



Sustainable social security: Four options



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ABSTRACT

Four options to make the social security sustainable under the coming demographic shift are presented; increase payroll taxes by 6 percentage points, reduce replacement rates by one-third, raise the normal retirement age to 73, or means-test the benefits and reduce them in income. The paper accounts for labor supply at both intensive and extensive margins and analyzes welfare effects across agents that differ in age, wealth and cohorts. While the four policies all achieve the same goal, economic outcomes differ significantly. Options to curtail benefits encourage own savings and capital accumulation, while the payroll tax increase and the means-test reduce work effort. Future generations prefer options to reduce benefits, but current generations prefer to finance the transition with payroll taxes.

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1. Introduction

“U.S. fiscal policy is unsustainable. [...] That can’t possibly be true because government budget constraints are going to make it sustainable. [...] Certain promises that people have made about taxes, entitlements, ..., those are incredible. They are not going to fit together. U.S. fiscal policy is sustainable. [...] It’s uncertain because it’s not clear which of these incredible promises is going to be broken first”.

[Thomas Sargent, Nobel Prize Press Conference at Princeton University, October 10, 2011]

The coming demographic shift will pose a significant fiscal challenge on the budget of the social security system in the U.S. The long-run sustainability of the pension system must come with a reform of the existing system to close the budget gap. The question is which of the “incredible promises” is to be broken, how much adjustment is needed and what will be the consequence.

Life expectancy has grown dramatically during last decades to 77 years in 2000 and it is projected to reach 85 years by the end of the century.¹ At the same time, birth rates have declined sharply and the total fertility rate stands at about 2.0 in 2000. The dependency ratio is projected to rise rapidly from the current 22% and reach 38% in 2050 and 45% in

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¹ These life expectancies are based on the average of male and female period life expectancies, as reported in [Bell and Miller \(2005\)](#).

2100.² More retirees will receive benefits, while fewer individuals work and contribute to the system through taxes. The policy debate and public concerns appear to be mostly focused on the insufficient fund of the pension system imputed from simple accounting exercises. Economic distortions, however, that would emanate from fiscal adjustments to maintain the pay-as-you-go system could exacerbate the fiscal problem. To quantify the effects of the demographic shift and fiscal consequences, we develop an economic model in which individuals make decisions on consumption, savings, labor participation and work hours over a life cycle in a competitive production economy.

The paper builds a model with endogenous saving and labor supply at both extensive and intensive margins and considers four policy options that would make the social security system self-financed and its budget balanced every year; (1) raise the payroll tax by 6 percentage points, (2) reduce the replacement rates of the benefit formula by one-third, (3) increase the normal retirement age from 66 to 73, or (4) make the system means-tested and let the benefits decline one-to-one with income. All of the four options are shown to achieve the same goal of making the system self-financed. The economies, however, implied by alternative policies differ significantly from each other in terms of aggregate economic activities as well as the behavior of individuals along the life cycle. Reducing the spendings through scaling down the benefit replacement rates or raising the normal retirement age will provide strong incentives to increase savings to supplement retirement consumption and the capital stock will be significantly higher than in the other two options. The higher payroll taxes will have negative work incentives and the participation rates in the first option will be much lower than in the second and third options. The average years of work is 44.5 years in option 1, while it is 46.7 and 46.2 years in options 2 and 3, respectively. The option, however, that discourages work effort the most, is the last option of means testing the benefits. The policy significantly reduces the labor force participation among the elderly. The labor force participation will plummet once individuals reach the normal retirement age and only 4.3% of those at age 65–85 will participate, while about 12 to 19% of those individuals would remain in the labor force in other reforms.

We also compute transition dynamics and study welfare effects of alternative policy options across individuals that differ in age and wealth at the time of a reform, as well as across current and future generations. Policies to reduce benefits encourage economic activities, but there will be large welfare costs on the current generations. While future generations will prefer lower benefits and lower taxes, current generations would prefer to finance the demographic transition through taxes, especially the middle-aged individuals who have already contributed to the program through payroll taxation.

This paper builds on the vast quantitative research on social security reforms and aging demographics in the tradition of general-equilibrium life-cycle models pioneered by Auerbach and Kotlikoff (1987).³ Existing papers study effects of particular and often ad hoc reforms of the current social security system. For example, Nishiyama and Smetters (2007) simulate a 50% privatization and İmrohoroglu and Kitao (2009) study the effects of half and full privatization of social security system in the U.S. This paper presents a set of policy options that make the social security self-financed as the economy faces the coming demographic shift. The set encompasses the range of possible and well debated reforms and we quantify the magnitude of changes under each option that would restore the long-run sustainability of the program, taking into account the responses to reforms in aggregate variables as well as life-cycle behavior of individuals.

Most papers in the quantitative general-equilibrium literature including the papers listed above assume that labor supply is either exogenous or endogenous only in the intensive margin. Our model endogenizes labor supply in both margins and examines the changes in participation as well as work hours in response to reforms. Recent exceptions are İmrohoroglu and Kitao (2012) and Díaz-Giménez and Díaz-Saavedra (2009). İmrohoroglu and Kitao (2012) incorporate endogenous participation as well as social security benefit claims and focuses on two particular reforms to change retirement ages. Díaz-Giménez and Díaz-Saavedra (2009) study the effects of reform of the Spanish pension system to raise the retirement age in a model with endogenous retirement decisions. Reforms are shown to affect both margins in different ways and exhibit a considerable degree of heterogeneity in the responses across them.

The rest of the paper is organized as follows. Section 2 presents the model economy and the calibration of the model is discussed in Section 3. Section 4 presents the quantitative findings of the paper. Section 5 concludes.

2. Model

This section describes the details of the economic model and presents individuals' recursive problem and the definition of a stationary equilibrium.

2.1. Demographics

The economy is populated by overlapping generations of individuals. Individuals enter the economy at age j_0 and face lifespan uncertainty. The conditional probability of survival from age j to age $j + 1$ is denoted as s_j . The maximum possible age is $j = J$, with $s_J = 0$. The size of new cohort grows at a constant rate n . Individuals derive utility from leaving bequest

² The dependency ratio is defined as the ratio of population above age 65 to that of age 20 to 64. Source: Bell and Miller (2005) for life expectancy and the Census for dependency ratio: <http://www.census.gov/population/www/projections/>.

³ See, for example, Conesa and Krueger (1999), De Nardi et al. (1999), Kotlikoff et al. (1999, 2007), Altig et al. (2001), Nishiyama and Smetters (2007), Attanasio et al. (2007) and İmrohoroglu and Kitao (2009).

at death, denoted as $u_B(b)$ for the amount of assets left b at death. Bequests are assumed to be collected and distributed as a lump-sum transfer to the entire population. Individuals enter the economy with no assets except for the transfer of the lump-sum bequests.

2.2. Endowments

Each individual can allocate one unit of disposable time to leisure or market work. Individuals' earnings are given by $y_L = \tilde{\omega}h$, where $\tilde{\omega}$ denotes the wage rate per work hour h of each individual and is determined as

$$\tilde{\omega} = \omega(j, h)\eta w.$$

$\omega(j, h)$ is the part of the wage that depends on the age and work hours of each individual and η denotes an idiosyncratic labor productivity that evolves stochastically. w is the wage rate determined in the market as discussed in Section 2.4.

2.3. Preferences

Individuals order the sequence of consumption and labor supply over the life cycle according to a time-separable utility function

$$E \left\{ \sum_{j=j_0}^J \beta^{j-j_0} u(c_j, h_j) \right\},$$

where β is the subjective discount factor and the expectation is with respect to the shocks associated with the time of death and idiosyncratic labor productivity. Consumption and labor supply at age j are denoted as c_j and h_j , respectively.

2.4. Technology

Firms are competitive and produce output according to a constant returns to scale technology of the form $Y = F(K, L) = K^\alpha (AL)^{1-\alpha}$, where K and L are aggregate capital and labor inputs and α is capital's share of output. A is the total factor productivity which we assume is constant. Capital depreciates at a constant rate $\delta \in (0, 1)$. The firm rents capital and hires labor from individuals in competitive markets, where factor prices r and w are equated to the marginal productivities as $r = F_K - \delta$ and $w = F_L$.

2.5. Social security

The government in the benchmark economy operates a pay-as-you-go pension system similar to the current U.S. system. A proportional tax τ^s is imposed on earnings of working individuals up to the maximum amount of y^s , above which the social security tax phases out to zero. Once reaching the normal retirement age j_R each retired agent starts to receive benefits ss . The amount of the benefits is determined as a concave function of an individual's average lifetime earnings. We will consider reforms of the social security system in Section 4.

2.6. Fiscal policy

The government spends an exogenous amount of G on public purchases of goods and services and issues one-period riskless debt D' , which pays the interest rate of r . Besides social security taxes, revenues are raised from taxation on labor income, capital income and consumption at proportional rates denoted as τ^l , τ^k and τ^c . The labor income tax τ^l is determined in equilibrium so that the following consolidated government budget constraint is satisfied every period:

$$G + (1+r)D + \sum_x ss(x)\mu(x) = \sum_x [\tau^l \tilde{\omega}h(x) + \tau^s \min\{\tilde{\omega}h(x), y^s\} + \tau^k r(a(x) + b) + \tau^c c(x)]\mu(x) + D', \quad (1)$$

where $\mu(x)$ denotes the measure of individuals in individual state x , D is the debt issued in the previous period and D' is the proceeds of the debt issued in the current period.⁴

2.7. Market structure

The markets are incomplete and there are no state contingent assets to insure against the idiosyncratic labor income and mortality risks. Individuals can, however, imperfectly self-insure against risks by accumulating one-period riskless assets. Individuals are not allowed to borrow against future income and transfers, i.e. $a_j \geq 0$ for all j .

⁴ In stationary equilibrium, all aggregate variables grow at a constant rate n and $D' = (1+n)D$.

2.8. Individuals' problem

The state vector of each individual is given as $x = \{j, a, \eta, e\}$, where j denotes age, a assets accumulated in the previous period, η the idiosyncratic labor productivity, and e the index of cumulated labor earnings that determine the social security benefit. Given the states, each individual optimally chooses consumption, saving and labor supply.

The problem is solved recursively and the value function $V(x)$ of an individual in state x is given as follows:

$$V(j, a, \eta, e) = \max_{c, h, a'} \{u(c, h) + \beta s_j E[V(j+1, a', \eta', e')] + (1-s_j)u_B(a')\}$$

subject to

$$c + a' = (1+r)(a+b) + \tilde{\omega}h + ss(x) - T(x),$$

$$a' \geq 0,$$

$$e' = e, \quad \text{for } j \geq j_R,$$

where $T(x)$ denotes the taxes paid by an individual in state x ,

$$T(x) = \tau^c c + \tau^k r(a+b) + \tau^l \tilde{\omega}h + \tau^s \min\{\tilde{\omega}h, y^s\}.$$

The state e that represents cumulated labor earnings evolves according to the sequence of realized labor productivity shocks and endogenously chosen work hours.

2.9. Stationary competitive equilibrium

For a given set of exogenous demographic parameters $\{s_j\}_{j=1}^J$ and $\{n\}$ and government policy variables $\{G, D', ss, \tau^s, \tau^k, \tau^c\}$, a stationary competitive equilibrium consists of agents' decision rules $\{c(x), h(x), a(x)\}$ for each state x , factor prices $\{w, r\}$, labor income tax rate $\{\tau^l\}$, a lump-sum transfer of accidental bequests $\{b\}$ and the measure of individuals $\{\mu(x)\}$ that satisfy the following conditions:

1. Individuals' allocation rules solve their recursive optimization problems defined in Section 2.8.
2. Factor prices are determined competitively.
3. The lump-sum bequest transfer is equal to the amount of assets left by the deceased

$$b = \sum_x a(x)(1-s_{j-1})\mu(x). \quad (2)$$

4. The labor and capital markets clear:

$$L = \sum_x \omega(j, h)\eta h(x)\mu(x), \quad (3)$$

$$K = \sum_x (a(x) + b)\mu(x) - D. \quad (4)$$

5. The labor income tax satisfies the government budget constraint defined in Eq. (1).
6. The goods market clears:

$$\sum_x c(x)\mu(x) + K' + G = Y + (1-\delta)K. \quad (5)$$

7. The distribution of individuals across states is stationary. $\mu(x) = R_\mu[\mu(x)]$, where R_μ is a one-period transition operator on the distribution.

3. Calibration

This section presents the parametrization of the model. The model period corresponds to a year. The unit of the agents in the model is an individual. For the data that is used to derive the target moments of calibration, we use male and female individual data except for the asset data as we discuss below. More details about the sample selection for each moment are discussed below. The parameters are summarized in Table 1.⁵

⁵ The dollar amounts in the calibration are normalized in terms of the average earnings based on the average earnings of workers in our PSID samples (\$48,000 in 2006 dollars or \$52,000 in 2010 dollars). Outcomes of the model in various figures in Section 4 are expressed in 2010 dollars.

