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Fiscal Cost of Demographic Transition in Japan

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Fiscal Cost of Demographic Transition in Japan[1]

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Abstract

This paper quantifies the fiscal cost of the demographic transition that Japan is projected to experience over the next several decades, in a life-cycle model with endogenous saving, consumption, and labor supply in both intensive and extensive margins. Retirement waves of baby-boom generations, combined with a rise in longevity and low fertility rates, will raise the old-age dependency ratio to 85% by 2050, the highest among major developed countries. The demographic shift will generate a significant budget imbalance as the government faces rising costs for public pension and health and long-term care insurance. In the long run, the labor income tax rate needs to rise by 13.5% or the consumption tax rate by 14.3% to balance the budget, assuming no other change in policies. The transition, however, involves more significant adjustments, and we simulate alternative pension reforms that can mitigate fiscal pressures.

Keywords: Social security reform, Demographic transition, Retirement, Public pension program, Health insurance, Long-term care insurance, Japanese economy
JEL classification: E2, E6, H3, J1

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1 Introduction

There is much fear that aging demographics in Japan could stifle the third-largest economy of the world as it faces rising public expenditures and shrinking labor force and tax revenues. This paper quantifies the fiscal cost of demographic transition that Japan is projected to experience over the next several decades and evaluates the impact on the economy under alternative policy scenarios in the short and long-run.

We simulate our model starting with the demographics of 2010 and follow the population dynamics using official projections over the next five decades through 2060. Figure 1 shows the age distribution of the population in 2010, which indicates the waves of retirement that will hit the economy during coming decades. In addition, while fertility rates remain well below the replacement rate, the number of prime-age individuals at 20-64 is expected to fall dramatically, from above 75 millions in 2010 to 30 millions in 2080 as shown in figure 2(a). Figure 2(b) plots the path of projected old-age dependency ratios, defined as the ratio of population aged 65 and over to age 20-64. As the first and second baby-boom generations successively reach the retirement age, the ratio will rise from below 40% to almost 90%.[1]

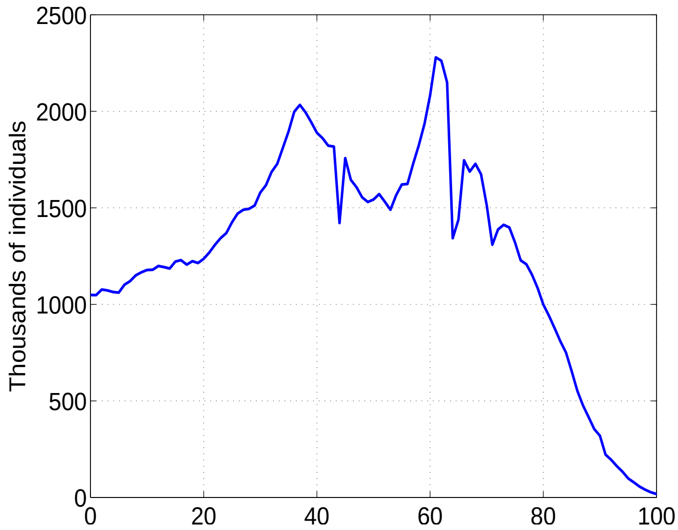
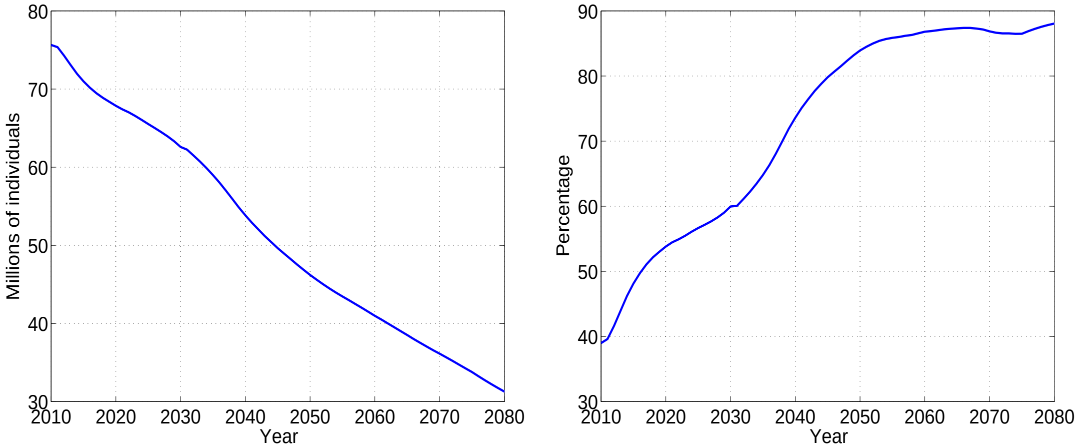


Figure 1: Population by age in 2010

[1]In general, individuals born in 1947-1949 (age 63-65 in 2010) in Japan are called as the first baby-boom generation and those born in 1971-1974 (age 39-42 in 2010) the second baby-boom generation, who are mostly children of the first baby-boomers. There has not been a rise in fertility rates which would give a rise to the third baby-boom.



(a) Population at age 20-64

(b) Old-age dependency ratio: ratio of population aged 65 and above to 20-64.

Figure 2: Demographic projections (IPSS)

After 2060, up to when official demographic projections are available, we assume that fertility rates will start to recover gradually so that growth rate of the number of individuals at age 25 (which is the age to become economically active in our model) will reach 0% by 2150 and that conditional survival probabilities will stay at the projected level of 2060. Although the dependency ratio will rise and stay at a very high level for many years during the transition, it will eventually decline and stabilize at about 53% when the age distribution becomes stationary under our simulation assumptions. Life expectancy will rise from 83.5 in 2010 to 88.0 in the long-run.[2]

As a first exercise, we compute a change in the tax burden imposed on consumption, which is necessary to balance the government budget in the long-run when the demographic transition is complete and there is no change in policies except for the consumption tax rate. We find that consumption tax will have to rise from 5% in 2010 to 19.3% in the long-run. The sizeable adjustment is necessary despite the fact that average earnings of individuals will be significantly higher in the long-run. Individuals choose to work longer in both intensive and extensive margins to cover consumption over a longer expected life-time, which increases revenues from labor income taxes. In addition, people save more for a longer retirement period and earn more capital income as well. Since capital rises by more than labor, wage rate goes up, further increasing individuals' earnings. It is the massive rise in government expenditures on public pensions and health and long-term care insurances that makes the large increase in consumption tax inevitable. The expenditures for pension benefits and health and long-term care insurance will rise

[2]The numbers are the average of male and female. The life expectancy is estimated at 80.1 for male (86.9 for female) in 2010 and 84.7 (91.3) in 2060, according to the National Institute of Population and Social Security Research (IPSS).

from 10.3% and 5.9% of output, respectively, to 13.1% and 8.2% in the long-run.

Financing the demographic change by labor income taxes will be significantly more distortionary. The tax rate has to rise by 13.5%, a similar magnitude to the consumption tax, but labor force participation rates plummet compared to the case of higher consumption taxes, especially for older individuals. Employment rate at age 50-64 is 83% with the consumption tax hike, vs 76% with a rise in labor taxes, and it is 12% vs 5% above age 65. Given the low disposable income when labor income is taxed more heavily, saving will be lower throughout the life-cycle and the aggregate capital will be 26% below the level under higher consumption taxes.

More challenging, however, is the finance of the transition when the economy faces a surge in the old-dependency ratio over the next several decades. Using consumption taxes to balance the budget, the Japanese government would have to raise the tax to an unrealistically high level of 48% at the peak in 2080s. This is the result when we assume that the government would keep all the other fiscal variables unchanged throughout the transition. We consider alternative policy scenarios that would help mitigate the fiscal cost of the demographic transition, including reduction in pension benefits and an increase in the normal retirement age.

The peak tax rate on consumption will decline from 48% to 28%, if benefit schedule is shifted down by 20%, as embedded in the pension reform passed in 2004, and the normal retirement age is raised by five years, gradually over the next fifty years. If benefits are reduced further, by a total of 40%, consumption tax at the peak will be down to 19%. Reforms induce individuals to save much more on their own, replacing the expected transfer from the government at old ages. We interpret our results as indicating that a more explicit shift from publicly financed pay-as-you-go pension system towards private retirement saving can greatly reduce the tax burden, while raising assets that can be used as productive capital inputs and increase output.

Related papers: The paper builds on a literature that investigates fiscal challenges facing Japan as it goes through a rapid demographic transition and rising public expenditures. Hansen and İmrohoroğlu (2013) study the effects of rising government expenditures and transfer payments and use a neoclassical growth model of infinitely-lived agents, in a framework similar to the one developed by Hayashi and Prescott (2002). İmrohoroğlu and Sudo (2011) use a similar model to study the effects of alternative tax policies on the fiscal balance over the next few decades. Doi, Hoshi, and Okimoto (2011) estimate a required increase in tax revenues to achieve fiscal sustainabilities, taking into account projected costs of health and long-term care insurance.

Other studies attempt to quantify the fiscal cost of aging demographics and rising expenditures through dynamic accounting exercises, such as Fukawa and Sato (2009) and İmrohoroğlu, Kitao, and Yamada (2014). They provide useful guidance in evaluating the cost of demographic transition and identifying major factors that influence the government budget. The studies, however, do not fully take into account behavioral responses of individuals to changes in demographics and fiscal variables nor do they predict evolution of factor prices as aggregate variables shift over time.

Ihori et al. (2005) build a life-cycle model with public pension and health insurance programs and quantify the effects of aging demographics and public debt policy. Ihori et al. (2011) study effects of health insurance reform in a similar dynamic general equilibrium model. Yamada (2011) builds an overlapping generation model of heterogeneous households and analyzes effects of Japanese social security reforms. These papers assume exogenous labor supply and both hours and years of work remain unchanged.

Okamoto (2013) builds a life-cycle model with endogenous labor supply in intensive margin and studies welfare effects of social security reforms. Braun and Joines (2014) advance the literature by introducing medical expenditures paid by households and the government in a general equilibrium life-cycle model and simulate transition dynamics under alternative assumptions about public pension and health insurance programs. Both papers assume that labor productivity is deterministic over the life-cycle and that agents leave the labor force at a mandatory retirement age, that is, labor supply is endogenous only in intensive margin.

