Social Security Reform with Heterogeneous Mortality

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July 17, 2020

Abstract

Using a heterogeneous agent, life-cycle model of Social Security claiming, labor supply and saving, we consider the implications of lifespan inequality for Social Security reform. Quantitative experiments show that welfare is maximized when baseline benefits are independent of lifetime earnings, the payroll tax cap is kept roughly unchanged, and claiming adjustments are reduced. Eliminating the earnings test and the income taxation of Social Security benefits provides additional gains. The Social Security system that would maximize welfare in a "2050 demographics" scenario, characterized by longer lifespans and an increased education-mortality gradient, is similar to the one that would maximize welfare today.

JEL: E21, H24, H55, I38, J11

Keywords: Social Security, Mortality, Labor Supply, Welfare

1 Introduction

One of the most common proposals for stabilizing the Social Security system is to increase the normal retirement age (NRA). An appealing feature of this proposal is that it counters the secular trend toward longer lives, a major cause of Social Security's financial difficulties, by effectively delaying the age at which full benefits start. It is also well-known, however, that the longevity gap between rich and poor is large and growing over time (National Academies of Sciences, Engineering, and Medicine 2015; Chetty et al. 2016). This has generated concerns that raising the NRA would cut disproportionately the benefits of the poor (e.g., Krugman 2015). While these concerns can be mitigated by changing the progressivity of the benefit formula (Cremer et al., 2010), the more general question remains. If high-income workers live longer than low-income workers, should they work longer as well? Should they receive higher annual benefits?

When considering such questions, several conflicting principles come into play. (Cremer et al. 2010 provide a nice encapsulation. See also Ndiaye 2018.) Mirrlees's (1971) canonical framework highlights the tension between equalizing consumption and encouraging work by the most productive. In our setting, this implies that high-productivity workers should retire at older ages. With heterogeneous mortality, "equal consumption" must be defined as well. Solutions to social planners' problems often involve equating the weighted marginal utility of consumption across all surviving agents. This can imply equal per-period consumption flows, but larger lifetime transfers to the long-lived. Inevitably, optimal pension design is a quantitative exercise.

To examine these issues, we develop a heterogeneous-agent, life-cycle model of Social Security claiming, labor supply and saving. In the model, individuals face uncertain health, wages, medical spending and survival, the distributions of which vary by education level. The government collects income, payroll and consumption taxes, and provides Social Security, Medicare, Disability Insurance and means-tested social insurance. Individuals

can continue working while receiving Social Security benefits, but they may face financial disincentives to do so. After calibrating the model to the current U.S. economy and Social Security rules, we evaluate potential reforms.

In particular, we solve the following planning problem. Consider a stationary cross-sectional distribution of individuals that differ along a variety of demographic and economic dimensions. Holding fixed both aggregate Social Security expenditures and revenues, and maintaining general government budget balance, what are the Social Security rules that maximize the ex-ante utility of a newborn? We consider three sets of parametric reforms:

1. Changes to the payroll tax earnings cap and tax rate.

2. Changes to the formula converting an individual's earnings history to his baseline benefit (the Primary Insurance Amount, or PIA).

3. Changes to the trade-off between the age at which an individual first receives her Social Security benefits – and thus the length of the benefit stream – and the size of the annual benefit. Increases in the NRA can be interpreted as a special case. This trade-off is formally embodied in the early retirement penalties and delayed retirement credits, which increase or decrease an individual's annual benefits proportionally to his PIA.

All of the reforms that we study have appeared before as proposals, enacted changes or both. While the first two sets of reforms affect how Social Security benefits depend on wage realizations and *work* decisions, the third affects how benefits depend on *claiming* decisions. Because individuals can simultaneously work and receive Social Security benefits, their work and claiming decisions may appear to be disconnected. This is not the case, however, because the rate at which earnings translate into Social Security benefits is a function of the age at which the benefits are claimed and because benefit receipt itself generates work disincentives. These disincentives include benefit reductions through the Social Security earnings test and the way in which the income taxation of Social Security benefits increases the income taxation of earnings (Jones and Li, 2018).

Each set of reforms embodies the canonical trade-off between redistribution and productive efficiency. Raising the payroll tax cap lowers the tax rate but applies it to a broader range of earnings. This reduces taxes for most workers but raises marginal tax rates for the most productive. Linking Social Security benefits to lifetime earnings increases the returns to work but reduces transfers from high to low earners. Raising the returns to delayed claiming rewards longer careers but punishes those with low longevity.

Our general finding is that, relative to the Social Security policies currently in place, the policies that would maximize welfare would reduce work incentives in order to redistribute resources from high to low earners. Under these policies, the PIA would be independent of lifetime earnings, and claiming adjustments would be smaller, while the upper bound on taxable earnings would remain at more or less its current value. Collectively the reforms cause both earnings and employment to fall by 1-2%. We show, however, that eliminating the earnings test and the income taxation of Social Security benefits, as recommended by Jones and Li (2018), reverses more than two-thirds of the fall in earnings and more than half of the fall in employment. Combining the two sets of reforms also results in larger welfare gains. Because the earnings test and benefit taxation apply at older ages, when the elasticity of labor supply is especially high (French and Jones 2012; Karabarbounis 2016; Ndiaye 2018), eliminating them is an especially effective way to encourage work. Removing the provisions uncouples claiming decisions from retirement decisions; under the joint reforms, almost everyone claims benefits at age 62.

We then consider how heterogeneous mortality affects Social Security reform in the face of population aging. We construct a hypothetical "2050 demographics" scenario characterized by longer lifespans, lower population growth and an increased education-mortality gradient. We find that the Social Security system that would maximize welfare in the 2050 demographic environment is quite similar to the one that would maximize welfare today. In both cases, the PIA would be independent of individual earnings; the payroll tax cap would be higher in 2050 than at present; but the claiming adjustments

would not. Although increased longevity suggests that larger claiming adjustments are needed to promote longer careers, increased longevity also implies that the adjustments needed to induce claiming delays (and longer careers) are smaller.

The literature on Social Security reforms is immense (see, e.g., Feldstein and Liebman 2002). In their review, Börsch-Supan et al. (2016) contrast "parametric" reforms, where the basic design of the system is unchanged, with more fundamental "systemic" reforms, such as the switch from a pay-as-you-go to a fully funded system. We restrict ourselves to parametric reforms, holding fixed Social Security's "aggregate footprint."[1] Because the absolute size of a country's Social Security system can have first-order effects on its aggregate capital stock, our approach allows us to focus on distributional concerns. Within the literature on parametric reforms, our contribution is to consider all the reforms simultaneously, quantitatively, and while accounting for heterogeneity in income and health. Our exercise also stands out in its breadth: among other possibilities, we consider flat benefits and what is effectively a single claiming age.

While it has been long recognized that heterogeneous mortality affects the lifetime progressivity of Social Security (Aaron, 1977), and multiple studies have sought to quantify this effect (recent analyses include Goda et al. 2011; Bosworth and Burke 2014; National Academies of Sciences, Engineering, and Medicine 2015; and Sheshinski and Caliendo 2018), there has been relatively little progress in quantifying its implications for optimal policies. Laun et al. (2019) and Sánchez-Romero et al. (2019) consider how to maintain fiscal sustainability in the presence of heterogeneous demographic change. (Also see Conesa et al. 2019.) Although set in Norway, the structure of Laun et al.'s (2019) model is quite similar to ours. However, they focus on a handful of reforms, including some that change the pension system's aggregate footprint, while we seek optimal policies

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[1]An alternative approach used in the literature is to fix tax rates and require that benefit changes maintain Social Security budget balance (e.g., Huggett and Ventura 1999; Nishiyama and Smetters 2008; Bagchi 2019). When operating within a stationary demographic environment, this constraint is much the same as ours. The two constraints differ if one considers responses to major demographic changes.

with the footprint held fixed. Sánchez-Romero et al. (2019) consider systemic reforms in a general equilibrium framework with no health or wage uncertainty. Using a life-cycle model with heterogeneous mortality rates, Bagchi (2019) examines reforms to the Social Security benefit formula, but he does not consider claiming decisions. As we show below, claiming decisions and retirement decisions are at times closely linked, and changing the claiming adjustments is one of our principal reforms. Huggett and Ventura (1999) and Nishiyama and Smetters (2008), who also consider reforms to the benefit formula, do not allow for claiming decisions or heterogeneous mortality risk.

Huggett and Parra (2010) find the system of life-cycle taxes that implements the social planner's solution for a cohort of individuals, holding fixed the net resources extracted from that cohort. In a separate exercise, they find that the optimal Social Security benefit function, if considered in isolation, would decrease modestly in lifetime earnings. Ndiaye (2018) expands Huggett and Parra's (2010) framework to include a retirement choice. He finds that the optimal Social Security system would tie benefits more closely to earnings and strengthen the claiming adjustments. Huggett and Parra (2010) and Ndiaye (2018) show that Social Security reforms in isolation recover only a portion of the utility gains achievable under an optimal tax system. On the other hand, to make their exercise tractable, they impose a number of simplifications. Among the most important of these are the assumptions that all agents share a common, fixed lifespan and that agents receiving Social Security benefits are unable to work. In our robustness exercises, we show that these restrictions increase the sensitivity of retirement to claiming incentives and thus favor large claiming adjustments.

The remainder of the paper is organized as follows. In Section 2, we describe our model, while in Section 3, we describe its calibration. In Section 4, we present the policies that would maximize welfare in the current demographic environment. In Section 5, we discuss the 2050 demographic environment and the policies that would maximize welfare therein. In Section 6, we perform a number of robustness exercises. We conclude in

Section 7.

2 Model

Our behavioral model is similar to those of İmrohoroğlu and Kitao (2012) and Jones and Li (2018) but contains a considerably richer treatment of health, mortality and wages, including heterogeneity related to education. Our description borrows heavily from Jones and Li (2018).

2.1 Demographics

The population consists of overlapping generations. Each period represents two years. Let $j \in \{1, 2, \ldots, J\}$ denote age, where J represents the maximum lifespan. The population grows at the constant rate χ. Among other dimensions, new individuals differ in terms of education level (e). We assume the distribution of education is exogenous and constant over time.

Let $s_j(h_j, e)$ denote the survival rate between periods, which depends on each individual's age, health status (h_j), and education level. Health can take on five potential values: good $(h_j = 1)$, bad $(h_j = 2)$, work limitation $(h_j = 3)$, in a nursing home $(h_j = 4)$, and disabled $(h_j = 5)$. Health status affects individuals through five channels: the time endowment, the survival probability, health transitions, medical expenditures, and access to Disability Insurance (DI). We assume that all individuals in the disabled health state receive DI – our empirical definition of the disability state is DI receipt – and thus abstract away from the DI application decision and uncertainty over DI receipt. Because the reforms we consider are not intended for the disabled, we view this as a reasonable simplification.

2.2 Preferences

Each period surviving individuals receive utility from consumption (c) and leisure (l) according to the function $u(c, l)$. Leisure in turn depends on hours of work, n_j, health, and labor market participation in the previous period (n_{j-1}):

$$l_j = 1 - \sum_k \phi_{ke}^h I_{\{h_j=k\}} - \phi_e^n I_{\{n_j>0\}} - \phi^{re} I_{\{n_{j-1}=0 \text{ and } n_j>0\}} - n_j, \tag{1}$$

where $I_{\mathcal{A}}$ is the 0-1 indicator function that takes the value of 1 when event $\mathcal{A}$ occurs. The term $\phi_{ke}^h I_{\{h=k\}}$ reflects the time cost of being in health status k for a person with education level e. This cost is normalized to 0 for individuals in good health and is intended to reproduce the empirical observation that unhealthy people work less. The term $\phi_e^n I_{\{n>0\}}$ captures the fixed time costs of work for education level e. This term is intended to reproduce the observation that most people work full-time or not at all (see, e.g., Cogan 1981 and French and Jones 2012). The term $\phi^{re} I_{\{n_{j-1}=0 \text{ and } n_j>0\}}$ captures the time cost of reentering the labor market. Similar specifications for leisure have been used in, among other studies, French (2005) and French and Jones (2011). We assume that disabled individuals and nursing home residents cannot work.

When they die, individuals receive warm-glow utility from bequests according to the function $v(a)$, where a denotes the amount of assets bequeathed. Future utility is discounted using the factor β.

2.3 Earnings

Individuals that work at age j receive the wage w_j,

$$w_j = \omega(e, j, h_j) \cdot \eta_j \cdot \min\left\{1, \left(\frac{n_j}{\bar{n}}\right)^\zeta\right\}. \tag{2}$$

Wages depend on age, education and health through $\omega(e, j, h_j)$. η_j is an idiosyncratic productivity shock following a Markov process with transitions $\Pi_j^\eta(e, \eta_j, \eta_{j+1})$. The final term, $\min\{1, [n_j/\overline{n}]^\zeta\}$, imposes a penalty for working less than the full-time work load of $\overline{n}$. Following Aaronson and French (2004), we set ζ to 0.415, implying that half-time workers are paid 25% less than full-time workers. Imposing the part-time earnings adjustment leads total earnings, $W_j = w_j n_j$, to have increasing returns to scale in hours of work. This feature combines with the fixed time cost of work to encourage full-time work.

