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Mitigating America's demographic dilemma by pre-funding social security ☆

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Abstract

Financing Social Security benefits at current levels implies significant increases in payroll taxes within the next 20 years under current US demographic developments. Using a general-equilibrium overlapping-generations model with realistic patterns of fertility and lifespan extension, this study shows that future generations would be harmed during the demographic transition due to rising payroll taxes, which crowd out savings and slow real wage growth below the rate of technological progress. A faster rate of technological progress would mitigate only some of the payroll tax increase and its economic consequences but could not overcome them. Addressing the financing problem by reducing Social Security benefits as needed or by raising the eligibility age for benefits imposes major welfare losses on current or near term retirees. By contrast, a pre-funding of Social Security financed with consumption taxes more evenly spreads the welfare losses across generations, and it helps future generations, especially the poor, by stimulating capital formation.

JEL classification: E62; H55; J18

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1. Introduction

How will the United States economy fare in 30 years when 77 million baby boomers will have retired? By that time, twice the number of elderly will rely on only 18% more workers for financial support primarily delivered through Social Security and Medicare.

Based on ''intermediate'' economic and demographic assumptions, the government's Trustees project that Social Security is one-sixth short of the resources needed to pay benefits over the next 75 years. These estimates, though, understate the long-run problem: extending the projection horizon beyond 75 years doubles this shortfall.[1] Medicare, which provides health care to retirees, faces even larger long-run shortfalls.[2] Eliminating the imbalances in both programs beyond the 75-year horizon and without reducing benefits would require doubling the payroll taxes levied on employees and employers, thereby reducing labor supply incentives.

These demographic forecasts, however, are partial equilibrium calculations and, therefore, may miss important general equilibrium effects during the demographic transition. An aging society could theoretically benefit from accelerated real wage growth as the number of retirees with capital rises relative to the number of workers supplying labor (Auerbach et al., 1989; Bohn, 2001). Accelerated real wage growth could then limit the payroll tax increases necessary to balance Social Security. However, this process is not guaranteed since the larger payroll taxes also reduce the potential for saving and thus limit capital formation and growth.

Using a new general-equilibrium life-cycle model, this paper analyzes the economic impact of demographic changes and explores the economic and welfare impact of potential reforms. This study builds on the literature that followed Feldstein's (1974) article contending that Social Security lowers national saving, including Kotlikoff (1979), Auerbach and Kotlikoff (1983), and Seidman (1986). More recent papers have considered the importance of land, earnings uncertainty, political economy considerations, liquidity constraints and different options for funding Social Security. These studies include Hubbard and Judd (1987), Imrohoroglu et al. (1995, 1999), Kotlikoff (1996), Huang et al. (1997), Huggett and Ventura (1999), Cooley and Soares (1999a, b), De Nardi et al. (1999), Kotlikoff et al. (1998a, b, 1999, 2002), Raffelhüschen (1989, 1993), Bohn (2001) and Smetters and Walliser (2004).

While the model herein builds on the model of Auerbach and Kotlikoff (1987), it adds five important features for studying the impact of demographic changes: (i) more realistic demographics that allows the model to better capture the population-age distribution and distribution of inheritances, (ii) cohort-specific longevity to reflect the important impact of rising longevity on the age distribution, (iii) multiple earnings groups within each cohort to capture the impact that reforms have on different lifetime income groups,[3] (iv) the ability to simulate the model from non steady-state initial conditions in order to start with the prevailing age and wealth distribution, and (v) a close calibration of the model to US fiscal conditions and institutions.

[1] See the 2004 Social Security Trustees' report, Table 4.B7.

[2] See the 2004 Medicare Trustees' report, Table 2.B11, Table 2.C16, and Table 2.C22.

[3] Intra-generational heterogeneity was also included in Fullerton and Rogers's (1993) important study of fundamental tax reform.

The paper by De Nardi et al. (1999) is the closest antecedent to ours. Their model includes demographic change as well as idiosyncratic shocks to earnings and longevity. It is limited, though, to quadratic preferences, omits most of the other US tax and transfer programs, lacks intra-generational heterogeneity as well as consumption by children, and distributes all bequests at the beginning of adulthood. Their baseline simulation, like ours, shows a major increase over time in payroll tax rates but their model implies long-run payroll tax increases that are larger than ours.

Under our baseline simulation, where taxes rise to maintain Social Security benefits, macroeconomic conditions exacerbate rather than mitigate fiscal problems. Capital formation and saving is constrained by the rising payroll tax, and wage growth slows below the rate of technological change. The slow-down in wage growth requires further tax increases to maintain real government spending, which we assume to rise with economic productivity and the size of the population. A faster rate of technical progress relative to our baseline would expand the wage base at a faster rate and somewhat mitigate payroll tax increases. But it would still leave a major problem under current law since Social Security benefits at retirement are linked to average wage growth. As an alternative to increasing tax rates, we consider several reforms including reducing benefits as needed over time as well as increasing the retirement age. Our simulations show that these potential reforms impose major welfare losses on current or near term retirees.

Finally, we also simulate pre-funding Social Security by paying off the implicit liabilities of current and future workers accrued under the existing system with a tax levied on either wages or consumption. Such pre-funding in our model is not tied to any particular institutional savings arrangements since agents are not liquidity constrained and thus simply implement their own optimal consumption and savings paths. Thus, pre-funding in our model could be interpreted either as a mandatory government-run fully funded pension system—with workers adjusting their own savings outside the system to achieve their optimal savings path—or a system where agents simply save on their own behalf. We show below that, while pre-funding is far from being a free lunch for living generations, it spreads the pain more evenly than the other options and entails major welfare gains for future generations, particularly those with very low incomes.

The paper is organized as follows. Section 2 presents our model and calibration, paying particular attention to how we incorporate fertility and lifespan extension. Section 3 presents our baseline simulations under the demographic transition as well as the macroeconomic results from different potential reforms, including reducing scheduled benefits over time and pre-funding Social Security. The welfare implications of these reforms across generations and between income classes within generations are then discussed in Section 4. Section 5 concludes.

2. The model

This section describes our model as well as its calibration and solution method. Our life-cycle general equilibrium model builds, in part, upon the stationary-demographics model of Altig et al. (2001) that focused on tax reform. Since our federal tax system and production sector are same as in Altig et al., we provide only a brief sketch of those sectors. We instead focus our description on how we incorporate realistic demographics into the model.