In this paper, we incorporate transitory and permanent shocks to individuals' wages, that are estimated with micro data and endogenize labor supply in both intensive and extensive margins. Uninsurable wage uncertainty that individuals face over the life-cycle affects precautionary and retirement saving motives and drives dynamics of aggregate capital and factor prices.[3]

Regarding labor force participation, the data show that a large number of individuals work even after the normal retirement age of 65. The literature also finds that the labor supply elasticity tends to be higher among old-age individuals than prime-age workers in both intensive and extensive margins.[4] If a transition involves a large change in taxation, it is important to use a model that explains the pattern of labor supply as in the data and that is able to evaluate elastic responses to changes in demographics, fiscal policy and economic environment. We demonstrate that individuals' labor supply decision, especially in extensive margin, can vary significantly as they experience a rise in longevity and other changes in economic environment.

There are numerous studies that assess the impact of demographic transition and policy options in other countries. Attanasio, Kitao and Violante (2006 and 2007) build a multi-region model of the world focusing on the effects of similar, but unsychronized demographic trends across regions. İmrohoroğlu and Kitao (2009) study the effects of social security reforms in the U.S. with aging demographics and compare results under alternative assumptions on labor supply elasticity. Díaz-Giménez and Díaz-Saavedra (2009) build a model of endogenous labor force participation calibrated to the Spanish economy and simulate a reform to raise the retirement age. İmrohoroğlu and Kitao (2012) simu-

[3]Not only the economic outcomes but also normative evaluation of policy reforms can vary depending on whether a model incorporates wage uncertainty, as shown in papers such as Conesa and Krueger (1999) and Nishiyama and Smetters (2007).

[4]See for example Erosa, Fuster, and Kambourov (2014) and French (2005) for life-cycle estimates of labor supply elasticity.

late social security reforms in the U.S. as it goes through demographic aging in a model with endogenous saving and labor supply in two margins, as well as social security claim decisions, incorporating heterogeneity in health status and medical expenditures. Kitao (2014) explores four policy options to make the social security system self-financed in the U.S. but abstracts from rising fiscal costs of medical insurance programs.

Although almost all developed countries need to deal with similar fiscal issues associated with aging demographics, problems facing Japan are the most severe and challenging and deserve more serious analysis using rigorous economic models. Rising costs of not only the public pension system, but also health and long-term care insurance managed by the government pose a major challenge in public finance. Understanding the consequences of rapid demographic aging and alternative reforms in the Japanese economy will give an insight for policy analysis of other economies as well.

The rest of the paper is organized as follows. Section 2 presents the model and section 3 calibrates parameters of the model. Section 4 presents numerical results and discusses the transition dynamics and long-run effects of the demographic transition and alternative reforms. Section 5 concludes.

2 Model

This section presents the model and describes the definition of the competitive equilibrium.

2.1 Demographics

Individuals enter the economy at age $j = 1$ and live over a stochastic life-time. Individuals of age j at time t survive until the next period $t+1$ with probability $s_{j,t}$. The maximum age is J and $s_{J,t} = 0$ for all t. We assume that assets left by the deceased are distributed as a lump-sum bequest transfer to all surviving individuals, denoted as b_t. The size of a new cohort entering the economy grows at rate n_t.

2.2 Endowments, preferences and medical expenditures

Individuals have a unit of disposable time, which can be allocated to market work or leisure. A working individual earns $y_t = z\eta_j h w_t$, where z denotes idiosyncratic stochastic labor productivity, η_j age-specific deterministic productivity, h hours of work and w_t the market wage rate per efficiency unit at time t.

Individuals derive utility from consumption and leisure, denoted as $u(c,h)$ in each period and maximize the sum of discounted utility expected over the lifetime.

$$E\left\{\sum_{j=1}^{J}\beta^{j-1}u(c_j,h_j)\right\}, \tag{1}$$

where c_j and h_j represent an individual's consumption and labor supply at age j. The expectation is over the distribution of idiosyncratic labor productivity shocks and timing of death and β is the subjective discount factor.

Individuals incur medical expenditures each period, which depend on age and consist of health care and long-term care expenditures, denoted by $m^h_{j,t}$ and $m^l_{j,t}$, respectively. Part of the expenditures are paid by individuals based on age-dependent copay rates $\lambda^h_{j,t}$ and $\lambda^l_{j,t}$ for each insurance program and the rest is covered by the government through public health care and long-term care insurance programs. Total out-of-pocket expenditures of an individual at age j are given as

$$m^o_{j,t} = \lambda^h_{j,t} m^h_{j,t} + \lambda^l_{j,t} m^l_{j,t}. \tag{2}$$

Total national medical expenditures M_t consist of a part paid by the government M^g_t and by individuals M^o_t as out-of-pocket expenses;

$$\begin{aligned} M_t &= M^o_t + M^g_t \\ M^o_t &= \sum_j m^o_{j,t} \mu_{j,t} \\ M^g_t &= \sum_j \left[(1-\lambda^h_{j,t}) m^h_{j,t} + (1-\lambda^l_{j,t}) m^l_{j,t} \right] \mu_{j,t} \end{aligned}$$

where $\mu_{j,t}$ denotes the number of individuals of age j at time t.

2.3 Technology

Firms produce output Y_t using aggregate capital K_t, labor supply L_t and technology Z_t according to a constant returns to scale technology

$$Y_t = Z_t K^\alpha_t L^{1-\alpha}_t. \tag{3}$$

α is capital's share of output and capital depreciates at rate $\delta \in (0, 1)$. The rental prices of capital r^k_t and labor w_t are determined competitively and equated to the marginal product of each factor.

2.4 Government

The government operates a pay-as-you-go public pension system. Once reaching the normal retirement age, denoted as j_R, each individual starts to receive pension benefits $ss_t(e)$, which are determined as a function of an index e that summarizes the individual's average lifetime earnings up to the retirement age. Note that j_R is the age at which individuals start to receive public pensions, but they can continue to work until they choose to leave the labor force or they may stop working before reaching age j_R.

The government also provides medical insurance coverage for health and long-term care. As mentioned above, individuals pay fractions $\lambda^h_{j,t}$ and $\lambda^l_{j,t}$ of health and long-term care expenditures, $m^h_{j,t}$ and $m^l_{j,t}$, as a copay and the rest is covered by the government.

The budget constraint of the government is satisfied every period. Revenues are raised from taxation on earnings at a proportional rate τ^l_t, income from capital rented to firms at τ^k_t, interest rate earned on the government debt at τ^d_t, and consumption at τ^c_t, and newly issued government debt D_{t+1}, which pays riskless interest r^d_t. Expenditures consist of government purchases of goods and services G_t, payment of the principal and the interest on public debt D_t, public pension benefits, and health and long-term care insurance benefits M^g_t. In equilibrium, at least one of the fiscal variables needs to be adjusted to balance the budget every period.

We distinguish between the interest rates that are paid on the government debt and those paid on capital rented to firms, in order to capture the level of interest rate paid by the government which need not be the same as return from private capital and to approximate well the total interest expenses. Our model is not rich enough to endogenize individuals' asset allocation decisions and we follow Braun and Joines (2014) and assume that individuals allocate an exogenous fraction ϕ_t of savings to government debt and a fraction $(1-\phi_t)$ to firms' capital.[5] Therefore after-tax gross return on each unit of individuals' savings net of taxes is given as $R_t = 1 + (1-\tau^k_t)r^k_t(1-\phi_t) + (1-\tau^d_t)r^d_t\phi_t$.

The government budget constraint in each period is given as

$$\begin{aligned} & G_t + (1+r^d_t)D_t + \sum_x ss_t(x)\mu_t(x) + M^g_t \qquad (4) \\ &= \sum_x \left\{\tau^l_t y(x) + [\tau^k_t r^k_t \phi_t + \tau^d_t r^d_t (1-\phi_t)](a_t(x)+b_t) + \tau^c_t c_t(x)\right\} \mu_t(x) + D_{t+1}, \end{aligned}$$

where $\mu_t(x)$ denotes the measure of individuals in an individual's state x (explained below) at time t, D_t is the debt to repay this period and D_{t+1} is the proceeds of the debt issued at the end of the current period.

In the equilibrium computation, consumption tax τ^c_t (or labor income tax τ^l_t) is determined each period so that the budget constraint (4) is satisfied. In section 4, we consider alternative ways to finance the demographic transition and satisfy the budget requirement.

2.5 Market structure

The markets are incomplete and there is no state contingent asset to insure against idiosyncratic shocks. Individuals can buy and accumulate one-period riskless asset a_t, which is a composite of an investment in firms' capital and holdings of government bonds and pays after-tax gross interest R_t as defined in section 2.4. Individuals cannot borrow against future income and transfers and the assets must be non-negative.

[5] Hansen and İmrohoroğlu (2013) assume that individuals derive utility from holding government bonds to account for the large amount of Japanese government debt held domestically.

2.6 Individuals' problem

The problem of an individual is solved recursively and presented below without time subscripts. The state vector of each individual is given as $x = \{j, a, z, e\}$, where j denotes age, a assets saved and carried from the previous period, z idiosyncratic labor productivity, and e the index of cumulated labor earnings that determines each individual's social security benefits. Given the states, an individual optimally chooses consumption, saving and labor supply to maximize the utility from consumption and leisure today and the future values averaged over the distribution of states in the next period, $x' = \{j + 1, a', z', e'\}$. The value function $V(x) = V(j, a, z, e)$ of an individual in state x is given as follows.

$$V(j, a, z, e) = \max_{c,h,a'} \{u(c, h) + \beta s_j EV(j + 1, a', z', e')\}$$

subject to

$$\begin{aligned}
&(1 + \tau^c)c + a' + m_j^o = R(a + b) + (1 - \tau^l)y + ss(e) \\
&y = z\eta_j hw \\
&a' \geq 0 \\
&e' = \begin{cases} f(e, y) & \text{for } j < j_R \\ e & \text{for } j \geq j_R \end{cases}
\end{aligned}$$

The index for cumulated earnings is updated according to the function $e' = f(e, y)$ until individuals reach the normal retirement age j_R.