2.4 Medical Expenditures and Health Insurance

Each individual's health status (h_j) changes stochastically over the life cycle, following a Markov process with the age-dependent transition probability $\pi_j^h(h_{j+1} \,|\, e, h_j)$. Total medical expenditures, denoted by $m_j = m_j(h_j, \epsilon_j)$, depend on age, current health and the shock ϵ_j, an i.i.d. process with the stationary distribution $\Pi(\epsilon)$. Health insurance coverage is universal: Medicare covers DI recipients (after a two-year waiting period) and all individuals 65 and older ($j \geq J^M$), and private health insurance covers the rest of the population.[2] The medical expenses paid by the individuals themselves can be split into two parts: insurance premia, p_j, which are paid at the beginning of each period before the medical spending shocks for that period are revealed; and co-payments, $Q_j(h_j, \epsilon_j)$, which are paid at the end of each period after the shocks are revealed. Premia and co-payments follow

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p_j = \begin{cases} p^{\text{priv}} & \text{if } j < J^M \text{ and } h_{j-1} \neq 5 \\ p^{\text{mcr}} + p^{\text{supp}} & \text{otherwise,} \end{cases}
$$

$$
Q_j(h_{j-1}, h_j, \epsilon_j) = \begin{cases} (1 - \kappa^{\text{priv}})m_j(h_j, \epsilon_j) & \text{if } j < J^M \text{ and } h_{j-1} \neq 5 \\ (1 - \kappa^{\text{mcr}} - \kappa^{\text{supp}})m_j(h_j, \epsilon_j) & \text{otherwise,} \end{cases}
$$

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[2]The model abstracts from heterogeneity in private insurance access. Dynamic models with variable insurance eligibility and insurance take-up include Jeske and Kitao (2009) and Pashchenko and Porapakkarm (2013).

where the superscripts "priv", "mcr", and "supp" denote, respectively, private insurance, Medicare, and Medicare supplement insurance plans. $\kappa^i, i \in \{\text{priv}, \text{mcr}, \text{supp}\}$ is the insurer payment rate for insurance type i.

2.5   Government

The government collects taxes and provides social insurance. The difference between the government's revenues and its transfer spending is absorbed by direct spending (G). We assume further that the government collects all bequests, which it then distributes equally among surviving individuals, giving each the transfer B. This commonly-used,[3] if clearly counterfactual, assumption simplifies the model greatly.

Old-Age Insurance (OAI). Let J^E denote the Early Retirement Age (ERA), J^N denote the Normal Retirement Age (NRA), and J^L denote the Late Retirement Age (LRA). Individuals not receiving DI benefits $(h_j \neq 5)$ can choose any age from the ERA of 62 to the LRA of 70 to claim their Social Security benefits. OAI recipients receive benefits according to $A_k ss(\mathcal{E}_j)$, where: A_k, is an adjustment factor based on the benefit claiming age k, designed to capture early retirement penalties and delayed retirement credits; $\mathcal{E}_j$ is an index of the individual's 35 highest years of earnings, commonly known as Average Indexed Monthly Earnings (AIME); and $ss(\cdot)$ is a function that converts the earnings index into the Primary Insurance Amount (PIA).

Beneficiaries who are below the NRA and have labor income in excess of the earning limit y_j^{et} have their benefits withheld at a rate of τ_j^{et}: for each additional dollar earned, Social Security benefits are reduced by τ_j^{et}, until all benefits are withheld. Let T_j^{et} denote benefits lost through the earnings test, and let ss_j^* denote the remaining benefits. We have

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[3]Papers that employ this assumption include Kitao (2014), Conesa et al. (2019) and Laun et al. (2019).

$$T_j^{\text{et}}(ss_j, W_j) = \min\left\{ss_j, \; \tau_j^{\text{et}} \max\{0, \; W_j - y_j^{\text{et}}\}\right\}, \qquad (3)$$

$$ss_j^*(ss_j, W_j) = ss_j - T_j^{\text{et}}(ss_j, W_j). \qquad (4)$$

Any such reductions in current benefits, however, are offset by permanent increases in future benefits, implemented in our framework through increases in $\mathcal{E}_{j+1}$.[4] The net incentive generated by the earnings test depends on whether the increases in future benefits are actuarially fair; because the current crediting formula is considered actuarially fair for the average person, for most workers the net tax rate associated with the earnings test is small.

Social Security benefits are also subject to income taxes. An important feature of these taxes is that the amount of Social Security benefits subject to taxation is increasing in the beneficiaries' total income. At certain income levels, each additional dollar of earnings, in addition to being taxable itself, adds 50-85 cents of Social Security benefits to taxable income, increasing the effective marginal income tax rate on these earnings by 50% to 85%. Jones and Li (2018) show that this provision is potentially quite important.

Disability Insurance (DI). Each period before J^N, non-disabled individuals face the risk, given by $\pi_j^h(h_{j+1} = 5 \,|\, e, h_j)$, of moving onto the DI rolls. We assume that individuals entering the DI system remain in the system until they reach J^N, consistent with the extremely low rate (less than 1% per year) at which DI beneficiaries are terminated due to medical recovery. DI beneficiaries receive a benefit of $di_j = di(\mathcal{E}_j)$, which receives the same tax treatment as OAI benefits. Upon reaching J^N, DI recipients are transferred to OAI. We capture this in the model by having DI recipients transit to the other four health states at age J^N with probability $\pi_{J^N-1}^h(h_{J^N} \,|\, e, h_{J^N-1} = 5)$. Former DI recipients also receive a productivity value (η_{J^N}) drawn from the stationary productivity distribution

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[4]This is a simplification, as in actual practice benefits are adjusted only after a person reaches J^N.

for their education levels.

Taxes. The government collects income taxes, consumption taxes, payroll taxes, and Medicare premiums. Payroll taxes consist of two parts: a Medicare tax imposed on all earned income at the flat rate τ^{mcr}, and a Social Security tax imposed on earned income up to the taxable threshold y^{ss} at the flat rate τ^{ss}. Consumption taxes are imposed on all consumption goods at the flat rate τ^c. Income taxes are progressive and are based on taxable income y_j according to the tax function $T(y_j)$. Taxable income itself is the sum of asset income (ra_j), earnings (W_j) and the taxable portion of OAI or DI benefits, $SS(ss_j^* + di_j, ra_j, W_j)$.

Means-Tested Social Insurance. Means-tested social insurance can be thought as a combination of TANF, SNAP, SSI, uncompensated medical care and Medicaid. Following Hubbard et al. (1995), we assume that this program provides a consumption floor of $\underline{c}$. At the beginning of each period means-tested transfers are given by

$$tr_j = \max\left\{0, (1 + \tau^c)\underline{c} - y_j^d\right\}, \tag{5}$$

where y_j^d denotes total financial resources – the sum of assets, after-tax income and distributed bequests, less insurance premiums – prior to receiving means-tested transfers:

$$y_j^d = (1 + r)a_j + W_j + ss_j^*(ss_j, W_j) + di_j - T\big(ra_j + W_j + SS(ss_j^* + di_j, ra_j, W_j)\big)$$
$$- \tau^{\text{mcr}}W_j - \tau^{\text{ss}}\min\{W_j, y^{\text{ss}}\} + B - p_j. \tag{6}$$

2.6 The Individual's Problem

Individuals can be characterized by their age j and the seven-element state vector $\mathbf{x}_j = \{e, b_{j-1}, n_{j-1}, a_j, \eta_j, h_j, \mathcal{E}_j\}$, where e records the education level, b_{j-1} is an indicator function for OAI receipt in the previous period, n_{j-1} records labor force participation in the previous period, a_j records assets carried over from period $j-1$, η_j is the idiosyncratic

productivity shock, h_j is health status, and $\mathcal{E}_j$ is the earnings index. Note that b_{j-1}, n_{j-1}, and η_j are not active state variables for DI beneficiaries.[5]

At the beginning of each period, non-DI beneficiaries choose labor hours and whether to file an OAI claim (if they are age-eligible and have not already claimed). Claiming allows them to receive OAI benefits from the current period forward, and is not reversible. At this point, individuals' financial resources consist of their labor income, assets and asset income, DI or OAI benefits, and lump-sum bequest transfers, net of taxes and health insurance premiums. If this amount is below the consumption floor, government transfers via means-tested insurance bridge the gap. Individuals then choose how much to consume out of their (post-transfer) financial resources. They can save, but borrowing constraints prevent them from consuming more than their current resources.

At the end of each period, the medical expenditure shock ϵ_j is realized, which determines future assets, a_{j+1}. The survival shock comes next. Individuals who die receive warm-glow utility from bequests, while surviving individuals realize their new productivity (η_{j+1}) and health status (h_{j+1}), and enter the next period with state vector $\mathbf{x}_{j+1}$.

In recursive form, the individual's problem is

$$V_j(\mathbf{x}_j) = \max_{c_j, n_j, b_j} \left\{ u(c_j, l_j) + \beta E_j[s_j(e, h_j)V_{j+1}(\mathbf{x}_{j+1}) + (1 - s_j(e, h_j))v(a_{j+1})] \right\},$$

subject to equations (1)-(6) and:

$$(1 + \tau^c)c_j \leq y_j^d + tr_j, \tag{7}$$

$$a_{j+1} = y_j^d + tr_j - (1 + \tau^c)c_j - Q_j(h_{j-1}, h_j, \epsilon_j), \tag{8}$$

$$\mathcal{E}_{j+1} = f_j(\mathcal{E}_j, W_j, b_{j-1}, b_j, h_j), \tag{9}$$

$$n_j = 0, \quad \text{if } h_j \geq 4. \tag{10}$$

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[5]On the other hand, to capture the delay in Medicare eligibility, when considering DI recipients we add lagged health to the state vector. This allows us to distinguish new DI recipients from those who have received DI for at least 2 years.

Equation (7) prohibits borrowing to fund current goods consumption. Equation (8) describes the law of motion for assets. Note that individuals are allowed to take on medical expense debt. Equation (9) describes the law of motion of the earnings index $\mathcal{E}_j$, which depends on age, the index's current value, current earnings, and DI and OAI recipiency status. Equation (10) prevents nursing home residents and DI beneficiaries from working.

2.7 Stationary 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. Our equilibrium concept is identical to the one used in Kitao (2014). Appendix A provides a formal definition.

3 Calibration

3.1 Data

We have two main data sources: the Medical Expenditure Panel Survey (MEPS) and the Health and Retirement Study (HRS). The MEPS is a two-year rotating panel, with each individual interviewed five times over the two-year period. In each interview, individuals provide information on demographics, employment, income, health insurance coverage, health conditions, and medical spending. We use all 18 panels of MEPS, spanning 1996-2014, to estimate statistics for individuals under age 65. While the MEPS has data on older individuals, it does not track individuals who enter nursing homes.[6] We thus turn to the HRS, a panel survey of individuals aged 50 and above. The initial cohort of the HRS was first interviewed in 1992, with follow-up interviews approximately every other year since then. Younger cohorts enter in later years. We use wave 3 (1996) to

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[6]The share of individuals in nursing homes is almost zero for those under age 65, making MEPS a suitable dataset for this group.

wave 12 (2014) of HRS, the same period covered by the MEPS, to estimate statistics for individuals aged 65 and above. We also utilize the Panel Study of Income Dynamics (PSID) for wage and hours data at younger ages, and the Survey of Consumer Finances (SCF) for asset data.

Because our model is one of singles, and thus does not account for child-rearing and secondary earners, our data for employment, wages, and OAI claiming are only for men. For all other uses, we include both genders.[7] Unless otherwise noted, the data are expressed at a two-year frequency, the same as the model period; we aggregate the MEPS data to this frequency. Because we calibrate the benchmark economy to match the 2012 U.S. economy, all nominal values are denominated in 2012 dollars.

3.2   Demographics and Health Status

Individuals enter the economy at age 24 with two possible levels of education: with a Bachelors degree ($e = 1$) and without a Bachelor's degree ($e = 0$). The fraction of 24-year-olds with a Bachelors degree is set to 0.309, the share of college graduates among those aged 25 and older in 2012 reported by the Census (United States Census Bureau, 2019b). For each education level, we set the initial distribution of health to match that found in the MEPS at age 24. Individuals face uncertain mortality and die with probability 1 after age 106. The population grows at a constant annual rate of 1.1 percent, the average growth rate of the U.S.

We measure health statues, $h_t \in \{1, 2, 3, 4, 5\}$, as follows. 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. 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

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[7]Because the SCF measures assets at the household level, assets for married couples are split evenly.

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($h_j = 3$) if they report having health problems that limit their work capacity, 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. Appendix B provides more detail.

