Social Security Reform with Heterogeneous Mortality

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Appendices for Online Publication

Appendix A: Definition of equilibrium

Our approach will be to take wages and the interest rate from the data and to find the private insurance premium and government policies that produce budget balance for a stationary distribution of individuals.

Definition 1. *A stationary equilibrium is a collection of government policies, a lump-sum transfer, a private health insurance premium, individual decision rules, and a distribution* $\mu(\tilde{\mathbf{x}})$*,* $\tilde{\mathbf{x}} = [\mathbf{x}_j', h^-, \epsilon_j, j]'$ *(*h^- *is lagged health) of individuals, such that the following conditions hold.*

1. *Given government policies, the lump-sum transfer and the private health insurance premium, the decision rules solve the individual problem described in subsection 2.6;*
2. *The government budget is balanced:*

$$\int \Big[\tau^c c + T\big(ra + W + SS(ss^* + di, ra, W)\big) + 2\tau^{\text{mcr}} W + 2\tau^{\text{ss}} \min\{W, y^{\text{ss}}\} + T_j^{\text{et}}(ss, W) + p^{\text{mcr}} I_{\{j \geq J^M \ or \ h^- = 5\}}\Big] \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}}$$
$$= G + \int \big[ss + di + tr + \kappa^{\text{mcr}} m I_{\{j \geq J^M \ or \ h^- = 5\}}\big] \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}};$$

3. *Health insurers earn zero profits:*

$$p^{\text{priv}} \int I_{\{j < J^M \ and \ h^- \neq 5\}} \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}} = \int \kappa^{\text{priv}} m I_{\{j < J^M \ and \ h^- \neq 5\}} \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}};$$
$$p^{\text{supp}} \int I_{\{j \geq J^M \ or \ h^- = 5\}} \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}} = \int \kappa^{\text{supp}} m I_{\{j \geq J^M \ or \ h^- = 5\}} \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}};$$

4. *Total lump-sum transfers equal the non-negative assets of deceased individuals of each education level, with negative values of assets interpreted as uncompensated care:*

$$(1+r) \int I_{e=i}(1-s) \max\{0, a'\}\, \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}} = (1+\chi) \int I_{e=i} B_{ej}\, \mu(\tilde{\mathbf{x}})\, d\tilde{\mathbf{x}}; \quad i \in \{NC, C\}$$

5. *The distribution of individuals is stationary.*

The bequest transfer $B_{e,j}$ can be written as $B_{e0} b_j$, where B_{e0} measures bequests for people aged 60-61 and b_j is an age adjustment. Figure A1 plots b_j, which we take from the distribution reported in Feiveson and Sabelhaus (2018). B_{e0} is found in equilibrium.

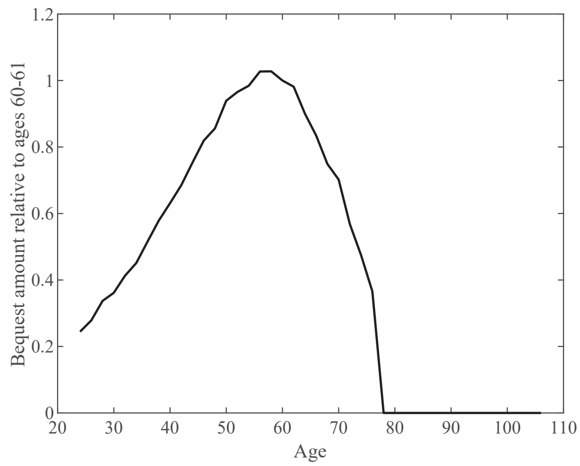


Figure A1: Distribution of Bequests over the Life Cycle

Note: Bequests for those aged 60-61 are normalized to 1.

Appendix B: Survival rates, health transition probabilities and medical expenditures

Health Measurement:

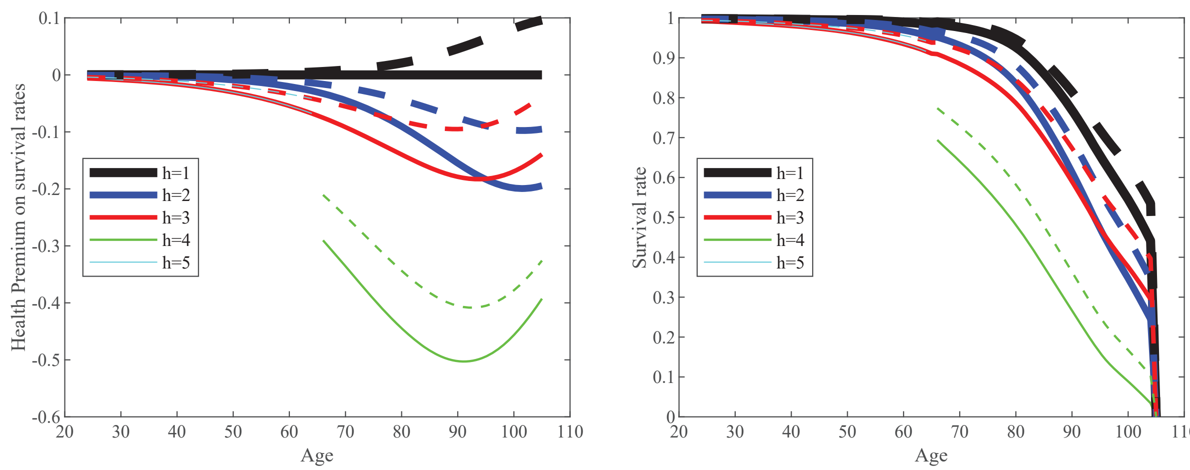
We allow health, h_j, to take on 5 potential values: good ($h_j = 1$), bad ($h_j = 2$), work limitation ($h_j = 3$), in a nursing home ($h_j = 4$), and disabled ($h_j = 5$). Individuals who are currently receiving DI benefits are classified as disabled ($h_j = 5$); this state is eliminated at age 66, when DI recipients are transferred to OAI. In the MEPS, we classify a respondent as a DI beneficiary if he/she receives Social Security or SSI income. In the HRS, we classify a respondent as a DI beneficiary if he/she ever receives Social Security or SSI income for his/her disabilities. Individuals over 65 who are currently in a nursing home with a stay of 60 days or longer are classified as being in a nursing home ($h_j = 4$). Among the remainder, individuals are classified as having work limitations ($h_j = 3$) if they report having health problems that limit their work capacity. In the MEPS, the question on work limitations is "is anyone in the family limited in any way in the ability to work at a job, do housework, or go to school because of an impairment or a physical or mental health problem?" The corresponding question in the HRS is "do you have any impairment or health problem that limits the kind or amount of paid work you can do?" Individuals without work limitations are classified as having bad health ($h_j = 2$) if their self-reported health status is fair or poor, and as having good health ($h_j = 1$) if their self-reported health status is excellent, very good or good.