2.7 Competitive equilibrium

Given a set of exogenous demographic parameters $\{s_{j,t}\}_{j=1}^J$ and $\{n_t\}$, medical expenditures $\{m_{j,t}^h, m_{j,t}^l\}_{j=1}^J$, and government policy variables $\{G_t, D_t, \tau_t^k, \tau_t^d, \tau_t^l, ss_t, \lambda_{j,t}^h, \lambda_{j,t}^l\}$, a competitive equilibrium consists of individuals' decision rules $\{c_t(x), h_t(x), a_{t+1}(x)\}$ for each state vector x, factor prices $\{r_t^k, w_t\}$, consumption tax $\{\tau_t^c\}$, accidental bequests transfer $\{b_t\}$, and the measure of individuals over the state space $\{\mu_t(x)\}$ such that:[6]

1. Individuals solve the optimization problems defined in section 2.6.

2. Factor prices are determined competitively.

$$\begin{aligned}
r_t^k &= \alpha Z_t \left(\frac{K_t}{L_t}\right)^{\alpha - 1} - \delta \\
w_t &= (1 - \alpha) Z_t \left(\frac{K_t}{L_t}\right)^{\alpha}
\end{aligned}$$

[6]The definition is based on the scenario where consumption tax τ_t^c is adjusted to balance the government budget. One could use a different fiscal variable to satisfy the budget constraint and define the equilibrium condition accordingly.

3. The lump-sum bequest transfer equals the amount of assets left by the deceased.

$$b_t = \sum_x a_t(x)(1 - s_{j,t-1})\mu_{t-1}(x)$$

4. The labor and capital markets clear.

$$\begin{aligned} K_t &= \sum_x \left[a_t(x) + b_t\right]\mu_t(x) - D_t \\ L_t &= \sum_x z\eta_j h_t(x)\mu_t(x) \end{aligned}$$

5. The consumption tax τ_t^c satisfies the government budget constraint (4).

6. The goods market clears.

$$\sum_x c_t(x)\mu_t(x) + K_{t+1} + G_t + M_t = Y_t + (1-\delta)K_t$$

3 Calibration

This section describes how parameters of the model are calibrated. The frequency of the model is annual. The unit of the model is an individual, who represents a household as head. We use male data for the labor market statistics to approximate behavior of household heads.

As a basis of the calibration, we first compute two economies in a steady state. The first approximates the economy of 2010, which we call the "initial steady state," and the second, called the "final steady state," differs from the first in demographics and assumes survival rates and a population growth rate based on the long-run estimates we discuss in more details below.[7] We then derive transition dynamics between 2010 and the final steady state by computing an equilibrium in each period. More detailed description of the computation is given in section 4. Tables 1 and 2 summarize calibrated parameters of the model.

3.1 Demographics

We assume that individuals enter the economy and become economically active at the age of 25 and live up to the maximum possible age of 110. Conditional survival rates $s_{j,t}$ and the growth rates of new cohort n_t are calibrated based on the estimates of survival

[7] As we discuss in section 4, the population is not stationary in the first steady state since we use the actual age-distribution in 2010. Agents in the steady state assume survival rates of 2010 in solving the optimization problem, and aggregate statistics are computed based on the actual age-distribution of 2010.

and fertility rates by the National Institute of Population and Social Security Research (IPSS), whose projections are available up to 2060. We use the survival rate estimates for 2010 in the initial steady state and 2060 for the final steady state. The cohort growth rates are assumed to be zero in the two steady states.

In computing the transition dynamics, we initialize the model in the first period with the actual population distribution in 2010 and use the estimates of survival rates and fertility rates for the variables $s_{j,t}$ and n_t to compute age distribution after 2011. We assume that survival rates will remain constant after 2060 and the growth rate n_t will gradually converge to 0 by 2150.

3.2 Endowments

Earnings of a worker are given as $y_t = z\eta_j h w_t$. The idiosyncratic component z consists of two parts, a permanent productivity shock and a transitory shock. We assume that the process of the shocks is given as

$$\begin{aligned} \widetilde{z}_t &= \omega_t + \varepsilon_t, \\ \omega_t &= \omega_{t-1} + \nu_t, \end{aligned} \tag{5}$$

where $\widetilde{z}_t = \log z_t$. The errors ε_t and ν_t are uncorrelated and iid across individuals, with mean zero and variances $\sigma^2_{\varepsilon t}$ and $\sigma^2_{\nu t}$. Lise et al. (2014) estimate a process as in (5) and we set the variance of the permanent shock σ^2_ν at 0.0078 and the transitory shock σ^2_ε at 0.03 in line with their estimates. In the computation, the state z consists of two components of idiosyncratic shocks, a permanent component ω and a transitory component ε.

The age-specific deterministic component η_j is calibrated to the life-cycle wage profile, based on the Basic Survey on Wage Structure (BSWS). The survey is carried out by the Ministry of Health, Labour and Welfare (MHLW), and it is a comprehensive national survey of the wage structure in major industries in Japan. We use the data for 2010 and figure 3 shows the life-cycle wage profile.

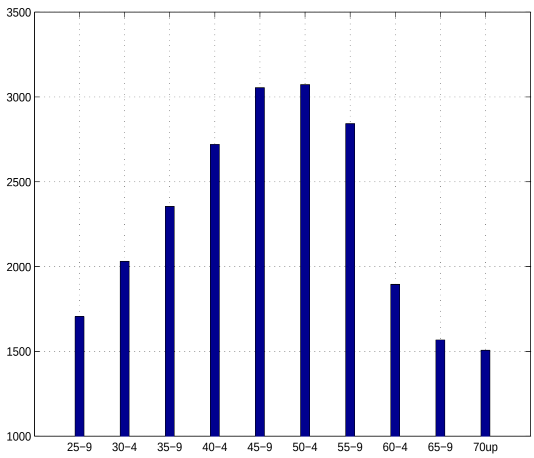


Figure 3: Wages over the life-cycle. Hourly wage in JPY (Source: BSWS)

3.3 Preferences

Instantaneous utility from consumption and leisure is given as

$$u(c,h) = \frac{[c^{\gamma}(1-h-i_p \cdot \theta_j)^{1-\gamma}]^{1-\sigma}}{1-\sigma}.$$

i_p is an indicator function, which takes a value of 1 if an individual participates in the labor market, that is, $h > 0$, and it is 0 otherwise. θ_j represents the utility cost of participation measured in terms of lost leisure time and varies by age.

Figure 4 shows employment rates by age, based on the Labor Force Survey (LFS) in 2010 conducted by the Statistics Bureau in the Ministry of Internal Affairs and Communications. Employment rates are high and mostly above 90% until late 50s and fall after age 60. Individuals work for 8 years on average after age 60 and the participation rate does not drop to zero after the normal retirement age or even after 70s. At age 65-69, the average participation rate is close to 50% and about 30% at 70-74.

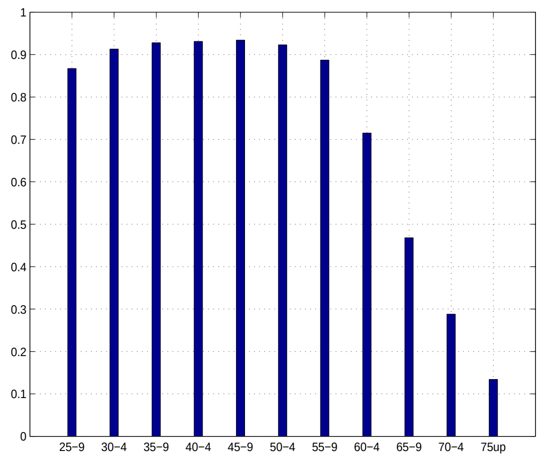


Figure 4: Employment rates over the life-cycle (Source: LFS)

To capture this pattern of labor force participation in the data, we assume that the cost of participation θ_j is zero before 60, turns positive thereafter and evolves according to an age-dependent function $\theta_j = \kappa_1 j^{\kappa_2}$. We calibrate the two parameters of the function so that the model matches the average work years above 60 and the fact that the participation rates fall gradually to reach zero in mid-80s in the initial steady state.

The preference weight parameter γ on consumption relative to leisure is set so that individuals on average spend 40% of disposable time at the market work. Average weekly hours of work are shown in Figure 5, which is based on the BSWS data in 2010. The risk aversion parameter σ is set at 3.0, which implies the relative risk aversion of 1.74, in line with the estimates in the literature.[8]

[8]With the non-separable preference, the relative risk aversion is given as $-cu_{cc}/u_c = \sigma\gamma + 1 - \gamma$.

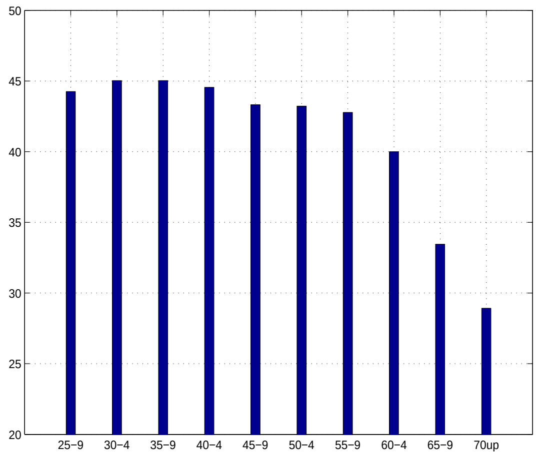


Figure 5: Work hours (weekly) over the life-cycle (Source: BSWS)

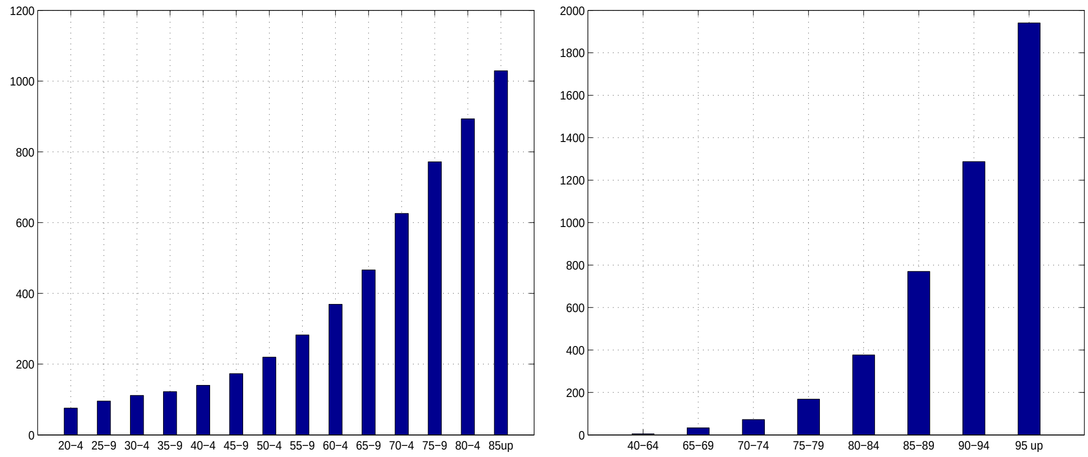
Hansen and İmrohoroğlu (2013) show that the capital-output ratio was in the range of 2.3 to 2.8 in 2000s. We set the subjective discount factor β in order to match the capita-output ratio of 2.5 in the initial steady state.

