning that their monthly pension payable is recalculated each year based on their contribution-paid periods and average historical earnings.

In this study, based on the historical context of the introduction of the Old-Age Pension System for Working Retirees, the system is defined as a combination of providing public pension benefits to working elderly households and adjusting the amount of benefits they receive. In the third policy experiment, this study considers the partial abolition of the Old-Age Pension System for Working Retirees. A full abolition in this study would mean that working elderly households no longer receive any pension benefit while earning labor income, which could create a sense of unfairness. Therefore, this study focuses specifically on the removal of benefit adjustments and suspensions to examine its impact on the economy and overall welfare.

To simulate the removal of benefit adjustments and suspensions under the Old-Age Pension System for Working Retirees, the formula for calculating employee pension benefits in the model is modified as follows:

$$tr_{SS,t}(i,b) = \mathbf{1}_{\{i \geq I_1\}} \psi_t \left[\kappa \, b \, I_P \, (1+\mu)^{I_1 - i} + tr_{NP,t}(\cdot) \right], \tag{51}$$

where $\kappa = 0.005481$ is the benefit multiplier, and I_P is the contribution-paid period.

After the policy change, households begin receiving public pensions at age 65 while being able to continue working without any reduction or suspension of their pension benefits. They remain enrolled in the public pension system until age 70, during which time they are required to pay pension contributions, and their pension benefits are periodically recalculated based on their contribution-paid periods and average historical earnings. Once households reach the age of 70, they are no longer covered by the public pension system, which means they no longer have to pay pension contributions, and their pension benefits are no longer subject to recalculation.

4.3.1 Life-Cycle Effects in the Long Run

Unlike policy experiments 1 and 2, the impact of this policy on the macroeconomy is relatively small. To facilitate comparison, Figure 10 illustrates the curve showing the difference between the steady-state equilibrium after implementation and the baseline. It is evident that households aged 65 and older are