Survival Rates:

Following Attanasio et al. (2010), we estimate the survival function in three steps. First, we estimate a logit model expressing the two-year survival rate as a function of age, education, health and calendar year:

$$\Pr(alive_{i,j+1,t+2}\,|\,alive_{ijt}) = \frac{\exp\begin{pmatrix} \alpha_0 + \alpha_1 j + \alpha_2 e_i + \sum_m \alpha_{3m} I_{h_{ijt}=m} \\ + \sum_m \alpha_{4m} I_{h_{ijt}=m} \times j + \alpha_5 (t-2014) \end{pmatrix}}{1 + \exp\begin{pmatrix} \alpha_0 + \alpha_1 j + \alpha_2 e_i + \sum_m \alpha_{3m} I_{h_{ijt}=m} \\ + \sum_m \alpha_{4m} I_{h_{ijt}=m} \times j + \alpha_5 (t-2014) \end{pmatrix}},$$

where e_i is individual i's education level and h_{ijt} is her current health status. Our estimation sample appends HRS data for older individuals to MEPS data for younger ones. To improve precision, individuals with work limitations or on DI are grouped together, as the two groups have similar survival rates. Given that our data cover 20 years, we estimate period (for $t = 2014$) rather than cohort survival rates.



(a) Premia

(b) Rates

Figure A2: Estimated Survival Premia and Rates by Age, Health and Education

Note: Solid series are for individuals without a bachelor's degree, and dashed series are for individuals with a bachelor's degree. Individuals receiving DI ($h = 5$) have the same survival rates as those with work limitations ($h = 3$).

Second, we use the results of the logit estimation, $\hat{s}_j(e, h_j)$, to calculate survival premia,

$\Delta_j(e, h_j)$, and approximate survival rates, $\tilde{s}_j(e, h_j)$:

$$\Delta_j(e, h_j) = \hat{s}_j(e, h_j) - \hat{s}_j(0, 1),$$
$$\tilde{s}_j(e, h_j) = \tilde{s}_j(0, h) + \Delta_j(e, h_j).$$

Figure A2(a) shows the resulting survival premia.

The final step is to calibrate $\tilde{s}_j(0, 1)$ to match aggregate survival rates:

$$\sum_{e,h_j} \rho(e, h_j)\tilde{s}_j(e, h_j) = \sum_{e,h_j} \rho(e, h_j)\big[\tilde{s}_j(0, 1) + \Delta_j(e, h_j)\big] = \overline{s}_j,$$

where $\overline{s}_j$ is the male survival rate for age group j in year 2010 (from Bell and Miller 2005), and $\rho_j(e, h_j)$ is the share of age-j individuals in our data with education e and health h_j. To reduce the effects of sampling error, we fit $\rho_j(e, h_j)$ to a fourth-order polynomial, separately for two segments of age groups, and use the predicted values in the calculations.

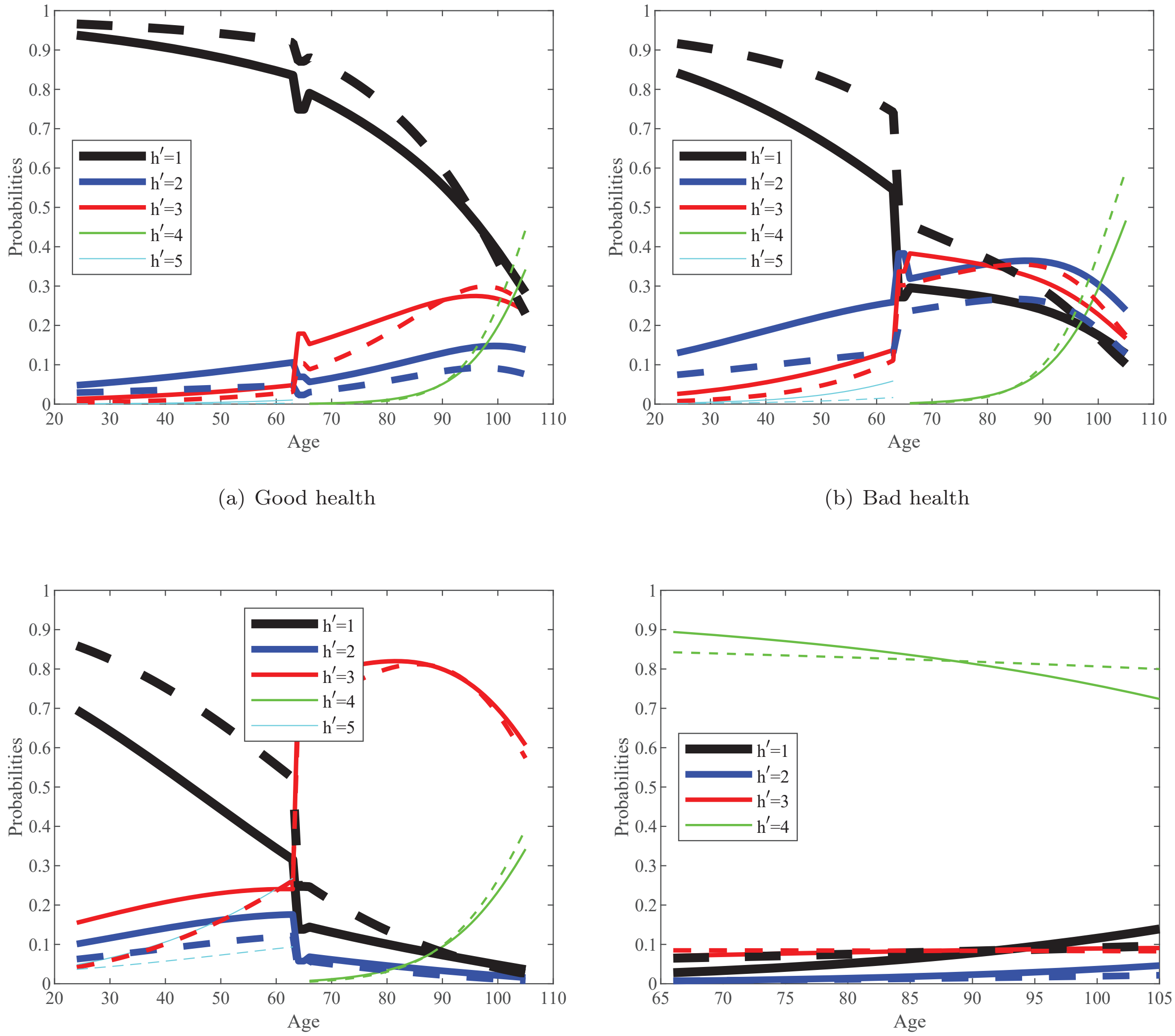
Figure A2(b) shows our estimated survival rates. Survival rates decrease with age. Relative to those in good health, those in bad health are more likely to die. Mortality rates are even higher for those with work limitations (who are combined with the disabled) and highest for those in a nursing home. Conditional on age and health, individuals with a college degree have higher survival rates than those without. At age 24, people with a college degree expect to live an additional 56.4 years; the average remaining lifespan for those without a degree is 50.4 years.