3.4 Medical expenditures

We use the administrative data of the Ministry of Health, Labour and Welfare (MHLW) for the calibration of medical expenditures. Figure 6 shows average health and long-term care expenditures by age. Long-term care expenditures are provided only for individuals aged above 40. Health expenditures show a steep increase after age 50, reaching over 1 million yen per year on average at age 85 and above. Individuals spend even more for long-term care and average spendings are approximately 1.3 million yen at age 90-94 and 1.9 million yen at 95 and above.[9]

[9]Note that the figures are unconditional average over the population at each age and the expenditures per user of long-term care are higher than the figures indicated.

Ideally one would incorporate uncertainty in health status and model cross-sectional heterogeneity in medical expenditures. We assume a deterministic profile of medical expenditures for simplification and for lack of data with enough samples to make inference of the expenditures by types (health and long-term care) at each age.



(a) Health care expenditures (b) Long-term care expenditures

Figure 6: Medical expenditures over the life-cycle (Source: MHLW). Average annual spending in JPY1,000.

The copay rates of health insurance $\lambda^h_{j,t}$ vary by age; 30% below age 70, 20% at 70-74 and 10% at 75 and above. For long-term care, copay rate $\lambda^l_{j,t}$ is 10% regardless of recipients' age.

In the computation of transition dynamics, we assume that medical expenditures grow at the same rate as the growth rate of the economy. Total expenditures, however, relative to aggregate output will rise as the fraction of old-age individuals increases. It will become increasingly more costly for the government to provide health and long-term care insurance benefits under aging demographics. As we will discuss in section 4, total medical expenditures in the initial steady state is 7.3% of output in the model, which is close to and in line with the data that stands at 7.8% in 2010. The part of medical expenditures covered by the government through health and long-term care insurance is about 80% of total expenditures, or 5.9% of output.

3.5 Technology

Output is produced by a constant returns to scale technology

$$Y_t = Z_t K_t^{\alpha} L_t^{1-\alpha}.$$

The capital share α is set at 0.362 and the capital depreciation δ at 0.089 based on Hayashi and Prescott (2002). We assume that the productivity Z_t grows at an annual rate of $g_t = 1\%$, which implies that per capita output grows at rate 1.57% ($= 1.01^{1/(1-\alpha)} - 1$) along the balanced growth path.[10] The level of productivity Z_0 in the initial period is set

[10] Hayashi and Prescott (2002) estimate the TFP growth rate at 2.4% over 1983-1991 and 0.2% for 1991-2000. See Fukao and Kwon (2006) for a comprehensive review of Japanese productivity estimates

for normalization so that the average earnings is 1.0 in the initial steady state.

3.6 Government

Social security: The government operates pay-as-you-go social security system and provides each retiree with benefits $ss(e)$, determined as a function of an index e that summarizes an individual's past earnings. The normal retirement age j_R is set at 41 (65 years old). The payment consists of two parts, as a sum of a basic pension payment denoted as $\overline{ss}$ and a part that is related to each individual's past earnings, according to the formula,

$$ss = \overline{ss} + \rho \cdot e.$$

$\overline{ss}$ represents the first tier of pension (*kiso-nenkin*) in the Japanese public pension system, which is fixed and provided irrespectively of an individual's past earnings.[11] In 2010, total expenditures for pension benefits were approximately 10% of output. We set the replacement rate ρ of the earnings-dependent part of the pension benefit so that the model matches this ratio in the initial steady state. The gross pension replacement rate defined in a standard way as a ratio of average pension benefits to the average earnings of insured workers is 38.2% in the initial steady state. The net replacement rate defined as a ratio of average benefits to the average after-tax earnings is 59.0%, as discussed in section 4.[12]

The index for past annual earnings e is updated recursively as

$$e_{t+1} = \frac{e_t \times (j-1) + \min(y_t, \overline{y})}{j}, \tag{6}$$

where the cap for counted earnings $\overline{y}$ is set at 10.44 million yen, which is based on the maximum annual earnings used in the computation of earnings index in the Japanese pension system.[13]

Government expenditures, public debt and taxes: The consumption tax is set at 5% in the initial steady state. Capital income tax is set at 40%, which is in the range of estimates of effective tax rates on capital income, for example, in Hansen and İmrohoroğlu (2013) and Braun and Joines (2014). The tax rate on the interest income

in the literature.

[11]The average payment was 54,600 yen per month (655,000 yen per year) in 2010. We set $\overline{ss}$ to 0.13 in the model, which is the ratio of the payment to the average earnings in 2010 (0.13=655,000/4,858,000). Note that we abstract from basic pension premium paid by non-working or self-employed adults below 60. Few people are out of labor force below age 60 in our model and workers are assumed to be hired as salaried employees, rather than self-employed.

[12]Note that the "official replacement rate" defined and used by the Japanese government is different from the standard definition used here. It is defined as the ratio of benefits to after-tax earnings for a hypothetical household that consists of a husband who has worked as a regular worker and been insured by employer-based pension (*kosei nenkin*) and a dependent housewife who has never worked.

[13]The amount consists of maximum counted monthly earnings of 620,000 yen and bi-annual bonus of 1,500,000 yen as set by the Japanese government.

from the government debt is set at 20%. Labor income tax rate that clears the government budget constraint in the initial steady state is 35.3%. The labor income tax in our model encompasses all taxes imposed on income from employment, including premium for transfer programs such as public pension and health insurance.[14] As discussed in section 4, when we adjust consumption tax rates to balance the government budget in the final steady state or during the transition, we keep the labor income tax rate at this level of the initial steady state to facilitate the analysis and comparison across different policies.

Government expenditures including the spending for health and long-term care insurance are 20% of aggregate output according to the National Accounts of Japan (SNA) in 2010 and we set the ratio G_t/Y_t to match this data. The government debt D_t is set at 100% of GDP, based on the SNA data at the beginning of 2010. The average number of years to maturity of outstanding government bonds is about 7 years and the average real interest rate on 7 year government bond is 1.0% in 2000-2010. We set the interest rate r_t^d on the government debt at this level. The fraction ϕ_t of individuals' saving allocated to government debt is determined endogenously in each period to guarantee the debt-to-GDP ratio, which we assume to stay at 100%.

[14]The pension premium of employed workers (*kosei-nenkin hokenryo*) is 16.058% of earnings in 2010, which will be raised by 0.0354% every year and stay at 18.3% in 2017 onwards.

Table 1: Parameters of the model (1)

Parameter	Description	Values/source
Demographics		
n_t	population growth rate	IPSS (2012)
$\{s_{j,t}\}_{j=1}^{J}$	conditional survival probabilities	IPSS (2012)
J	maximum age	86 (110 years old)
Preference		
β	subjective discount factor	1.0286
σ	risk aversion	3.0
γ	weight on consumption	0.37
$\{\kappa_1, \kappa_2\}$	disutility of labor force participation	$\{0.3, 7.0\}$
Labor productivity process		
z	idiosyncratic shocks	Lise et al. (2014)
η_j	age-dependent productivity	BSWS (2010)
Medical expenditures		
$m_{j,t}^{h}$	health care expenditures	MHLW (2010)
$m_{j,t}^{l}$	long-term care expenditures	MHLW (2010)
Technology and production		
α	capital share of output	0.362, Hayashi and Prescott (2002)
δ	depreciation rate of capital	8.9%, Hayashi and Prescott (2002)
Z_0	initial TFP level	1.165 (normalization)
g	TFP growth rate	1.0% (per-capita GDP growth 1.57%)

Table 2: Parameters of the model (2)

Parameter	Description	Values/source
Government		
τ_t^k	capital income tax	40%
τ_t^d	tax on government debt interest	20%
τ_t^c	consumption tax	5% (in 2010, varies by t)
τ_t^l	labor income tax	35.3% (in equilibrium)
$G_t + M_t^g$	government expenditures	20% of GDP, SNA (2010)
D_t	government debt	100% of GDP, SNA (2010)
r_t^d	government debt interest	1.0%
j_R	normal retirement age (benefit eligibility)	41 (65 years old)
$\overline{ss}$	basic pension payment	0.13
ρ	pension formula	0.30
$\lambda_{j,t}^h$	health insurance copay	30% (<70 yrs old), 20% (70-74 yrs old), 10% ($\geq$ 75 yrs old)
$\lambda_{j,t}^l$	long-term care insurance copay	10% (all ages)

4 Numerical results

This section presents numerical results of the model. Our focus is to quantify the fiscal cost of demographic transition expected over the next several decades. Before presenting the analysis of transition dynamics, we will first review long-run effects of demographic transition in the first two subsections, by comparing features of steady state economies. The separate analysis of the final steady state and transition dynamics will help isolate and identify effects of increased longevity from transitional effects associated with retirement of baby-boomers, when age distribution is non-stationary.

4.1 Steady state analysis I: long-run effects of demographic transition with no other policy change

In this section, we compare features of two steady state economies; the initial steady state which assumes survival probabilities of 2010 and the final steady state which takes the long-run projection of survival rates in 2060. As mentioned in section 3, the demographics are not stationary in the initial steady state since we impose actual age distribution of the population in 2010 in computing aggregate statistics. As shown in figure 2, the demographic structure, as it stands now, is far from stationary due to the post-war decline in fertility rates and two waves of baby-boom generations. We made a choice to use actual age-distribution in order to capture the demographic imbalance at the start of the transition and capture fiscal costs associated with it properly.