Table 1
Parameters of the model.

Parameter	Description	Values/source
<i>Demographics</i>		
n	population growth rate	1.2%
$\{s_j\}_{j=1}^J$	conditional survival probabilities	Bell and Miller (2005)
J	maximum age	81 (100 years old)
<i>Preference</i>		
β	subjective discount factor	0.9815
χ	weight on leisure	0.5123
γ	leisure utility curvature	4.0
$\{\kappa_i\}_{i=1}^3$	cost of labor force participation	{0.0531, 0.298, 2.780}
ϕ_B	weight on bequest utility	0.4386
<i>Labor productivity process</i>		
ρ_η	persistence parameter	0.97
σ_η^2	variance	0.02
ψ_j	age-dependent productivity	see text
<i>Technology and production</i>		
α	capital share of output	0.4
δ	depreciation rate of capital	8.2%
A	scale parameter	normalization
<i>Government</i>		
τ^k	capital income tax	30.0%
τ^c	consumption tax rate	5.0%
τ^l	labor income tax rate	22.1%
G	government purchases	20% of GDP
D	government debt	40% of GDP
τ^s	social security tax rate	10.6%
j_R	normal retirement age (benefit eligibility)	47 (66 years old)
y^s	social security maximum taxable earnings	\$106,800

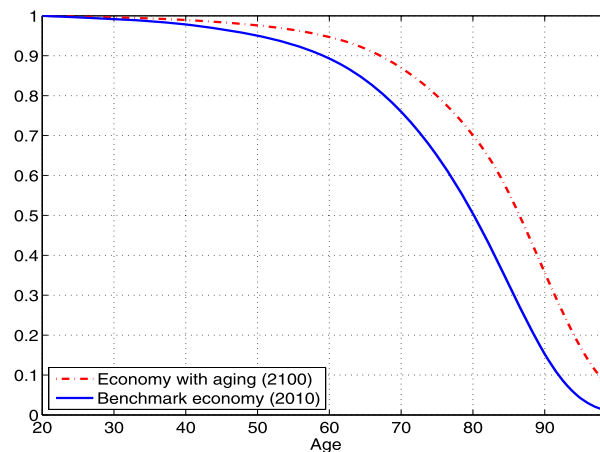


Fig. 1. Survival rates (unconditional): For each age j , the unconditional survival rates are computed as $\prod_{i=1}^j s_{i-1}$ with $s_0 = 1.0$.

3.1. Demographics

The conditional survival rates s_j are calibrated based on the life tables of Bell and Miller (2005). We use the estimates for the age-dependent survival rates of 2010 and take the average of the male and female figures. The growth rate n of the new entrants is set at 1.2%, the long-run average in the U.S. We assume that 20% of “new-borns” enter the labor force at each age between 20 and 24 every period. Individuals live up to the maximum age of 100 ($J = 81$).

When we simulate the economy under alternative demographics (which we call an “economy with aging”) in Section 4, we use the projected survival rates of 2100 from Bell and Miller (2005) and the population growth rate of 0.5%, based on the projections of the U.S. Census Bureau.⁶ Fig. 1 shows the unconditional survival rates for both economies.

⁶ <http://www.census.gov/population/www/projections/natdet-D1A.html>.

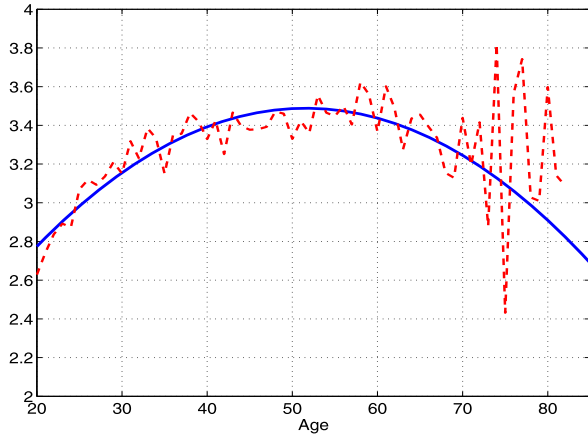


Fig. 2. Age-dependent labor productivity ψ_j : The dashed curve represents the log wage net of the hours effect from the PSID data and the solid line represents a fitted line using a polynomial.

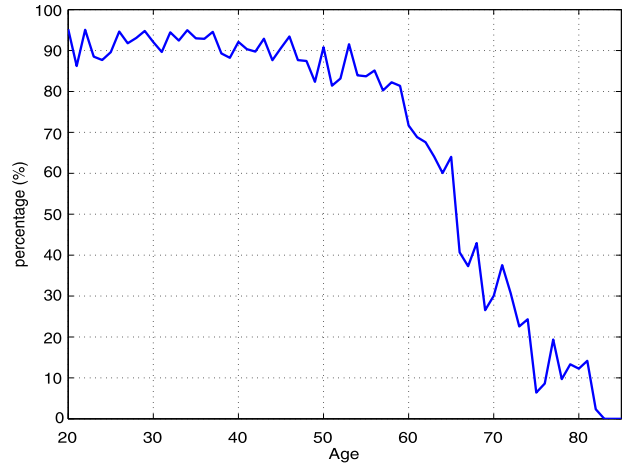


Fig. 3. Life-cycle profile of labor force participation rate: data.

3.2. Endowments, preferences, and technology

To obtain the life-cycle profile of labor market variables such as labor force participation, work hours and wage rates, we use the Panel Study of Income Dynamics (PSID) and its individual data for male and female heads of households.

3.2.1. Endowments

The idiosyncratic component η of a worker's wage is specified as a first-order autoregressive process in log with a persistence parameter $\rho = 0.97$ and the variance of the white noise $\sigma^2 = 0.02$, which lie in the range of estimates in the literature (see, for example, [Heathcote et al., 2010](#)). We approximate this continuous process with a five-state, first-order discrete Markov process.

The component $\omega(j, h)$ is a function of age and hours worked given as

$$\ln \omega(j, h) = \xi \ln h + \psi_j.$$

The coefficient ξ represents the part-time wage penalty and the value is set at 0.415, which implies that individuals who work 1000 hours per year earn 25% less per hour than those who work 2000 hours per year, as estimated by [Aaronson and French \(2004\)](#). We use work hour and wage data in the PSID data in 2007 to derive the age-specific profile of ψ_j as a residual wage net of the hours effect, $\{\ln \omega(j, h) - \xi \ln h\}$, using the life-cycle profile of average work hours.

[Fig. 2](#) shows the profile of age-dependent productivity ψ_j .⁷

3.2.2. Preferences

The instantaneous utility function takes the following specification:

$$u(c, h) = \frac{c^{1-\sigma}}{1-\sigma} + \chi \frac{(1-h-\theta_j \cdot i_p)^{1-\gamma}}{1-\gamma}. \quad (6)$$

The parameter χ represents the weight on utility from leisure relative to consumption. i_p is an indicator that takes a value 0 when $h = 0$ and 1 otherwise. θ_j represents the disutility associated with the participation in the labor market. We assume that the fixed cost of participation is measured in terms of lost time for leisure and varies by age.

[Fig. 3](#) shows the life-cycle profile of labor force participation rate in the PSID data, in which we define participation as working at least 300 hours in a given year.

Until individuals reach mid-50s, the profile is flat and a great majority of individuals participate in the labor force.⁸ The participation rate declines to about 70% by age 60 and falls sharply thereafter, reaching almost 0% in early-80s. Conditional on surviving, individuals who enter the labor market at age 20 spend about 44 years of their life participating in the labor market. We assume the functional form of $\theta_j = \kappa_1 + \kappa_2 j^{\kappa_3}$ for the age-dependent fixed cost of participation and calibrate

⁷ In Section 5.2, we study the sensitivity to alternative specification of age-dependent productivity, first assuming an age-invariant constant profile and second assuming no depreciation of productivity after the peak is reached in early 50s.

⁸ As mentioned above, our samples are male and female heads of households. Therefore participation rates as shown in [Fig. 3](#) are higher than what is reported for the general population, for example the CPS data. Head samples are used since agents in our model have a high attachment to the labor market and we do not have other mechanisms such as an incentive of secondary earners in a family or that of dependents.

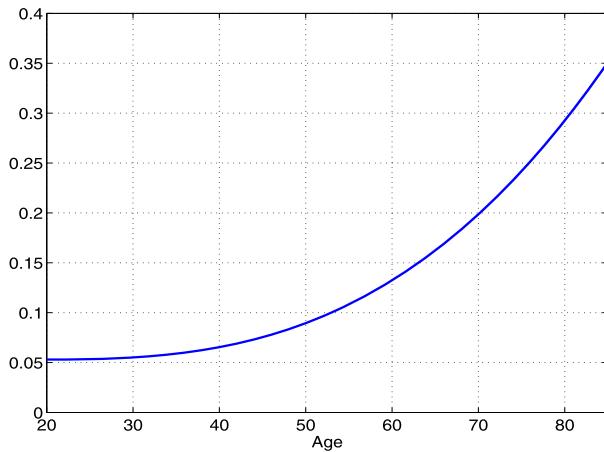
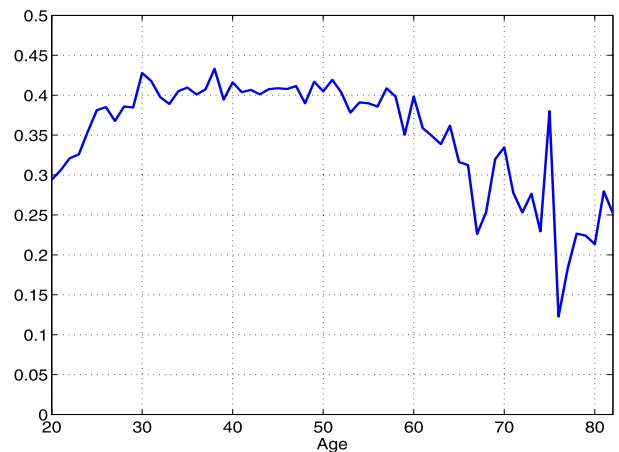
Fig. 4. Participation cost by age θ_j .

Fig. 5. Work hours over the life cycle: data.

the three parameters of the function to match these three targets, average participation rate at age 60 and in early 80s, and average work years over the life cycle.⁹ The profile of the participation cost θ_j is shown in Fig. 4. The average value of θ_j across all workers in the benchmark is 0.067, corresponding to about 1 hour per day, assuming 16 hours of disposable time. The value nearly doubles by age 60 to about 2 hours per day, or 770 hours per year.¹⁰

We assume that individuals make the participation decision between the ages of 20 and 85 and everyone withdraws from the labor market at 86 permanently.

The utility from bequest is assumed to be linear as in Kopczuk and Lupton (2007) and defined as $u_B(b) = \phi_B b$. The coefficient ϕ_B determines the relative weight on the bequest utility. According to the SCF, the ratio of the average wealth held by households above age 65 to those between age 20 and 64 is 1.5. Studies find many elderly keep large amounts of assets until very late in life. According to the SCF, households at age 65 and beyond hold 50% more assets than younger households of age 20–64 on average and we calibrate the value of ϕ_B to match the ratio.¹¹

The subjective discount factor β is set so that the model has a capital–output ratio of 3.0 in the initial steady state.¹² The parameter χ is chosen so that the average work hours of working individuals equal to 38% of disposable time as in the PSID data. Fig. 5 shows the hours profile over the life cycle from the PSID samples.¹³

We set the risk-aversion parameter σ at 2. The parameter γ is set at 4.0, which implies the intertemporal labor supply elasticity of about 0.32 on average. The value is in line with the estimates using the microdata, as surveyed in Browning et al. (1999).¹⁴

In order to assess the sensitivity of the labor supply with respect to each of the extensive and intensive margins, we simulate a model shutting down the adjustment of one margin at one time. See Section 5.1 for more details of the experiments.

3.2.3. Technology

The income share of capital α is set at 0.40, based on private and public fixed capital including the stock of durables. The depreciation rate δ is $0.082 = \frac{X/Y}{K/Y} - n$, which is implied by the equilibrium law of motion for the capital in the steady state, where we target an investment–output ratio X/Y of 0.28 and a capital–output ratio K/Y of 3.0.¹⁵ The TFP parameter A is set to normalize the unit of the model and to achieve the average earnings of 1.0 in the model's equilibrium.

⁹ For normalization, the age j in the formula is expressed as the years since age 20 as a fraction of workable years, that is, 66 years.

¹⁰ French and Jones (2011) estimate participation cost at age 60 as 826 in annual hours.

¹¹ Ideally we would like to have the profile of wealth for individuals in a household, to be consistent with the calibration of other variables. Given the difficulty in distinguishing assets of spouses and individuals in a household, we assume that the life-cycle profile of households wealth approximates that of individuals and use the household data.

¹² The capital stock is assumed to consist of private fixed capital, government capital and the stock of durables. Imputed income flows from the last two components of capital stock are added to measured GNP so that the measurements are consistent.