Health Transition Probabilities:

We estimate health transition probabilities using a multinomial logit model. Model predictors include age, education, health status, interactions of education and health with age, and a linear year trend.

$$\Pr(h_{i,t+2,j+1} = k) = \frac{\exp\left(\begin{array}{c} \zeta_0^k + \zeta_1^k j + \zeta_2^k e_i + \zeta_3^k e_i \times j + \sum_m \zeta_{4m}^k I_{h_{ijt}=m} \\ + \sum_m \zeta_{5m}^k I_{h_{ijt}=m} \times j + \zeta_6^k (t - 2014) \end{array}\right)}{\sum_l \exp\left(\begin{array}{c} \zeta_0^l + \zeta_1^l j + \zeta_2^l e_i + \zeta_3^l e_i \times j + \sum_m \zeta_{4m}^l I_{h_{ijt}=m} \\ + \sum_m \zeta_{5m}^l I_{h_{ijt}=m} \times j + \zeta_6^l (t - 2014) \end{array}\right)}, \tag{A1}$$

where $\Pr(h_{i,t+2,j+1} = k)$ is the probability that individual i of age j in calendar year t transits to health state k in the next model period. Consistent with the assumption that DI beneficiaries do not transit out of that state before reaching the NRA, the estimating sample is restricted to non-DI beneficiaries. We experimented with richer specifications, which included non-linear terms in age and the interactions of these non-linear terms with other controls. Probably because of the limited number of observations, the coefficients for these additional terms were not statistically significant.



(a) Good health (b) Bad health

(c) Work limitation (d) Nusing home

Figure A3: Health Transition Probabilities by Age

Note: Solid series are for individuals without a bachelor's degree, and dashed series are for individuals with a bachelor's degree.

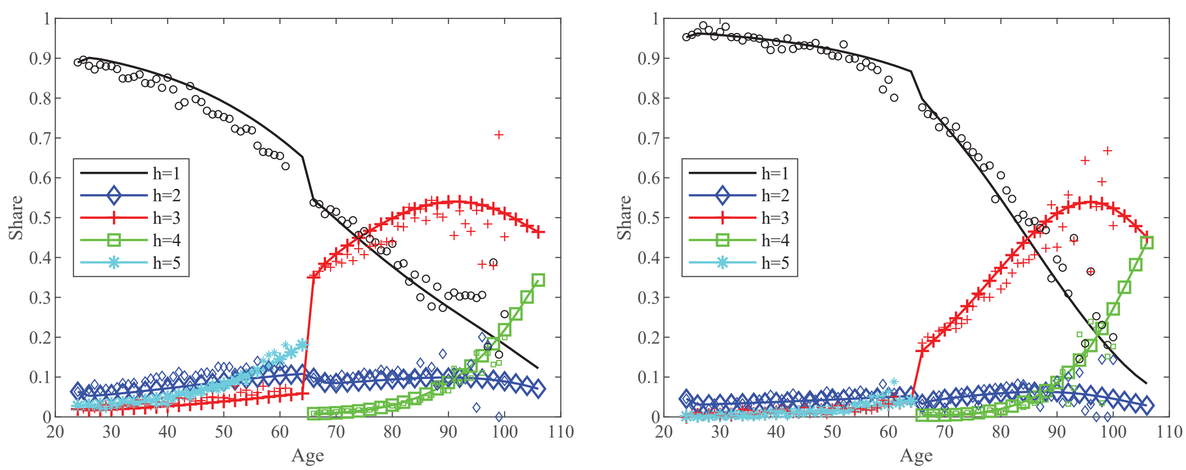
Given the differences in health categories (see section 3.2 in the main text), we estimate separate transition models for the MEPS and the HRS. For the MEPS, we estimate transitions at an annual frequency, to utilize more observations, and calculate two-year transition probabilities using

$$\Pr(h_{j+1} \mid e, h_j) = \sum_m \Pr(h_{j+1} \mid e, h_{j+0.5} = m) \times \Pr(h_{j+0.5} = m \mid e, h_j). \tag{A2}$$

The model switches from the MEPS categories to the HRS categories between ages 64 and 66. We estimate the probabilities for this transition as follows. First, we estimate transition probabilities from $h_j \in \{1, 2, 3, 5\}$ to $h_{j+1} \in \{1, 2, 3, 4\}$ for individuals aged 62-68 in the HRS sample. Second, we adjust the coefficients $\{\zeta_0^k\}_k, k \in \{1, 2, 3, 5\}$ so that the model-generated distribution of health by education at age 66 matches the distribution found in the HRS. For DI beneficiaries ($h = 5$) at age 64, the likelihood of transitioning to the good health, bad health, work limitation or nursing home state is, respectively, 0.0478, 0.0454, 0.8785, and 0.0282 for those without a bachelor's degree; and is, respectively, 0.0923, 0.0253, 0.8445, and 0.0379 for those with a bachelor's degree.

Figure A3 shows two-year transition probabilities for $h \in \{1, 2, 3, 4\}$. (Recall that the DI state is absorbing until age 66.) Each panel shows transition probabilities associated with an initial health status (h rather than h'). At any current state, people with a college degree are more likely to transition to good health. People are more likely to exit good health as they age. Between ages 64 and 66, individuals transition out of DI and begin to transition into nursing homes.

Figure A4 compares the model-generated distribution of health at each age to that in the data and shows that the constructed transition probabilities work well.



(a) Without a bachelor's degree

(b) With a bachelor's degree

Figure A4: Distribution of Health Status by Age and by Education: Data vs. Model

Note: Data series are represented by points, and model series are represented by solid lines.

Medical Spending in the HRS:

While the MEPS contains measures of both total and out-of-pocket medical expenditures, the HRS contains quality data only for out-of-pocket spending.[1] We approximate total medical spending in the HRS by multiplying out-of-pocket medical spending by the ratio of total to out-of-pocket spending found in the Medicare Current Beneficiary Survey (MCBS).

An additional problem with the HRS data is that our model explicitly accounts for Medicaid (through the consumption floor), but the HRS measure of out-of-pocket spending excludes Medicaid payments. To address this issue, we follow Kopecky and Koreshkova (2014) and restrict the HRS medical spending sample to those who are unlikely to receive Medicaid. In our case, we restrict the sample to those in the top three quintiles of the permanent income (PI) distribution, the construction of which we describe in the next paragraph. De Nardi et al. (2016, Table 8) show that households in the top three current income quintiles of the MCBS have similar medical expenditures, including low levels of Medicaid spending. Using the top three PI quintiles of the HRS, our measure of total medical expenses at older ages equals the HRS out-of-pocket spending measure multiplied by 4.5, the ratio of total to out-of-pocket spending for the top three income quintiles in the MCBS (De Nardi et al., 2016, Table 8).

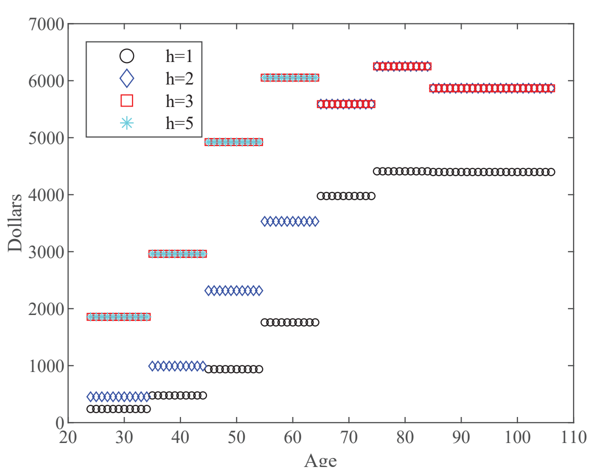
To estimate PI, we follow De Nardi et al. (2021). We first calculate the sum of household pension income and Social Security income. We then regress this sum on a quadratic function of age, interacted with employment status and household structure (dummies for single male, single female, and couples), using fixed effects. The percentile rank of each person's fixed effect is our measure of PI.