Steady-state analysis will help understand what to expect in the very long-run when demographic transition is complete and population distribution is stationary. For the purpose of comparing aggregate statistics between initial and final steady states, the size of the total population in the final steady state is adjusted so that it is consistent with the population size when the demographic transition is complete. Total population in the final steady state of the model (aged 25 to 110) is 70% lower than in the initial steady state.

Table 3 summarizes changes in aggregate variables between the initial and final steady states under two scenarios, with demographic aging financed by an adjustment of consumption tax and by labor income tax, respectively. A rise in longevity expected over the next five decades (2010-2060) will increase the old dependency ratio in the model (the ratio of population above age 65 to that of age 20-64) from 39.8% in 2010 to 56.1%. We assume that there is no change in the economy except for demographics and one tax rate that is adjusted in order to focus on effects of higher longevity. The social security system, in particular, remains the same and retirees receive benefits according to the same benefit formula as discussed in section 3. Total benefits, however, paid by the government will differ as the number of retirees and their earnings history will change endogenously. Age-dependent medical expenditures of each individual are assumed to remain the same and are adjusted only for the growth rate of the economy. Per-capita expenditures, however, will be higher in the final steady state since the average age of the economy is higher with a rise in longevity and there are relatively more old-age individuals, whose medical expenditures are significantly higher than young individuals.[15]

[15]For the purpose of comparing across different final steady states and later transition paths implied by alternative policies, we use the demographic shift financed by consumption taxes as a benchmark. The government expenditures G_t and government debt D_t are determined as a given percentage of output as set in section 3 and we use the level of them determined in the benchmark in other experiments, that is, the experiments are neutral with respect to the level of government expenditures and debt.

Table 3: Steady state comparison: effect of demographic transition financed by consumption tax vs labor income tax. No other policy change.

Variables	Initial SS	Final SS (1) adjust τ^c	Final SS (2) adjust τ^l	vs (1)
Dependency ratio (65 up/20-64)	39.8%	56.1%	56.1%	
Labor tax τ^l	35.3%	35.3%	48.8%	
Consumption tax τ^c	5.0%	19.3%	5.0%	
Output Y	1.000	0.237	0.206	−13.1%
Capital K	1.000	0.256	0.189	−26.3%
Labor L	1.000	0.227	0.217	−4.6%
Consumption C	1.000	0.205	0.183	−10.8%
Interest rate r	4.52%	3.52%	5.74%	
Wage w	1.000	1.045	0.951	−8.9%
Avg work hours	0.401	0.407	0.430	
Participation rates				
25-54	100.0%	100.0%	100.0%	
55-69	79.2%	82.7%	76.1%	
70-90	8.9%	11.6%	5.0%	
Avg work years	43.0	44.5	42.2	
SS gross replacement rate*	38.2%	35.2%	36.7%	
SS net replacement rate*	59.0%	54.4%	71.7%	
SS spending/Y	10.3%	13.1%	13.9%	
Total med spending M/Y	7.3%	9.8%	11.3%	
Govt med spending M^g/Y	5.9%	8.2%	9.5%	

* Gross replacement rate is defined as the ratio of average pension benefits to average gross earnings of working individuals below normal retirement age. Net replacement rate is the ratio to average *after-tax* earnings.

With a rise in life expectancy, individuals have stronger incentives to work and earn more and accumulate a greater amount of wealth to cover expenditures for a longer lifetime. As shown in the second column of table 3, when the demographic change is financed by consumption taxes, individuals stay in the labor force longer and the average number of work years increases by 1.5 years, from 43 in the initial steady state to 44.5. The participation rates rise by 3.5 percentage points at age 55-69 rise and by 2.7 percentage points above 65. As shown in figure 7, both participation rates and average work hours rise throughout the life-cycle.[16]

[16] Note that figure 7(b) shows average work hours of individuals who are working. They increase after age 70 because there is a strong selection among old workers. Those who remain in labor force after late 60s are much more productive than the average of the same age group and have stronger incentives to

Note that average work hours of all workers in table 3 show only a small increase from 0.401 to 0.407, because the decomposition of work force is different and there are relatively more old-age individuals who tend to work for fewer hours. Individuals' saving also rises dramatically as shown in figure 8(b), and they accumulate significantly more wealth by the time they reach the retirement age compared to the initial steady state. Since the increase in aggregate capital is greater than the rise in aggregate labor supply, capital-labor ratio rises in the final steady state and the interest rate decreases from 4.5% to 3.5% and the wage rate increases by about 5%.

Given the rise in the dependency ratio, total expenditures for pension benefits are 13.1% of output, an increase of 2.8 percentage points relative to the initial steady state. What also adds to the government expenditures through aging demographics is the rise in medical expenditures covered by the government. As shown in the bottom row of the table, health and long-term care spending incurred by the government rises from 5.9% of output to 8.2%, an increase of 2.3 percentage points. As a result of rising pension and medical expenditures, the consumption tax needs to rise significantly, by 14.3 percentage points to 19.3% in the long-run.

To highlight the effect of higher government spendings for pension benefits and medical insurance programs, table 4 shows a change in consumption tax when we exogenously fix those expenditures in the government budget of the final steady state. More precisely, if the ratio of pension spending were fixed at 10.3% of output as in the initial steady state, the consumption tax would be 12.1%, increasing only by 7.1 percentage points, rather than 14.3 percentage points in the baseline scenario. There would be slightly less but similar drop in consumption tax if the government spending for medical insurance were to stay at 5.9% of output, the level in the initial steady state. If both were unchanged relative to output, the consumption tax would be just 1.8 percentage point above the initial steady state, indicating that the future of these two age-dependent programs would be critical in evaluating rising cost of the coming demographic transition.

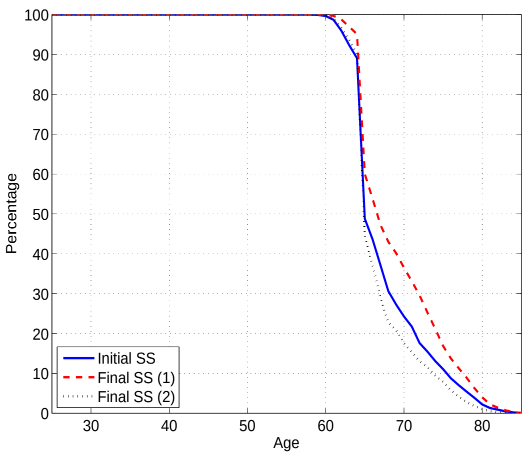
Table 4: Roles of rising expenditures for pension benefits and medical expenditures: demographic shift financed by consumption taxes. Partial equilibrium analysis.

	Initial SS	Final SS (1)	Fixed SS/Y	Fixed M^g/Y	Fixed both
Consumption tax τ^c	5.0%	19.3%	12.1%	13.3%	6.8%
SS spending/Y	10.3%	13.1%	10.3%*	13.1%	10.3%*
Govt med spending M^g/Y	5.9%	8.2%	8.2%	5.9%*	5.9%*

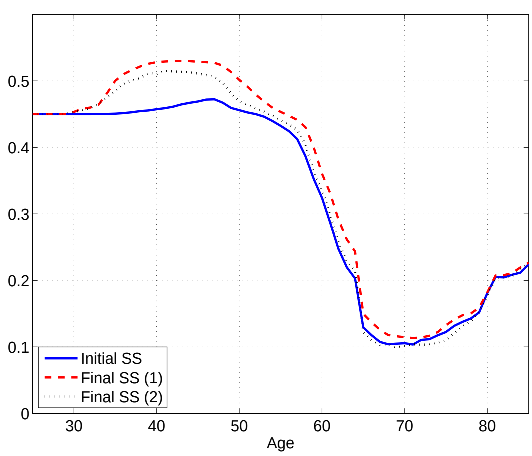
The ratios with an asterisk * are exogenously fixed in the government's budget.

work. For example, productivity of workers at age 75 is 50% higher than the average of this age and this difference increases with age. Work hours averaged across all individuals including those out of the labor force monotonically decline in age.

The picture of the long-run steady state will look very different if aging demographics are financed by labor income taxes. As shown in the last two columns of table 3, the tax rate must increase by 13.5 percentage points and nearly one-half of wages will be taxed away by the government, which generates significant work disincentives and reduces individuals' disposable income. Labor supply will be much lower than in the first scenario, where the demographic shift was financed by consumption taxes. The number of average work years is 42.2, well below 44.5 years in the consumption-tax scenario and even lower than in the initial steady state. As shown in figure 7, both participation rates and work hours are lower than in the consumption tax scenario. Participation rates are significantly lower among old-age individuals, whose labor supply is more elastic to changes in net wage. Individuals work for more hours than in the initial steady state, but the labor income net of taxes are much lower, as shown in figure 8(a). Therefore although individuals wish to save more for longer retirement, they are unable to do so given the low disposable income. Individuals save much less throughout the life-cycle as shown in figure 8(b) and aggregate capital is as much as 26% lower than in the economy with higher consumption tax. Given the lower capital, the wage rate is also lower, which further reduces the life-cycle earnings of individuals.

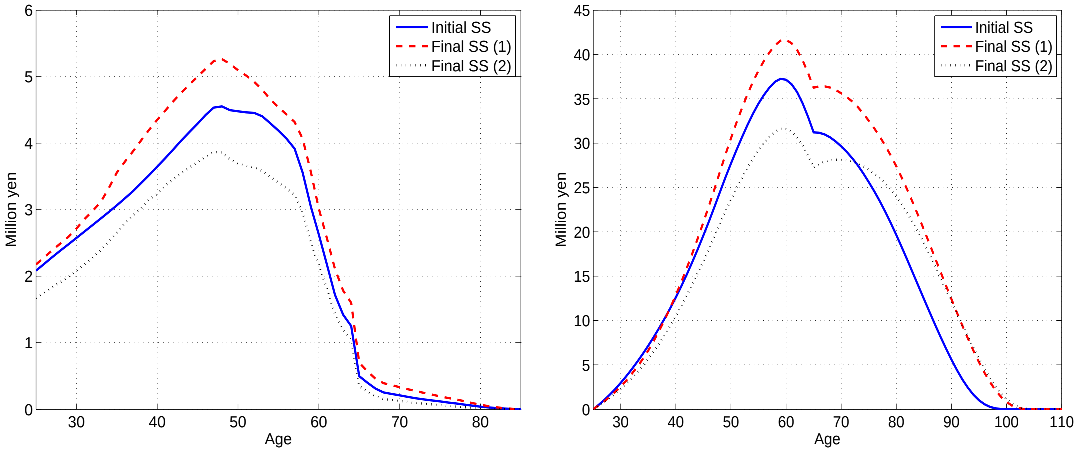


(a) Labor force participation



(b) Work hours

Figure 7: Labor supply over the life-cycle: in "initial steady state (SS)", "final SS (1)" with adjustment of consumption tax and "final SS (2)" with adjustment of labor tax.