3.3   Survival Rates

Given that our data cover 18 years, we estimate period (for 2012) rather than cohort survival rates. Following Attanasio et al. (2010), we proceed in three steps. First, we estimate from the MEPS and HRS a logit model expressing the two-year survival rate as a function of age, education, health, and calendar year. 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, $\tilde{s}_j(e, h_j)$:

$$\Delta_j(e, h_j) = \hat{s}_j(e, h_j) - \hat{s}_j(0, 1), \tag{11}$$

$$\tilde{s}_j(e, h_j) = \tilde{s}_j(0, 1) + \Delta_j(e, h_j). \tag{12}$$

The final step is to calibrate $\tilde{s}_j(e, 1)$ so that the model matches aggregate survival rates for calendar year 2010 (from Bell and Miller 2005). A more detailed description of our procedure can be found in Appendix B. Our estimates imply that at age 24, people with a college degree expect to live an additional 56.7 years; the average remaining lifespan for those without a degree is 52.7 years.

3.4   Health Transitions

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; once again our base year is 2012. Given the differences in

health categories (see section 3.2), we estimate separate transition models for the MEPS and the HRS. The details of our procedure, including a description of how we handle the switch from the MEPS health measures at age 64 to the HRS health measures at age 66, can be found in Appendix B.

Our estimates show that at any given age individuals without a Bachelor's degree on average have worse health than individuals with a Bachelor's degree. Because bad health leads to lower survival rates, the mortality disadvantages of the less educated are mediated in part through poorer health. Of particular note is the probability of DI receipt. At age 64, over 20% of those without a Bachelor's degree are receiving DI. The corresponding fraction for those with a Bachelor's degree is half as large.

3.5   Medical Expenditures and Health Insurance

For individuals 65 and younger, we use medical spending data from the MEPS. The MEPS contains measures of both total and out-of-pocket medical expenditures. We set the coinsurance rate for private insurance to 27.2%, the ratio of out-of-pocket medical expenditures to total expenditures for those covered by private insurance.

In contrast to the MEPS, the HRS contains quality data only for out-of-pocket medical expenses: the way in which we impute total medical expenses for the HRS can be found in Appendix B. We assume that for those receiving Medicare, Medicare and Medicare Supplement insurance cover 54.7% and 12.5%, respectively, of total expenditures (De Nardi et al., 2016, Table 8). The Medicare premium is set to $3,310 to match the sum of part B and part D premia over a two-year span. The premia for private and Medicare Supplement insurance are set in equilibrium, and take the values of $4,640 and $3,210, respectively, for the benchmark economy.

We allow the medical spending shock ϵ to take on three values. As in Kitao (2014), we capture the long tail in the distribution of medical expenses by using: a small shock

with a 60% probability, a medium shock with a 35% probability, and a large shock with a 5% probability. We report the values of these shocks in Appendix B.

3.6 Wages

We estimate the wage profile $\omega(e, j, h_j)$ and the process for the wage shock η_j from our data. Because each MEPS panel spans only two years, we use wage data from the PSID for ages 24-64. We use HRS data for older ages.

We begin by estimating a fixed effects wage profile. The coefficients from this regression do not provide an unbiased estimate of $\omega(e, j, h_j)$, however, because they are estimated only on the wages of those who work. To control for this bias we apply the correction developed in French (2005). Appendix C describes the procedure and presents (in Figure 14) both the uncorrected and corrected wage profiles. With the corrections imposed, wages fall steadily after age 55, and at any age individuals in worse health receive lower wages.

We use the residuals from the first-step fixed effect regression to estimate the AR(1) productivity shock η_j, again following the procedure used by French (2005). Appendix C describes the procedure and shows (in Table 5) the resulting parameter estimates. Individuals with a Bachelor's degree experience larger but less persistent shocks than individuals without a Bachelor's degree. The initial distribution of productivity shocks by education and by health is set to match the distribution of the estimated fixed effects.

3.7 Government

We calibrate government policy parameters to those in effect in 2012.

OAI. Social Security benefits depend on the index $\mathcal{E}_j$, the beneficiary's average earnings over his 35 highest earnings years. Because keeping track of 35 years of earnings is infeasible, we use an approximation for $\mathcal{E}_j$ similar to that used by Imrohoroğlu and Kitao

17

(2012). We assume that before the ERA, $\mathcal{E}_j$ equals the individual's average earnings. Between the ERA and the benefit claiming age, $\mathcal{E}_j$ is updated whenever current earnings are greater than the earnings index. Once OAI benefits have been claimed, $\mathcal{E}_j$ is updated only to reflect the benefits that are withheld due to the earnings test.[8] We also impose the statutory restriction that in each period the earnings applied to $\mathcal{E}_j$ is bounded above by the payroll tax cap y^{ss}.

OAI benefits are given by $A_k ss(\mathcal{E}_j)$, where $ss(\cdot)$ is a piecewise linear function and A_k is an adjustment factor based on the benefit claiming age k.[9] The rules for $ss(\cdot)$, $\{A_k\}_k$, and the earnings test are based on the rules facing the 1943-54 birth cohorts. To facilitate our search for optimal policies, we do not use the rules themselves but use parsimonious approximations; this allows us to search over a small set of parameters when finding the optimum. The approximations are

$$\widehat{ss}(\mathcal{E}) = ss_1 + ss_2(\mathcal{E} + ss_4)^{ss_3}, \text{ where } ss_4 = \left(\frac{\max\{-ss_1, 0\}}{ss_2} \right)^{1/ss_3}, \tag{13}$$

$$\widehat{A}_k = \left(\frac{k}{J^N} \right)^A. \tag{14}$$

In the approximation of $ss(\cdot)$, equation (13), ss_1 (when positive) is the benefit level for those with no earnings, while ss_2 and ss_3 control how benefits rise with average earnings. ss_4 is an adjustment factor that ensures the benefit is non-negative. Variants of this approximation appear in Bagchi and Jung (2019) and Cottle-Hunt and Caliendo (2019). In the approximation of A_k, equation (14), A controls the sensitivity of the adjustment to the claiming age k. When benefits are claimed at the normal retirement age, J^N ($= 66$ for the benchmark economy), there is no adjustment. As shown in Figure 1, the approximations work very well.

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[8]In actual practice, $\mathcal{E}_j$ continues to be updated for high current earnings even after benefit claiming. This is a relatively rare event, however, and in the interest of simplicity we rule it out.

[9]Following Jones and Li (2018), we capture the effect of A_k and the earnings test through adjustments to $\mathcal{E}_j$; this allows us to find the consumer's decision rules without having to keep track of k.

(a) PIA formula, $ss(\mathcal{E}_j)$ (b) Claiming adjustment, A_k
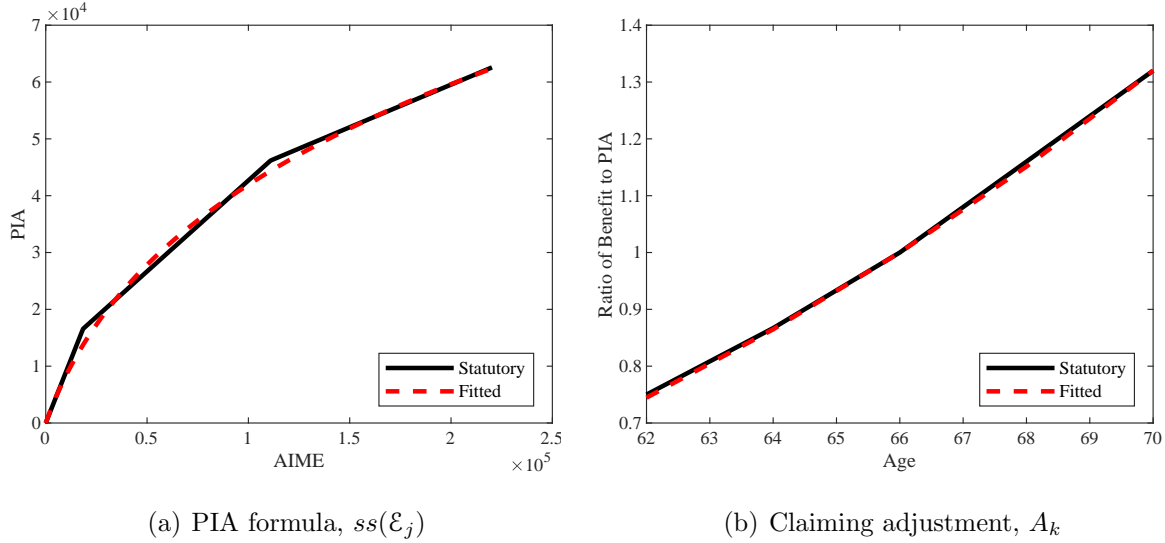
Figure 1: Social Security Rules: Statutory and Approximated

DI. DI benefits are based on average earnings at the time the benefits are claimed. There is no adjustment for early claiming: $di_j = ss(\mathcal{E}_j)$. At age 66, DI beneficiaries are transferred to OAI.

Taxes. The Social Security payroll tax rate τ^{ss} is 6.2 percent, and the taxable earnings limit y^{ss} is \$220,200. The Medicare payroll tax rate τ^{mcr} is 1.45 percent. (Recall that τ^{ss} and τ^{mcr} are calibrated to only the employee share (one-half) of payroll taxes.) Following Gouveia and Strauss (1994), we use the following tax function:

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

We use the values of λ_0 and λ_1 estimated by Gouveia and Strauss (1994), and we set λ_2 so that in a balanced budget equilibrium direct government spending (G) equals about 23% of total earned income.[10]

As described in Section 2.5, the portion of Social Security benefits subject to income

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[10]Direct spending is about 15% of GDP (The World Bank, 2016), and labor income comprises about two-thirds of GDP, consistent with the baseline specification. The consumption tax is set to 6%, the value found by Mendoza et al. (1994).

taxes depends on the net benefits themselves, $ss_j^*(ss_j, W_j)$, and "combined income", $Y_j^{\text{CI}} = ra_j + W_j + 0.5ss_j^*$. The exact formula is

$$SS(ss_j^*, ra_j, W_j) = \begin{cases} 0 & \text{if } Y_j^{\text{CI}} < 25000 \\ \min\{0.5ss_j^*, 0.5(Y_j^{\text{CI}} - 25000)\} & \text{if } 25000 \leq Y_j^{\text{CI}} < 34000 \\ \min\{0.85ss_j^*, \ 4500 + 0.85(Y_j^{\text{CI}} - 34000)\} & \text{otherwise.} \end{cases}$$

Means-Tested Insurance. The consumption floor is set to \$3,500 per year, which is roughly the value estimated by De Nardi et al. (2010) (\$3,800 in 2012 dollars).

3.8 Preferences

The flow utility function is specialized as:

$$u(c_j, l_j) = \frac{1}{1 - \sigma}\left(c_j^\gamma l_j^{1-\gamma}\right)^{1-\sigma},$$

with leisure, l, defined in equation (1). γ determines the weight on consumption relative to leisure. We set σ to 7.5, the (approximate) value estimated by French (2005) and French and Jones (2011) and used by Jones and Li (2018), who employ utility functions and wage processes very similar to ours. Deceased individuals derive utility from bequests according to

$$v(a) = \psi_1 \frac{(\psi_2 + \max\{a, 0\})^{\gamma(1-\sigma)}}{1 - \sigma}. \tag{15}$$

where ψ_2 is set to \$500,000, as in De Nardi (2004) and French (2005). The maximum operator ensures that debt due to medical expenditure shocks is waived upon death.

The remaining preference parameters are calibrated by fitting the model to a set of labor supply – employment and hours – and asset targets. The employment targets come

from our principal data sets, the MEPS and the HRS,[11] while our asset targets come from the 2013 SCF. To control for business cycle fluctuations, we regress employment and the inverse hyperbolic sine of assets (for multiple SCF waves) on aggregate unemployment and GDP growth rates (along with age and cohort dummies), and replace the realized business cycle effects with the effects predicted at the average rates of unemployment and GDP growth. We assume that the average worker spends 33% of his time endowment at work.[12]

Table 1 lists the parameters and associated targets, along with the model's fit. The set of parameters that determine the fixed cost of working and the time cost of not being in good health ($\phi_e^n, \phi_{je}^h, e \in \{0,1\}, j \in \{2,3\}$) are calibrated to match average employment by health and education for individuals aged 66-75.[13] The parameter ϕ^{re}, the cost of reentering the labor market, is calibrated to match the reentry rate of individuals aged 66-75. We target those aged 66-75 because we want the model to match the employment incentives facing older individuals. The discount factor β is set to match the median assets of individuals aged 46-54, an age group accumulating wealth for retirement. (The pre-tax interest rate is set to 0.05 per year, the value suggested in Cooley (1995).) ψ_1 is calibrated to match median assets for individuals aged 76-85, an older group closer to death.

3.9   Model Fit

Although the model is calibrated to match several broad targets, it can be assessed along dimensions that are not targeted.

Employment and Hours: Figure 2(a) shows the model's fit of aggregate employ-

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[11]A person is considered employed if he worked more than 500 hours in the HRS or PSID, or earned more than 500×$7.25 in the MEPS.

[12]If an individual has 16 waking hours each day, and work absorbs exactly one-third of his annual time endowment ($365 \times 16 = 5,840$), he will work 1,947 hours per year.

[13]The time cost for those on DI or in a nursing home is set to that for people with work limitations.