Estimated Medical Spending:

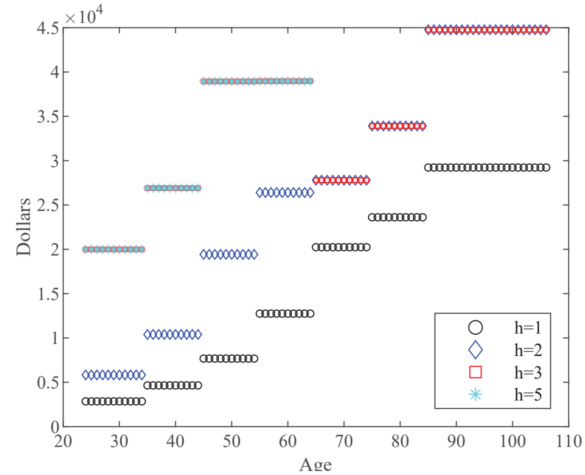
We allow the medical spending shock ϵ to take on three values. Following Kitao (2014), we use: a small shock with a 60% probability, a medium shock with a 35% probability, and a large shock with a 5% probability. To increase the cell size, individuals are pooled into 10-year age bins (a 15-year bin for the oldest). Figure A5 shows our estimated expenditures.[2]

[1] This amount includes the cost of end-of-life care. We thank Eric French for sharing the code for processing the HRS exit files.

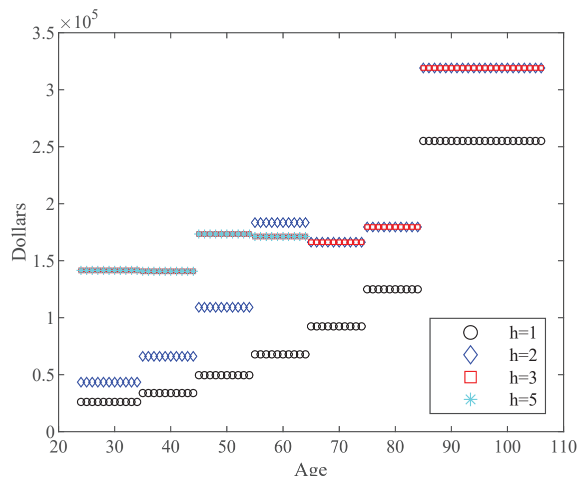
[2] Not shown in Figure A5 are the values for the nursing home state. Due to the small number of observations, we estimate one set of values for all ages. These are, from small to large, \$31,930, \$362,839 and \$712,808.



(a) Small



(b) Medium



(c) Large

Figure A5: Total Medical Expenditures by Age, Health and Shock Realization

Note: Expenditures measured at a two-year frequency. Data for health statuses 3 and 5 are combined over ages 24-65, and data for health statuses 2 and 3 are combined over ages 66+.

Appendix C: Wages

Recall that wages are given by

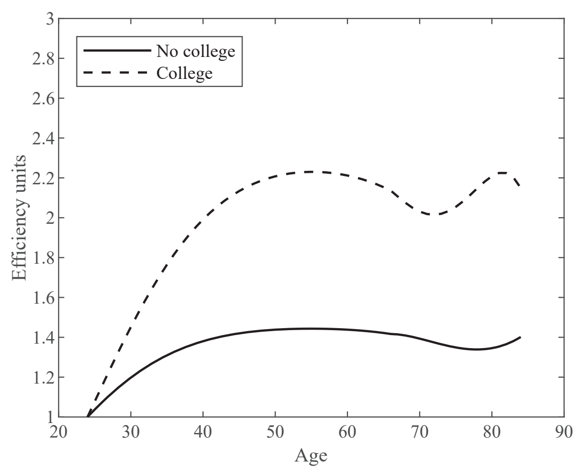
$$w_j = \omega(e, j, h_j) \cdot \eta_j \cdot \left(\min\left\{1, \max\{0.5, \frac{n_j}{\bar{n}}\}\right\}\right)^{\zeta}. \tag{A3}$$

We measure worker productivity, $\omega(e, j, h_j)\eta_j$, as wages divided by the part-time wage penalty. Because each MEPS panel spans only two years, we use wage data from the Panel Study of Income Dynamics (PSID) for ages 24-64. We use HRS data for older ages.

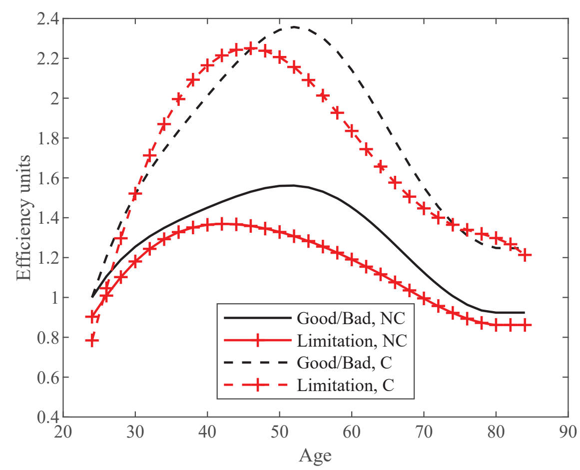
We begin by estimating a standard fixed-effects wage profile:

$$\ln\left(\frac{w_{ij}}{\left(\min\left\{1, \max\{0.5, \frac{n_j}{\bar{n}}\}\right\}\right)^{\zeta}}\right) = \sum_{\upsilon=1}^{4} \theta_{0\upsilon} j^{\upsilon} + \sum_{\upsilon=1}^{4} \theta_{1\upsilon} e_i j^{\upsilon} + \gamma_i + \varsigma_{ij}, \tag{A4}$$

where w_{ij} is the hourly wage rate for individual i of age j, n_{ij} is working hours, γ_i is an individual fixed effect and ς_{ij} is a time-varying residual. We allow wages to differ by education and age but not health, because wages differ little across health statuses after they are adjusted for the part-time penalty and because the disaggregated estimates are less precise. Figure A6(a) shows the fixed-effects estimates.



(a) PSID data (fixed effects)



(b) Model

Figure A6: Age Efficiency Profiles

The fixed-effects profiles show wages continuing to rise even at very old ages. These profiles are not an unbiased estimate of $\omega(e, j, h_j)$, however, because they are estimated only on the wages of those who work. If individuals with unusually large wage decreases are more likely to retire, the fixed-effects estimate of $\omega(e, j, h_j)$ will overstate wage growth at older ages. We account for this bias with the correction developed in French (2005). In brief, using our model to simulate wage and employment histories and estimate fixed-effects wage profiles for workers, we set $\omega(e, j, h_j)$ so that the simulated estimates of $\{\theta_{0\upsilon}, \theta_{1\upsilon}\}_\upsilon$ match those found in the data. This involves an interactive process where the model is solved and simulated, and the estimate of $\omega(e, j, h_j)$ is updated to reflect differences between the PSID and simulated fixed effects profiles. Figure A6(b) shows the corrected profiles, which are allowed to vary by health. Wages fall steadily after age 55, and the wages for those with work limitations are often much lower. The initial level of the wage rate is set to be the average fixed effect for all individuals of age 24, and it is \$16.6 per hour for those without a bachelor's degree and \$20.6 for those with a bachelor's degree.