¹³ The hours are expressed as a fraction of disposable time, based on 15 hours per day times 365 days.

¹⁴ Note that the actual elasticity depends on the age and work hours of each individual. The average elasticity is computed based on the average work hours of 0.38 and the average participation cost of 0.13, $(1/\gamma) * (1 - 0.38 - 0.13)/0.38$ with $\gamma = 4$. The elasticity is higher for individuals who work less and are older.

¹⁵ Note that we abstract from technological growth since we also consider preference specifications that are not consistent with a balanced growth path. This allows us to implement utility functions with alternative values of the coefficient of relative aversion and labor supply elasticity separately that are considered in the literature.

3.3. Government

3.3.1. Social security

In the benchmark economy, the government runs a pay-as-you-go social security program that captures the features of the system in the U.S. We set the social security tax rate τ^s at 10.6% with the maximum taxable amount of $y^s = \$106,800$ as it is in the U.S. in 2009–2011. The benefit, or the Primary Insurance Amount (“PIA”), is determined as a concave piecewise linear function of the career-average earnings (“AIME”), which we capture through the state variable e . In 2010, the marginal replacement rate is 90% for the average earnings up to \$9132, above which the replacement rate falls to 32%. For earnings above \$55,032, the replacement rate is 15%.¹⁶ See Appendix A for more details about the computation of the AIME and PIA.

The social security’s replacement rate, defined as the ratio of the average benefits to the average earnings of workers, is 40% in the benchmark model.

3.3.2. Government expenditures, public debt and taxes

In the benchmark economy, we set the government spending G at 20% of output, which is the average ratio of government consumption expenditures and investment to GDP in the post-war period. The ratio of federal debt held by the public to GDP is set at 40%. We assume a consumption tax rate of 5% and a capital income tax rate of 30%. The labor income tax is set so that the overall government budget constraint is satisfied.

4. Numerical results

In this section, we will first present the outcome of the benchmark economy, focusing on the life-cycle profile of individual decision variables. We will then simulate the model with the shift in demographics, which is financed by four different policy options and assess the economic effects of alternative policies. Finally, we compute the transition dynamics from the calibrated benchmark economy to a new economy under an alternative policy and analyze the welfare effects from the transition.

4.1. Benchmark economy

Fig. 6 shows the labor force participation of individuals along the life cycle in the benchmark model. As we saw in the calibration section and in Fig. 3, in the data the labor force participation lies in the range of 90–100% until mid-50s and the profile is very flat in this age range. Thereafter, the participation starts to decline gradually and then sharply in mid to late-60s, eventually reaching below 20% by age 70 or so. Our model generates this pattern although we do not capture the relatively small fraction of young individuals who do not participate in the labor market, partly because our model is not rich enough to incorporate various possible reasons for non-participation such as time for human capital investment or child-bearing, and unemployment among other factors. The model generates a gradual decline in labor force participation starting in 50s and more sharply in 60s. The pattern of the withdrawal from the labor market in the model is explained by the combination of the rising participation cost, a decline in the labor productivity and wages at mid to old ages and the income effect that is strengthened through the rise in wealth and consumption as they age.

Fig. 7 shows the profile of work hours in the benchmark model. Hours are fairly flat initially and lies in the range of 0.35 and 0.45 between ages 20 and 50, while trending down as they age. Hours are much lower at very old ages, falling to about one quarter of disposable time by age 70 and continuing to decline thereafter. The overall pattern of hours profile is consistent with the data as shown in Fig. 5, although the model does not capture the mildly hump-shaped profile in the data, in which hours start low in early 20s and rise during the first 10 years. Incorporating the time set aside for human capital investment or short-term or part-time jobs that a relatively large number of younger individuals undertake during the years of ‘job churning’ is likely to improve the fit.

Fig. 8 shows the life-cycle profile of average assets by age. Individuals in the model save and accumulate wealth for three reasons; precautionary savings to insure against idiosyncratic income and mortality risks, retirement savings to supplement consumption after withdrawing from the labor force and savings to leave bequests. Individuals start to accumulate wealth at young ages to build a buffer stock of savings to insure against earnings risks and they maintain a significant amount of wealth even at very old ages to insure against the risk of outliving and to leave the optimal amount of bequests (see, for example, De Nardi et al., 2010).

The social security system currently runs a surplus and the revenues from the payroll taxes exceed the spendings on the benefits. In our benchmark model, the program runs a surplus in the magnitude of 0.44% of GDP every year, corresponding to the current magnitude of the surplus in the U.S. social security system. With the projected shifts in demographics, the spendings will significantly exceed the revenues if there is no reform. If we were to make the program sustainable, the budget gap needs to be filled by some form of taxation or reduction in benefits. We will explore the reform options in the next section.

¹⁶ The bend points for the PIA formula are adjusted every year. The maximum monthly benefit is determined as the PIA that corresponds to the maximum taxable earnings.

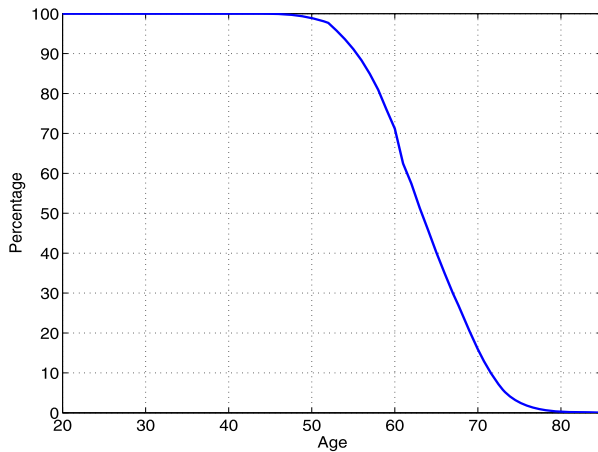


Fig. 6. Life-cycle profile of labor force participation rate.

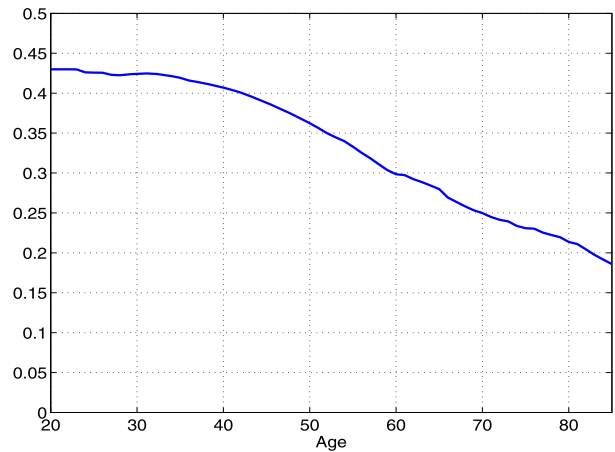


Fig. 7. Life-cycle profile of work hours.

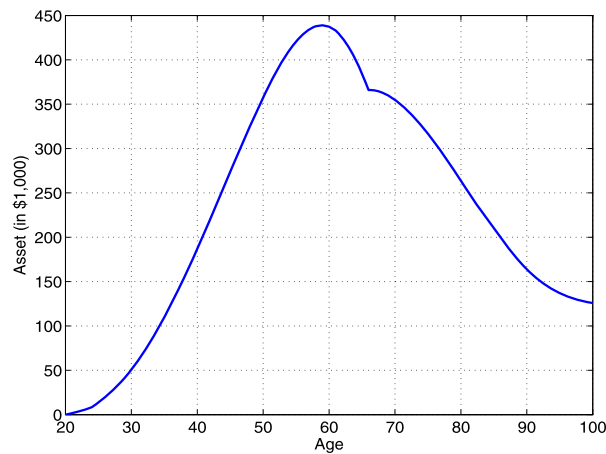


Fig. 8. Life-cycle profile of wealth.

4.2. Policy options

In this section, we study four policy options to deal with the change in demographics and balance the budget of the social security program. Long-run effects of a reform are analyzed first, with a special emphasis on the changes in the labor supply in intensive and extensive margins. In the next section, we will study transition dynamics and welfare effects of reforms.

As mentioned above, we assume the demographics implied by the projected survival rates and population growth rates for 2100 in this “economy with aging.”¹⁷ The implied old-age dependency ratio, which is defined as the ratio of individuals above age 65 to those at age 20–64, nearly doubles from 23.7% in the benchmark economy to 39.8% in the economy with aging. The life expectancy at birth implied by the survival rates are 77.8 years and 84.2 years in the two economies, respectively.¹⁸

In what follows, we study policy options to fill the budget gap associated with the social security and to make the program self-financed. Differently from the benchmark economy, in which we imposed a consolidated budget constraint of Eq. (1) and backed out the labor tax rate that satisfies it, we assume an independent budget equation for the social security program as in (7) below, separately from the general government budget in (8), which excludes cash flows associated with the social security program. As in the benchmark economy, we adjust τ^l to satisfy the general government budget (8),

¹⁷ The survival rates are based on the estimates of Bell and Miller (2005) in 2100 and the population growth rate is based on the growth rate of the number of individuals at age 20 in 2100 according to the Census projections.

¹⁸ We use period life tables of Bell and Miller (2005) for 2100 and 2100 to approximate the mortality risks in the initial and final steady states, respectively. The period life expectancies reported in Bell and Miller (2005) are 77.7 and 84.2 as the average of male and female. Our numbers are very close but do not match them exactly because we truncate the maximum age of individuals at 100 and abstract from death probability before the model's first age of 20.

$$\sum_x ss(x)\mu(x) = \sum_x \tau^s \min\{\tilde{\omega}h(x), y^s\}\mu(x), \quad (7)$$

$$G + (1+r)D = \sum_x [\tau^l \tilde{\omega}h(x) + \tau^k r(a(x) + b) + \tau^c c(x)]\mu(x) + D'. \quad (8)$$

When we simulate alternative policy options in the economy with aging, we assume that per-capita government expenditures and debt are fixed at the levels in the initial benchmark economy. We keep them at the same level across experiments in order to control for the level of revenues needed to finance them and focus on the effects of alternative social security reforms.

We will consider four policy options that we discuss below and in each of the policy options, we solve for the value of a policy parameter to make the social security program self-financed and satisfy the program's budget equation (7) with equality. In the first, which we call as option 1, the benefits remain untouched and the payroll tax rate τ^s is adjusted to balance the program's budget. This option maintains the benefit function for each retiree but implies an increase in the total pension expenditures, whose cost falls on workers through payroll taxes.

The other three options will keep the payroll tax rate at the benchmark level, but adjust the benefits in different ways to balance the budget. In option 2, benefits for each retiree are reduced by proportionally scaling the benefit function. The replacement rate for given past income will decline as a result. In option 3, the normal retirement age is raised from 66 to make the spendings match the payroll tax revenues.¹⁹ Compared to option 1, agents will have stronger incentives to accumulate wealth to cover the consumption after retirement. Under these two options, the nature of the universal coverage provided by the pension system remains the same but the total expected benefits will be reduced by the adjustment of benefit years (option 3) or the amount in each year (option 2).

Option 4 introduces means testing in the provision of the benefits. It also reduces the total expenditures but differs from options 2 and 3 in that some retirees will be either completely or partially excluded as recipients based on the means test. We adjust the level of income where the benefits start to phase out so that payroll tax revenues are enough to cover total benefit expenditures. Means test is an implicit tax on earnings and capital income from accumulated wealth. Depending on the level of the threshold, the policy can bring sizeable distortions on the economic incentives and negatively affect aggregate capital and labor inputs.²⁰

In order to facilitate comparison with the benchmark and across four policy options, we will first focus on the first option and contrast the results with those in the benchmark economy. The first option is essentially a “do-nothing” policy, which keeps the benefits intact in terms of replacement rates and eligibility. We will then use the first option as a reference point and compare three other options in terms of deviations in various economic variables from the first option. These steps will help distinguish between the effects of the demographic shift and those of alternative fiscal adjustments.

4.2.1. Option 1. Payroll tax increase (“do-nothing” on benefits)

Table 2 compares the benchmark economy and the first option, in which the demographic shift is financed through an increase in payroll taxes. Since the demographics differ in two economies and the relative size of the population is indeterminate, the changes in aggregate variables (capital, labor, consumption and social security benefit spending) are expressed in terms of changes in per capita levels.

The payroll tax needs to increase by 5.7 percentage points, from 10.6% to 16.4%, and the total taxes on earnings (sum of labor income tax and payroll tax) rise by 9.3 percentage points, from 32.7% to 42.0%. The tax has to increase significantly to finance the rise in the social security benefits for retirees, which grows by more than 50% compared to the benchmark economy.