Table 1: Calibrated parameters

Para.	Interpretation	Value	Target	Data	Model
γ	Consumption weight	0.323	Average hours of workers	0.333	0.334
β	Discount	0.948	Median assets (000s), 46-55	86.1	86.5
ψ_1	Bequest intensity	1,605	Median assets (000s), 76-85	168.2	167
ϕ_0^n	Participation cost, NC	0.036	Empl., 66-75, good health, NC	0.335	0.334
ϕ_1^n	Participation cost, C	0.014	Empl., 66-75, good health, C	0.452	0.456
ϕ_{20}^h	Bad health cost, NC	0.029	Empl., 66-75, bad health, NC	0.225	0.223
ϕ_{21}^h	Bad health cost, C	0.010	Empl., 66-75, bad health, C	0.376	0.372
ϕ_{30}^h	Limitation cost, NC	0.063	Empl., 66-75, limitation, NC	0.103	0.103
ϕ_{31}^h	Limitation cost, C	0.056	Empl., 66-75, limitation, C	0.224	0.223
ϕ^{re}	Reentry cost	0.013	Reentry, 66-75	0.066	0.066

Note: NC and C denote, respectively, individuals without and with a 4-year college degree.

ment. The model overstates employment at younger ages, especially prior to age 30. At these ages, only the disabled fail to work. In the model, individuals in their 20s want to accumulate precautionary savings (Low, 2005); there is no possibility of parental support. The model also rules out the possibility of continuing education. On the other hand, the model captures quite well the employment decline from age 50 forward, as well as the persistence of employment into fairly old ages. Figure 2(b) compares the model's predictions for aggregate working hours to those found in the PSID and HRS. The close fit of total hours indicates that at younger ages the model simultaneously over-predicts employment and under-predicts hours conditional on employment.

Figure 3 shows the model's ability to reproduce life-cycle trends in employment across education and health groups. Consistent with data, in the model individuals without a Bachelor's degree retire earlier than individuals with a Bachelor's degree, and individuals with bad health or work limitations retire earlier than individuals with good health.

Assets and OAI claims: Figure 4 shows median assets by age, revealing a good fit. Despite low earnings at young ages, individuals start saving very early in their careers in order to accumulate precautionary savings (Low, 2005). In the model, assets increase

(a) Employment
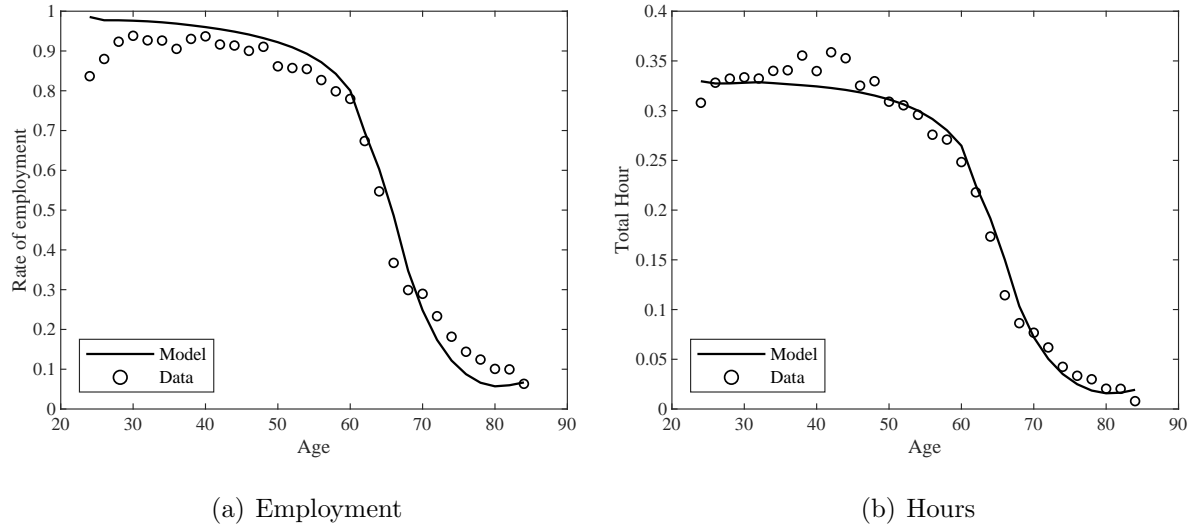
(b) Hours

Figure 2: Employment Rates and Total Hours by Age

Source: Employment data from the MEPS and HRS. Hours data from the PSID and HRS.
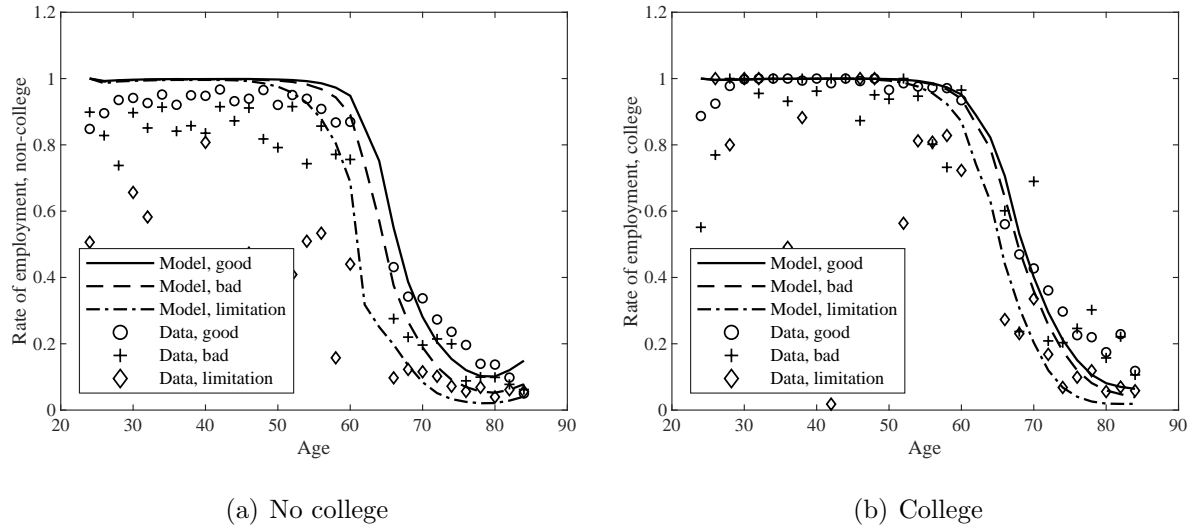

(a) No college

(b) College

Figure 3: Employment Rates by Age, Health and Education

Source: Employment data from the MEPS and HRS.

until people reach their early 60s; as people start to retire, they spend down their assets and wait for the optimal time to claim OAI benefits. Asset levels increase between age

70 and 84, and are almost unchanged after age 85. Three mechanisms account for the slow asset decumulation after retirement: the bequest motive, precautionary savings for longevity risks, and the need to pay for medical expenses, especially nursing home costs.
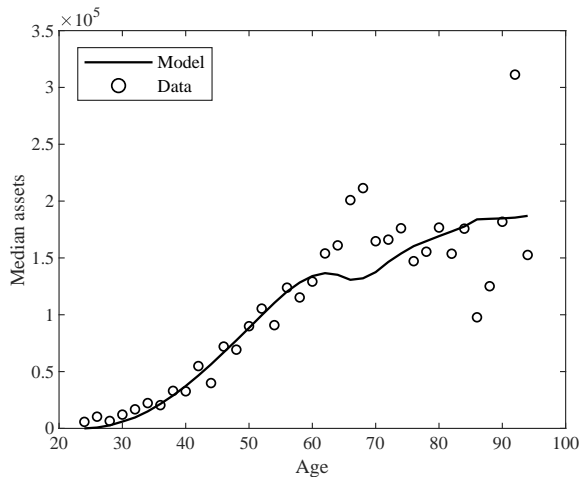

Figure 4: Median Assets by Age

Note: Asset data from the 2013 SCF.

Figure 5 displays OAI recipiency rates.[14] Although the model does not target these rates, Figure 5(a) shows that it matches the general claiming patterns. The model understates age-62 claiming in 2012 by about 17 percentage points (pp). This may be due to the absence within the model of illiquid housing wealth.[15] If individuals who wish to retire early have few liquid assets, they may need to claim their Social Security benefits at younger ages (c.f., Kahn 1988; Kaplan and Violante 2014). Illiquid housing may also explain why assets in the data do not dip when people are in their early 60s. Figure 5(b) shows that within the model people without a college degree are more likely to claim early, consistent with their shorter lifespans. It bears noting that Figure 5 does *not* account for DI. By age 62, about 16% of the population is on DI, most of them without a college degree.

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[14]In the model, as in actual practice, DI beneficiaries are transferred to OAI at age 66.

[15]Pashchenko and Porapakkarm. (2018), who study claiming in some detail, find it to be sensitive to discount and interest rates.

In recent years there has been an ongoing trend toward later claiming, even though people born between 1943 and 1954 – the cohorts making retirement decisions in our analysis – face the same NRA and claiming adjustments. In addition to the claiming decisions observed in 2012, Figure 5(a) shows claiming in 2016, which more closely resembles the model's predictions.
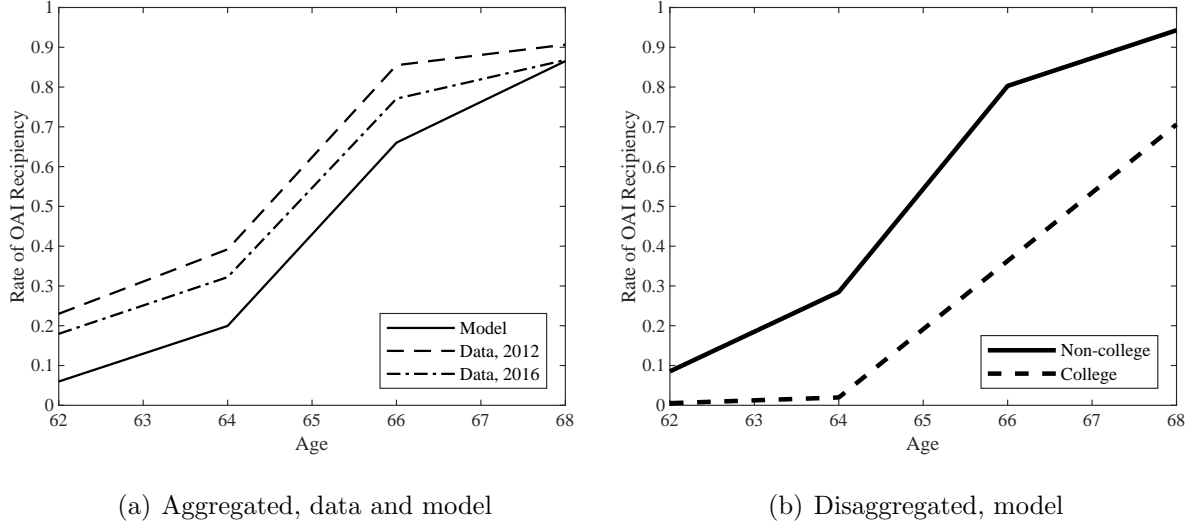

(a) Aggregated, data and model   (b) Disaggregated, model

Figure 5: OAI Recipiency Rates by Age, Education and Health

Note: The claiming rate for the data is computed as the age-by-age ratio of male retired worker beneficiaries for 2012 (year-end) from the SSA Statistical Supplement (Social Security Administration 2014, Table 5.A1.1) to the estimated male population (United States Census Bureau 2019a, average of July 2012 and July 2013, and July 2016 and July 2017). In panel (b), solid series are for individuals without a Bachelor's degree, and dashed series are for individuals with a Bachelor's degree.

Income and Lifespan Heterogeneity: Table 2 shows, for three model specifications, mean lifetime earnings (discounted at an annual rate of 5%) and life expectancy for each lifetime earnings quintile. The first two columns show results for the baseline model. Individuals in the top earnings quintile earn nearly 4 times as much as those in bottom quintile, and they live 11 years longer. By way of comparison, (Chetty et al., 2016, Figure 3) found that in 2015, the age-40 life expectancy of men in the bottom household income quartile was about 10 years lower than that of men in the top quartile.

The difference for women was 6 years. Noting that we condition on lifetime, rather than current, earnings, our mortality gradient is arguably similar to Chetty et al.'s (2016).

Table 2: Earnings and Expected Lifespan by Lifetime Earnings Quintile

| Earnings Quintile | Baseline | | No Educational Differences in Demographics | | No Health or Educational Differences | |
	Lifetime Earnings ($000s) (1)	Expected Lifespan (Years) (2)	Lifetime Earnings ($000s) (3)	Expected Lifespan (Years) (4)	Lifetime Earnings ($000s) (5)	Expected Lifespan (Years) (6)
Bottom	441	70.8	445	71.4	577	71.9
Fourth	694	77.9	695	78.3	778	78.6
Third	869	79.0	862	79.0	927	79.4
Second	1,109	80.1	1,092	79.4	1,105	79.6
First	1,703	82.0	1,672	80.0	1,439	80.1
Ratio Q5/Q1	3.86	1.16	3.75	1.12	2.49	1.11

4 Welfare Maximizing Policies

We turn to finding the policies that maximize aggregate welfare, which we define as the ex-ante lifetime utility of a newborn. We search over 5 parameters: the payroll tax cap y^{ss}; the parameters ss_1, ss_2 and ss_3 of the benefit function $\widehat{ss}(\mathcal{E})$ (see equation (13)); and the curvature parameter A of the claiming adjustment function $\widehat{A}_k$ (see equation (14)). However, we require the welfare maximizing policy to generate the same aggregate expenditures – to do this we adjust all benefits proportionally – as the baseline policies, eliminating a degree of freedom. Because our goal is to maximize welfare while holding Social Security's aggregate footprint fixed, we also adjust payroll taxes so that the reformed system collects the same revenues as the baseline policies. We assume that changes in the payroll tax rate $(2 \cdot \Delta \tau^{ss})$ and the payroll tax cap (y^{ss}) apply only to workers and report them accordingly.