2.1. The household's problem

2.1.1. Preferences

Following Fullerton and Rogers (1993) and Altig et al. (2001), we sort households into 12 "full lifetime" earnings classes, that is, by the present value of lifetime income if households worked the maximum time allotment throughout their lifetime. Income groups 1 and 12 comprise the bottom and top 2% of lifetime wage income earners, respectively, while groups 2 and 11 represent the remaining 8% of the top and bottom deciles. Income groups 3–10 cover the remaining population with each group representing one decile.

The household representing lifetime income class m becomes an independent economic actor at age 21 and maximizes utility over its lifespan extending to age d (death).[4] Lifetime utility is derived from (i) parents' lifetime consumption vector, $c_{\mathrm{p},}$ and lifetime leisure vector, l_{p}; (ii) the consumption and leisure vectors by children (or kids), c_{k} and l_{k}, below age 20 residing with their parents; and (iii) a bequest b^m per child. Household utility is additive with $V(,)$, $H(,)$, and $Z()$ representing the sub-utility functions for consumption and leisure by parents and children, and from bequests:

$$U^m = V(c_{\mathrm{p}}^m, l_{\mathrm{p}}^m) + H(c_{\mathrm{k}}^m, l_{\mathrm{k}}^m) + Z(b^m). \tag{1}$$

To closely represent the actual heterogeneity in parental ages within a cohort, we assume that the household representing that cohort has "fractional children" of varying ages. We define a function "kid weight," $kw(i,j)$, as the fraction of children of age $i \in [1,20]$ with a parent age j. For example, if $kw(7,35) = 0.05$, 5% of 7-year-olds have parents who are age 35. We also assume that children must be at least 20 years younger than their parents and those parents older than 45 do not give birth to more children, which makes some kid weights equal to zero.

The sub-utility functions for adults and children are specified as constant elasticity of substitution (CES), where ρ represents the intratemporal elasticity of substitution between consumption and leisure, γ represents the intertemporal elasticity of substitution, α gives the weight on leisure, and δ is the pure rate of time preference:

$$V(,) = \frac{1}{1-\frac{1}{\gamma}} \sum_{j=21}^{d} \left(\frac{1}{1+\delta}\right)^{j-21} \left[c_{\mathrm{p},j,m}^{1-\frac{1}{\rho}} + \alpha l_{\mathrm{p},j,m}^{1-\frac{1}{\rho}}\right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}} \tag{2}$$

and

$$H(,) = \frac{1}{1-\frac{1}{\gamma}} \sum_{j=21}^{d} \left(\frac{1}{1+\delta}\right)^{j-21} \sum_{i=1}^{20} \phi_i kw(i,j) \frac{P(i)}{P(j)} \left[c_{\mathrm{k},i,m}^{1-\frac{1}{\rho}} + \alpha l_{\mathrm{k},i,m}^{1-\frac{1}{\rho}}\right]^{\frac{1-\frac{1}{\gamma}}{1-\frac{1}{\rho}}}. \tag{3}$$

The CES formulation allows for varying consumption-leisure shares over the life cycle and more realistic labor supply elasticities. However, it does not accommodate simple analytical solutions.

The utility a parent enjoys from children is the sum of the welfare of all the children living in a parent's household at each age of the parent. ϕ_i is the adult-equivalency scale for age-i children and $P(i)$ is the size of cohort aged i. Children's consumption is expressed in

[4]As described later in the calibration section, the lifespan, d, is indexed to the cohort's birth year in order to account for improvements in mortality. We do not show the time index on variables to avoid unwieldy notation.

per-capita terms of adults by correcting children's consumption by the ratio of children to adults, $P(i)/P(j)$.

The utility for bequests is derived as the sum of utility derived from bequests made to all "fractional" children at the end of life, expressed in per-capita terms of the bequeathing cohort:

$$Z() = \left(\frac{1}{1+\delta}\right)^{d-21} \left(\sum\nolimits_{i=21}^{d} kw(i,d)P(i)/P(d)\right)\mu^m [b^m]^{1-\frac{1}{\gamma}}, \tag{4}$$

where μ is the preference for bequests differing by income. We assume that each cohort aged j receives a share of these bequests per capita that is equal to its weight kw of the children of the dying cohort. Smoothing the receipt of bequests throughout the life-cycle instead of concentrating them at a single point in time allows for a more plausible life-cycle distribution of assets. Bequests are assumed to be passed to members of the same lifetime income group.

2.1.2. Budget constraints

Lifetime utility maximization by 21-year-old born in year t is subject to the following budget constraint (where, again, we do not subscript variables by time for notational simplicity):

$$\begin{aligned}
&\sum\nolimits_{j=21}^{d} \left[w_{j,m}(E - l_{\mathrm{p},j,m}) - c_{\mathrm{p},j,m} - T_{j,m}\right] \prod\nolimits_{s=1}^{j-21} \frac{1}{1+r_{t+s-1}} \\
&\quad - \sum\nolimits_{j=21}^{d} \sum\nolimits_{i=1}^{20} \left(kw(i,j)\frac{P(i)}{P(j)} c_{\mathrm{k},j,m}\right) \prod\nolimits_{s=1}^{j-21} \frac{1}{1+r_{t+s-1}} \\
&\quad + \sum\nolimits_{j=21}^{d} kw(j,d) b^m \prod\nolimits_{s=1}^{j-21} \frac{1}{1+r_{s-1}} \\
&\quad = b_d^m \sum\nolimits_{i=21}^{d} kw(i,d) \frac{P(i)}{P(d)} \prod\nolimits_{j=1}^{d-21} \frac{1}{1+r_{j-1}}.
\end{aligned} \tag{5}$$

The first term in Eq. (5) includes the present value of the household's labor income derived from total time endowment E net of leisure l, multiplied with wage rates w. We assume that the prospective wage rate is zero for children below the age of 20, and, hence, they do not work before forming their own household at age 21. The variable r is the interest rate. This budget constraint says that the present value of labor income and all bequests a household receives over the lifetime (the third line of the budget constraint) must pay for parental consumption $c_{\mathrm{p},j,m}$ and net tax payments $T_{j,m}$ (first line), consumption by children $c_{\mathrm{k},j,m}$ (second line), and bequests b_d^m left at death to decendents (right hand side of the budget constraint). Net taxes T include consumption, capital income, labor income, and net social insurance taxes as well as old-age transfers. As discussed below, factor prices, taxes, and benefits levels are derived from general equilibrium conditions and the government's budget constraint.