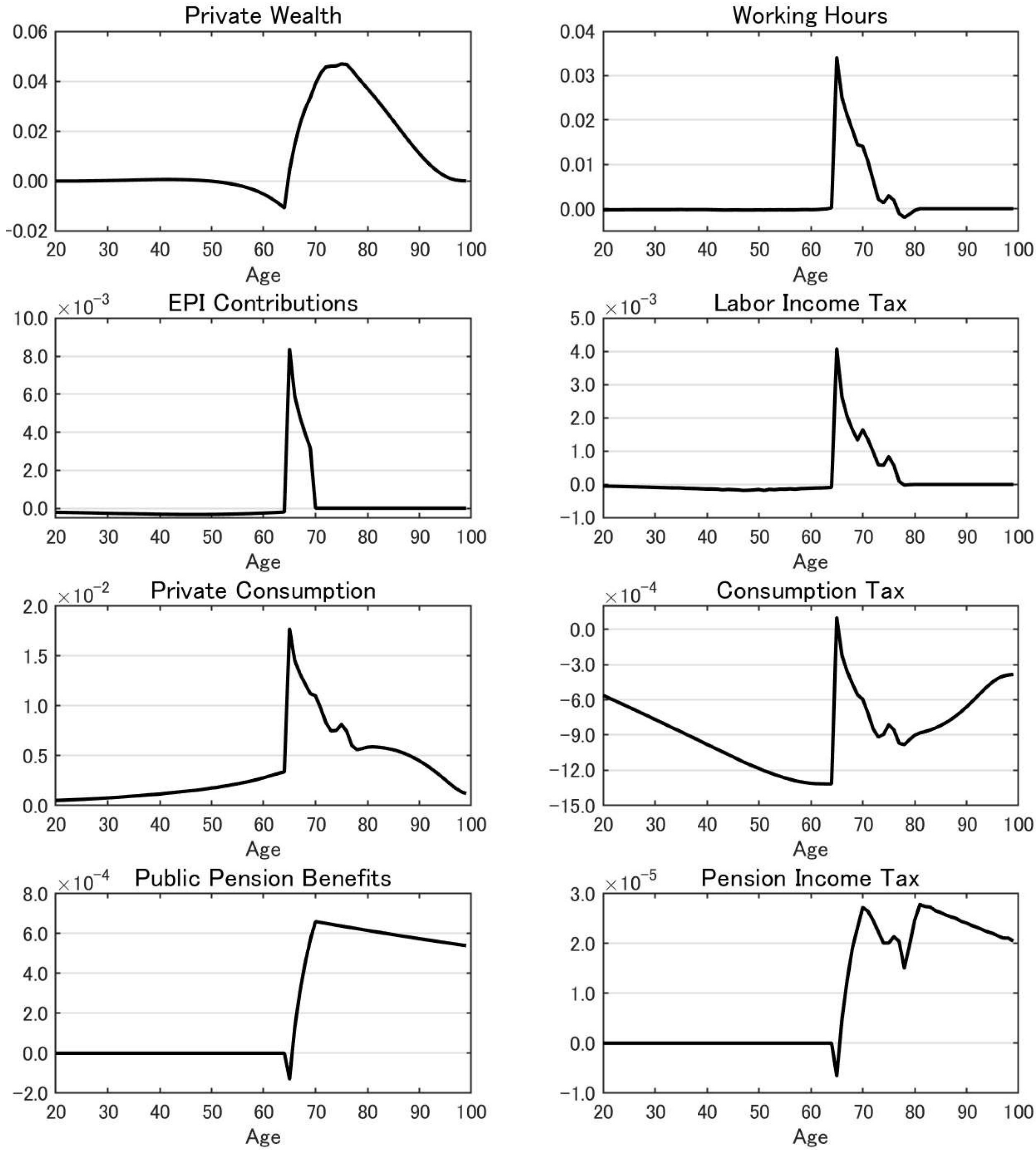

Figure 10: Life-Cycle Effects of Removing Pension Adjustments

more responsive to this policy experiment, indicating that these households are the most affected by the pension adjustments and suspensions under the Old-Age Pension System for Working Retirees. This is particularly true for households aged 65 to 69, as working during this period not only does not reduce their pension income but also results in updates to their future pension benefits, because their average historical earnings and pension contribution-paid periods are updated until the age of 70. Therefore, these elderly households are more willing to work and are consequently more significantly affected.

Private wealth, particularly that of households aged 65 and older, would increase after the policy

Table 4: Transition Effects of Removing Pension Adjustments (%ch. from the baseline economy)

Year	1	6	11	21	51	101	151	Long run
Capital Stock	0.00	-0.09	-0.09	0.12	0.29	0.33	0.33	0.32
Labor Supply	-0.03	-0.01	0.47	0.67	0.68	0.67	0.67	0.67
Gross Domestic Product	-0.02	-0.04	0.24	0.44	0.52	0.53	0.53	0.53
Private Consumption	0.09	0.10	0.38	0.66	0.83	0.85	0.85	0.84
Interest Rate[a]	-0.00	0.01	0.04	0.04	0.03	0.02	0.02	0.02
Wage Rate	0.01	-0.03	-0.23	-0.22	-0.16	-0.14	-0.14	-0.15
Consumption Tax Rate[a]	-0.00	0.01	-0.14	-0.25	-0.29	-0.30	-0.30	-0.29
EPI Contribution Adjustment Factor	0.01	0.02	-0.33	-0.20	-0.18	-0.19	-0.19	-0.19
Welfare of Age 20 Households	0.19	0.22	0.25	0.32	0.37	0.38	0.38	0.37

[a] Changes in percentage points from the baseline economy.

change. In contrast, private wealth for households aged 50 to 64 decreases, as their working ability begins to decline in their 50s in this model. Working hours would increase for households between 65 and 76, while decreasing slightly for other working households. These shifts occur because, after the policy change, households eligible for pension benefits can work freely without any reduction or suspension of their pension benefits. As a result, EPI contribution, labor income tax payment, and private consumption would all increase slightly , especially for households aged 65 and older. Economic activity would be revitalized, prompting the government to lower the consumption tax rate to maintain balance, resulting in a decrease in consumption tax payments across households.

Public pension benefits would decrease slightly at age 65 after the policy change because households anticipate that they can work more and earn more without their pension benefits being adjusted once they become eligible. This expectation leads households aged up to 65 to reduce their labor supply. Additionally, as will be explained in the next section, the wage rate would decrease while the interest rate would increase after this policy change. These factors reduce households' average historical earnings at age 65 compared to the baseline, resulting in a decrease in public pension benefits.

Pension income tax payments would increase among eligible households. The presence of the dip can be attributed to higher household pension benefits compared to the baseline, which reduce the incentive to work beyond age 70. As a result, the basic exemption is more heavily allocated to pension income rather than labor income, leading to the observed shift.