Despite the increase in labor taxes, individuals work more than in the benchmark economy, both in intensive and extensive margins, in order to supplement the retirement consumption for longer expected periods. The average work hours increase by 2.1% and the average number of years to work rises from 44.0 to 44.5 years. Fig. 9 shows the changes in labor force participation rates and average work hours over the life cycle. Labor supply in both margins increase across all ages.²¹ Although individuals work more, the average after-tax earnings will decline since the rise in labor supply and wage rate is not large enough to offset the increase in taxes. As a result, disposable income falls and both assets and consumption decline with the demographic shift financed by the tax increase. Capital per capita falls by 5.3% and consumption declines by 5.5%, as shown in Table 2. Note that per-capita labor declines despite the rise in labor force participation and work hours due to the age-decomposition effect. That is, there are relatively more old-age individuals who are not in the labor force and the labor supply from a smaller fraction of the population is used for the production of the aggregate economy.²²

¹⁹ Since the model is in annual frequency, we find the annual age that minimizes the imbalance of the social security budget. As a result, there will be a small, but non-zero surplus or deficit, which is combined into the general government budget.

²⁰ Means-tested reform has not been studied in the literature as extensively as the other reforms. Exceptions are a paper by Sefton et al. (2008) that studies the role of means testing in the U.K. state pension system and Tran and Woodland (2012) who analyze the reform of the means-tested public pension program in Australia.

²¹ Note that the average labor force participation of agents at age 65–85 declines slightly as shown Table 2. This is due to the change in the decomposition, that is, in the economy with aging the average age is higher and there is a greater fraction of older individuals who participate less.

²² If we compute labor per ‘working-age’ individual of age 20–64, it is higher by 5.4% under option 1 than in the benchmark economy.

Table 2
Benchmark and demographic shift financed by payroll tax increase (option 1).

	Benchmark	Economy w/aging Option 1
Capital (per capita)	–	–5.3%
Labor (per capita)	–	–7.0%
Average work hours	–	+2.1%
Consumption (per capita)	–	–5.5%
Wage	–	+0.7%
Interest rate	5.19%	5.04%
Total labor taxes $\tau^y + \tau^s$	32.7%	42.0%
– Labor income tax τ^y	22.1%	25.7%
– Social security tax τ^s	10.6%	16.4%
<hr/>		
Social security		
Benefit spending (per capita)	–	+53.8%
Avg replacement rate	39.6%	38.8%
<hr/>		
Labor force participation		
Age 20–49	100.0%	100.0%
Age 50–64	81.0%	82.3%
Age 65–85	12.9%	12.4%
Avg work years	44.0	44.5

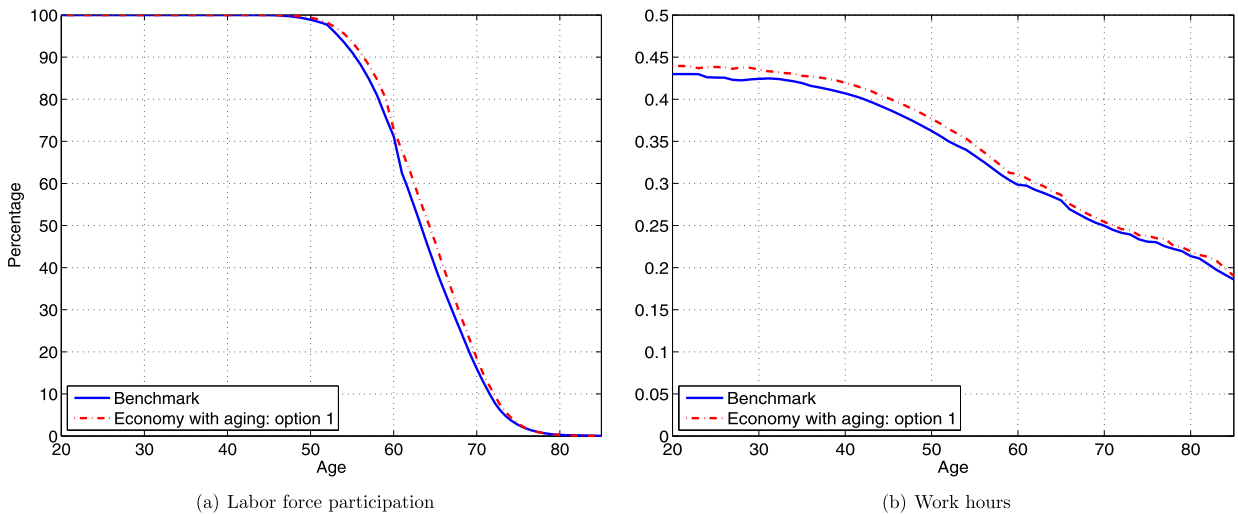


Fig. 9. Labor supply in benchmark and option 1.

Next we will compare four alternative policies to sustain the social security budget, all in the economy with aging. We use the first option of raising the payroll taxes as a reference point of comparison. The results are summarized in Table 3. Changes are expressed as a deviation from the economy that implements the first policy option.

4.2.2. Option 2. Replacement rate cut

In option 2, we reduce benefit replacement rates by shifting down the benefit formula proportionally for given level of past earnings e , that represents past earnings of individuals. The payroll tax rate τ^s remains at 10.6% as in the benchmark economy. For the program's budget to balance, the benefit scale must decline by about one-third (32.6%). The social security's average replacement rate declines sharply from 38.8% under option 1 to 26.2%.

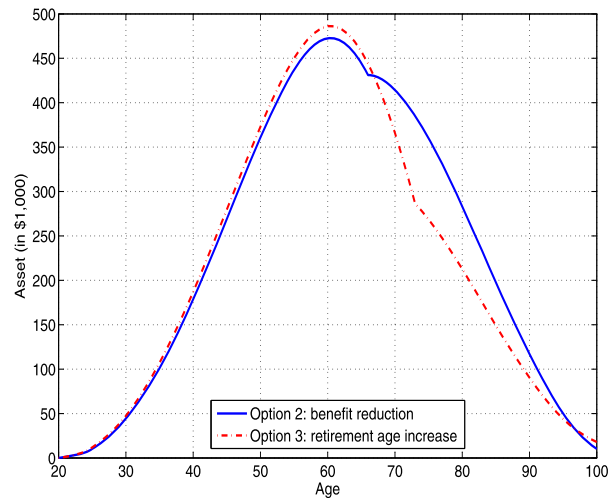
With lower benefits provided by the government, individuals save and accumulate wealth more aggressively to supplement retirement consumption. As a result, the aggregate stock of capital is 15.5% higher than in option 1. The significant rise in capital will raise the capital-labor ratio and the interest rate declines from 5.0% under option 1 to 4.0%.

Individuals work longer compared to option 1 and the participation rate at age 50–64 and 65–85 will rise by 5.6 and 7.0 percentage points, respectively, to 87.9% and 19.4%. The average number of years that individuals work along the life-cycle increases by more than two years, from 44.5 to 46.7 years. Since the age decomposition of workers changes and there are relatively more of old-age individuals, who work fewer hours than the young, the average work hours decline by 2.5%. The aggregate labor supply increases but only by 0.7%. Given the sizeable decline in the interest rate, the consumption and labor supply profiles become flatter. As a result, individuals work relatively more at older ages and the average work hours of younger individuals decline slightly, which contribute to a muted change in the aggregate labor supply.

Table 3

Comparison of alternative reforms.

	Option 1 Tax increase	Option 2 Benefit cut	Option 3 Retire. age	Option 4 Means test
Aggregate variables				
Capital	–	+15.5%	+11.0%	–2.3%
Labor	–	+0.7%	+0.9%	–0.9%
Average work hours	–	–2.5%	–1.6%	+1.5%
Consumption	–	+4.4%	+3.7%	–1.6%
Wage	–	+5.6%	+3.9%	–0.6%
Interest rate	5.0%	4.0%	4.3%	5.2%
Tax rates				
Total labor taxes $\tau^y + \tau^s$	42.0%	34.7%	35.1%	36.8%
– Labor income tax τ^y	25.7%	24.1%	24.5%	26.2%
– Social security tax τ^s	16.3%	10.6%	10.6%	10.6%
Social security				
Benefit spending	–	–31.2%	–31.2%	–35.8%
Avg replacement rate	38.8%	26.2%	38.9%	24.5%
Labor force participation				
Age 20–49	100.0%	100.0%	100.0%	100.0%
Age 50–64	82.3%	87.9%	86.9%	81.5%
Age 65–85	12.4%	19.4%	17.6%	4.3%
Avg work years	44.5	46.7	46.2	42.9

**Fig. 10.** Assets over the life cycle in options 2 and 3.

A more smooth life-cycle profile of both consumption and labor supply, together with a sizeable increase in the aggregate consumption level, leads to a favorable welfare effect in the long run, as we discuss in Section 4.3.

4.2.3. Option 3. Normal retirement age increase

In the third option, the normal retirement age is raised to reduce the benefit spendings and balance the budget of the social security. As in option 2, the payroll tax rate remains the same at 10.6%. The retirement age will have to rise by 7 years from 66 to 73 years old to close the budget gap.²³

As shown in Table 3, effects on aggregate variables are very similar to those under the option 2 studied above, not only qualitatively but also quantitatively. Fig. 10 shows, however, the life-cycle patterns of saving that are somewhat different in options 2 and 3. In option 3, individuals start to decumulate wealth more quickly after the peak is reached at around age 60 to finance their consumption, while the pace of decumulation is much slower under option 2. Once individuals reach the retirement age of 73, they are entitled to higher benefits than in option 2 (note the replacement rate of 38.9% vs. 26.2%) and the assets will decline more slowly.

²³ The exact budget balance of the social security program is a small deficit that corresponds to 0.07% of the GDP, since we assume the retirement age to be in integers.

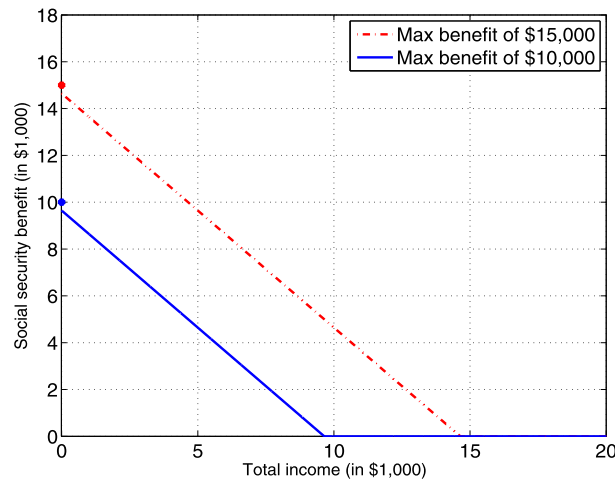


Fig. 11. Means-tested social security benefit under option 4: examples.

The policies of reducing the replacement rate and raising the normal retirement age both reduce the total expected benefits. Therefore it is not surprising that we observe similar response, where the agents accumulate more savings and work longer. In the long run also, both policies bring a large welfare gain of a similar magnitude. There is, however, difference in the life-cycle profile of savings as the timing of starting to decumulate wealth differs as shown in Fig. 10. It also explains why we have somewhat smaller change in capital under option 3 at +11.0%, than +15.5% under option 2.²⁴

4.2.4. Option 4. Means-tested benefits

Lastly, we introduce means test in the determination of the social security benefits. This option appears to be less commonly debated than the previous three options in the U.S.²⁵ Many countries including Australia, Denmark and France have a component of the social security system that are means tested. Australia is a notable example, in which is the pillar of the basic pension system known as the “Age Pension” is subject to both asset and income test.²⁶ We assume a simple form of means testing, which allows the benefits to fall one-to-one with income above a threshold level.

Denote by \bar{ss} the social security benefits without the means test, and the actual benefit after the test would be

$$ss = \max\{\bar{ss} - \max(y - \bar{y}, 0), 0\}, \quad (9)$$

where y is the total income of each individual. \bar{y} is the cutoff level of income above which the benefits decline one-to-one until they reach zero and it is the policy parameter that is determined so that the social security program is self-financed. The max operator inside the bracket guarantees that the benefits do not exceed the upper limit of \bar{ss} . The value of \bar{y} that makes the social security budget in Eq. (7) hold with equality is almost zero, -0.0068 in model units (or $-\$350$). To illustrate the benefit adjustment by the means test, Fig. 11 shows the benefit as a function of total income, for two types of individuals with different past earnings and maximum benefit entitlement \bar{ss} of \$15,000 and \$10,000. When the income exceeds certain levels (slightly less than \$15,000 and \$10,000, respectively), the benefits will be completely exhausted through the means test. The benefits will vary with income of each individual in a given year.

As shown in the last column of Table 3, means testing the social security benefits will reduce both aggregate capital and labor supply, a result that is in stark contrast from options 2 and 3, although all of the three options have a common goal of controlling the spending side of the equation by cutting down the benefits in different ways. In particular, the labor participation of older individuals will decline significantly under the means test. The participation rates for individuals of ages 50–64 and 65–85 are 81.5% and 4.3% respectively, 0.8 and 8.1 percentage points lower than in option 1. The participation rates are significantly lower than under the previous two options, which gave individuals strong incentives to work longer to supplement retirement consumption. The average work years is 42.9 years, more than 3 years shorter than in options 2 and 3.