(a) Net labor income (b) Total assets

Figure 8: Net labor income and assets over the life-cycle: in "initial steady state (SS)", "final SS (1)" with adjustment of consumption tax and "final SS (2)" with adjustment of labor tax.

The analysis of the steady state shows that the fiscal cost of rising longevity and old-age dependency ratio, but the impact on key economic variables can vary greatly depending on how it is financed. Higher labor taxes will discourage participation of middle to old-age individuals and undermine their ability to save for retirement. In the next section, we will briefly discuss additional long-run analysis under alternative scenarios about the pension system, before we discuss the transition dynamics in the following two sections.

4.2 Steady state analysis II: pension reforms

In the long-run steady states presented above, we assume that there is no change in the pension system. In this section, we consider a few scenarios of pension reforms that mitigate fiscal cost of demographic transition. In the first, we adjust the benefit schedule so that the pension payments are lower by fixed percentage points for any given level of past earnings. In the second, we keep the benefit schedule unchanged but raise the retirement age from current 65.

We identified in the previous section that raising labor taxes to cover rising expenditures is highly distortionary and costly. Therefore in what follows, we will focus on fiscal adjustment by consumption taxes. For the purpose of comparing features of final steady states implied by different policies, we use the final steady state (1) studied above, which is financed by consumption taxes as a benchmark.

Results for the first set of experiments to lower benefits are shown in table 5. By shifting down the benefit schedule by 20% and 40%, consumption tax in the long-run can be reduced from 19.3% to 11.5% and 3.8%, respectively. The significant decrease is possible not only because of the reduction in benefits, but also because of an increase in overall economic activities and increased tax revenues. Lower retirement benefits make individuals save more aggressively for retirement and work longer in both intensive and extensive margins throughout the life-cycle. With a 20% cut in benefits, the aggregate capital, labor and output will be higher by 14%, 3% and 7% respectively. Since the capital increases by more than labor, the interest rate will decline and wage rates will rise, which further encourages work efforts. With a 20% reduction of benefits, individuals will work for 1.5 years longer and the participation rates will increase by 3.5 percentage points at age 50-64 and by 5.6% at 65 and above, compared to the baseline case of no reform. The rise in earnings contributes to an increase in labor income tax revenues and reduces the pressure for higher taxes on consumption. Under the two scenarios, total consumption also increases by 5.0% and 10.2%, respectively, expanding the tax base. Total spending for pension benefits is 10.2% of output, which is no different from the level in the initial steady state.

The pension reform signed into law in 2004 includes an adjustment of benefits according to the "macro-economic slide" formula, which would lower benefits as the number of insured individuals decreases and life-expectancy rises. The slide, however, has not been triggered as the adjustment is capped by inflation rates. According to the official fiscal projections (*zaisei kensho*) released in 2014, the officially-defined "replacement rate" will decline from the current 62.7% to 50-51% when the adjustment is completed in 30 years, which implies a reduction of approximately 20% in benefits for given level of past earnings.[17] If the slides are successfully implemented and benefit schedule is shifted down by 20%, the first results presented in this section would approximate what to expect in the long-run. The net replacement rate, as shown in table 5, will fall by more than 20%, from 59% in the initial steady state to 43% in net and from 38% to 28% in gross, as earnings in the denominator will be larger in the new equilibrium of our model.

[17]The official definition of the replacement rate is different from the standard definition of the replacement rate and the one used in the paper, as explained in more detail in section 3.

Table 5: Benefit reduction: final steady state

Variables	Bench	Benefit cut 20%	Benefit cut 40%
Consumption tax τ^c	19.3%	11.5%	3.8%
Output Y	–	+6.6%	+14.2%
Capital K	–	+13.9%	+31.1%
Labor L	–	+2.6%	+5.6%
Consumption C	–	+5.0%	+10.2%
Interest rate r	3.52%	2.72%	1.92%
Wage w	–	+3.8%	+8.2%
Avg work hours	0.432	0.431	0.429
Participation rates			
25-54	100.0%	100.0%	100.0%
55-69	82.7%	86.2%	90.8%
70-90	11.6%	17.2%	24.2%
Avg work years	44.5	46.0	48.0
SS gross replacement rate	35.2%	27.7%	20.3%
SS net replacement rate	54.4%	42.7%	31.4%
SS spending/Y	13.1%	10.2%	7.4%

Table 6 summarizes impacts of policies to raise the retirement age from 65 to 67 and 70. Effects are similar to the scenarios of reducing benefits qualitatively, although changes are smaller quantitatively. Individuals save more for retirement when they are young, but assets are dissaved more rapidly when many individuals start to leave the labor force while they have not yet reached the retirement age, which explains a smaller increase in aggregate capital compared to the reforms to reduce replacement rates. Individuals work for more years to cover old-age consumption and average work years increase by 0.9 and 2.3 years when the retirement age is raised to 67 and 70, respectively.

Table 6: Retirement age increase: final steady state

Variables	Bench	Retirement age 67	70
Consumption tax τ^c	19.3%	15.8%	10.8%
Output Y	–	+1.1%	+3.1%
Capital K	–	+1.5%	+4.6%
Labor L	–	+0.9%	+2.3%
Consumption C	–	+1.7%	+4.4%
Interest rate r	3.52%	3.47%	3.34%
Wage w	–	+0.2%	+0.8%
Avg work hours	0.432	0.428	0.423
Participation rates			
25-54	100.0%	100.0%	100.0%
55-69	82.7%	87.7%	94.7%
70-90	11.6%	12.7%	14.5%
Avg work years	44.5	45.4	46.8
SS gross replacement rate	35.2%	35.6%	35.9%
SS net replacement rate	54.4%	55.0%	55.5%
SS spending/Y	13.1%	11.8%	9.9%

What is, however, truly challenging is the demographic transition that Japan is expected to face over the coming decades. The retirement waves of the first baby-boom generation, followed by the second, will put significant pressures on sustainability of the government's budget for an extended period. We will analyze transition dynamics in the next two sections.

4.3 Transition analysis I : demographic transition financed by consumption taxes with no policy change

In this section, we study equilibrium paths of our model making a transition from the economy of 2010 to the final steady state.[18] The transition will start in the initial year with the actual demographic structure of 2010 and we let the demographics evolve according to projected survival rates and fertility rates over the next five decades, up to 2060, the final year for which the IPSS's projection is available. After 2060 we assume that the survival rates will remain constant and the growth rate of entrants to the economy at age 25 will converge to the value in the final steady state, which we had set to zero, gradually by 2150. All variables including macro and micro ones can change every period during

[18] In the computation we compute an equilibrium over 291 years, from 2010 to 2300. We set the number large enough so that all variables will converge to those in the final steady state smoothly.

the transition. In order for the government to satisfy the budget constraint in equation (4) each period, at least one policy parameter has to be adjusted. We use consumption tax rate τ_t^c to absorb the fiscal imbalance and guarantee that the government budget is balanced. We keep all the other fiscal variables unchanged throughout the transition. In the next section, we assume alternative scenarios about the pension system and study how a reduction in government spending through reforms can mitigate fiscal costs of demographic transition.

During the transition, as shown in figure 2(b), old-age dependency ratio will rise sharply as the baby-boom generations continues to hit the retirement age. The dependency ratio (the ratio of population aged 65 and above to age 20-64) will stay above 85% for several decades after 2050 and reach the peak of 88% in early 2080s. This is the period when the government will face the severest challenge in balancing the budget as it faces higher spending for old-age transfer programs and a rapid decline in tax revenues as the labor force shrinks.

Figure 9 shows the path of equilibrium consumption tax rates in 2010-2200, which demonstrates rising costs of financing retirees' transfers via pension, health and long-term care insurance. The tax will rise rapidly from below 5% in 2010 to 30% by 2040 and reach the peak of 47.9% in 2083, with a total increase of 40 percentage points from 7.6% in 2015. After 2080, as fertility rates rise and population growth rates recover to the long-run level, the equilibrium tax rates will decline and eventually reach the final steady state level of 19.3%, as shown in table 7.

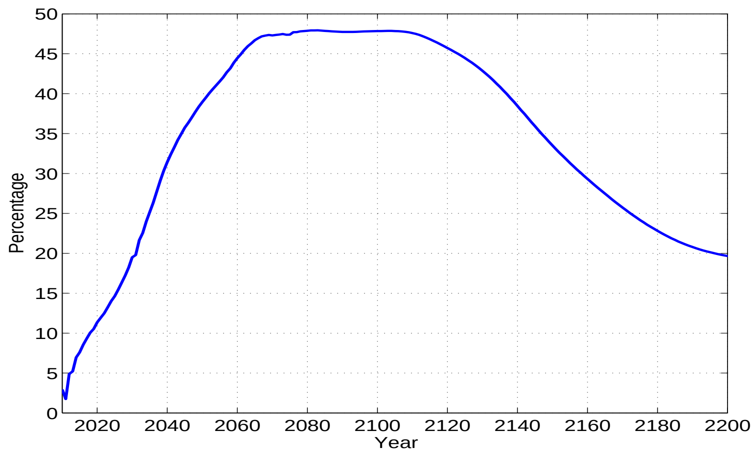
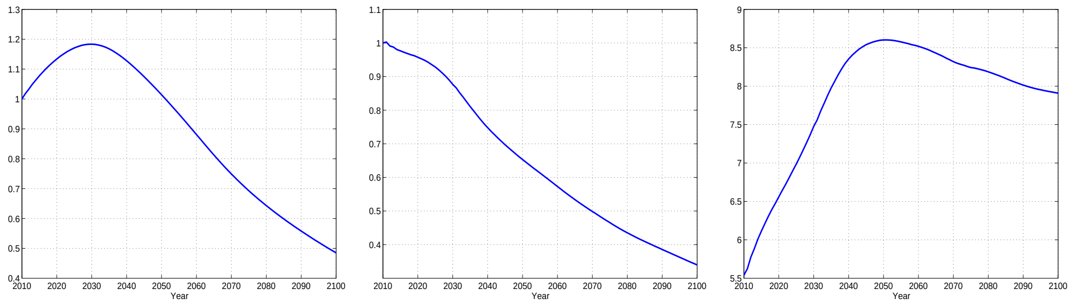