In conclusion, the policy of adjusting and suspending pension benefits under the Old-Age Pension System for Working Retirees negatively impacts macroeconomic variables, including household capital stock, effective labor supply, and aggregate consumption, especially for households aged 65 and older.

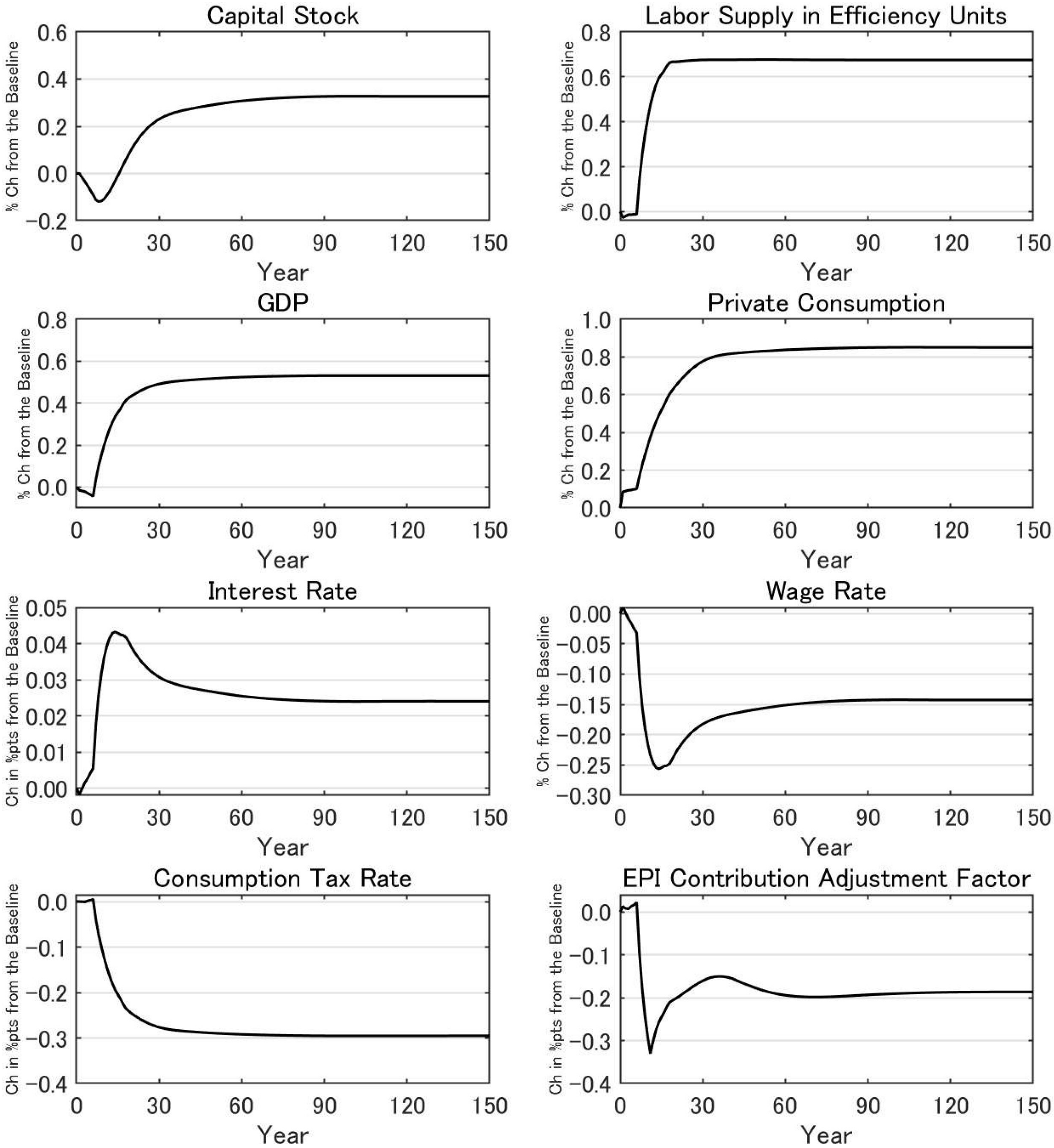

Figure 11: Transition Effects of Removing Pension Adjustments (%ch. from the baseline economy)