²⁴ In a model that allows for endogenous timing of claiming benefits, the reform of raising the normal retirement age, that is, when individuals can receive full (100%) benefits, would be equivalent to the reduction in benefits, provided that benefits claimed before or after the normal retirement age are adjusted by the same rates. Reforms, however, are different if the age window to start receiving benefits is shifted with the normal retirement age (say, from age 62–70 to age 65–73). Our model assumes a retirement age window that is degenerate, and the reform shifts the window; an example that distinguishes between a reform to reduce the benefit replacement rate and a reform to raise the retirement age. We abstract from the choice of retirement age and see, for example, Imrohoroglu and Kitao (2012) for a model that treats the benefit claim and labor market decisions separately.

²⁵ There is, however, some means testing of benefits in the general U.S. social system, such as the Supplemental Security Income (SSI) provides benefits to the aged or disabled individuals subject to the test on the level of income and resources.

²⁶ http://www.centrelink.gov.au/internet/internet.nsf/payments/age_pension.htm provides details about the Age Pension.

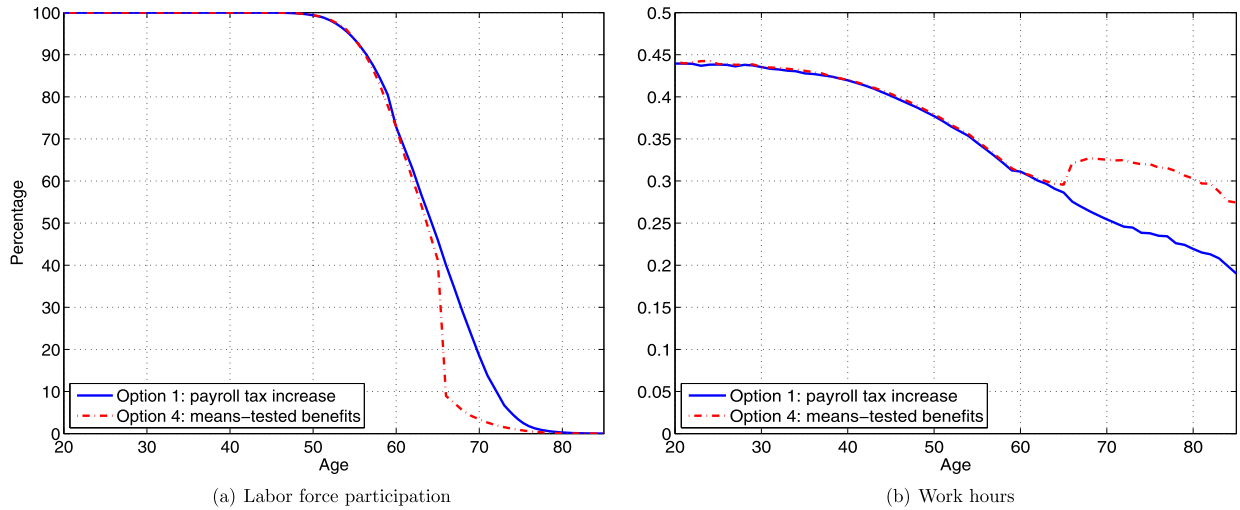


Fig. 12. Labor supply over the life-cycle in options 1 and 4.

Fig. 12 shows life-cycle profiles of labor supply in options 1 and 4, which exhibit strong disincentives on participation from the means testing once individuals reach the retirement age of 66. The small number of individuals who remain in the labor force are the ones with very high productivity and they work longer hours to exploit the high wage, with most of them making earnings well beyond the point where the social security benefits are exhausted due to the means test. Assets decline more sharply as well since the test is on the total income including returns from savings and works as an implicit tax on not only earnings but also capital income and savings.

4.3. Transition dynamics and welfare analysis

In this section we will analyze transition dynamics triggered by social security reform and study welfare effects from the transition. We will focus on the first three options that we considered above, the options to raise payroll taxes, to reduce replacement rates and to increase the normal retirement age.²⁷ We assume that the economy starts in the steady state implied by the benchmark model that we calibrated and analyzed in Section 4.1, which we call “initial steady state.” At the beginning of period 1, a new policy is announced and implemented. The economy will then start to make a transition to a new steady state which is implied by the new social security policy, and we call this economy as “final steady state.” The economies in the final steady state implied by alternative policies are the ones that we studied in Section 4.2.

The economy will also experience demographic transitions, starting in period 1. The mortality risks will improve gradually over time and the survival rates increase linearly over 90 years from the rates of 2010 that we used in the benchmark economy to the projected survival rates of 2100.²⁸

As in Section 4.2, we will first study the results of option 1, which is a policy to adjust the tax and “do nothing” about the benefits. We will then use the transition path of option 1 as a benchmark and compare the paths of other options relative to the benchmark. For each policy option, a transition path is computed. There are many possible ways to introduce the new policy and we assume that the adjustment will be gradual and the policy variable in each option will adjust over 50 periods and converge to the level in the final steady state. In option 1, the payroll tax increases linearly over 50 periods from the benchmark level of 10.6% to 16.4% in the final steady state. In option 2, the benefit scale (replacement rates for given past earnings) shifts down linearly every period and declines by a total of about one-third (32.6%) over 50 periods. In option 3, the normal retirement age is raised by one year every 7 periods starting in period 2 so that the retirement age will reach 73 in 50 periods, which we found will almost balance the social security budget in the long run. More detailed description of the computation is provided in Appendix B.

Fig. 13 shows the transition dynamics of capital and labor supply per capita, interest rate and labor income tax rate when the option 1 is implemented. It is a policy to raise the payroll taxes to make the social security program sustainable without making any changes about the benefit schedule or the retirement age. Fig. 13(a) shows the transition of capital over time. Capital stock rises initially as the survival rates increase and agents increase saving for retirement. Over time, however, the decrease in the labor supply and earnings will reduce the disposable income and the level of the saving will

²⁷ We do not discuss in the paper the transition analysis for option 4 of meas-testing benefits, but computational results are available upon request from the author. Given the large negative effects on economic activities and fiscal burden, it is unlikely to be a viable option for the social security reform. Our results also suggest large negative welfare effects on current and many future generations through the transition.

²⁸ Note that the complete convergence of demographics will take more years after the survival rates converge in 90 years. We also assume that the growth rate of new cohorts declines linearly over 90 years from 1.2% in the benchmark economy to 0.5%, the projection of the U.S. Census Bureau.

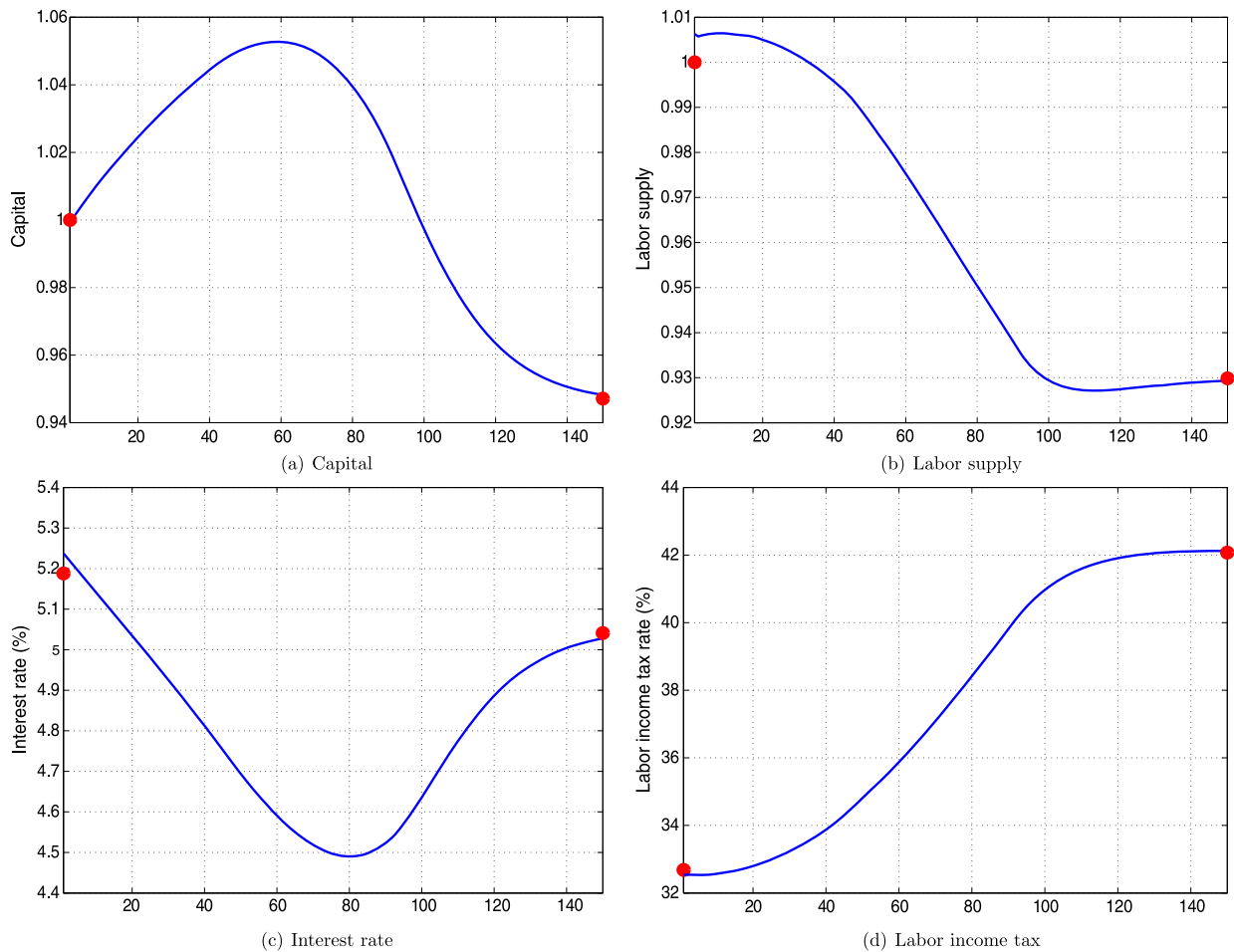


Fig. 13. Transition dynamics: option 1: payroll tax increase. Two circles in each plot at the first and last periods indicate the levels in the initial and final steady states. The levels of capital and labor supply are normalized so that they take the value of one in the initial steady state. On horizontal axes are the number of years elapsed since the announcement of the new policy.

start to decline. The sharp increase in capital while the demographic change takes place implies a decline in the rental rate of capital and the interest rate falls from above 5.2% to 4.5%, which bounces back to around 5% as the capital starts to decline in later periods.

As shown in Fig. 13(b), the demographic transition implies a significant decline in the labor supply of the economy, with the average labor supply per person in the economy falling by 7 percentage points through the transition. The sharp increase in labor income taxes, as shown in Fig. 13(d), will add to the decline in labor supply, as we also studied in Section 4.2. Without any change in the benefits, the demographic transition will imply a steady increase in the labor income taxes from slightly above 32% to about 42%.

Fig. 14 compares the transition dynamics of variables under options 2 and 3 to those of option 1 that we just studied. Given the gradual decline in the benefits or the increase in the normal retirement age, agents have stronger incentives to accumulate wealth for retirement and capital starts to rise even more sharply than in option 1. Labor supply will jump up by about one percentage points in both options 2 and 3, as some agents will try to make up for a decline in social security benefits by working longer.

The rise in earnings will expand the tax base and the labor income tax will decline by a few percentage points during initial decades of the policy change but start to rise as the labor supply falls sharply thereafter. Under option 3, the path of labor income taxes non-smooth since the retirement age will be raised every seven years in a discrete fashion and there is a discrete improvement in the government budget, which makes the labor tax decline in the year of raising the retirement age.²⁹

²⁹ The paths of the tax rates would be smooth if the retirement age is adjusted more gradually and the model is in a higher frequency, for example in a monthly frequency. The path of labor supply is also non-monotonic induced by the movements in the labor income tax rates.