Figure 9: Consumption tax rate 2010-2200: benchmark transition with no policy change

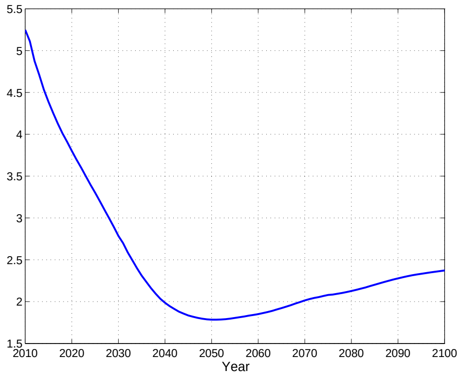
A rise in longevity encourages more saving and labor supply as we discussed in section 4.1 and increases individuals' saving and aggregate capital. This positive effect on aggregate capital is offset by a decline in population and also by the aging demographics. As the average age increases there are relatively more retirees who allocate a greater portion of disposable income to consumption than younger individuals who save at a higher rate. As shown in figure 10(a), the capital will rise initially as individuals experience a rise in longevity but it will decline monotonically after mid 2020s as the two negative effects dominate the positive effect. Aggregate labor supply also declines sharply and falls by 1/3 by 2050 and 2/3 by the end of the century. The capital-labor ratio rises as the initial rise and following slow decline in capital dominates a drop in labor during the first few decades of transition but the ratio will start to fall after 2050 as the capital starts to decline more rapidly and the trend continues through the end of the century, as shown in figure 10(c).



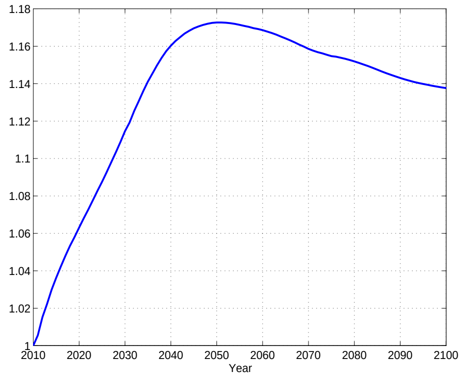
(a) Aggregate capital (b) Aggregate labor (c) Capital-labor ratio

Figure 10: Aggregate capital, aggregate labor supply and capital-labor ratio 2010-2100

Figure 11 shows the path of factor prices. As the capital-labor ratio increases during the first decades, the interest rate will decline from 5.3% in 2010 to 1.8% in 2050 before it starts to increase. Labor becomes more and more scarce during the initial decades of the transition, when a large number of baby-boomers reach the retirement age and exit the labor force. The change will generate a large gain in wage rate, which increases by as much as 17% by 2050. The wage rate will start to decline as the demographic structure starts to stabilize with the rise in the fertility rates.



(a) Interest rate



(b) Wage

Figure 11: Interest rate and wage rate 2010-2100

Table 7 summarizes values of key variables during the transition and shows how they converge to the final steady state, which we presented in section 4.1. The levels for aggregate output, capital, labor and wage rates are expressed as the ratio to the value in 2010, the first period of the transition.[19]

Table 7: Transition financed by consumption taxes

Year	τ_t^c	Y_t	K_t	L_t	r_t	w_t
2010	3.0%	1.000	1.000	1.000	5.25%	1.000
2030	19.5%	0.977	1.183	0.877	2.78%	1.115
2050	38.9%	0.766	1.014	0.653	1.78%	1.173
2070	47.3%	0.578	0.749	0.499	2.01%	1.159
2100	47.8%	0.386	0.485	0.340	2.37%	1.138
2200	19.7%	0.227	0.256	0.212	3.64%	1.071
2300	19.3%	0.228	0.260	0.212	3.52%	1.077

Roles of rising pension and medical expenditures: Figure 12 shows the path of total pension benefits paid by the government as a ratio to aggregate output. Expenditures rise rapidly from 10% of output in 2010 to almost 20% in 2080s and stay above 18% until 2130, before declining gradually to reach the level of 13% in the long-run. Figure 13 shows the transition path of medical expenditures, as well as the decomposition by the type of

[19]Note that the values in the final steady state relative to the 2010 are not necessarily the same as those expressed as the ratio to the initial steady state in table 3, since the values in the initial steady state and those in the first period the transition are not necessarily the same although they are mostly very close. For the same reason, the consumption tax rate in 2010 is not 5%, the level in the initial steady state since the tax revenues and expenditures are not the same.

spendings (health care and long-term care) and by the payer (government and households). Both health and long-term care expenditures will rise over the next several decades but the latter will rise more sharply with the increase in dependency ratios and a rise in longevity, because long-term care expenditures are much higher for older individuals as seen in figure 6 in section 3. As shown in the right panel of figure 13, most of the increase in medical expenditures will be borne by the government, which, assuming no change in policy, covers 90% of long-term care spending and 70-90% of health care expenses, with the highest coverage rate of 90% for all individuals above 75.

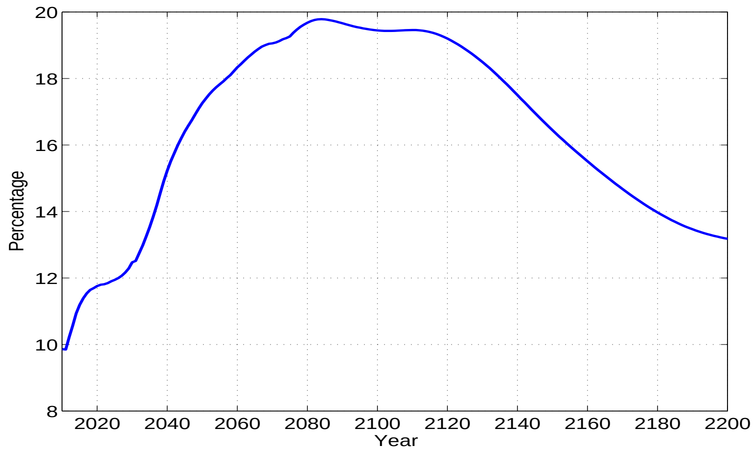
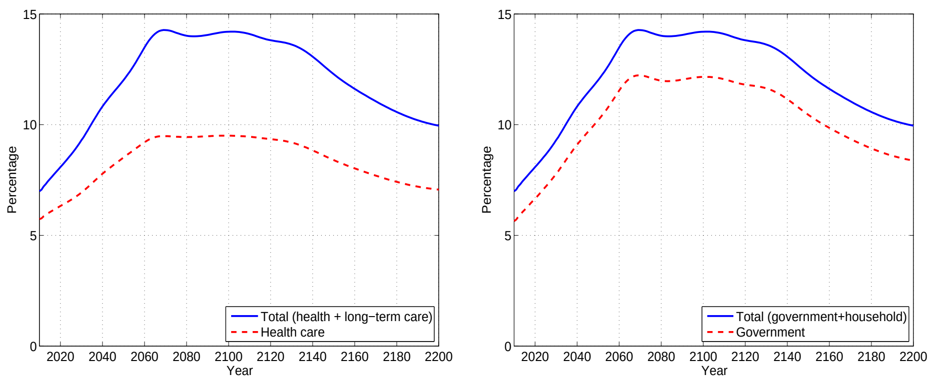


Figure 12: Pension expenditures 2010-2200 (% of aggregate output)



(a) Health and long-term care expenditures (% of aggregate output)

(b) Expenditures paid by government and households (% of aggregate output)

Figure 13: Medical expenditures 2010-2200

Figure 14 shows the path of consumption tax rates when we exogenously and hypothetically assume that expenditures for pension benefits, health and long-term care insurance borne by the government are fixed in terms of ratios to aggregate output throughout the transition.[20] Equilibrium consumption tax would be significantly lower with fixed pension expenditures relative to output and the peak tax rate would be 25%, nearly half of 48% in the baseline scenario. The effect of fixed public medical expenditures is also large, saving by additional 10-15 percentage points of consumption taxes during the peak years of 2070-2110. In the next section, we will simulate the model under alternative assumptions about the pension system, satisfying the government budget in a general equilibrium.

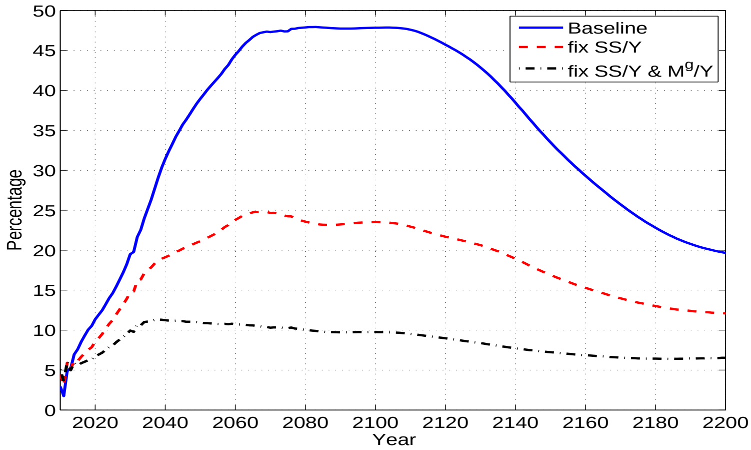


Figure 14: Consumption tax rate 2010-2200. SS_t/Y_t and M_t^g/Y_t fixed constant.

4.4 Transition analysis II : demographic transition financed by consumption taxes with pension reform

Next we study transition dynamics when pension benefits are reduced over time. We consider three alternative scenarios; in the first, benefit schedule is gradually lowered by 20% over the period of 50 years, from 2010 to 2060. In the second, the normal retirement age is raised by five years from 65 to 70, by one year every decade starting in 2020 and through 2060, at the same time as the benefits are reduced by 20% as in the first scenario. In the third, the normal retirement age is raised to 70 and benefits are reduced further by 40%.