We maintain general government budget balance by changing the tax parameter λ_0, holding public goods (G) fixed. We fix DI benefits at their benchmark levels as well. Although interactions between OAI and DI are undoubtedly important, in our model DI claiming is treated as exogenous. We include DI recipiency to ensure that our analysis of OAI reforms is not driven by disability-related outcomes; we do not analyze DI itself.

4.1 Benchmark environment

Column (1) of Table 3 summarizes the optimal policies for our benchmark environment. The optimal policies have three important features: (1) the cap on taxable earnings changes only modestly; (2) the PIA does not depend on average lifetime earnings; (3) the adjustments for early or late claiming are smaller than the current adjustments.

Cap on taxable earnings (y^{ss}). The first line of Table 3 shows that the optimal cap on taxable earnings equals 197% of median AIME, roughly the current level (see column (0)). Raising the upper bound on taxable earnings has two main effects. The first is that a larger tax base leads to a lower payroll tax rate (Figure 6(a)), increasing employment among both the college and non-college educated (Figure 6(b)). The second is that it raises the marginal tax rate for workers with earnings near the previous cap. These are among the most-skilled workers in the economy. Figure 6(c) show that average earnings (over all individuals) generally fall as the tax cap rises. Even as employment increases, the decrease in labor supply among the most-skilled is enough to reduce average earnings. The effect is most pronounced among the college-educated.

Figure 6(a) shows that increasing the cap leads to lower bequests. The increased employment associated with the lower payroll tax rate leads workers to claim their Social Security benefits at older ages. Retirees receive higher annual benefits, reducing the wealth they carry into very old ages. Given that SS expenditures are held fixed, it is not surprising that the median benefit available to age-66 claimers – the median PIA

Table 3: Current and Optimal Policies in Stationary Equilibrium

	Current Demographics			2050 Demographics		
	Current	Optimal 1	Optimal 2	Current	Optimal 1	Optimal 2
Benefit Taxation and Earnings Test	Yes	Yes	No	Yes	Yes	No
	(0)	(1)	(2)	(3)	(4)	(5)
Tax cap / median age-62 AIME	2.18	1.97	2.03	2.18	3.09	3.10
Age-66 benefit (PIA) percentiles (000s)						
10th percentile	30.7	43.6	42.8	21.0	33.9	34.4
median	42.1	43.7	43.2	28.9	33.9	34.8
90th percentile	55.1	43.9	43.7	37.8	33.9	35.1
Benefits relative to age-66 benefit						
age 62	0.74	0.78	0.80	0.74	0.81	0.80
age 70	1.32	1.26	1.23	1.33	1.22	1.23
Benefit claiming						
age 62	6.0%	30.7%	81.5%	1.8%	26.8%	85.4%
age 66	66.0%	100.0%	100.0%	36.8%	99.8%	100.0%
Employment						
age 62	69.6%	64.1%	66.6%	74.4%	69.4%	72.7%
age 70	24.8%	21.5%	25.6%	38.4%	37.8%	40.7%
Aggregate behavior						
employed	76.4%	75.1%	75.9%	73.4%	72.3%	73.1%
hours—employed	0.33	0.33	0.33	0.33	0.33	0.33
earnings ($000s)	87.7	86.7	87.4	97.1	95.9	96.5
assets ($000s)	123.3	129.3	133.8	200.5	205.2	208.8
bequests ($000s)	6.1	6.4	6.8	10.5	10.7	11.2
consumption ($000s)	73.5	72.9	74.1	87.1	86.3	87.3
τ_{ss}	6.2%	6.5%	6.8%	5.0%	4.8%	5.5%
λ_0	25.8%	25.9%	25.5%	25.8%	26.1%	25.8%
Residual government budget (000s)						
revenues	23.6	23.6	23.6	28.5	28.5	28.5
expenses	3.3	3.3	3.3	4.2	4.2	4.2
balance	20.3	20.3	20.3	24.3	24.3	24.3
Internal (annual) rate of return on OAI and DI						
all households	1.15%	1.15%	1.15%	0.48%	0.48%	0.48%
no college degree	1.61%	1.96%	1.91%	0.94%	1.81%	1.69%
college degree	0.54%	-0.12%	-0.06%	0.25%	-0.31%	-0.25%
Consumption equivalent variation						
all households		1.16%	2.31%		1.50%	2.22%
no college degree		1.38%	2.57%		1.98%	2.76%
college degree		-0.06%	0.88%		0.37%	0.92%

– changes little.[16] The small differences that do appear are due to changes in claiming patterns and changes in the maximum benefit, which is tied to the cap: to maintain the expenditure target, these necessitate small changes in PIA levels.

The final panel of Figure 6 shows welfare effects, which we measure as the ex-ante consumption equivalent variation (CEV), the proportional increase in lifetime consumption needed to make a newborn individual in the benchmark economy as well off as a newborn in the counterfactual economy.[17] Because we construct Figure 6 using the optimal values of $\widehat{ss}(\mathcal{E})$ and $\widehat{A}_k$, the CEV, which is relative to the current Social Security policies, is generally positive. Although expanding the cap from its benchmark level reduces aggregate earnings, most households benefit from the lower payroll tax rate. Low values of the taxable limit thus lead to significant welfare losses. This dynamic reverses once the cap reaches its optimal value, although the losses from setting the cap above its optimal value are small.

PIA formula $\left(\widehat{ss}(\mathcal{E})\right)$. Returning to Table 3, column (1) shows that the optimal PIA function is flat in lifetime earnings. This is a radical departure from current U.S. rules, where individuals at the 90th percentile of the PIA distribution receive 70% more than those at the 10th percentile, but not unprecedented internationally. As Börsch-Supan et al. (2016, Table 1) document, although most countries include an earnings-related component in their public pensions, a non-trivial number provide only a basic benefit.

As with any form of worker compensation, changing the PIA formula generates both income and substitution effects. Figure 7 provides more detail. Although the PIA depends on three parameters (subject to an expenditure constraint), to simplify the discussion Figure 7 characterizes policies with a single variable, the 90-10 benefit ratio. Higher values of this dispersion ratio correspond to a stronger positive relationship between earnings and
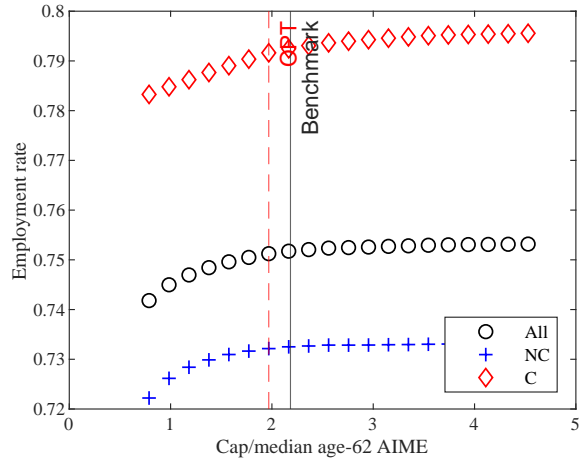
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[16]Because we account for earnings test credits in our simulations by modifying AIME ($\mathcal{E}_j$), we calculate this hypothetical benefit using age-62 AIME.
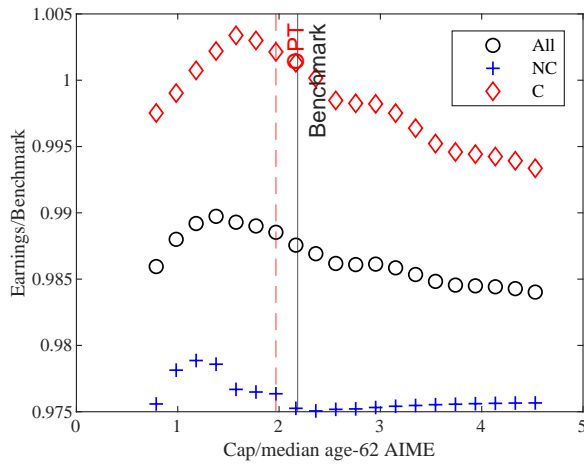
[17]We calculate this as $\left(\frac{\text{lifetime utility}_{\text{reform}} - \text{utility from bequests}_{\text{benchmark}}}{\text{lifetime utility}_{\text{benchmark}} - \text{utility from bequests}_{\text{benchmark}}}\right)^{1/[\gamma(1-\sigma)]} - 1$, with all utility measured ex-ante.
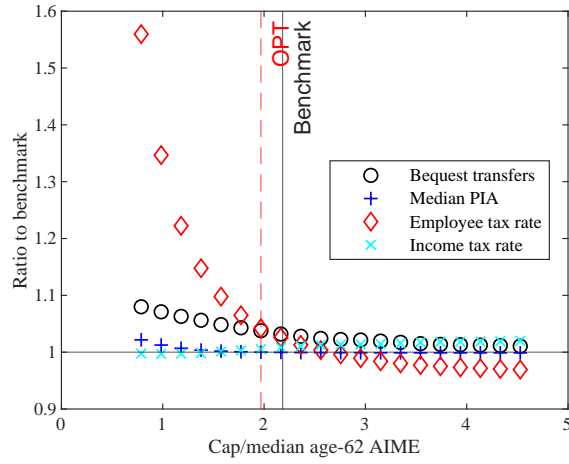
(a) Equilibrium variables

(b) Employment rate

(c) Earnings

(d) CEV %

Figure 6: Effects of changing the limit on taxable earnings

benefits. Figure 7(c) shows that tying the PIA more tightly to AIME increases aggregate earnings. Holding total benefits fixed, a steeper earnings gradient causes benefits for non-college workers to fall. This income effect, which encourages work, is reinforced by the substitution effect from tying benefits to earnings. Employment and earnings both rise monotonically in the 90-10 ratio. For college-educated workers, the income effect of
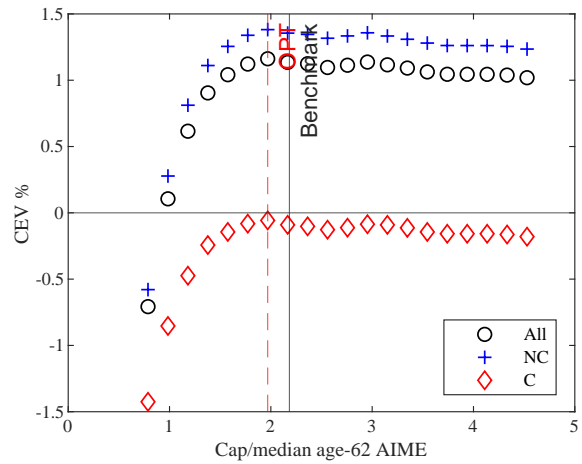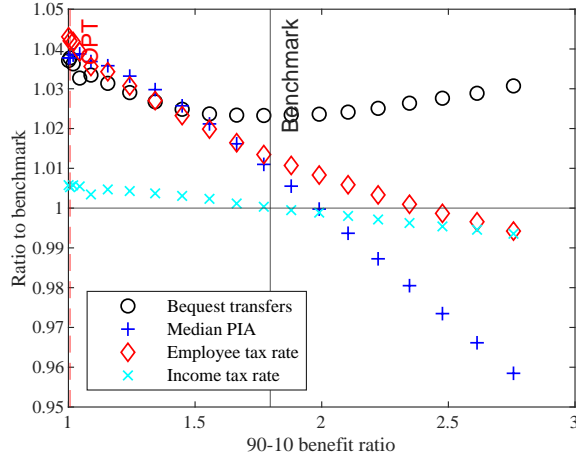
(a) Equilibrium variables
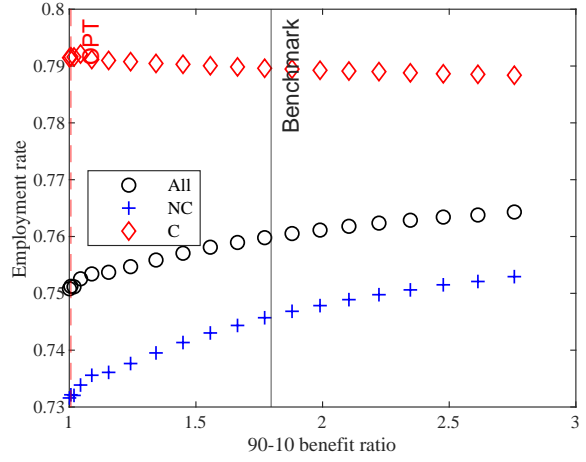
(b) Employment rate
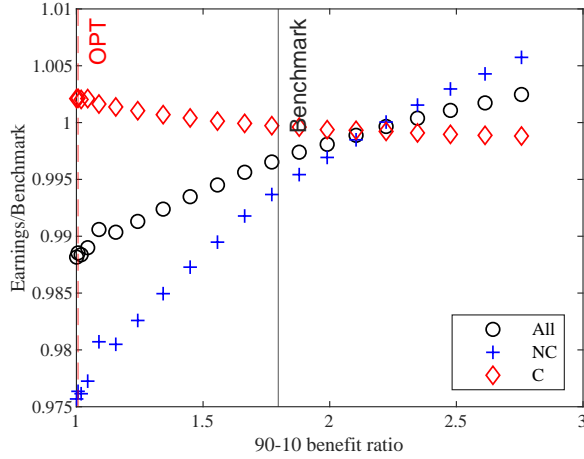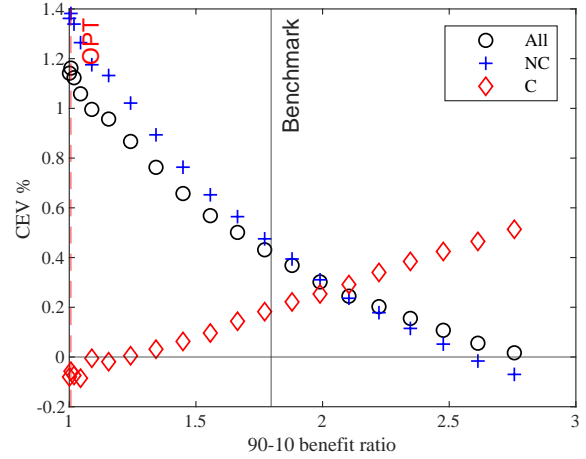
(c) Earnings