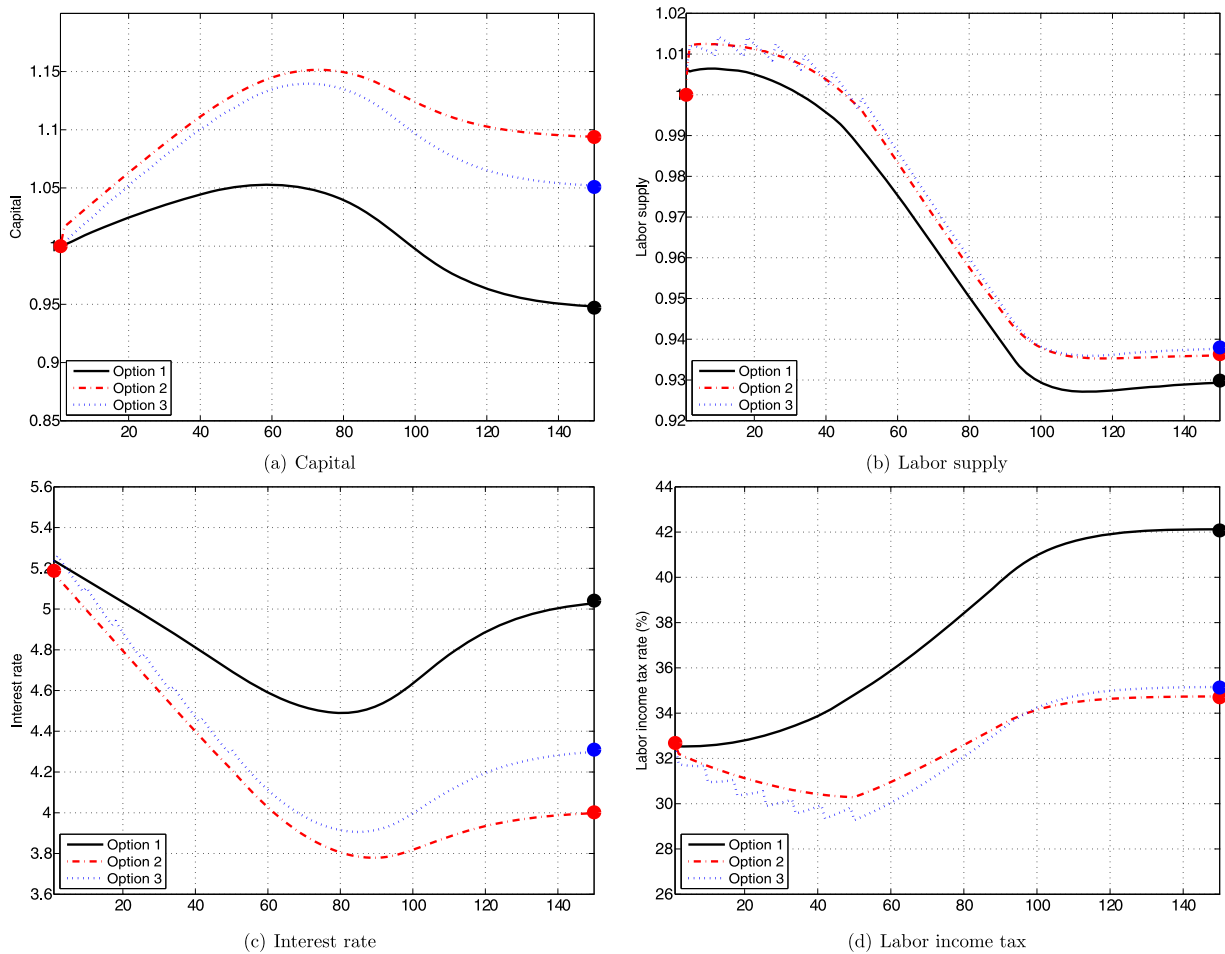


Fig. 14. Transition dynamics of capital and interest rates: comparison of options. Two circles in each plot at the first and last periods indicate the levels in the initial steady state and final steady state for each option. The levels of capital and labor supply are normalized so that they take the value of one in the initial steady state. On horizontal axes are the number of years elapsed since the announcement of the new policy.

4.3.1. Welfare analysis

In order to evaluate and compare the welfare effects of a reform, we will use the transition path implied by option 1 as the benchmark and ask whether agents will prefer another option, for example option 2, versus option 1 and quantify the magnitude of welfare gains or losses between the two options. More precisely, we compute a one-time positive transfer to agents in each state in period 0 that will make them indifferent between the benchmark (option 1) and the alternative. Depending on which option the agent prefers, the transfer can be either to an agent who would be in the benchmark or to an agent in an economy with a different option.

We will also study welfare effects for future generations. The amount of transfer is computed that will make a new-born agent indifferent between being born into the economy that is transitioning under option 1 and another economy that had implemented another option.

Figs. 15 and 16 show the welfare effects of options 2 and 3, respectively, relative to option 1. A positive amount of transfer, for example \$10,000 in option 2, indicates that agents in that particular state prefer option 2 to option 1. The magnitude of the gain under option 2 is equivalent to a one-time transfer of \$10,000, for example. Similarly, a negative number indicates that agents will be worse off in option 2 than in option 1.

The figures suggest that almost everyone in the current generations would prefer the “do-nothing” policy of option 1, which would preserve social security benefits while allowing the payroll tax rate to rise to absorb the cost of demographic transitions. In the long run, however, agents born in future will prefer the benefit reduction either by a cut in replacement rates or an increase in the normal retirement age, rather than facing high payroll taxes to sustain the current benefit schedule.

The (a) plot in each figure indicates welfare effects on agents that are alive at the time of the reform announcement by the level of wealth for four age groups, 35, 50, 65 and 80, as examples. Within each age group, wealthier agents are worse off under both options to reduce benefits. As we saw in Fig. 14, the interest rate falls much more rapidly in options 2 and 3

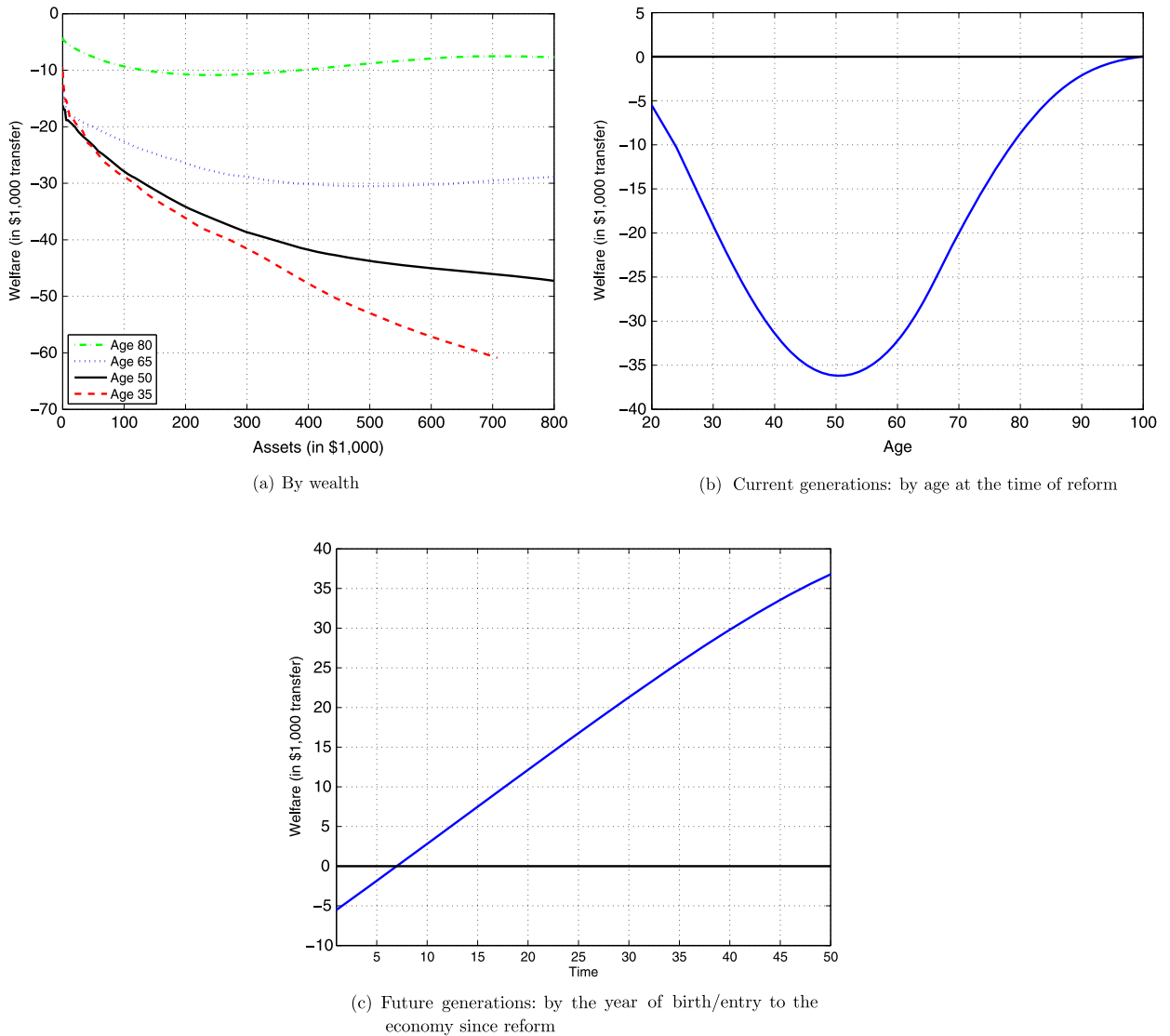


Fig. 15. Welfare effect: option 2 – replacement rate cut.

than in option 1 since agents accumulate more savings in anticipation of the lower retirement benefits. The fall in interest rate will hurt the wealthy more as the return on their wealth declines rapidly. The younger rich will suffer more as they will also face a prolonged period of low interest rates during the transition. However, the average welfare effects for young agents in 20s and 30s are not as severe as those for the middle aged in 40s and 50s since they do not own much wealth. The (b) plot in each figure shows the average welfare effect by age. Note that the effects are not monotonic for option 3, since the normal retirement age is raised every 7 years in a discrete fashion.³⁰ Those who are already retired are impacted much from option 1 or 3, as reflected in small welfare effects shown in Fig. 16(b). In option 2, however, retirees at the time of the policy announcement will also face a gradual decline in benefits and the welfare effects are more negative.

The (c) plot in each figure represents the welfare effect on future generations, indexed by the birth year expressed as the number of years elapsed since the new policy was announced. Although almost all in the current generations and future generations born during the first several years suffer from the policy change and they would prefer option 1 that preserve the benefits, future generations will gain significantly more from the benefit reduction options.

As we saw in Fig. 14, reforms of options 2 and 3 imply much lower taxes than in option 1 and both capital and labor are higher. The output will be significantly greater than in option 1 and agents will enjoy a higher level of consumption in

³⁰ Agents who are right behind the threshold (hence need to wait two more years after agents that are older by just one year have retired) can be much worse off than agents who are one year older than them. The profile would be smooth if the model employs a higher frequency and the retirement age is raised more smoothly.

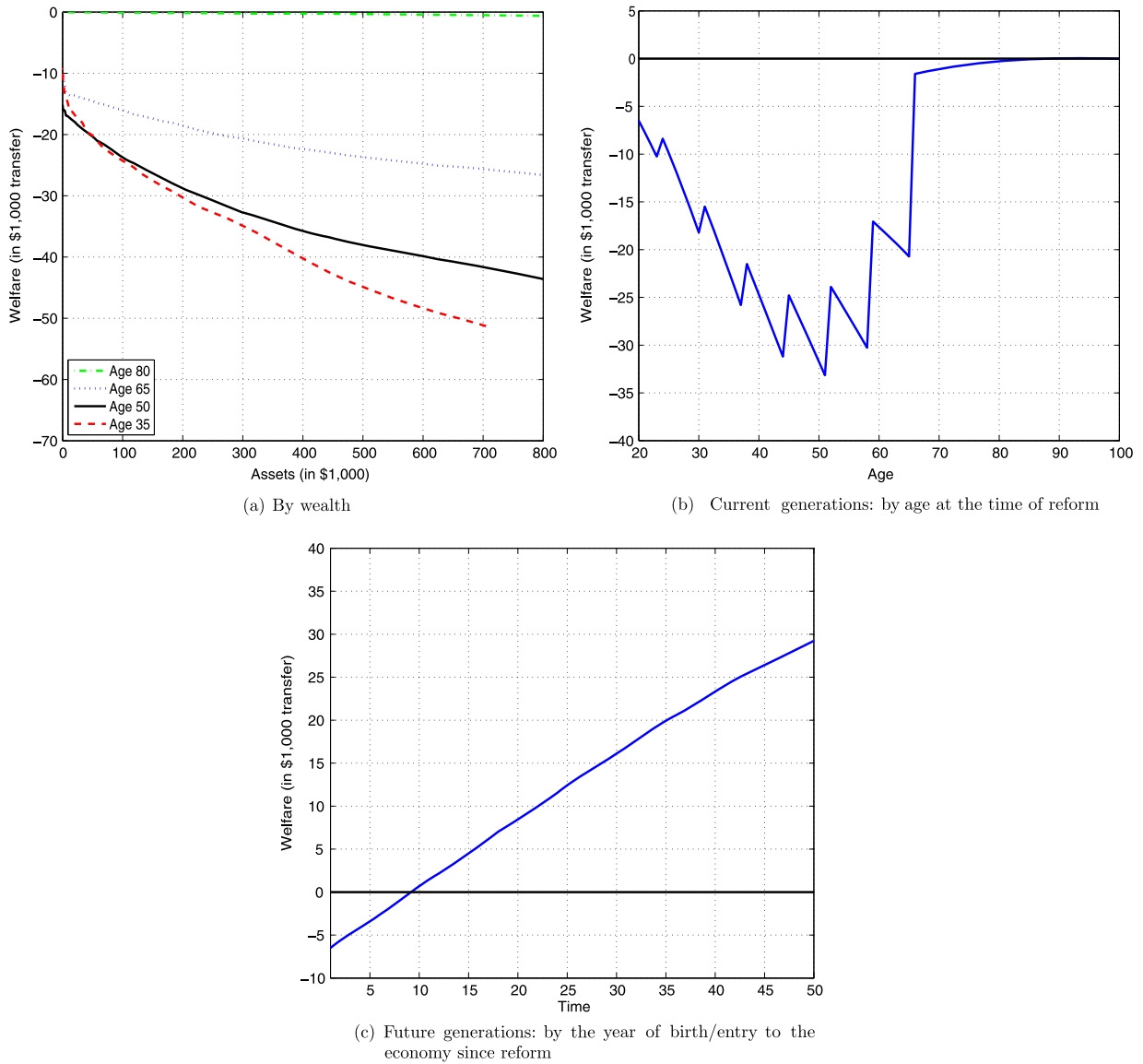


Fig. 16. Welfare effect: option 3 – normal retirement age increase.

the long run. In the final steady state, the welfare gain of options 2 and 3 on new-born agents is equivalent to a one-time transfer of \$58,000 and \$41,000, respectively, relative to the welfare under option 1.³¹

In summary, we find that it is much more efficient in the long run if the government deals with the demographic transition with the benefit reduction. This can be done either through reduction in the replacement rates or an increase in the normal retirement age. In the short run, however, these options will severely hurt current generations, especially the middle-aged agents who face much lower benefits despite all the contribution they have made through payroll taxation. They would prefer a transition financed through an increase in payroll taxes.