2.1.3. Calibration of preferences

In line with the previous literature, the pure time preference rate, δ, is set to 0.02, and the intratemporal and intertemporal substitution elasticities, ρ and γ, are set to 0.4 and 0.25, respectively. The parameter α is chosen so that agents devote, on average, 6.4 h to labor per day during their prime working years (ages 21–55), equivalent to 40% of their available time endowment of 16 h per day. As discussed by Altig et al. (2001), these parameter choices generate a Frisch elasticity of labor supply (MaCurdy, 1981) of 0.465, which is in line with the labor supply literature.[5] The bequest parameters μ^j for each earnings class j are calibrated such that the ratio of the bequest to economy-wide mean income corresponds to the ratio originally estimated by Menchik and David (1982), as updated by Fullerton and Rogers (1993), and inflation-adjusted to the year 2000. Bequests range from \$20,000 to \$450,000 for earnings group 8 through group 12.

2.2. Technological change

Given our use of flexible CES preferences, the standard assumption of labor-augmenting technological change is not compatible with reaching a steady state. In particular, households' demand for leisure would increase across cohorts, eventually exceeding the time endowment. As discussed in Auerbach et al. (1989), we therefore use a different type of labor-augmenting technological change by assuming that technical progress causes the time endowment of each successive generation to grow at rate λ. This increasing endowment can be interpreted as a rising human capital endowment that allows agents born later in time to reach both higher income and leisure levels. Because the endowment grows at a steady rate, there is no underlying time trend imparted to the economy-wide real wage per unit of human capital at time t, w_t. However, wages *per worker* would rise at the assumed secular rate of technological change. For our baseline, we assume a 1% value for λ, the rate of technological change consistent with long-run patterns for the US.

2.3. Wage profiles

To capture different skills by age and lifetime income group we apply an efficiency parameter ε_j^m to the basic wage rate w_t. The wage rate for an agent of type m and age j, $w_{j,m,,t} = \varepsilon_j^m w_t$, is determined through the function

$$\varepsilon_j^m = \mathrm{e}^{a_0^m + a_1^m j + a_2^m j^2 + a_3^m j^3}(1+\lambda)^j h_j, \tag{6}$$

with parameters a_1 to a_3 fitted from panel data as described in Altig et al. (2001). Secular growth in real wages, not captured in a, is explicitly added through the technological growth factor λ. By introducing equal growth in the lifetime time endowment and in real wages over the life cycle we replicate two key features of traditional labor-augmenting technical change: in steady state, real lifetime earnings grow at the rate of technical change, and the age-wage profile is steepened by this same rate of technical change. The final factor determining real wage growth in Eq. (6) is the variable h_j, an old-age productivity factor that helps generate realistic old-age labor supply by reducing productivity at age 62 (sensitivity analysis is performed in Section 3). Wage rates derived from Eq. (6) result in peak hourly wages valued in 2000 dollars of \$4.00, \$14.70, and \$79.50 for individuals in lifetime income classes 1, 6, and 12, respectively, generating annual incomes between \$9,000 and \$130,000.

[5] See Browning et al. (1998), Blundell et al. (1993), Mulligan (1998), and Ziliak and Kniesner (1999).

2.4. Government

Government in our model collects taxes and issues debt to finance government purchases of goods and services at time t (G_t), interest payments on the existing stock of debt, and old-age and disability transfers. Government goods and services are assumed to be unproductive and generate no utility to households.[6] Government purchases and government debt grow with the population and technological progress, in line with the historical observation that government spending as share of economic activity has not followed a downward trend. Income tax rates are adjusted endogenously to finance these expenditures.

2.4.1. Tax system

Our benchmark tax system approximates the salient features of the 2000 US federal, state, and local tax system, as described in Altig et al. (2001). It features separate wage and capital income taxes, and a consumption tax, with an adjustment of the tax bases to capture tax evasion. Including the federal tax system is important because reforms to Social Security will influence the size of the various tax bases—and hence the tax rates—required to finance G.

The wage-income tax structure has four elements: (i) a progressive marginal rate structure based on the 2000 federal statutory tax rates for individuals; (ii) a standard deduction of \$4000 and exemptions of \$5660 (assuming about 1.2 children per agent, consistent with population growth assumption), which both grow implicitly with technological change; (iii) using estimates from the *Statistics of Income,* an approximation of itemized deductions which are applied only when they exceed the amount of the standard deduction; and (iv) adjustments to earnings—ability profiles to reflect non-pension components of labor compensation consistent with tax return data. The marginal (average) labor income tax rates of 24 (14)% and 18 (11)% generated by the model for the highest and average income group, respectively, are close to empirical estimates.

Based on Auerbach (1996), the capital income tax rate is set at 20%, and 20% of new capital may be expensed, generating a 16% effective tax rate on new capital. In addition to the federal taxation, capital and wage income are subject to a linear state income tax of 3.7%, which produces the correct share of total revenue raised at the state level in 2000.

We impose an 8.8% tax on consumption expenditures consistent with the level of business and excise taxes in the national accounts. However, because contributions to both defined benefit and defined contribution pension plans receive consumption tax treatment, we levy an additional 2.5% tax on household consumption expenditures to account for the consumption-tax treatment of labor compensation in the form of pension benefits (Auerbach, 1996). This 2.5% tax replaces the wage tax that otherwise would apply to the pension benefit component of labor compensation, which is not included in our wage tax base.

2.4.2. Social Security, Medicare, and disability

The model closely reflects US old-age and social insurance system programs, notably old-age and survivors insurance (OASI), disability insurance (DI), and Medicare (HI). OASI is a defined-benefit program that pays pension income to retirees and their survivors

[6] Since G remains fixed in all of our experiments, incorporating G into the utility function is unimportant.

based on a progressive benefit formula. In particular, OASI determines each retiree's level of retirement benefits based on a measure of average indexed monthly earnings (AIME) over a 35-year work history subject to a wage ceiling. Wages exceeding this ceiling are not counted as contributions nor reflected in benefits. As human capital endowment grows, the ceiling per worker rises with technological change at rate λ over time. The AIME is converted into a primary insurance amount according to a progressive bend-point formula that determines initial monthly pension payments.