Table A1: Persistence and Variance of the Productivity Shocks

	Non-college	College
Autocorrelation Coefficient	0.958	0.939
Innovation Variance	0.013	0.021

To estimate the process for the productivity shock η_j, we again follow French (2005) and assume that the fixed-effects residual, $\gamma_i + \varsigma_{ij}$, follows

$$\gamma_i + \varsigma_{ij} = \eta_{ij} + \varepsilon_{ij} + \varkappa\varepsilon_{ij-1}, \tag{A5}$$

where ε_{ij} is white noise measurement error. Assuming that η_{ij} follows an AR(1) process, we can find its parameters, and the parameters of the MA(1) measurement-error process, by matching the autocovariances of $\gamma_i + \varsigma_{ij}$, using standard error components calculations. Table A1 reports the parameters for η_j.

Appendix D: Labor supply elasticities

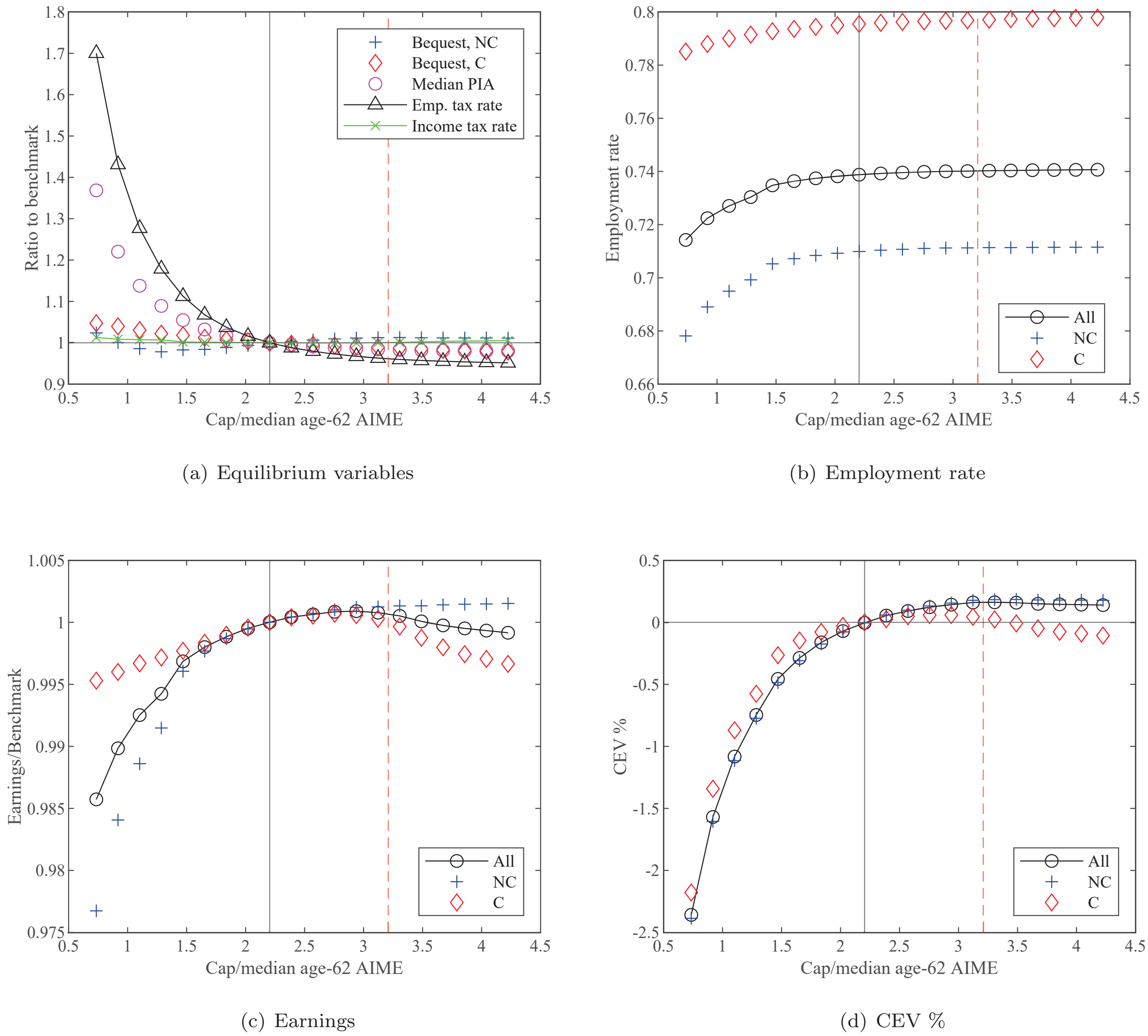
Table A2: Decomposition of total hours elasticity for anticipated wage changes

	Temporary change			Permanent change		
Age	30	60	70	30	60	70
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Total Hours						
In the year of the change	0.08	0.78	4.45	0.08	0.81	4.33
Over the entire life	-0.01	0.01	0.03	0.20	0.25	0.11
In the years prior to the change	0.00	0.00	0.00	0.00	0.00	-0.01
In the years after the change	-0.01	-0.16	-0.21	0.25	2.58	4.64
Panel B: Employment						
In the year of the change	0.01	0.58	3.73	0.00	0.65	4.00
Over the entire life	-0.01	0.01	0.03	0.17	0.25	0.13
In the years prior to the change	0.00	0.01	0.01	0.00	0.01	0.00
In the years after the change	-0.01	-0.15	-0.18	0.22	2.29	4.39
Panel C: Hours of work for workers						
In the year of the change	0.07	0.20	0.52	0.07	0.15	0.23
Over the entire life	0.00	0.00	-0.01	0.02	-0.01	-0.03
In the years prior to the change	0.00	0.00	-0.01	0.00	-0.01	-0.02
In the years after the change	-0.01	-0.01	-0.03	0.06	0.20	0.18

Appendix E: Detailed Policy Effects: Alternative Baseline

Figures 6, 7 and 9 in the main text show the effects of changing individual policy instruments – the payroll tax cap, the PIA formula and claiming adjustments – when the other policy instruments are held fixed at their welfare-maximizing values. One potential concern with such an analysis is its sensitivity to “cross-partial” effects: to what extent do the effects of changing one policy instrument depend on the values assigned to the other instruments? In this appendix, we consider the effects of changing the policy instruments when the other instruments are held at their *baseline* values. We also reinstitute the earnings test and benefit taxation, so that the policy changes represent deviations from the current Social Security system.

Figure A7, the analogue to Figure 6 in the main text, shows the effects of changing the payroll tax cap. Comparing the two figures shows that not only are the effects similar qualitatively, but that the welfare-maximizing tax cap in the full optimization exercise, shown by the dashed red line, comes close to maximizing welfare in the current exercise (panel (d)). While the level of the CEV is lower in Figure A7(d) than in Figure 6(d), the value of the tax cap at which the CEV is maximized is virtually identical. By these metrics, the cross-partial effects are quite modest.