5. Sensitivity analysis

In this section, we will discuss sensitivity of our numerical results to alternative assumptions about the specification of the model and calibration. Three sets of analysis are presented; first, we simulate a model with alternative parameters that define preferences of individuals and affect their labor supply behavior. In the second, we study the roles of the age-

³¹ The long-run welfare effect of option 4 is equivalent to a transfer of about \$6000, smaller than the gains under options 2 and 3, but still a plus relative to option 1 that involves higher taxes.

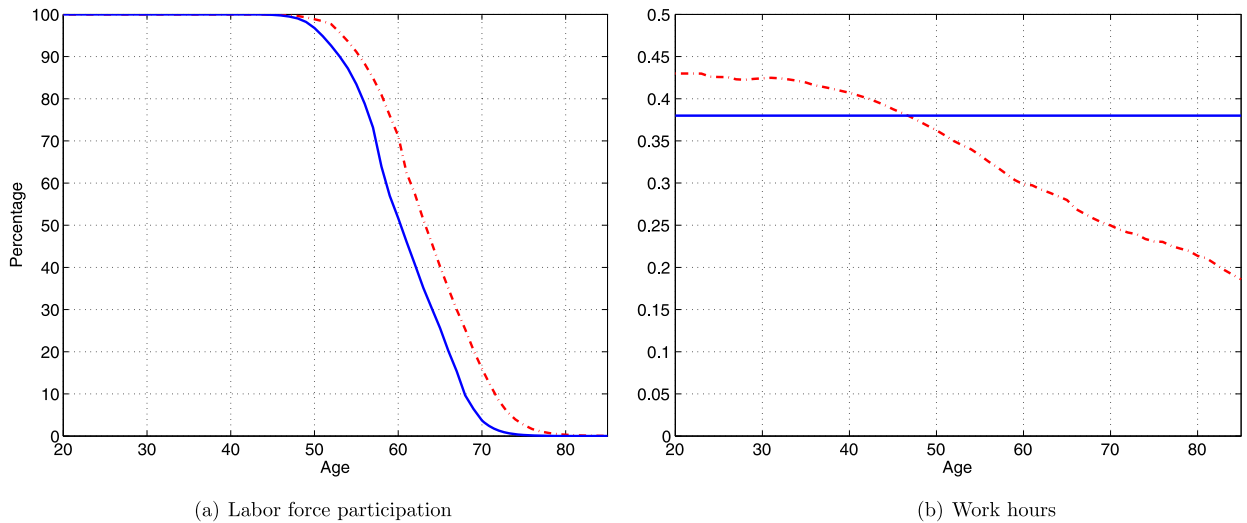


Fig. 17. Labor supply over the life cycle: no intensive margin choice. Dashed lines represent the profiles of the benchmark economy for comparison.

efficiency profile by computing an equilibrium with different shapes of the labor productivity profile. Finally, we simulate reforms under alternative scenarios about the demographic transition and study its impact on labor disutility.

5.1. Sensitivity analysis: preferences and labor supply

Agents in our model make labor supply decisions in both extensive and intensive margins and optimally allocate their time to leisure and market work, taking into account the utility cost of participation as well as that of an additional hour of work. To better understand the life-cycle allocation of labor supply in the two margins, we will first simulate a model without the choice of intensive margin, where agents at each age simply decide whether or not participate. If they decide to participate, they will work for fixed hours, which we set exogenously at 0.38 of disposable time, the average hours of work in the benchmark economy.

Second, we simulate a model where agents face zero participation cost and optimally choose hours of work. We make all individuals leave the labor force at an exogenous retirement age of 64, after working for 44 years, which is the average years of work in the benchmark economy. Finally, we assume that agents face an age-independent fixed cost of participation, which is set at the participation cost at the average age among all workers in the benchmark economy. In the experiments, all the other parameters remain the same as in the benchmark economy and any difference in the economic outcome is driven by the change in the preference specification.

When agents are not allowed to adjust hours, participation rates of middle to old-age individuals decline relative to the benchmark case. Fig. 17 compares the labor supply profiles in the benchmark and under the model with no choice of intensive margin. The effect of the aging demographic also differs from that of the benchmark economy. Without endogenous hours decision, there is a much larger increase in the participation rate, especially among old individuals. For example, under option 1, in which the transition is financed by a rise in payroll taxes, the participation rate increases by 5.3 percentage points at age 50–64 and by 1.2 percentage points at age 65 and up, while in the benchmark economy the changes were an increase of 1.2 percentage points at 50–64 and a decrease of 0.5 percentage point at 65 and up.³² In the benchmark economy, individuals are able to adjust both margins when they are faced with a rise in longevity and an increased need to earn more to save for longer retirement. Without the ability to adjust the intensive margin, they would choose to work much longer in years.

Fig. 18 shows the labor supply profiles when the participation cost is set to zero, or eliminated, and individuals are forced to leave the labor force after 44 years. Few individuals stop working before the exogenous retirement age and the participation rate remains above 90% even in 60s. Individuals also choose to work long hours before the mandatory retirement than in the benchmark economy.

Finally, what if the participation cost is constant but not zero? We set the disutility parameter θ_j fixed at 0.067, the value which corresponds to the participation cost at age 41, the average age of all workers in the benchmark economy. Unlike in the previous experiment, the retirement is not exogenous and there is no forced exit from the labor force. The fixed disutility of 0.067 implies a significant reduction in the cost of participation for older individuals, and their participation rate is much

³² All the tables and figures that show the results of the sensitivity analysis in this section, including the results of policy experiments under the economy with aging are available from the author upon request. They are not displayed here to save the space.

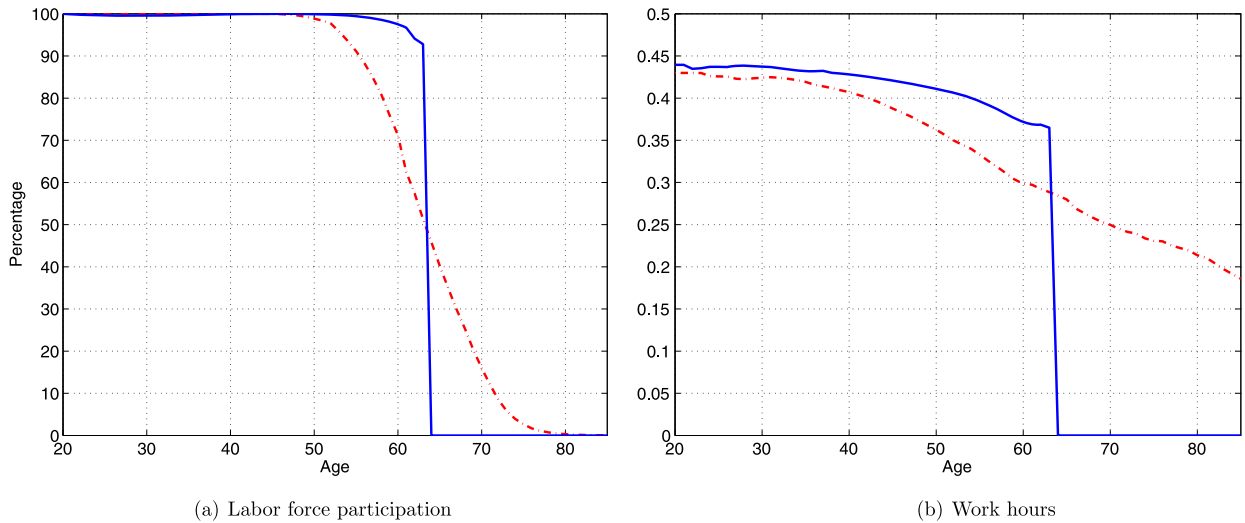


Fig. 18. Labor supply over the life cycle: zero participation cost. Dashed lines represent the profiles of the benchmark economy for comparison.

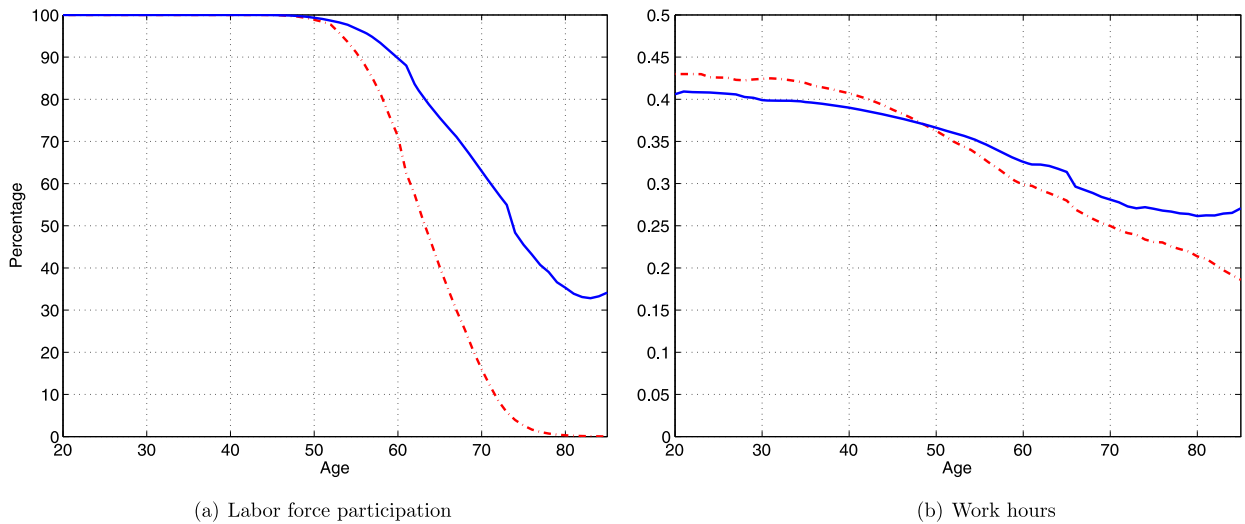


Fig. 19. Labor supply over the life cycle: fixed participation cost. Dashed lines represent the profiles of the benchmark economy for comparison.

higher than in the benchmark economy.³³ Hours profile becomes flatter over the life cycle as the marginal disutility is age-invariant conditional on participation and it is higher (lower) for young (old) individuals than in the benchmark case. (See Fig. 19.)

Accounting for both margins of adjustment helps the model to match the labor supply profiles in the data and abstracting from one margin can imply a much larger response in the other margin when we simulate policy experiments.

5.2. Sensitivity analysis: life-cycle labor productivity

In order to understand the roles of the age-dependent exogenous component of the productivity profile over the life cycle, we simulate a model with alternative specifications of the productivity process.³⁴ First, we assume that the productivity does not follow the age-dependent process and set the value of the component ψ_j fixed at the average among all workers in the benchmark economy. Second, we assume that there is no depreciation of the productivity once it reaches the peak in early 50s and stays constant thereafter.

³³ We assumed that labor productivity falls to zero after age 86, which explains the small increase in participation at the last working age of 85.

³⁴ Note that we only change the age-dependent component of productivity ψ_j and the idiosyncratic part of productivity η remains the same as in the benchmark economy.