The model closely reproduces these settings by generating a model-based AIME that indexes past covered earnings to the growth in the economy-wide real wage per unit of human capital. In doing so, it excludes earnings above the model's maximum taxable earnings. Pension benefits in the model replace between 25% and 75% for the lifetime richest and lifetime poorest, respectively. Since approximately 50% of OASI benefits are paid to survivors and spouses, we multiply benefits by a factor of two. The model also reflects the fact that Social Security's eligibility age will slowly increase from 65 to 67 over time under current law. Finally, in our simulations of different policies, we adjust OASI benefits for changes in consumption tax rates, reflecting the fact that they are indexed to consumer price inflation.

Medicare and DI are modeled in a straightforward way. Medicare benefits accrue as a fixed benefit to all households above the Medicare eligibility age. The total Medicare bill thus fluctuates with the size of the elderly population. Should demand for medical care rise faster than the number of eligible households, our model could underestimate the economic effects generated by Medicare's imbalance in the long run. Similarly, disability is modeled as a fixed benefit to the households below the eligibility age for OASI benefits.

To finance the government's transfer programs, we distinguish between OASI, DI, and HI payroll taxes. The annual values for the payroll tax rates are determined endogenously to finance the aggregate value of the benefits paid by each of these programs. Households in our model understand the link between the OASI payroll tax and future benefits. As a result, the effective marginal tax rate on OASI contributions is less than the statutory rate, and it differs by age and income class,[7] except for agents with earnings above the taxable ceiling who face a zero marginal tax. DI and HI taxes are pure wage taxes since future benefits are not linked to contributions. DI is levied on payroll below the taxable ceiling whereas HI is levied on all earnings.

2.5. Demographics

We calibrate the model's demographics using population data and projections from the Social Security Administration (SSA). An initial population-age distribution is used to fill $P(i)$ for the year in which we start our projections. Projected birth rates are then used to fill $P(i)$ for future years. The distribution of births among living generations is used to calibrate the kid weight function kw, which we assume to stay constant over time. The Social Security population projections extend through 2075, after which we assume birth rates stabilize. The age at death (life expectancy) d is estimated using the SSA's unisex life

[7] In particular, young households face relatively larger effective tax rates on their contributions since the difference between market interest rate and Social Security's lower internal rate of return is compounded over many years. Households in higher income classes also face larger effective tax rates due to the progressivity of benefits.

expectancy table conditional on reaching age 65. Life expectancy equals 82 for the initial year 2000 and, based on Social Security's projections, increases to 83 by 2010, 84 by 2030, and 85 by 2060.[8]

Table 1 compares our model's predicted population totals as well as population shares with those forecast by the SSA. Our population totals line up quite well over the next 30 years, but understate projected population growth thereafter. In 2030, the model predicts there will be 22.8% more Americans alive than are now living. The comparable Social Security figure is 22.6%. The model also does a very good job tracking population shares. In 2075, the model predicts that 23% of the population will be 65 and older—the same share predicted by Social Security. In that year, the model's and Social Security's predicted shares of those under age 20 differ by only 1 percentage point. Note that the US population is predicted by both Social Security and our model to get old and stay old. Thus, unless policy is changed, the economic implications of America's aging will be here to stay.

Since we begin our simulations during a transition rather than from a steady state, our model requires an initial level and distribution of assets by age and earnings class. To obtain these initial conditions, we calculated the average net worth by age of household head in the 1998 Survey of Consumer Finances. The asset profile for the 12 earnings classes is then derived by assuming net assets are proportional to lifetime incomes, as approximated with earnings at age 40. We scale this initial allocation of net worth by age and earnings class by a constant factor until the model produces a realistic year-2000 national saving rate.

2.6. Production

We assume that output (net of depreciation) is produced by identical competitive firms using a standard Cobb–Douglas production function, with a capital coefficient equal to 0.25. The aggregate supply of capital at a point in time is obtained from summing over individual asset holdings less the value of government debt. The aggregate supply of labor at each point in time is calculated by summing together the effective labor supplies of all agents, given by the time endowment less leisure, multiplied by the efficiency parameter calculated from Eq. (6).

2.7. General equilibrium and solution method

Starting from the initial calibration of the economy, the model uses a Gauss–Seidel algorithm to solve the perfect foresight general-equilibrium transition path to a new steady state over a period of 275 years. The calculation starts with a guess for the time-paths of the aggregate supplies of capital and labor (and thus factor prices) and then iterates on those variables until a convergence criterion is met. Factor price time-paths in conjunction with time-paths of tax rates (including payroll taxes) and certain shadow prices determine the household sector's supplies, over time, of labor and capital. Household choices are

[8]As discussed by Fullerton et al. (2002), assuming all members of a given cohort die at the expected age of life misses some of the redistributive properties of Social Security arising (i) from lower-income households with shorter life expectancy offsetting to some extent the progressive benefit formula and (ii) from the provision of survivor and children's benefits as well as the dispersion of death dates.

Table 1
Comparing the model's and social security's population projections

Year	Social security population projections				The model's population			
	Total population index (100 in 2000)	Population shares			Total population index (100 in 2000)	Population shares		
		0–19	20–64	65+		0–19	20–64	65+
2000	100.0	0.29	0.59	0.12	100.0	0.29	0.59	0.12
2005	104.1	0.28	0.60	0.12	104.6	0.27	0.60	0.13
2010	108.1	0.27	0.60	0.13	108.6	0.26	0.59	0.15
2020	116.0	0.25	0.58	0.16	116.0	0.25	0.57	0.18
2030	122.6	0.25	0.56	0.20	122.8	0.24	0.54	0.22
2050	131.2	0.24	0.56	0.21	124.2	0.23	0.53	0.23
2075	140.3	0.23	0.54	0.23	125.8	0.24	0.53	0.23

derived from first-order conditions of the utility function subject to budget constraints. In optimizing household choices, the model includes the constraint that leisure not exceeds the endowment of time and solves the problem of the kinked budget constraint arising from standard deductions from taxable income.[9] We also address the non-convexity in the budget constraint due to the maximum taxable earnings for OASI and DI taxes by simply assuming that earnings groups 8 through 12 face no marginal payroll tax on their labor supply, but only an inframarginal payroll tax equal to the payroll tax rate times the payroll tax ceiling. This treatment results in very minor misalignments of marginal tax rates for income groups 7 and 8 at certain ages, without impact on our results.