(d) CEV %

Figure 7: Effects of changing the PIA formula

linking benefits to earnings is negative, at least for high earners, and both employment and income fall (Figure 7(b)). The increase in non-college earnings is steeper, however, and these workers constitute the majority of the labor force. Aggregate earnings rise.

Figure 7(a) shows that the relationship between benefit dispersion and bequests is U-shaped. Tying benefits more closely to earnings reduces the need of richer households to save, reducing bequests, which by construction are luxury goods. On the other hand,

higher values of the 90-10 ratio also result in higher benefits for the rich, and thus higher wealth. Around the benchmark value of the 90-10 ratio, the second effect starts to dominate the first, and bequests begin to rise.

Figure 7(d) shows that, labor supply notwithstanding, the welfare effects of changing the PIA formula are driven by redistribution. As the 90-10 ratio increases, benefits are moved from less-educated to more-educated workers, lowering the welfare of the first group and raising the welfare of the second. Within education groups, there is also redistribution between individuals with different wage and health histories. Overall, moving from the current PIA function to a flat one raises the CEV by 0.7%.

Figure 7(d) also shows that that welfare is increasing even as the benefit formula becomes completely flat. Allowing the benefits to *decrease* in lifetime earnings would increase welfare even further. This is because the tax and transfer system as a whole is not sufficiently redistributive. Given that we examine only part of this system, we view a flat Social Security benefit formula as a natural lower bound for our exercise.
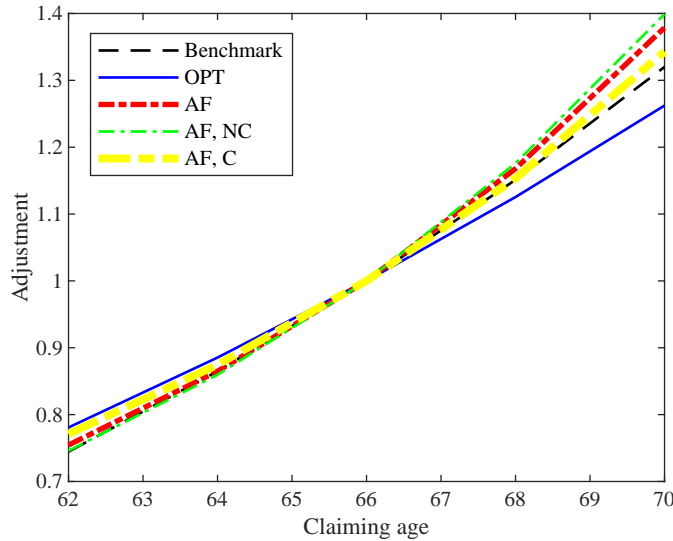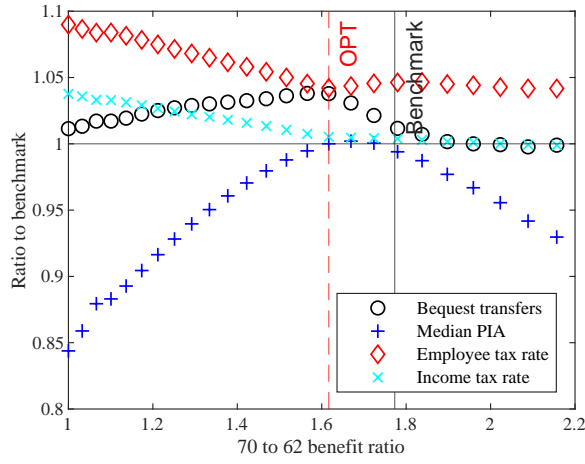

Figure 8: Claiming age adjustments

Claiming adjustment $(\widehat{A}_k)$**.** Figure 8 shows both the current (dashed black line)

and optimal (solid blue line) benefit adjustments for early or late claiming, relative to benefits at the NRA. The figure also shows the actuarially fair adjustments, based on the model's mortality rates and a post-tax interest rate of 3% per year. Comparing slopes reveals that under the current rules, the Social Security adjustments are more or less actuarially fair prior to the NRA, but less than fair post-NRA.

In Figure 9(a), median age-66 benefits are plotted against the size of the claiming adjustment, measured as the ratio of age-70 to age-62 benefits. Two mechanisms are in play. First, larger claiming adjustments will induce delayed claiming. This can raise or lower aggregate expenditures, depending on the sizes of the adjustments. Second, holding claiming dates fixed, larger adjustments will reduce expenditures on early claimers and raise expenditures on those who claim late. Figure 9(a) shows that when the claiming adjustments are small, and most individuals claim early, increasing the claiming adjustment generates cost savings and thus higher benchmark PIA levels. In this region of the policy space, larger claiming adjustments raise annual benefits for late claimers not only directly but also indirectly, through higher values of the PIA. As adjustments continue to grow the expenditure effects reverse, and base benefits fall.

Figure 9 also shows that as claiming adjustments increase, and more workers delay claiming, employment and earnings both rise. Figure 9(a) shows that payroll taxes fall until the 70-62 benefit ratio reaches 1.6. After this point, delayed claiming reduces Social Security-related income taxes to such an extent that payroll taxes have to be increased. Higher earnings initially lead bequests to rise, but as the adjustments grow and workers claim at increasingly later dates, they increasingly rely on their Social Security benefits.

The welfare effects of the claiming adjustments are driven both by their direct effects on benefits and on their induced effects on labor supply. Larger claiming adjustments initially lead to higher statutory benefits and significantly higher earnings, increasing welfare. As adjustments continue to rise, their effect on the PIA reverses, earnings growth diminishes, and benefits shift from the short-lived (low earners) to the long-lived. The CEV begins to

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(a) Equilibrium variables
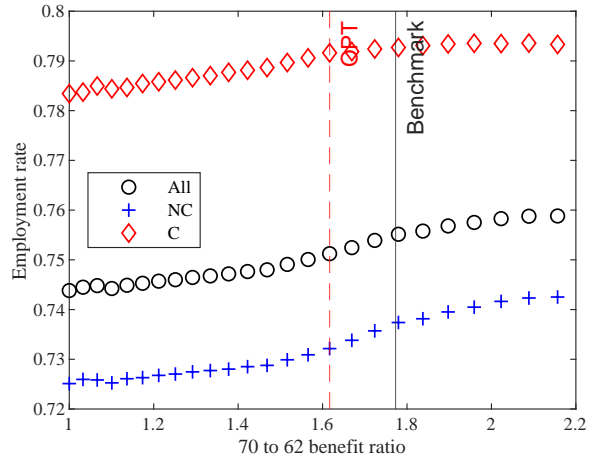
(b) Employment rate
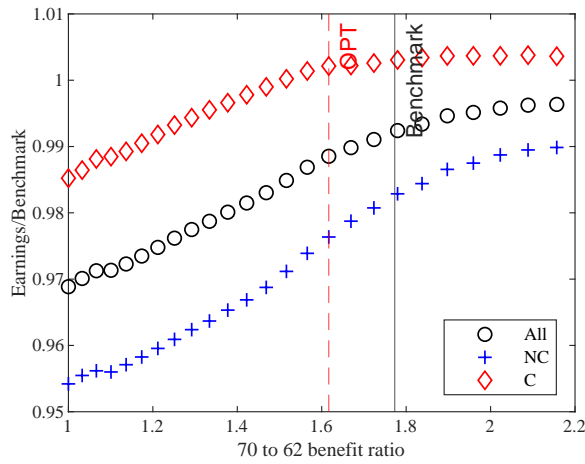
(c) Earnings
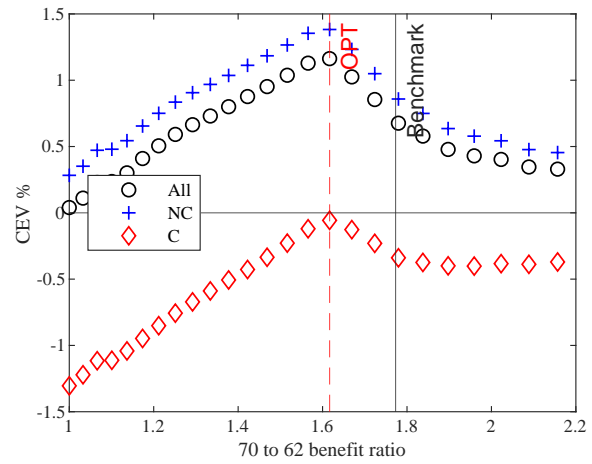
(d) CEV %

Figure 9: Effects of changing the claiming age adjustments

fall. Moving from the optimal claiming adjustment to the one currently in place reduces CEV by about 0.5%.

Discussion. Relative to the policies currently in place, the optimal Social Security policies reduce work incentives in order to redistribute resources from high to low earners. Benefits are disconnected from earnings; and the rewards to delayed claiming (and longer careers) are reduced; only the payroll tax is relatively unchanged. Comparing the first

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two columns of Table 3 shows that under the optimal policies, the number of people claiming benefits at age 62 rises by 25 pp. The aggregate employment rate declines by 1.7% and average earnings decline by 1.1%. Receiving smaller benefits, high-earnings workers save and bequeath more, raising aggregate bequests. Consumption declines by 0.8%. Nonetheless there is a CEV gain of 1.16%. The gain goes entirely to those without college degrees; the college-educated experience a loss of about -0.06%.

To quantify the extent to which Social Security redistributes resources, we calculate internal rates of return on Social Security benefits and taxes for the college- and non college-educated. Column (0) of Table 3 shows that the existing system is already fairly redistributive, with annual returns of 1.61% and 0.54%, a difference of 1.1 pp, for those without and with college degrees, respectively. Our estimates contrast with Goda et al. (2011) who calculate returns using Social Security earnings histories. They find rates of return to be moderately progressive (i.e., decreasing in lifetime earnings) for women and slightly regressive for men. (Our mortality rates apply to both sexes.) A major reason for the difference is that our model accounts for benefit taxation and DI. Removing these two elements causes our estimated rate of return for the non college-educated to fall to 0.87% and our estimated rate for the college-educated to rise to 0.62%. Our results differ more from Sánchez-Romero et al.'s (2019) estimates for men born in 1960, which are fairly regressive, with rates of return for the 2nd and 4th income quintiles of 1.1pp and 2.4pp, respectively (Table 4, case DB-II). It seems unlikely that the differences are due solely to the modelling of Social Security benefits, as the ratio between the top and bottom quintiles of lifetime Social Security benefits reported by Sánchez-Romero et al. (2019, Figure 2), 1.8, is similar to our 90-10 ratio for the PIA, 1.79. DI and benefit taxation again account for some of the difference.

In any event, the optimal Social Security rules described in column (1) are far more redistributive than the current rules. The rate of return for those without a college degree is 2.1 pp higher than the rate for those with a degree, which is in fact negative. It is

notable that under our optimal policies the less-educated earn a higher rate of return despite our utilitarian welfare criterion. A utilitarian social planner, seeking to equate marginal utilities among the living, will naturally place more weight on the long-lived.