Figure 15 shows the equilibrium path of consumption tax rates under the three scenarios, together with the benchmark path in which there is no change in pension policy. The fiscal burden is significantly mitigated under reform scenarios and the peak consumption tax rate falls from 48% in the baseline to 37%, 28% and 19%, under the three cases, respectively.

[20]These are not general equilibrium results as the sum of benefits received by households do not match what is included in the government budget. We present the simulation results to highlight the contribution of these transfers to the tax rates. This is a transition version of the exercise presented in table 4 in the context of a steady state.

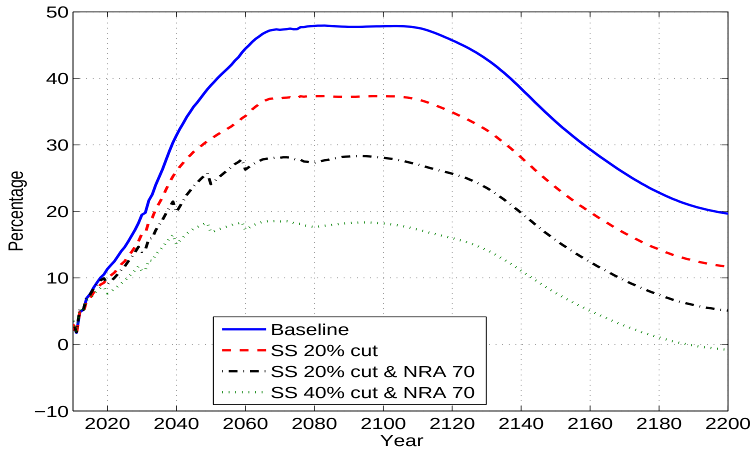
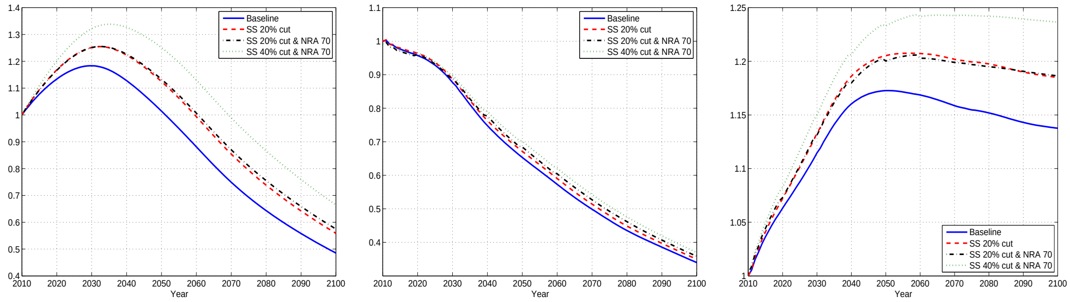


Figure 15: Consumption tax rate 2010-2200: pension reforms

As we saw in section 4.2, although the reforms will directly reduce individuals' life-time assets due to lower expected transfers after retirement, individuals who anticipate the change will save more on their own to smooth consumption over the life-cycle and undo the reduction in life-time assets. Implicit retirement saving provided by the government will be replaced by private own savings. The difference, of course, is that the former is financed by pay-as-you-go intergenerational transfer through taxation and the implicit assets one expects to receive in future cannot be used productively as an input of production. Private saving, however, is rented out and contributes to additional aggregate capital and increases output.[21] Output increases even further since the policy also increases aggregate labor because agents work longer to save more for retirement. As shown in figure 16, both aggregate capital and labor are much higher than in the baseline case under all three reform scenarios. As the capital rises by more than labor, the wage rate will be higher than in the baseline case, which provides further incentives to work more.

[21]Note that a fraction of private saving will be used to purchase government debt, but because the level of government debt does not vary across experiments by assumption, additional saving will raise the private capital.



(a) Aggregate capital (b) Aggregate labor (c) Wage

Figure 16: Aggregate capital, aggregate labor supply and wage 2010-2100: pension reforms

A sudden or rapid change in the retirement age or pension benefits of those who have already retired would significantly deteriorate welfare of retirees or those who are close to the retirement age, as they are caught unprepared by a drop in future transfers they had counted on. The scenarios that we considered in this section implement reform gradually, phasing in the adjustment over fifty years. Younger individuals in particular anticipate the reduction in benefits in future, as well as the path of consumption taxes that will be lower than in the baseline case, given the reduced government expenditures. Welfare effects on individuals belonging to different cohorts will differ as a result of changes in individual behaviors and variables such as tax rates and factor prices which they take as exogenous. Next section will study welfare effects of pension reforms relative to the baseline case in which there is no change in the pension program.

4.5 Welfare effects of reforms

In this section we study welfare effects of different scenarios to finance the demographic transition discussed above. We evaluate welfare of individuals who are already economically active in 2010, when the reforms are announced, and also of future generations, who will enter the economy after 2010. In quantifying welfare effects, we ask individuals of each cohort whether they prefer to live in the baseline economy where the pension program remains unchanged, or in another economy where a reform is implemented. We compute consumption equivalence, that is, the level of percentage change in consumption across all possible states in the remainder of an individual's life that would make her indifferent between the baseline and alternative scenarios. If the consumption equivalence is positive, it implies that the individual prefers reform. The individual prefers the status quo and the baseline economy if the consumption equivalence is negative.

Figure 17 shows welfare effects of three transition scenarios under each of the three pension reforms considered in section 4.4. Indicated in the figure is the consumption equivalence for each cohort of individuals that enter the economy in a given year at the initial model age of 25. For example, the left-most point for year 1950 is the consumption equivalence of individuals who entered the economy at age 25 in 1950 and reached age 85 in 2010, when reform begins. Reforms to reduce benefits by lowering replacement rates or by raising the normal retirement age will reduce the welfare of individuals that are alive at the time of the reform. In particular, individuals close to the retirement age will experience the largest welfare loss. They will enjoy lower consumption tax rates compared to the baseline scenario, but negative effects from lower benefits dominate. Lower interest rates during the transition compared to the baseline case also hurt retirees who rely more on capital income than young individuals. Future generations, however, will benefit from lower benefits. As shown in the figure, if benefits are reduced by 20%, cohorts entering 2100, for example, will benefit from the reform by about 3% in terms of consumption equivalence. If the benefits are reduced further by 40% and the normal retirement age is raised to 70, the welfare effects will be close to 8% in consumption equivalence.[22] Although they will receive lower pension benefits in future when they retire, consumption is much less expensive net of taxes throughout the life-cycle. Individuals work longer and save much more for retirement, which leads to a rise in production through higher capital and labor supply. They will enjoy higher wages and the life-time consumption will be higher as well.

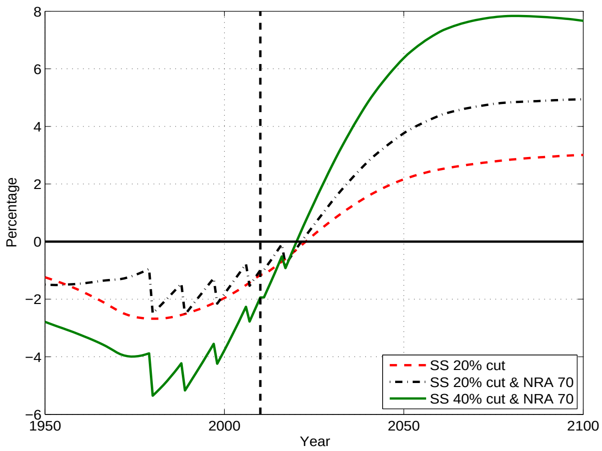


Figure 17: Welfare effects of pension reforms by cohort: consumption equivalence.

5 Conclusion

This paper builds a life-cycle model of heterogeneous agents, in which individuals optimally choose a sequence of consumption, saving, labor force participation and work

[22]Given the annual frequency of the model, we change the retirement age in a discrete manner, by one year every decade, which explains the five spikes in the figure when retirement age is raised by five years. The transition path and figures of the welfare effects would be smooth if the change was introduced more gradually, say by 1 month each year, etc.

hours over the life-cycle. Individuals' decisions are subject to uninsurable idiosyncratic uncertainty in labor productivity and life-expectancy as well as health and long-term care expenditures that increase in age. Coming waves of baby-boom generations' retirement pose a significant challenge on sustainability of the government budget throughout the century, coupled with the demographic transition characterized by low fertility and rising longevity. The purpose of the paper is to quantify the fiscal cost of demographic transition that Japan is projected to face and has to deal with over the next several decades. We analyze changes in individuals' behaviors during the transition and how they translate into different paths of aggregate variables and factor prices. We identify two key factors, rising expenditures for pension and medical insurance programs, that threaten fiscal sustainability and quantify the contribution of each factor in the long-run and during the transition.

In the long-run, when individuals live longer, they work more in both intensive and extensive margins and accumulate more wealth to support consumption for a longer retirement period. These positive effects, however, would be wiped away if the demographic aging is financed by a rise in labor income taxes, since it discourages work incentives and reduces net income that can be saved for retirement.

The transition is a very different story and involves a more dramatic change in taxes. If all the other policy parameters remain the same, the consumption tax will have to rise by 40 percentage points from 2015 to the peak of 48% when the dependency ratio approaches 90%. The fiscal burden, however, can be significantly mitigated by a gradual adjustment of the pension benefit schedule and the normal retirement age. The peak tax rate can be reduced by 20 percentage point, when the benefits are reduced by 20% and the normal retirement age is raised by 5 year gradually over the next fifty years.

Although the rising fiscal burden in the coming decades is inevitable, the transitional cost on individuals' welfare and aggregate economy can be mitigated if such reforms are implemented gradually, allowing individuals to have enough time to reoptimize allocation of labor supply and savings for the remainder of their life.

Results of the paper suggest that a gradual shift from the current pay-as-you-go pension system run by the government towards a self-financed private pension scheme may effectively help control fiscal cost of demographic transition, at the same time as allowing individuals to stock up enough savings for retirement. This is an issue that needs further exploration in a model that distinguishes between public and private retirement pensions. We also note that the paper abstracts from heterogeneity within a household, in particular the role of female labor force participation and fertility decisions, which are considered as most important issues facing the government. These are important issues that need to be studied in a more detailed model of a household, which we also leave for future research.

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