Although we have no proof for the uniqueness of generated transition paths, Laitner (1984) has proved uniqueness in a linearized version of the original Auerbach–Kotlikoff model for the same utility- and production-function parameter values used herein. Also, we arrive at the same long-run steady state from a wide range of initial conditions.

The initial equilibrium matches key characteristics of the US economy. In addition to demographic characteristics it features a realistic national saving rate of 4.6%, a pre-tax return to capital of 7.5%, and an aggregate OASDHI payroll tax of 13.7%, which is within 0.6 percentage points of the current cost rate for these programs. The capital-output ratio of 3.3 is within the lower range of recent estimates based on market valuations of assets. The model's characterization of the tax system also generates average marginal tax rates and aggregate tax revenues values close to observable figures (see Altig et al., 2001).

3. Macroeconomic effects of demographic transition and reforms

This section presents the macroeconomic developments during the demographic transition under our baseline calibration discussed above and explores their sensitivity to changes in assumptions of longevity, productivity in old age, and technological change. We then consider two reforms of the existing pay-as-you-go OASI program that would limit the required increases in the OASI tax rate. Lastly, we analyze policies that fully

[9] Altig et al. (2001) describe the strategy for solving the kinked budget constraint.

pre-fund the OASI system, but differ with respect to the method of financing benefits accrued under the old system.

3.1. The demographic transition: baseline calibration

The first panel in Table 2 shows how key macroeconomic variables evolve in our base-case transition in which OASDHI tax rates are adjusted through time to finance the benefits of those programs on a strictly pay-as-you-go basis. Note that, due to increases in technological progress, the total *effective* labor supply continues to increase despite the aging of society. By 2030, effective labor supply is almost 60% larger than its initial value; it is projected to grow by only 24% absent technological change. Over the same time period, the capital stock increases by about 37%. As capital formation cannot keep up with the combined growth of the population and labor productivity, capital becomes relatively more scarce and the return to capital rises by almost 100 basis points until 2030. Real wages (measured per worker) increase owing to rising productivity, but their growth rate slows below the rate of technological change over the next decades.

One reason for these developments is the presence of the Social Security and Medicare programs. As the last column of Table 2 shows, between 2000 and 2030 the endogenous OASDHI payroll tax projected by the model rises by 77%, from 13.7% to 24.3%, with most of the increase occurring between 2010 and 2030.[10] This increase is within the vicinity of the 68% rise projected by the SSA, which does not take into account general equilibrium effects on labor supply and output. In 2075, the model's and SSA's projected cost rates are almost identical. As the payroll tax rises, it significantly reduces the national saving rate and thus the potential for capital accumulation that occurs in these two decades. The payroll tax also stays very high for the rest of the century, reaching 26.5% in 2100, and preventing a recovery of saving rates later.

A second factor is the increase over time in general revenue taxation. As previously mentioned, the federal income tax is modeled as a combination of a flat capital income tax, a progressive wage tax, and a flat consumption tax. Along the economy's baseline transition path, we adjust the intercept of the marginal wage tax rate function to generate enough revenue to finance a fixed level of government consumption, adjusted for increases in population and labor productivity. As wages grow more slowly than productivity, tax rates must rise to maintain government consumption, and the average labor income tax rate (excluding payroll taxes) increases from 11.3% in 2000 to 12.3% in 2030, further diminishing workers' disposible income.

A third potential reason is that the economy is not starting its aging process from a steady state. If, for historic reasons, including past fiscal policy and high asset valuations in 2000, the capital is unusually abundant, the country may already be embarked on a transition path toward declining saving rates absent demographic changes.

3.2. The demographic transition: sensitivity analysis

Table 3 summarizes the results for varying the baseline assumptions for longevity, productivity in old age, and the rate of technological change. SSA longevity projections

[10]Recall that our model's 13.7% value for the tax rate in 2000 is lower than the actual 15.3% OASDHI tax rate because we incorporate payroll taxes in excess of benefit costs as part of general revenue finance.