4.3.2 Macroeconomic Effects in the Transition Path

The results are summarized in Table 4 and Figure 11. In this policy experiment, the adjustments and suspensions of EPI benefits are assumed to be removed for households aged 59 or younger in year $t = 1$. This means that households aged 60 and older in year $t = 1$ would still face the possibility of their EPI benefits being reduced or suspended while working. Upon the policy announcement in year $t = 1$, households aged up to 60 anticipate that their pension benefits will no longer be reduced or suspended, even if they work more after turning 65. This expectation influences households' labor decisions and

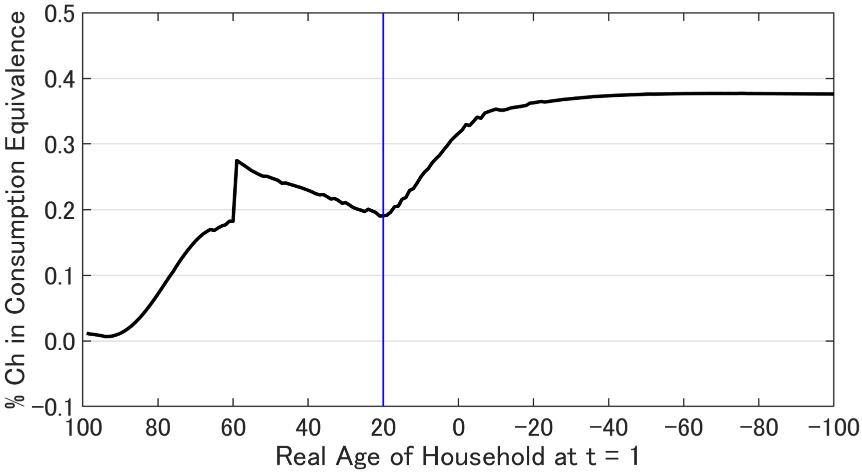

Figure 12: Welfare Effects of Removing Pension Adjustments (%ch. in consumption equivalence)

saving behavior. Households would reduce their current savings, leading to a 0.09% decrease in capital stock in year $t = 6$. Additionally, working households would choose to enjoy more leisure time, resulting in a 0.01% decrease in labor supply in year $t = 6$.

In the long run, as the target households reach age 65 and beyond, they would increase their labor supply by 0.67% compared to the baseline economy. In this policy experiment, households exhibit less motivation to save actively. As a result, capital stock would decrease more easily in the short run, and grow less in the long run than labor supply. In the long run, capital stock would increase by 0.32%. Consequently, the wage rate would decrease by 0.03% in year $t = 6$, and by 0.15% in the long run. The interest rate would increase by 0.01 percentage points in year $t = 6$, and by 0.02 percentage points in the long run.

Economic activity would increase over time. In year $t = 6$, the GDP would initially decrease by 0.04%, and increase by 0.53% in the long run. Influenced by the prospect of higher incomes in retirement, households would prioritize current consumption over savings, leading to a 0.10% increase in consumption in year $t = 6$ and a 0.84% increase in the long run.

The EPI contribution adjustment factor, $\psi_{p,t}$, would increase by 0.02% in year $t = 6$ but decrease by 0.19% in the long run. With restrictions removed, households work more and contribute more to pensions, reducing the burden on the pension sector. The consumption tax rate, which would increase slightly by 0.01 percentage points in year $t = 6$, would decrease by 0.29 percentage points in the long run.

4.3.3 The Impact on Welfare

The effects of removing pension adjustments and suspensions under the Old-Age Pension System for Working Retirees are significantly smaller than those of the previous two policies, with minimal impact on welfare. Since the policy targets households aged 59 and younger in year $t = 1$, as well as those entering the economy in the future, the welfare effects are most pronounced for the 59-year-old households in year $t = 1$, as shown in Figure 12.

For households aged 60 and older in year $t = 1$, a slight reduction in the consumption tax rate would lead to modest increases in their consumption and minor improvements in welfare. Furthermore, as indicated in the last row of Table 4, the welfare of newborn households in the economy would improve due to the policy experiment, corresponding to a long-run increase equivalent to 0.37% of the baseline consumption path. Overall, although the impact is minimal, this policy can be considered beneficial for enhancing welfare and benefits the largest number of households among the three policy experiments.

5 Concluding Remarks

This study extends a large-scale heterogeneous overlapping generations model to analyze the effects of three proposed reforms on labor supply, macroeconomy, and welfare in the Japanese pension system. The model developed in this study is calibrated based on the 2022 Japanese economy, capturing Japan's distinctive and complex income tax and social security systems. This approach not only provides a theoretically sound framework but also highlights the significant quantitative impacts of the proposed reforms, ensuring more reliable simulation results.