(a) Equilibrium variables

(b) Employment rate

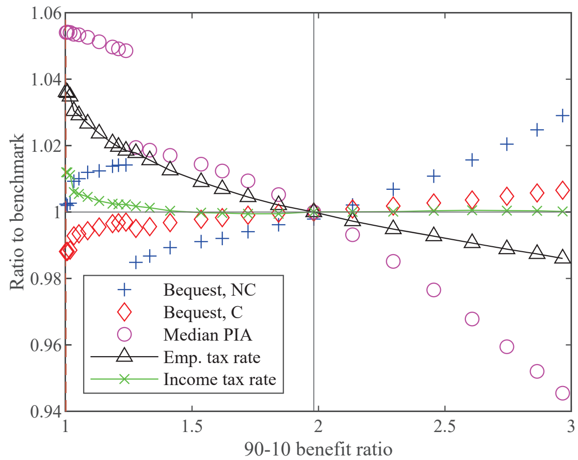
(c) Earnings

(d) CEV %

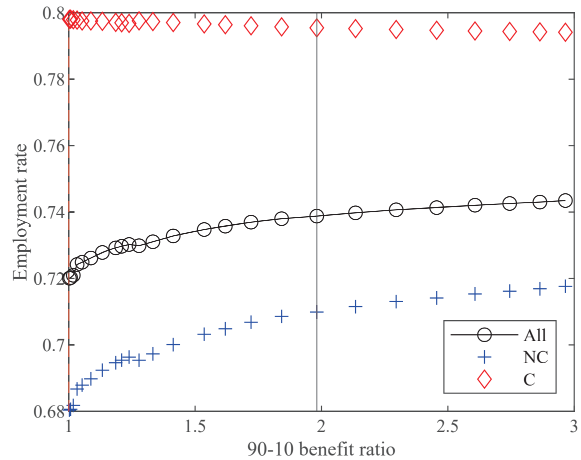
Figure A7: Effects of Changing the Limit on Taxable Earnings, using Current Policies

Note: Non-tax cap policies set to their benchmark values; earnings test and benefit taxation in effect. Solid black and dashed red lines denote current and welfare-maximizing payroll tax cap, respectively. Consumption equivalent variation calculated relative to baseline specification.

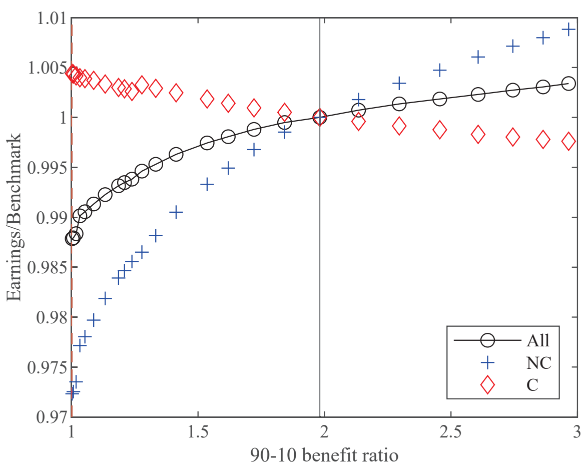
Figure A8 shows the effects of changing the PIA formula. Once again, the patterns shown in the alternative exercise are quite similar to those found in the main text.



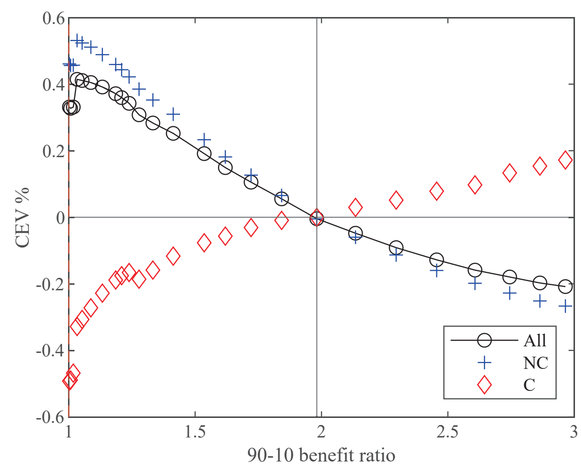
(a) Equilibrium variables



(b) Employment rate



(c) Earnings

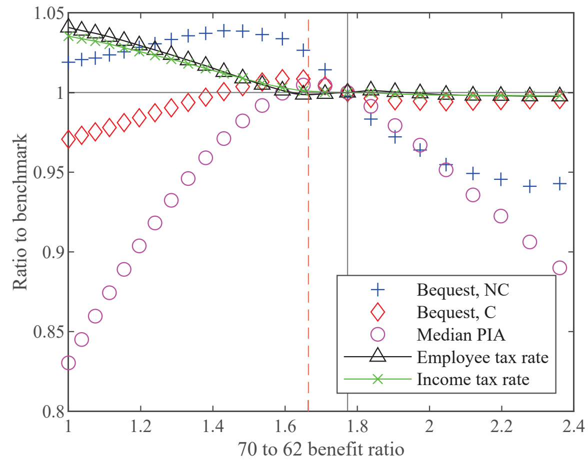


(d) CEV %

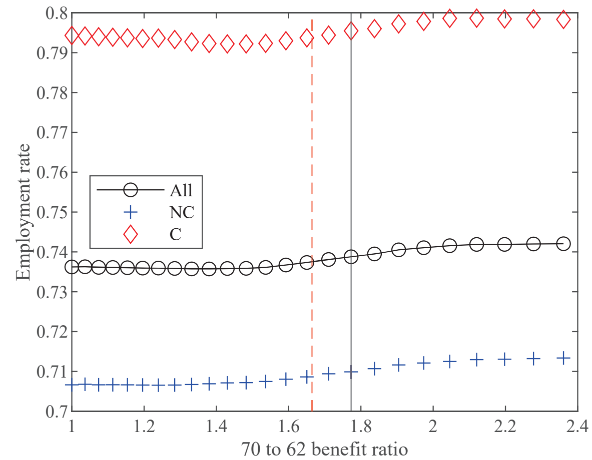
Figure A8: Effects of Changing the PIA Formula, using Current Policies

Note: Non-PIA policies set to their benchmark values; earnings test and benefit taxation in effect. Solid black and dashed red lines denote current and welfare-maximizing PIA formulae, respectively. Consumption equivalent variation calculated relative to baseline specification.