Table 2
Summary simulation results

	Year	National income	Capital stock	Effective labor supply	National saving rate	Real pre-tax wage	Interest rate	OASDHI cost rates	
								Model	SSA
Baseline case	2000	1.000	1.000	1.000	0.046	1.000	0.075	0.137	0.131
	2005	1.091	1.064	1.101	0.044	1.042	0.077	0.145	0.136
	2010	1.191	1.137	1.209	0.047	1.087	0.079	0.158	0.147
	2020	1.361	1.271	1.393	0.030	1.191	0.081	0.197	0.183
	2030	1.529	1.366	1.587	0.011	1.297	0.084	0.243	0.220
	2050	1.889	1.500	2.039	0.015	1.521	0.095	0.257	0.237
	2075	2.479	1.845	2.736	0.023	1.908	0.101	0.264	0.262
	2100	3.303	2.421	3.663	0.027	2.436	0.103	0.265	na
50% benefit cut	2000	1.000	1.000	1.000	0.065	1.000	0.076	0.136	0.131
	2005	1.096	1.094	1.096	0.062	1.049	0.076	0.135	0.136
	2010	1.200	1.198	1.201	0.063	1.102	0.076	0.138	0.147
	2020	1.387	1.403	1.382	0.048	1.224	0.075	0.148	0.183
	2030	1.578	1.578	1.578	0.029	1.347	0.076	0.156	0.220
	2050	1.967	1.886	1.995	0.027	1.620	0.079	0.167	0.237
	2075	2.602	2.423	2.665	0.033	2.056	0.082	0.171	0.262
	2100	3.472	3.218	3.561	0.035	2.633	0.082	0.171	na
Raise eligibility age by 3 more Years	2000	1.000	1.000	1.000	0.059	1.000	0.076	0.136	0.131
	2005	1.094	1.084	1.097	0.055	1.047	0.076	0.137	0.136
	2010	1.196	1.177	1.203	0.057	1.098	0.077	0.141	0.147
	2020	1.381	1.356	1.389	0.042	1.212	0.077	0.156	0.183
	2030	1.557	1.500	1.577	0.020	1.329	0.079	0.192	0.220
	2050	1.934	1.721	2.011	0.021	1.580	0.085	0.204	0.237
	2075	2.551	2.166	2.694	0.028	1.995	0.089	0.209	0.262
	2100	3.401	2.861	3.603	0.031	2.549	0.090	0.209	na
Consumption-tax pre-funding	2000	1.000	1.000	1.000	0.063	1.000	0.076	0.047	0.131
	2005	1.096	1.093	1.098	0.062	1.049	0.076	0.051	0.136
	2010	1.201	1.199	1.202	0.066	1.102	0.076	0.056	0.147
	2020	1.396	1.434	1.383	0.059	1.230	0.074	0.068	0.183
	2030	1.598	1.674	1.574	0.046	1.368	0.072	0.081	0.220
	2050	2.056	2.230	2.001	0.051	1.687	0.070	0.081	0.237
	2075	2.753	3.145	2.633	0.048	2.201	0.066	0.081	0.262
	2100	3.684	4.299	3.499	0.046	2.844	0.065	0.081	na
Wage-tax pre-funding	2000	1.000	1.000	1.000	0.052	1.000	0.074	0.044	0.131
	2005	1.094	1.070	1.102	0.054	1.043	0.076	0.048	0.136
	2010	1.198	1.162	1.211	0.062	1.092	0.076	0.052	0.147
	2020	1.350	1.309	1.364	0.035	1.208	0.076	0.064	0.183
	2030	1.548	1.451	1.582	0.027	1.318	0.079	0.077	0.220
	2050	2.044	1.894	2.096	0.053	1.602	0.080	0.080	0.237
	2075	2.808	2.977	2.753	0.057	2.148	0.070	0.081	0.262
	2100	3.774	4.243	3.630	0.048	2.809	0.066	0.081	na

tend to be more pessimistic than latest forecasts by demographers. The more optimistic Lee–Carter projection (updated from Lee and Carter, 1992) foresees 65-year-old Americans in 2050 living to age 86—3 years longer than SSA predicts. Using the

Table 3
Sensitivity of baseline results

	Year	National income	Capital stock	Effective labor supply	National saving rate	Real pre-tax wage	Interest rate	OASDHI cost rate	Cost rates SSA
Lee–carter life expectancy	2000	1.000	1.000	1.000	0.051	1.000	0.076	0.136	0.131
	2030	1.541	1.403	1.590	0.014	1.305	0.083	0.249	0.220
	2100	3.358	2.480	3.715	0.026	2.441	0.102	0.291	n/a
Higher productivity through age 65	2000	1.000	1.000	1.000	0.041	1.000	0.076	0.137	0.131
	2030	1.539	1.353	1.607	0.011	1.290	0.086	0.241	0.220
	2100	3.330	2.408	3.711	0.026	2.425	0.105	0.263	n/a
2% rate of technical progress	2000	1.000	1.000	1.000	0.051	1.000	0.087	0.140	0.131
	2030	1.753	1.509	1.843	0.022	1.732	0.101	0.217	0.220
	2100	7.453	5.593	8.202	0.047	6.508	0.115	0.197	n/a

Lee–Carter assumptions, the payroll tax generated by our model would be 0.6 percentage points higher in 2030 than in our baseline case, and exceed the baseline by 2.6 percentage points in 2100. However, the need to save for a longer retirement stimulates some additional capital accumulation as well as more labor supply. In the long run, the economy's output and wage rates are, therefore, essentially unchanged compared with the baseline.

Table 3 also shows the effect of assuming that workers remain fully productive through age 65—by adjusting the productivity factor h in Eq. (6)—rather than through age 62 under the baseline. Aggregate effective labor supply increases by 60.7% by 2030 relative to 58.7% under the baseline. Young and middle-aged agents, anticipating their longer productive work lives, work less at younger ages, offsetting some of the labor supply increases of older cohorts. Higher productivity in old age also reduces capital accumulation at younger ages and reduces the aggregate capital stock, resulting in a slow-down in wage growth. In 2030, for example, the real wage is somewhat lower in this scenario compared with the baseline. Overall, the somewhat smaller wage growth offsets the increases in labor supply and thus the payroll tax remains largely unaffected.

Finally, Table 3 shows that doubling of the rate of technological change from 1% to 2% per year helps mitigate some of the increase in payroll taxes along the transition. This dampening occurs because, while Social Security benefits are wage-indexed before retirement, they are only CPI-indexed after retirement under both current law and in our model. A faster rate of technological change, therefore, increases the size of the tax base relative to aggregate Social Security benefits paid. In 2030, the OASDHI tax rate, for example, is 24.3% in the base case, but only 21.7% with 2% technological progress. The corresponding tax rates in 2100 are 26.5% and 19.7%. Still, even under a sustained doubling of technological progress, the payroll tax would have to rise by 6 percentage points by the end of the century. Moreover, the rise in the payroll tax still limits savings and wage growth. Thus, even though payroll tax increases are mitigated under this scenario, they remain an important factor in slowing wage growth below the rate of technological change over the next century. At the same time, as should be expected, driven by the faster productivity growth, output per worker and wages rise at a significantly faster rate than under the baseline.

3.3. A 50% benefit cut

To help limit the rise in payroll taxes over time, we first consider a 50% reduction in OASI benefits over time. The cut is phased in over the next 30 years, with benefits for each year's *new* set of retirees declining an additional 1/30th of 50%.

Table 2 shows that limiting the growth in payroll tax rates allows the capital stock to rise faster than under the baseline and thus generates faster real wage growth. In the long run, wages increase by 20% more compared with the baseline. Under this policy, OASDHI tax rates in 2030 and 2100 are 2.0 and 3.5 percentage points, respectively, above the 2000 level, significantly less than the 11 and 13 percentage points under the baseline. The containment of taxes under this scenario increases the disposable income of younger cohorts and, by limiting old-age transfers, also increases their incentive to save, thus stimulating significantly more capital formation than under the base case. However, the rise in the payroll tax—albeit muted compared to the base case—still mitigate growth in output and wages under this scenario.