The main conclusions of this paper are as follows. In the long run, cutting public pension benefits proportionately by 20% would decrease the EPI contribution adjustment factor by 20.2%, effectively reducing the pension contribution burden on working households. Capital stock would increase by 7.4%, labor supply would increase by 0.9%, the GDP would increase by 3.6%, and private consumption would increase by 3.3%. In terms of welfare effects, households aged 20 would, on average, experience a 5.9% improvement in the consumption equivalence measure. These findings suggest that cutting public pension benefits by 20% could serve as an effective public pension reform plan, if budgetary balance is achieved by reducing the consumption tax rate in response to higher economic activity.

Raising the pension eligibility age by five years would decrease the EPI contribution adjustment factor by 16.0% in the long run. Labor supply would increase by 0.9%, close to the first policy experiment. However, capital stock would increase by 3.8%, almost half that of the first policy experiment. GDP would increase by 2.1%, and private consumption would increase by 2.2% in the long run. In terms of welfare effects, households aged 20 would, on average, experience a 2.4% improvement in the consumption equivalence measure in the long run. While not as impactful as the first policy experiment, raising the pension eligibility age by five years could serve as an effective public pension reform plan, if budgetary balance is maintained through a reduction in the consumption tax rate in response to higher economic activity.

Removing pension adjustments and suspensions under the Old-Age Pension System for Working Retirees is the least effective reform, with the EPI contribution adjustment factor decreasing by only 0.19% in the long run. GDP would increase by 0.53%, and private consumption would increase by 0.84% in the long run. In terms of welfare effects, households aged 20 would experience a modest 0.37% improvement in their welfare in the long run. However, this policy change highlights the role of pension adjustments and suspensions in discouraging elderly labor force participation. After the policy change, labor supply would increase by 0.67% in the long run, with households aged 65 and older being the most positively impacted. While its overall macroeconomic effects are limited, removing pension adjustments and suspensions under the Old-Age Pension System for Working Retirees would be effective in encouraging labor force participation among older households.

In summary, this study examines the effects of three pension reform proposals that ultimately resulted in a reduction in the burden of pension contributions. The policy experiment of reducing public pension benefits by 20% reveals that an economy with lower benefit levels and lower contribution burdens performs better in terms of both welfare and efficiency. Furthermore, the findings suggest that if the pension reforms implemented between 2004 and 2017 had set a lower target contribution rate while adjusting benefit levels accordingly, the economy might have been more prosperous today. For the second policy experiment, while raising the pension eligibility age by five years has a relatively smaller impact on capital accumulation, it effectively promotes labor supply and proves to be a beneficial policy for the economy. The third policy experiment, it shows that removing pension adjustments and suspensions under the Old-Age Pension System for Working Retirees is advisable. Although its effects are small, it has a positive impact on improving welfare and increasing labor supply.

To simplify the computation, this study adopts approximations for the basic exemption, employment income deduction, and pension income deduction. While this simplification introduces minor inaccuracies in labor income tax for low-income households and pension income tax for working elderly households, it ensures stable numerical convergence. Considering that social insurance contributions in Japan are deductible, this study incorporates a simplified version of health insurance in addition to public pension system. However, as the model does not account for the impact of health status on households' decision-making, health insurance primarily functions as a proportional tax in this framework.

This study does not incorporate gender heterogeneity. In Japan, wage disparities between men and women still exist, influencing pension income through differences in average historical earnings. As a result, households of different genders are likely to respond differently to public pension policy reforms. Incorporating marital status into the analysis would make it possible to capture Japan's complex spousal exemptions and the NP benefits for dependent spouses, which were not considered in this study but may significantly affect the results. Introducing gender and marital status, along with a more accurate reflection of deduction details, is left for future research.

While the model developed in this study focuses on the old-age pension system, it could also be applied to analyze the macroeconomic impacts of tax reforms, such as increases in the consumption tax rate. Additionally, the model could examine how the distribution of social insurance contribution rates between employers and employees, the effects of government cash transfers to households during the COVID-19 pandemic, and other policy changes influence the macroeconomy and welfare. If health status were incorporated, the model could be further extended to explore the impacts of health insurance reforms. In summary, expanding the model presented in this paper would enable preliminary evaluations of various fiscal policy measures in Japan, providing valuable insights for policy recommendations.

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