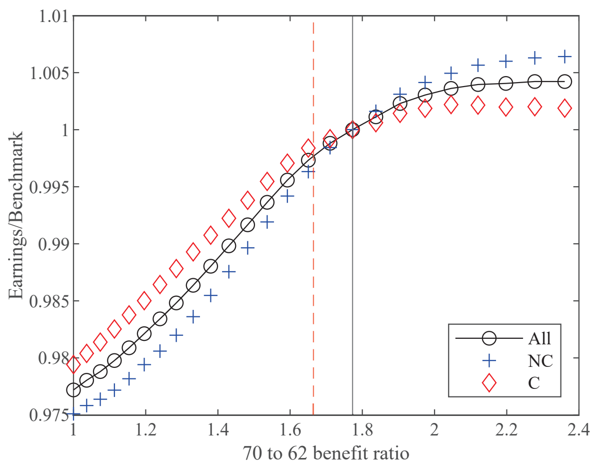
Figure A9 shows the effects of changing the claiming adjustments. Because benefit taxation and the earnings test both discourage work by Social Security beneficiaries, in this alternative exercise



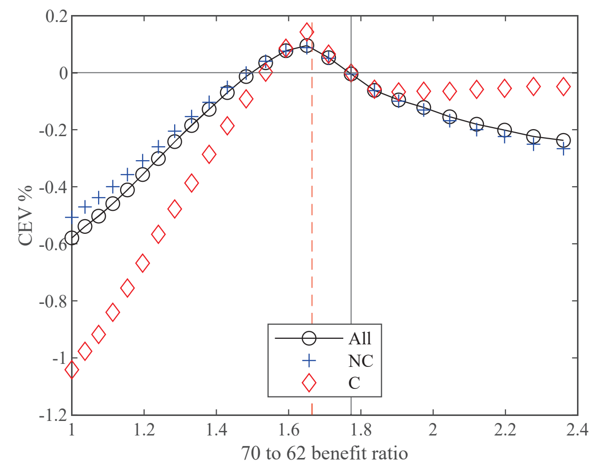
(a) Equilibrium variables



(b) Employment rate



(c) Earnings



(d) CEV %

Figure A9: Effects of Changing the Claiming Age Adjustments, using Current Policies

Note: Non-claiming adjustment policies set to their benchmark values; earnings test and benefit taxation in effect. Solid black and dashed red lines denote current and welfare-maximizing claiming adjustments. Consumption equivalent variation calculated relative to baseline specification.

employment and earnings respond to claiming adjustments across their entire range. Changes in earning in turn affect taxes and bequests. Nonetheless the optimal claiming adjustment in this exercise is quite similar to the one we find when considering all reforms together.

Appendix F: Alternative Versions of the 2050 Demographic Environment

In the "2050 demographics" scenario examined in the main text, we balanced the Social Security budget by reducing benefits. In Table A3 below, we compare our findings for this exercise (shown in columns (1)-(2)) to one in which the Social Security budget is balanced through higher taxes. In particular, columns (3)-(4) of Table A3 repeat the exercises of columns (1)-(2) under the assumptions that the Social Security benefit formula remains at its absolute 2014 values and payroll taxes are raised to balance the budget. Comparing the two sets of columns shows that the optimal policies are robust to how the Social Security budget is balanced.

In columns (5)-(6), we analyze a variant of the 2050 environment where lifespans increase for all individuals (not just the college-educated), while in columns (7)-(8) and (9)-(10) we consider variants where the growth in the number of college graduates is 20% lower or 20% higher than the 17.6 pp increase ($0.496 - 0.320$) assumed in the previous columns. The optimal policies for all these variants are similar to those shown in columns (1)-(2).

Table A3: Current and Optimal Policies: 2050 Demographics

	Preferred 2050 Specification		2014 SS Rules		Longer Lifespans at All Educ. Levels		Fewer College Graduates		More College Graduates	
	Current	Optimal 2	Current	Optimal 2	Current	Optimal 2	Current	Optimal 2	Current	Optimal 2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tax cap / median AIME	2.20	3.23	2.20	3.22	2.20	3.20	2.20	3.25	2.20	3.22
Age-66 benefit (PIA) percentiles (000s)										
10th percentile	20.4	36.6	29.6	53.4	21.1	36.6	20.8	36.8	20.1	36.4
median	30.8	36.6	44.6	53.5	31.8	36.9	31.4	36.9	30.2	36.4
90th percentile	40.5	36.6	58.6	53.5	41.8	37.1	41.3	36.9	39.8	36.4
Benefits relative to age-66 benefit										
age 62	0.74	0.80	0.74	0.78	0.74	0.80	0.74	0.80	0.74	0.80
age 70	1.33	1.23	1.33	1.26	1.33	1.24	1.33	1.23	1.33	1.23
Benefit claiming										
age 62	2.4%	88.7%	4.1%	88.7%	1.8%	89.0%	2.5%	88.2%	2.2%	89.3%
age 66	31.2%	100.0%	48.4%	100.0%	29.2%	100.0%	33.5%	100.0%	28.9%	100.0%
Employment										
age 62	78.6%	75.9%	75.8%	69.0%	77.8%	75.4%	77.6%	75.1%	79.5%	76.9%
age 70	37.5%	38.2%	29.3%	30.0%	32.6%	33.5%	36.5%	37.3%	38.5%	39.2%
Aggregate behavior										
employed	73.6%	73.1%	71.2%	70.1%	73.0%	72.5%	73.3%	72.8%	73.9%	73.4%
earnings ($000s)	101.7	101.1	99.6	98.8	99.5	98.9	99.5	99.0	103.8	103.2
assets ($000s)	183.1	196.0	155.0	169.0	175.5	188.6	174.0	187.1	192.1	205.1
consumption ($000s)	90.3	90.9	87.5	88.0	88.0	88.7	88.0	88.6	92.5	93.1
τ_{ss}	5.0%	5.4%	8.4%	8.8%	5.3%	5.7%	5.2%	5.6%	4.8%	5.2%
λ_0	25.8%	25.5%	25.8%	25.5%	25.8%	25.4%	25.8%	25.5%	25.8%	25.5%
Internal (annual) rate of return on OAI and DI										
all households	0.11%	0.08%	0.43%	0.43%	0.11%	0.09%	0.11%	0.08%	0.11%	0.08%
no college degree	0.26%	1.07%	0.46%	1.37%	0.48%	1.15%	0.24%	1.02%	0.28%	1.12%
college degree	0.04%	-0.47%	0.41%	-0.10%	-0.09%	-0.58%	0.04%	-0.52%	0.04%	-0.42%
Consumption equivalent variation										
all households		1.40%		1.33%		1.62%		1.44%		1.37%
no college degree		1.39%		1.34%		1.68%		1.43%		1.36%
college degree		1.42%		1.31%		1.44%		1.46%		1.39%

Note: Columns (1)-(2): 2050 specification discussed in main text. Columns (3)-(4): 2014 SS benefit rules in effect, not scaled down to match 2014 SS spending target. Columns (5)-(6): Lifespans increased proportionally at all education levels. Columns (7)-(8) and (9)-(10): The fraction of the population with a college degree grows 20% less and 20% more, respectively, than in the main text. Current: Current SS rules. Optimal 2: Earnings test and benefit taxation eliminated, optimal SS parameters.

Appendix G: General Equilibrium

To impose general equilibrium, we assume that the aggregate production function takes the canonical Cobb-Douglas form,

$$Y = AK^{\alpha}L^{1-\alpha}.$$

Assuming that capital (K) and labor (L) are paid their marginal products, we have

$$\frac{\alpha}{1-\alpha} = \frac{(r+\delta)K}{\overline{w}L},$$
$$A = \frac{\overline{w}}{1-\alpha}\left(\frac{K}{L}\right)^{-\alpha},$$

where δ is the depreciation rate and $\overline{w}$ is the aggregate wage. We assume further that r is also the interest rate earned by individual savers and that the wage of individual i at age j equals the product $\overline{w} \cdot w_{i,j}$, where $w_{i,j}$ is the idiosyncratic component described in equation (2) of the main text.