3.4. Increasing social security's eligibility age

Another way to partially contain rising payroll taxes is to raise the eligibility age for Social Security. In addition to the 2-year increase to age 67 already in the baseline, we consider an additional 3-year increase to age 70, thereby reducing outlays by an additional 17% (Table 2). Not surprisingly, although the OASDHI tax hike is somewhat mitigated, the effect is smaller relative to the 50% benefit cut. Even a significant increase in the OASI eligibility age would thus not suffice to prevent major increases in the rate of payroll taxation, exceeding 7 percentage points in the long run. Overall, compared with the baseline, this scenario increases output and wages by stimulating capital formation, However, the impact is muted compared with the 50% benefit cut.

3.5. Pre-funding social security

Our next two simulations shown in Table 2 contemplate a more dramatic change to the OASI program, namely completely pre-funding it *at the margin* by paying out only those benefits accrued under the current system. To be precise, the simulations pay the OASI benefits of current retirees in full, and then linearly phase out OASI benefits for future retirees over a 45-year period starting in 2000, giving each future retiree a value roughly equal to the amount they have already accrued under Social Security. In addition, each pre-funding policy replaces the OASI tax with a new tax that finances all accrued benefits during the transition period. After the transition is completed, workers finance all their retirement spending out of their own saving and no longer receive OASI transfers. Since workers in our model are not liquidity constrained, the results do not depend on any institutional arrangements attendant to the new policy, that is, retirement savings could be accumulated under a mandatory government program or individually.

3.5.1. Paying for the transition with a consumption tax

Consider first using a specially dedicated consumption tax to finance the transition.[11] The required consumption tax rate is initially 10.1%. It rises to 13.6% in 2020 and then gradually declines to zero over time, reaching zero in 2062 when Social Security has been fully phased out.[12] The remaining payroll tax for DI and HI is reduced to 4.7%, and grows by 3.4 percentage points over time as the demographics also raise the cost rate for the HI program.

This reform leads to considerably faster increase in output, capital and wages compared with the baseline. By 2030, the capital stock is 22.5% larger than under the baseline, and by 2100, it is 78% larger. Although long-run labor supply is somewhat smaller than under the baseline, the stimulus to capital formation leads to 11% more output than under the baseline by 2100, and the real wage is 17% larger. However, these gains arrive slowly. By 2030, the real wage is only 5.5% larger than it would have been in the absence of pre-funding. This relatively slow adjustment is not surprising given the enormous overhang of accrued OASI benefits that need to be paid off and thus limit the initial potential for capital formation as younger workers face both consumption taxes and the need to save for their own retirement.

3.5.2. Paying for the transition with a wage tax

Table 2 also shows the macroeconomic effects of paying for the transition with a new dedicated tax on (uncapped) wages. The long-run macroeconomic effects are identical to the consumption tax case since Social Security is fully pre-funded in both cases and both dedicated taxes eventually return to zero.[13] However, the macroeconomic gains from wage-tax financing arrive more slowly; in fact, the capital stock rises at about the same rate as under the baseline over the next 30 years.

Consumption tax financing produces relatively faster macroeconomic gains because it places more of the transitional tax burden on older workers and retirees—especially the wealthy—whose consumption of non-Social Security wealth is exposed to higher after-tax prices. In contrast, the wage tax falls largely on younger households with relative higher marginal propensities to save. A consumption tax also represents, in part, a lump-sum tax on the economy's initial wealth since consuming accumulated wealth becomes more costly without the possibility to respond to the tax change at the margin. Because lump-sum taxes are non-distortionary, the consumption tax provides workers with better overall incentives to work and save than the wage tax.

4. Welfare and distributional effects of reforms

As suggested above, invariably some generations will be negatively affected by demographic change either under the baseline or under various policy reforms. Tradeoffs exist both between and within generations. Our model attempts to capture both dimensions.

[11]Recall that Social Security benefits are adjusted for inflation, which includes the consumption tax.

[12]Social Security is fully phased out in 2062 rather than in 45 years because the youngest worker alive in 2000, who will collect a partial Social Security retirement benefit someday, will live about 17 years in retirement.

[13]Table 2 shows that the economies under both financing methods are almost, but not yet fully, converged by 2100. The simulations, however, calculate all macroeconomic variables until 2275 to ensure convergence.

Table 4 shows the welfare implications of different policies across three lifetime income classes—1, 6, and 12—and across several generations for the reforms described in Section 3. The welfare changes are measured as the equal percentage increase in both consumption and leisure that is needed by an agent in each remaining year of life under the baseline transition to achieve the same level of remaining lifetime utility as under the new policy. This measure is known as the "equivalent variation" of the policy change.

4.1. Reducing benefits

The welfare effects from the gradual 50% reduction in OASI benefits are fairly benign on the oldest elderly at the time of the reform whose benefits are unchanged. But the reform is beneficial for all agents born in the long run, particularly the poorest (class 1) whose welfare increases by almost 11%. The poor especially gain from reducing Social Security over time because their entire labor income is subject to the payroll tax and they are forced to accumulate most of their pre-reform retirement wealth in the form of Social Security. Despite the progressive Social Security benefit formula, the poorest are subject to large opportunity cost resulting from the low rate of return of Social Security wealth compared to the rate of return on capital. In contrast, richer households' labor incomes partially escape the payroll tax due to the payroll tax ceiling, and thus they are able to invest a much larger proportion of their wealth at the capital rate of return. Moreover, poorer households receive fewer bequests relative to their potential lifetime income, which implies that more of their saving under the baseline is in the form of Social Security wealth. Translated into welfare gains and losses, the poorer therefore gain relatively more from reducing Social Security wealth holding (see also Kotlikoff et al., 1998b).

However, a 50% benefit cut imposes rather large welfare losses on initial middle-aged and low-income agents who are close to retirement and, therefore, experience most of the benefit cut without reaping the economic gains in the form of lower payroll taxes and a larger capital stock. The poorest agents who are age 60 at the time of the reform, in particular, face a 7.0% loss. Their highest-earning contemporaries (class 12) have a much smaller welfare decline, equal to 0.935%, because they have a comparatively small stake of their retirement wealth in Social Security.