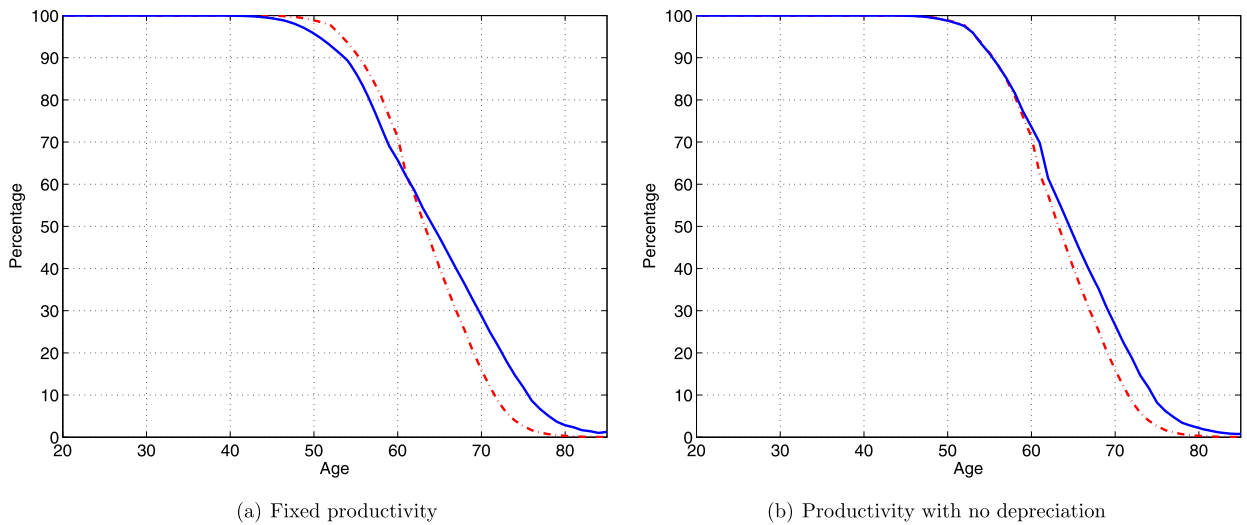


Fig. 20. Labor force participation: sensitivity to life-cycle productivity. Dashed lines represent the profiles of the benchmark economy for comparison.

Table 4

Sensitivity analysis: survival rates.

Survival rates	High	Benchmark	Low
Option 1: Tax increase			
Total labor taxes $\tau^y + \tau^s$	45.2%	42.0%	40.7%
– Labor income tax τ^y	26.2%	25.7%	25.6%
– Social security tax τ^s	19.0%	16.3%	15.1%
Option 2: Benefit cut			
Average replacement rate	22.7%	26.2%	28.4%
Option 3: Retirement age			
Retirement age	76	73	72
Option 4: Means test			
Income cutoff \bar{y}	–\$2,000	–\$350	\$1,220

Fig. 20 demonstrates the change in the labor force participation profile under the two experiments. The left panel shows that the profile becomes flatter when labor productivity is fixed, with more people leaving the labor force before age 60 but more people continue to work after age 60 and exploit the productivity that does not decline. Similarly, if there is no depreciation, the labor force participation rate will remain higher in 60s and 70s as shown in Fig. 20(b). The reform experiments in the economy with aging show similar results as in the economy with the baseline productivity specification.³⁵

5.3. Sensitivity analysis: demographic transition

5.3.1. Survival rates

We assumed that the demographics follow the projections of the Social Security Administration (Bell and Miller, 2005) and used the survival rate projections for 2100 as long-run values. There is, however, high uncertainty about how the mortality risks will evolve over time and we simulate two alternative scenarios about future survival rates, high and low. In the high scenario, we proportionally adjust the long-run survival rates at each age upwards so that the life expectancy is 89.2, 5 years longer than that of the benchmark economy with aging.³⁶ In the low scenario, we adjust down the survival rates and the life expectancy is 79.2, 5 years shorter than in the benchmark.

Table 4 shows the required change in the policy variables under the four policy options, where the demographic transition is financed by alternative tools to achieve the goal of balancing the social security budget. When taxes are raised to finance the demographic transition, total labor taxes have to increase to 45.2% while they are much lower at 40.7% if the survival rates grow more slowly than in the benchmark. Although individuals with longer life expectancy have incentives to work longer and earn more to save for consumption after retirement, such incentives will be offset by the higher tax rate and the labor force participation exhibits little change.³⁷

³⁵ Detailed results for all experiments are available from the author upon request.

³⁶ The adjustment is capped above by the maximum survival rate of 1.0.

³⁷ The full set of results is available from author upon request.

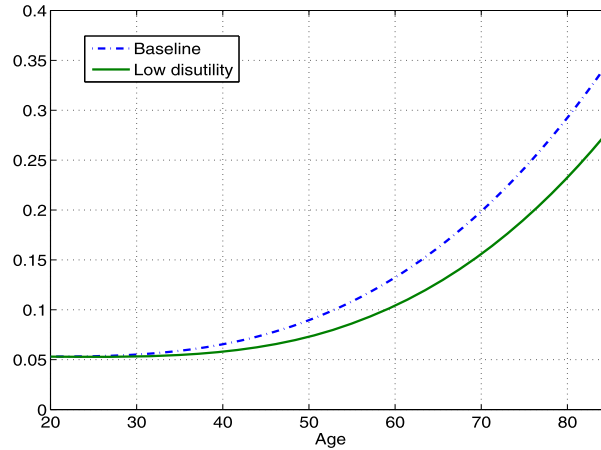
Fig. 21. Participation cost by age θ_j : sensitivity analysis.

Table 5

Sensitivity analysis: lower participation cost.

	Option 1 Tax increase	Option 2 Benefit cut	Option 3 Retire. age	Option 4 Means test
Labor force participation				
Baseline calibration				
Age 20–49	100.0%	100.0%	100.0%	100.0%
Age 50–64	82.3%	87.9%	86.9%	81.5%
Age 65–85	12.4%	19.4%	17.6%	4.3%
Avg work years	44.5	46.7	46.2	42.9
Lower participation cost				
Age 20–49	100.0%	100.0%	100.0%	100.0%
Age 50–64	88.0%	91.8%	91.3%	86.9%
Age 65–85	19.5%	27.5%	25.8%	6.3%
Avg work years	46.7	48.9	48.4	44.1

Under option 2, where benefits are reduced to cope with the aging demographics, the average replacement rate has to fall to 22.7% under the high scenario. If the retirement age is raised to contain the total pension spending, the eligibility age has to be as high as 76. Under the means-test option, the cutoff income level \bar{y} is much lower with higher life expectancy, implying that benefits are taxed away more heavily through the test.

5.3.2. Work disutility and longevity

In the baseline experiments, we calibrate participation costs by age so that the life-cycle profile of labor participation lines up with the data and we keep the same disutility function in policy experiments with aging demographics. In this section we consider a case where the participation cost falls with the improvement in the longevity. More precisely, we adjust down the disutility as if the agent was x years younger when the life expectancy increases by x years and compute the participation cost at age j as $\theta_j = \kappa_1 + \kappa_2(j - x)^{\kappa_3}$, while keeping the values of the parameters κ 's the same as in the benchmark economy.³⁸ Fig. 21 shows the profile of participation costs under the baseline calibration and the sensitivity analysis.

As shown in Table 5, the decline in the work disutility will have a significant impact on the labor force participation of middle to old-age individuals. For example, the participation rate under option 1 would rise from 82.3% to 88.0% at age 50–64 and from 12.4% to 19.5% at age above 65. The tax base will be expanded and the total labor tax rate to balance the government budgets is 40.0%, lower than 42.0% under the baseline calibration. Such a change in the participation cost might occur naturally, in particular with the advancement of health and medical technology. The experiment also suggests that policies that would reduce utility cost of work, especially for the old, can have a large impact on the participation rates and the fiscal situation of the social security as we go through the demographic transition.

6. Conclusion

The social security is not sustainable as it is. The Trust Funds will start to decline soon and be exhausted eventually. The solution is to restore the balance, either by reducing benefits or by raising taxes. The question is what the options

³⁸ There are numerous other functions that one could think of and this is just one example to index the disutility with the life expectancy. The idea is to show the impact of the disutility change on the results of the policy experiments.

are, how big the adjustment has to be under each option, and what the economic consequences and welfare effects are.

We present four policy options to make the social security self-financed and sustainable in light of the coming demographic aging. The options are motivated by recent policy debate and some experience in other countries. We show that the program's budget will balance each year if we take one of the four options; (1) raise the payroll tax by 6 percentage points, (2) reduce the benefit replacement rates by one-third, (3) increase the normal retirement age from 66 to 73, or (4) make the system means-tested and benefits decline one-to-one with income. Although all of these options achieve the same goal of balancing the social security budget, economic and welfare consequences differ significantly across them.

We developed a rich model that approximates key macro- and microfeatures of the U.S. economy, in which individuals make life-cycle decisions of consumption, saving and labor supply in both intensive and extensive margins in a competitive production economy. In particular, the model allows endogenous timing of withdrawing from the labor market and we have shown that options have very different effects on labor force participation and retirement decisions of individuals. The paper suggests that fiscal policy can have significant effects on the pattern of individual labor supply over the life cycle.

Although our model captures key dimensions of heterogeneity across individuals in age, financial and social security wealth and labor productivity, we abstract from other dimensions of potential interest such as unemployment, health status or other sources of expenditures. There are public programs other than social security that pose similar or possibly greater sustainability risks such as Medicaid and Medicare. These extensions are left to be explored in future research.

Appendix A. Social security benefit formula

Social security benefits are determined as a concave piecewise linear function of the Average Indexed Monthly Earnings ("AIME"). The AIME measures the worker's career-average earnings and it is computed as the average of a beneficiary's 35 highest annual earnings.³⁹

In the model, we are not able to keep track of the entire history of earnings due to the limitation in the computation capacity. To approximate the AIME formula, we take the following strategy, which follows French (2005). The state variable e summarizes the average earnings and approximate the role of the AIME. We assume that during the first 35 years after individuals enter the economy, the state variable e is updated recursively as

$$e_{t+1} = e_t + \frac{y_{L,t}}{35}$$

where y_L is the covered earnings, that is, $y_L = \min\{\tilde{\omega}h, y^s\}$. Since we cannot store the information of 35 highest earnings for each individual in the computation, we assume that after 35 years the state is updated only if the new earnings exceed the current state of e_t ;

$$e_{t+1} = e_t + \max\left\{0, \frac{y_{L,t} - e_t}{35}\right\}.$$

The Primary Insurance Amount ("PIA") is based on the AIME as

$$PIA_t = \begin{cases} 0.9 \times AIME_t & \text{if } AIME_t \leq \$9132, \\ \$8219 + 0.32 \times (AIME_t - \$9132) & \text{if } \$9132 < AIME_t \leq \$55,032, \\ \$22,907 + 0.15 \times (AIME_t - \$55,032) & \text{if } AIME_t > \$55,032. \end{cases}$$

The social security benefit ss in the model corresponds to the PIA and determined as a function of the state variable e , which corresponds to $AIME$ in the above formula.

Appendix B. Computation methods

B.1. Computation of steady state

Given the high nonlinearity of the individual problems, I solve for the equilibrium on the discretized space of individual states, deriving value functions at each state grid and moving backwards from the last age. We summarize the steps to compute the stationary equilibrium of the model:

- Step 1: Guess a set of equilibrium variables, which consist of aggregate capital K , labor supply L , labor income tax τ^l and bequest b .
- Step 2: Solve individuals' problems and derive policy functions at each state.
- Step 3: Compute the distribution of individuals across states.
- Step 4: Compute aggregate moments implied by the distribution and verify if equilibrium conditions are satisfied. If not, update guesses for the equilibrium variables and return to Step 2.

³⁹ The AIME considers earnings only up to the maximum earnings cap, which is \$ 106,800 in 2009–2011.

B.2. Computation of transition dynamics

We assume that the economy is in the initial steady state in period 0 and the new policy is announced and implemented in period 1. The economy makes a transition to reach the final steady state in period T . Choose T large enough so that the transition path is not affected by increasing T . We set T at 200, which satisfies the criteria.

- Step 1: Guess the path of equilibrium variables, which consists of aggregate capital K , labor supply L , labor income tax rate τ^l and bequest b .
- Step 2: Use the value functions of the final steady state as the values in period T and solve agents' problem backwards from period $T - 1$.
- Step 3: Use the distribution of agents in the initial steady state as the distribution in period 0 and compute the path of the distribution using the policy functions derived from Step 2.
- Step 4: Compute the path of aggregate capital, labor supply and bequests using the distribution derived in Step 3. Check if they are the same as the guesses. Also check if the government budget constraint is satisfied in each period. If equilibrium conditions are not satisfied, adjust the values of the equilibrium variables and go back to Step 2.

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