In the baseline specification, we set $r + \delta = 0.10 + 0.16 = 0.26$, or 0.13 on an annual basis. We also normalize $\overline{w}$ to 1, so that in the baseline specification the wage $w_{i,j}$ equals individual i's productivity at age j. Setting K and L to mean assets and earnings, respectively, in the baseline specification yields $\alpha = 0.2412$ and $A = 1.2555$.

When searching for optimal policies in general equilibrium, we fix α and A at their baseline values and set r and $\overline{w}$ so that the aggregate capital stock K equals total asset holdings and the aggregate labor input L equals total productivity-weighted hours of work (the sum of $w_{i,j}n_{i,j}$). The first four columns of Table A4 show the results of the general equilibrium exercises. Column (1) reproduces the baseline specification with the current Social Security rules. Column (2) shows the welfare-maximizing Social Security rules and their effects; the welfare gains are larger than before, but the optimal policies themselves change very little. Column (3) shows that cutting Social Security expenditures in half has significant benefits even when the structure of Social Security is otherwise unchanged. Column (4) shows that the optimal rules in a half-sized Social Security system are almost identical to the optimal rules in the full-sized one.

Appendix H: Income Tax Reforms

Following Gouveia and Strauss (1994), we use the following income tax function:

$$\widetilde{T}(y) = \lambda_0[y - (y^{-\lambda_1} + \lambda_2)^{-1/\lambda_1}].$$

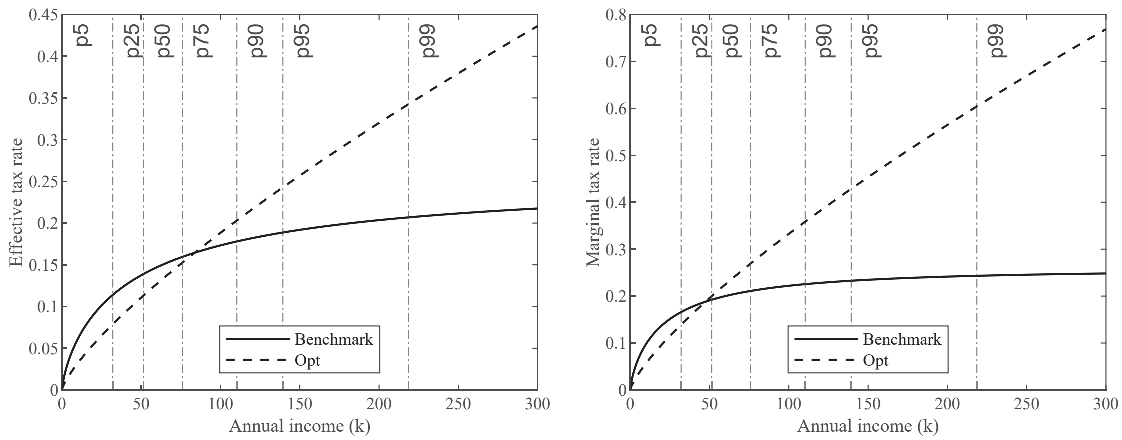
To assess the scope for redistribution through income taxes, we search for the optimal value of the parameter λ_2, keeping the Social Security rules at their current configuration. (We adjust λ_0 to maintain budget balance.) Figure A10 shows that the optimized tax function is significantly

Table A4: Optimal Policies under Alternative Equilibrium and Tax Assumptions

	GE Effects		GE: SS Halved			Optimal Income Taxes	
	Current	Optimal 2	Current	Optimal 2	Current	Current	Optimal 2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tax cap / median AIME	2.20	3.02	2.20	3.14	2.20	2.20	3.15
Age-66 benefit (PIA) percentiles (000s)							
10th percentile	29.6	47.1	14.8	22.8	29.6	29.6	39.9
median	44.6	47.1	22.3	22.8	44.6	44.6	43.0
90th percentile	58.6	47.1	29.3	22.8	58.6	58.6	45.5
Benefits relative to age-66 benefit							
age 62	0.74	0.78	0.74	0.83	0.74	0.74	0.84
age 70	1.32	1.27	1.32	1.19	1.32	1.32	1.17
Benefit claiming							
age 62	8.1%	87.7%	4.9%	87.6%	8.1%	9.1%	85.3%
age 66	74.9%	100.0%	30.1%	100.0%	74.9%	70.0%	100.0%
Employment							
age 62	69.9%	66.2%	79.3%	80.1%	69.9%	74.6%	72.0%
age 70	23.9%	26.5%	45.3%	51.6%	23.9%	26.9%	31.0%
Aggregate behavior							
employed	73.9%	74.0%	79.4%	80.5%	73.9%	75.6%	75.8%
earnings ($000s)	92.0	93.8	100.4	102.5	92.0	91.3	91.7
assets ($000s)	112.4	120.2	139.8	148.6	112.4	96.2	106.0
consumption ($000s)	77.0	78.4	82.5	84.1	77.0	75.1	76.3
τ_{ss}	6.2%	6.2%	3.1%	3.0%	6.2%	6.2%	6.3%
λ_0	25.8%	24.9%	22.7%	21.9%	25.8%	5498.1%	5374.5%
Input prices							
interest rate (r)	0.100	0.091	0.076	0.069			
aggregate wage ($\overline{w}$)	1.000	1.011	1.032	1.042			
Consumption equivalent variation							
all households		1.93%	4.77%	6.72%		1.95%	3.29%
no college degree		1.99%	4.68%	6.66%		2.38%	3.70%
college degree		1.49%	5.41%	7.11%		-0.69%	0.78%

Note: Columns (1)-(2): Labor and capital markets clear. Columns (3)-(4): Labor and capital markets clear, Social Security spending halved. Column (5): Column 1 of Table 3. Columns (6)-(7): Income tax set to maximize welfare. Current: Current SS rules. Optimal 2: Earnings test and benefit taxation eliminated, optimal SS parameters.

more redistributive than the baseline one. Panel (a) of the figure shows that, relative to the benchmark, the optimal function lowers taxes on the bottom three income quartiles of the income distribution, while increasing the tax burden of the remainder. Column (6) of Table A4 shows that this intervention increases the welfare of the non-college educated by 2.4%, while decreasing that of college graduates by 0.7%.



(a) Average tax rates

(b) Marginal tax rates

Figure A10: Benchmark (panel a) and optimal (panel b) income tax functions

Note: The benchmark and optimal income tax functions are $0.258 \times \left[y - (y^{-0.768} + 0.000195)^{-1/0.768}\right]$ and $54.9805 \times \left[y - (y^{-0.768} + 0.0000004)^{-1/0.768}\right]$, respectively. The vertical dash-dot lines mark the percentiles of total earned and interest income among those aged 24-59 in the benchmark economy, with the fifth percentile (p5) being 0.

Adopting this new tax function, we then search for the optimal Social Security policies. The welfare-maximizing Social Security policies in this setting, shown in column (7), are quite similar to those in our baseline model.

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