The pattern of these welfare changes is similar if scheduled benefits are instead reduced by raising Social Security's eligibility age by three years. However, because benefits are cut by a smaller percentage under this reform relative to the 50% benefit cut, the losses to older generation and gains to future generations are somewhat smaller.

4.2. Prefunding benefits

Pre-funding, either by financing the transition with a consumption tax or a wage tax, generates larger welfare gains for low- and middle-income agents born in the long run than the benefit cuts discussed above. Class 1 and class 6, for example, experience welfare gains of 21% and 19%, respectively. By contrast, class 12 only gains 5%. As shown in Table 2, these gains are the result of a significant increase in real wages (15%) and a decline in payroll taxes (20 percentage points) relative to the baseline.

Pre-funding avoids the large welfare losses for middle-aged to older generations alive at the time of the reform that we found with benefit cuts. Instead, burdens are more evenly spread throughout the transition. Although we phase out all OASI benefits, welfare losses

Table 4
Welfare effects of selected policies (base-case percentage change in remaining lifetime consumption and leisure needed to achieve policy-induced utility level)

	50% benefit cut			Increase eligibility age by 3 more years			Consumption tax financed pre-funding			Wage tax financed pre-funding		
Generation's year of birth relative to policy start year	Class 1	Class 6	Class 12	Class 1	Class 6	Class 12	Class 1	Class 6	Class 12	Class 1	Class 6	Class 12
−81	0.020	0.025	0.018	0.012	0.015	0.011	−0.121	−0.493	−0.622	−0.041	−0.053	−0.038
−70	−3.701	−2.585	−0.735	−3.088	−2.292	−0.639	−0.574	−0.978	−1.271	−0.150	−.214	−0.214
−60	−7.049	−4.599	−0.935	−6.179	−3.985	−0.776	−1.502	−1.972	−1.507	−0.272	−.513	−0.263
−50	−5.180	−3.288	−0.787	−4.423	−2.417	−0.558	−2.858	−2.598	−1.605	−0.551	−1.349	−0.277
−40	−3.136	−1.748	−0.640	−1.631	−.917	−0.376	−2.935	−2.294	−1.813	−0.797	−1.945	−0.888
−30	−.467	−0.246	−0.419	0.148	.100	−0.224	−1.641	−1.177	−1.810	0.217	−1.822	−1.700
−20	1.871	1.494	0.142	1.612	1.241	0.149	0.876	1.258	−1.125	2.506	−1.121	−3.037
5	8.468	7.176	1.583	5.317	4.556	1.013	9.407	8.480	.941	9.194	4.782	−1.568
30	10.320	9.483	2.383	6.219	5.778	1.459	17.982	16.019	3.994	16.399	14.082	3.004
55	10.795	10.221	2.735	6.473	6.283	1.673	20.172	18.353	4.994	19.589	17.828	4.754
80	10.959	10.450	2.823	6.561	6.420	1.725	20.692	18.921	5.221	20.551	18.794	5.165

never exceed 3% for any household; with wage tax financing, losses never exceed 2%. For example, while households in income class 1 who are age 60 at the time of the reform lose 7% in welfare under a 50% reduction in benefits, they lose only 1.5% with pre-funding financed by a consumption tax and just 0.27% with wage-tax financing.

With consumption tax financing of the transition, the initial elderly are largely protected by the indexation of Social Security benefits to prices including the new consumption tax. Thus, their losses are limited to their consumption out of their own saving, and among those age 70, for example, lower-income retirees are affected less than higher-income retirees. Retirees can also avoid some of the consumption taxes by leaving larger bequests. Among workers aged 30–50 welfare losses are more pronounced since they pay higher consumption taxes for most of their lives. As a result, the reform is slightly regressive for these workers since the phase-out of progressive benefits is not compensated quickly enough by rising wage levels. However, given the speed with which economic gains are generated, the 20-year-olds alive at the reform, who are about to enter the labor force, gain from reform except those in the highest-income groups—this despite the fact that 20-year-olds will pay higher consumption taxes for an extended period.

With wage-tax financing of the transition, the initial elderly and those about to retire at the time of the reform face only small welfare declines since they earn little if any wage income. Older workers also fare better under the wage tax relative to a consumption tax. For example, the welfare of 50-year-olds at the time of the reform in income class 6 declines by 1.3% whereas it declines by 2.6% under the consumption tax. However, younger workers at the time of the reform mostly fare worse with wage-tax financing. For example, the initial 20-year-olds in class 6 lose 1.12% in welfare whereas they gained 1.26% under consumption-tax financing. Similarly, those in class 6 born 5 years after the reform gain only 4.8% under wage-tax finance but 8.5% under consumption tax finance. In sum, wage tax financing of the transition protects higher-income elderly and distributes the losses during the transition among more generations, but at the cost to some young workers who suffer from the slower rise in incomes.

5. Conclusions

Our simulation model tracks the nation's aging process well. Although it abstracts from several features of economic reality, it gives new insights into the general equilibrium feedback effects of the demographic transition. The sharp run-up in the payroll tax over the next three generations under the baseline reduces saving and slows the growth of real wages below the rate of technological change. Preventing payroll taxes from dramatically rising by reducing Social Security' scheduled benefits would impose major welfare losses on middle-aged and older generations alive at the time of the reform.

As an alternative to reducing scheduled benefits, we also examine the option to pre-fund retirement saving. Our simulations show that it could avoid the payroll tax hikes and generate major benefits for future generations. However, paying off the accrued liabilities of the old system imposes burdens on generations alive at the time of the reform. Still, the welfare losses tend to be spread out much more evenly between generations and produce much larger long-run gains relative to either the baseline or relative to cutting scheduled benefits. The economic benefits of pre-funding for future generations arise more quickly under consumption- than wage-tax finance, however, at the cost of somewhat higher welfare losses for middle-aged generations.

Our model could be questioned because of its stylized nature. It abstracts from the choice of education (see Heckman et al., 1998), uncertainty, international trade, monetary policy, borrowing constraints, and a number of other aspects of economic reality. Whether the inclusion of those factors would materially alter our conclusions is a question for future research. However, we believe that the pending demographic change is severe enough that most models of the economy would generate a similar fiscal dilemma.

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