A handful of papers have examined the effects of changing the progressivity of the Social Security benefit formula, employing a range of modelling assumptions and reaching a variety of conclusions. Using a model where there are no earnings-mortality links of any sort, Nishiyama and Smetters (2008) conclude that benefits should be increasing more rapidly in earnings than under current rules, arguing that the distortions associated with a progressive benefit formula outweigh the gains from risk-sharing. Huggett and Parra (2010), in contrast, find that benefits should be *decreasing* in lifetime earnings. While they also treat earnings and mortality as independent, their analysis differs from Nishiyama and Smetters (2008) in terms of equilibrium concept and household composition, in both cases being more similar to ours. On the other hand, Ndiaye (2018), whose model differs from Huggett and Parra's (2010) primarily in having a retirement decision, reaches the same general conclusion as Nishiyama and Smetters (2008). Ndiaye (2018) also finds that the claiming adjustments should be amplified; we discuss this finding in the robustness section below.

Bagchi (2019) develops a model where mortality depends on earnings. He also finds that the optimal benefit formula is one that is less redistributive, i.e., has benefits more closely tied to earnings, than the current rules. One potential reason why Bagchi's (2019) finding differs from ours is the assumption of endogenous mortality. In his framework labor supply decisions affect length of life, while in our framework exogenous differences in health and education, which affect mortality, also affect earnings. As Hall and Jones (2007) show, spending on longevity affects lifetime utility in ways fundamentally different from that of spending on consumption. Bagchi and Jung (2019) find that when mortality is exogenous but tied to health, the optimal benefit is independent of earnings; in an earlier version of Bagchi (2019) where mortality depends on wealth, Bagchi (2016) finds

a flat benefit to be optimal. Bagchi's papers differ from our model in other ways: they all impose closed-economy equilibrium, while we hold wages and interest rates fixed; we consider claiming decisions, the earnings test, and benefit taxation, while they do not.

4.2 Benchmark environment, no earnings test or benefit taxation

Because the amount of Social Security benefits subject to income taxation increases in total income, the income taxation of these benefits can significantly raise the marginal tax rate on earnings, discouraging individuals from simultaneously working and receiving benefits. This dynamic, along with the earnings test, implies that claiming decisions are in part retirement decisions. Jones and Li (2018) showed that, under the existing benefit formula, eliminating both the earnings test and benefit taxation increases labor supply and welfare. We now introduce these reforms, increasing the payroll tax to maintain budget balance, and solve again for optimal policies. Column (2) of Table 3 shows the results. Column (2) shows that the optimal taxation limit, benefit formula and claiming adjustments are more or less independent of the earnings test or benefit taxation. Eliminating the latter two provisions, however, generates significant increases in employment, earnings, consumption and welfare. Over half of the employment loss generated by the reforms in column (1) is offset by the reforms in column (2), as is 70% of the earnings loss. Consumption actually rises relative to its baseline value. The combined reforms considered in column (2) allow Social Security to be more redistributive than at present, while imposing fewer distortions than in column (1). Notably, college- as well as non-college-educated workers benefit from the joint reforms.

Removing the earnings test and the income taxation of benefits uncouples the claiming and labor supply decisions. As we move from column (0) to column (1), the increase in age-62 claiming, from 6.0% to 30.7%, is accompanied by a fall in age-62 employment,

from 69.6% to 64.1%. In contrast, moving from column (1) to column (2) shows that the large increase in age-62 claiming, from 30.7% to 81.5%, is accompanied by an *increase* in age-62 employment, from 64.1% to 66.6%. Most of the people not claiming OAI benefits at age 62 are those on DI.[18] Claiming becomes an actuarial decision, and almost everyone finds it worthwhile to claim at the ERA of 62.[19]

Because we scale benefits to keep total expenditures constant, the optimal adjustment is not unique. When everyone claims at age 62, one could simultaneously reduce the early claiming penalty, which would raise benefits, and reduce the benefits available at the normal retirement age, which would lower them. Benefits at age 62 would be unchanged and everyone would continue to claim at that age. The results shown in column (2) are found with the curvature parameter A set to 3.5.[20]

5 Heterogeneous mortality and fiscal sustainability

Recent history suggests that the longevity gap between rich and poor will continue to grow (National Academies of Sciences, Engineering, and Medicine 2015; Chetty et al. 2016), even as ongoing trends in aggregate longevity and fertility leave the Social Security increasingly unsustainable. As we evaluate proposals to restore fiscal balance, distributional concerns may play a role.

To consider these interactions, we introduce what we call "2050 demographics". First, we reduce the annual population growth rate n to 0.43%, to match the growth rate between 2050 and 2055 projected by the World Bank (median variant). Second, following

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[18]In calculating claiming rates, we treat individuals who claim OAI at age 62 but transition to the DI state at age 64 as not receiving OAI at age 62. Because our measure of disability is positive only when a person receives DI benefits, we find it plausible to assume these people applied simultaneously for OAI and DI at age 62 and received approval for DI by age 64.

[19]About 2.5% of population delays claiming without receiving DI. This group consists of individuals with high medical debt, who would be at the consumption floor even if they received Social Security benefits. By delaying, they raise their future benefits without affecting their current income. As long as delaying raises their benefits, they will continue to do so.

[20]This restriction also applies to the results for the 2050 demographics shown in column (5).

Conesa et al. (2019), we linearly extrapolate the fraction of the population with a 4-year degree to 2050, using Census data for the period 1970-2018 (United States Census Bureau, 2019b). This suggests that in 2050, roughly half (49.6%) of the population will have a 4-year degree.

The next step is to use the SSA projections (Bell and Miller, 2005) to estimate the increase in life expectancy between 2010 and 2050. We assume that this increase accrues only to those with college degrees. Using our baseline and 2050 estimates of educational attainment, we find that in order to match the SSA lifespan predictions, the life expectancy of college graduates must increase from 80.75 to 85.79 years.

It is almost surely the case that these changes to mortality and education will be accompanied by changes in health and wages. If improved mortality implies improved health, it is likely that both work capacity (e.g., Coile et al. 2016) and wages at older ages will rise. On the other hand, as more people earn college degrees, the composition of the two education groups will change (Bound et al., 2015). For this exercise, we assume that improved mortality "stretches" the wage profile for college graduates, replacing $\omega(C, j, h_j)$ with $\max\left\{\omega(C, j, h_j), \omega\left(C, j\frac{80.75}{85.79}, h_j\right)\right\}$. We stretch their health transition probabilities in a similar way. Finally we decrease proportionally the mortality rates for the college-educated to achieve our life expectancy target of 85.79 years. The wage, health and mortality profiles for those without a college degree remain at their baseline values.

We begin by imposing the current Social Security rules, using the claiming adjustments for someone born in 1960. To achieve budget balance, we proportionally decrease the current benefit formula until we match aggregate benefits for our benchmark economy. Li (2018) and Laun et al. (2019) show that such an adjustment, as opposed to shifting the benefit schedule rightward in the claiming age, is more efficient.[21] In any event, a proportional adjustment is in keeping with our practice of fixing Social Security's total

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[21]In particular, these papers find that raising the early retirement age leads to a significant increase in DI use, offsetting any saving in retirement benefits.

expenditures. Column (3) of Table 6 shows the results for this "current rules" scenario.

Introducing the 2050 demographics lowers the aggregate employment rate from 76.4% (column (0) of Table 3) to 74.4%. This reduction is due entirely to an older population; at every age, employment rates are higher in 2050 than at present. An older population also implies a reduction in Social Security benefits: the median PIA falls from $42,100 at present to $28,900. PIA values fall further because of delayed claiming. In 2050 only 1.8% of the population applies for OAI at age 62. With longer lives and lower benefits, individuals increase their saving, and assets rise by over 60%. The rise in consumption is much smaller, around 20%.

Column (4) shows the policies that are optimal when the earnings test and benefit taxation remain in effect. These are quite similar to the optimal policies for the current demographic environment shown in column (1). Once again benefits are flat in AIME. The claiming adjustments are also similar across demographic regimes. Increased longevity affects the optimal adjustment in opposing ways. With longer lifespans there is a greater need to promote work at older ages. This argues for larger adjustments. On the other hand, with longer lives the same credits are more likely to induce claiming delays; this can be seen by comparing claiming in column (1) with its 2012 equivalent. Smaller credits may therefore be more cost-effective. In the case at hand, the net effect is that the adjustments are smaller than those in Table 3, but only slightly so. The one exception is the optimal payroll tax limit, which rises about 40% under the 2050 demographics. Recalling from Figure 6(d) that the welfare effects of changing the payroll tax cap vary little across a wide range of values, the reason for the higher optimal cap is unclear.

Column (5) repeats the exercise in column (2) of Table 3 – finding the optimal policies when the earnings test and income taxation of benefits are removed – for the 2050 environment. Once again the change in demographics has little effect on the optimal policies.

There are of course many ways to bring Social Security into balance. In Appendix D

we repeat the exercises of columns (3) - (5) under the assumption that the Social Security benefit formula remains at its absolute 2012 values and payroll taxes are raised to balance the budget. Comparing the two sets of results shows that our findings are robust to how the Social Security budget is balanced.

6   Alternative Specifications

6.1   Demographics do not depend on education

In our model, health and income interact in two general ways. First, individuals with a college degree enjoy better health, lower mortality, and higher wages. Second, within either education group, individuals with worse health have lower wages and a smaller time endowment, leading to fewer hours of work and shorter lifespans. The first mechanism reflects an endowment realized upon birth, while the second reflects shocks realized over the entire life cycle.[22] To disentangle these mechanisms, we estimate a single set of health and mortality processes for all education levels, re-calibrate the model, and search again for optimal policies. The third and fourth columns of Table 2 show the revised mortality gradient. Removing education-related differences in health reduces the mortality gradient somewhat – the lifespan difference between the bottom and top quintiles falls from 11.2 to 8.6 years – but has almost no effect on the earnings quintiles. The first three columns of Table 7 (in Appendix E) present the policies that would be optimal in this environment. Comparing these policies to those in the first three columns of Table 3 shows that the education-related demographic effects have very little effect on the optimal policies. Even the welfare effects are similar to those shown in Table 3; college-educated individuals, who still receive higher wages, still benefit less from the reforms.

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[22]The health shocks also include endowment shocks, namely shocks to initial health.

6.2   No health- or education-related differences

Next we simplify the model further, by removing health and education entirely, and re-calibrate it again. Individuals now share a common wage and mortality process, and differ only in the realizations of these processes. The final two columns of Table 2 show the mortality gradient for this specification. Even without health shocks the mortality gradient is significant, with people in the top lifetime earnings quintile living 8.2 years longer than those in the bottom. This reflects the small but significant risk at dying at a very young age. On the other hand, removing health-and education-related effects compresses the lifetime earnings distribution: the ratio of the top earnings quintile to the bottom falls from 3.86 to 2.49. Nonetheless, columns (4)-(6) of Table 7, which present the policies that would be optimal in this environment, show that these policies remain similar to the optimal policies for the baseline environment.

6.3   Claiming and retirement are linked

In the baseline model, Social Security claiming and labor supply are distinct decisions. Although the earnings test and benefit taxation may discourage Social Security recipients from working, in both the baseline model and real life many do. A common simplification, however, is to assume that Social Security recipients cannot work (e.g., Ndiaye 2018). Because claiming is usually assumed to be irreversible (as we do), in this environment retirement is irreversible as well.

The first three columns of Table 4 show results for the specification where claiming Social Security leads to permanent retirement; the model is recalibrated to match the data. In such a framework, the principal way to increase labor supply at older ages is to encourage delayed claiming. The optimal claiming adjustments shown in columns (2) and (3) are thus much larger than those currently in place. Under current rules, the benefit for someone claiming at age 70 is 77% larger than that of someone claiming at 62. In

column (2), the difference is 497%. This differs significantly from the baseline model, where the optimal claiming adjustments are smaller than the ones currently in place. On the other hand, the optimal benefit formula is still flat, as in the baseline model, and the optimal payroll tax cap is modestly smaller than the current one, which is also similar to our findings for the baseline model. It bears noting that, relative to the baseline model, eliminating the earnings test and benefit taxation has a smaller effect on labor supply and welfare. With labor supply tied to Social Security, the earnings test is irrelevant; benefit taxation continues to generate wealth effects and alter after-tax rates of return.

6.4 Fixed Lifespans

The final alternative we consider is one where, in addition to linking claiming and retirement, we remove all health- and education- related effects, and assume that everyone shares a common, certain lifespan. This specification is very similar to the one considered by Ndiaye (2018), who extends Huggett and Parra (2010) to allow for a flexible retirement date. Huggett and Parra (2010) and Ndiaye (2018) need a tractable framework because they derive optimal systems of taxes and transfers, finding the solution to social planning problems. However, they also consider piecemeal reforms to the current Social Security system that can be compared to our results.

Columns (4)-(6) of Table 4 show that the optimal policies in this environment involve significant claiming adjustments. The optimal policies also involve a positive relationship between lifetime earnings and Social Security benefits. This contrasts with most of our specifications, where the optimal benefit differs only by claiming date. By way of comparison, Ndiaye (2018) finds that the optimal policies also involve a large claiming adjustment and benefits that increase in lifetime earnings (to a greater extent than under the current rules). Our results suggest that these findings may be driven in part by modelling assumptions.

Table 4: Current and Optimal Policies: Alternative Specifications

	Claiming = Retirement & Retirement Irreversible			Columns (1)-(3) & Fixed Lifespans		
	Current	Optimal 1	Optimal 2	Current	Optimal 1	Optimal 2
Benefit Taxation and Earnings Test	Yes	Yes	No	Yes	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Tax cap / median age-62 AIME	2.18	1.65	1.64	2.18	2.61	2.62
Age-66 benefit (PIA) percentiles (000s)						
10th percentile	30.7	26.3	29.6	30.7	23.8	31.8
median	42.1	26.3	29.6	42.1	28.6	33.9
90th percentile	55.1	26.4	29.6	55.1	34.2	36.2
Benefits relative to age-66 benefit						
age 62	0.745	0.398	0.457	0.745	0.460	0.536
age 70	1.320	2.378	2.091	1.320	2.077	1.800
Benefit claiming						
age 62	0.7%	0.0%	0.0%	9.4%	0.0%	0.0%
age 66	46.8%	17.3%	17.5%	51.9%	0.0%	0.4%
Employment						
age 62	79.3%	80.0%	80.2%	90.5%	96.5%	96.8%
age 70	25.7%	34.7%	42.4%	27.8%	53.8%	58.2%
Aggregate behavior						
employed	77.2%	78.1%	78.7%	83.6%	88.2%	88.6%
hours—employed	0.339	0.336	0.335	0.336	0.331	0.332
earnings ($000s)	90.1	90.1	90.7	94.2	96.6	97.2
assets ($000s)	123.3	131	130.8	119.8	119.3	119.5
bequests ($000s)	6.2	6.6	6.8	7.7	7.7	7.7
consumption ($000s)	75.5	76.2	76.7	80.3	82.3	82.7
τ^{ss}	6.20%	6.65%	6.94%	6.20%	5.77%	5.99%
λ_0	25.80%	25.45%	25.26%	25.80%	24.84%	24.63%
Residual government budget (000s)						
revenues	24.1	24.1	24.1	20.3	20.3	20.3
expenses	3.3	3.3	3.3	1.9	1.9	1.9
balance	20.8	20.8	20.8	18.4	18.4	18.4
Internal (annual) rate of return on OAI and DI						
all households	1.13%	1.13%	1.12%	-0.19%	-0.14%	-0.12%
no college degree	1.54%	1.64%	1.58%			
college degree	0.57%	0.35%	0.45%			
Consumption equivalent variation						
all households		0.92%	1.32%		0.79%	0.77%
no college degree		1.05%	1.49%			
college degree		0.31%	0.54%			

7 Conclusion

In this paper we consider how the implications for Social Security reform of the large and growing income gradient in mortality. We construct a heterogeneous agent, life-cycle model of Social Security claiming, labor supply and saving, and calibrate it to the economic and demographic environment for 2012. Under our calibration, agents in the top lifetime earnings quintile live on average 11 years longer than those at the bottom. We then examine changes to: the formula converting an individual's earnings history to his baseline benefit; the payroll tax earnings cap and tax rate; and the trade-off between the age at which an individual first receives her Social Security benefits and the size of the annual benefit. Our analysis suggests that welfare is maximized when baseline benefits are independent of lifetime earnings, the payroll tax cap is set at roughly its current value, and claiming adjustments are reduced. Eliminating the earnings test and the income taxation of Social Security benefits would yield additional welfare gains.

We then examine a hypothetical "2050 demographics" scenario characterized by longer lifespans, lower population growth and a steeper education-mortality gradient. The Social Security system that would maximize welfare in the 2050 demographic environment is quite similar to the one that would maximize welfare today. While longer careers would be beneficial in the 2050 environment, with longer lifespans agents would be willing to work longer even if the Social Security rules did not change.

There are a number of promising directions along which to extend our framework. The first would be to introduce marriage and spousal benefits, as in Sánchez-Marcos and Bethencourt (2018), Nishiyama (2019) and Borella et al. (2019). A second is to consider the entire tax and transfer system, rather than just Social Security. It is not immediately obvious how to make such an analysis tractable. Our results suggest that commonly-used demographic simplifications, such as a fixed lifespan, may have important policy implications.

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For Online Publication: Appendices

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:*

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

3. *Health insurers earn zero profits:*

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

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

$$(1+r) \int (1-s) \max\{0, a'\} \, \mu(\tilde{\mathbf{x}}) \, d\tilde{\mathbf{x}} = (1+\chi)B;$$

5. *The distribution of individuals is stationary.*

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

Health measurement:

We allow health, h_t, 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:

$$\Pr(alive_{i,j+1,t+2} \,|\, alive_{ijt}) = \frac{\exp\left(\begin{array}{l} \alpha_0 + \alpha_1 j + \alpha_2 e_i + \sum_m \alpha_{3m} I_{h_{ijt}=m} \\ + \sum_m \alpha_{4m} I_{h_{ijt}=m} \times j + \alpha_5(t - 2012) \end{array}\right)}{1 + \exp\left(\begin{array}{l} \alpha_0 + \alpha_1 j + \alpha_2 e_i + \sum_m \alpha_{3m} I_{h_{ijt}=m} \\ + \sum_m \alpha_{4m} I_{h_{ijt}=m} \times j + \alpha_5(t - 2012) \end{array}\right)},$$

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 18 years, we estimate period (for $t = 2012$) rather than cohort survival rates.

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 10(a) shows the resulting survival premia.

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

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

where $\bar{s}_j$ is the gender-weighted 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.
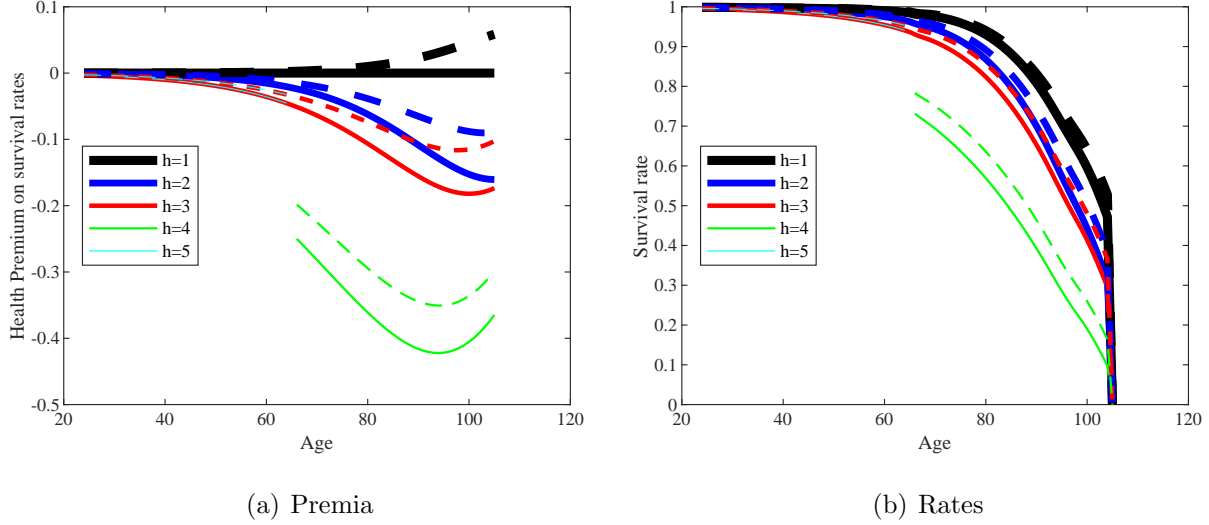

(a) Premia　　　　　　　　　　　　　(b) Rates

Figure 10: 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 ($h = 3$).

Figure 10(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 56.7 years; the average remaining lifespan for those without a degree is 52.7 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.

$$\Pr(h_{i,t+2,j+1} = k) = \frac{\exp\left(\begin{array}{l}\zeta_0^k + \zeta_1^k j + \zeta_2^k e_i + \zeta_3^k e_i \times j + \sum_m \zeta_{4m}^k I_{h_{ijt}=m} \\ + \sum_m \zeta_{5m}^k I_{h_{ijt}=m} \times j + \zeta_6^k(t-2012)\end{array}\right)}{\sum_l \exp\left(\begin{array}{l}\zeta_0^l + \zeta_1^l j + \zeta_2^l e_i + \zeta_3^l e_i \times j + \sum_m \zeta_{4m}^l I_{h_{ijt}=m} \\ + \sum_m \zeta_{5m}^l I_{h_{ijt}=m} \times j + \zeta_6^l(t-2012)\end{array}\right)}, \quad (16)$$

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.

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

$$\Pr(h_{j+1} \mid e, h_j) = \sum_m \Pr(h_{j+1} \mid e, h_{j+0.5} = m) \times \Pr(h_{j+0.5} = m \mid e, h_j). \quad (17)$$

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 transiting to the good health, bad health, work limitation, and nursing home state is, respectively, 0.0627,

0.0618, 0.8674, and 0.0081, for those without a Bachelor's degree; and is, respectively, 0.0857, 0.0303, 0.8840, and 0.0001 for those with a Bachelor's degree.

(a) Good health

(b) Bad health

(c) Work limitation

(d) Nusing home
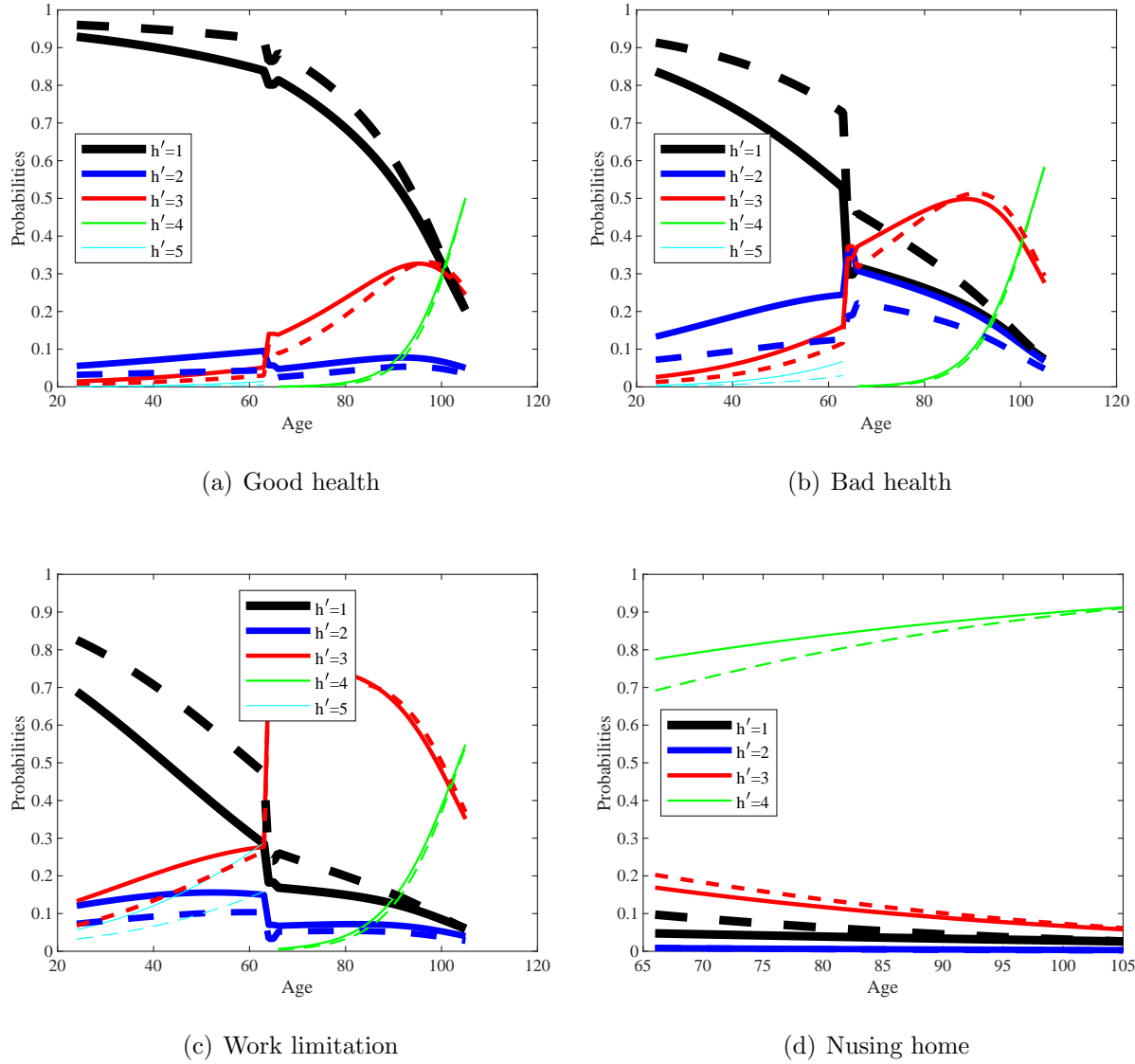
Figure 11: Health Transition Probabilities by Age

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

Figure 11 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 transit 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 12 compares the model-generated distribution of health at each age to that in the data, and shows a that the constructed transition probabilities work well.

(a) W/O a Bachelor's degree
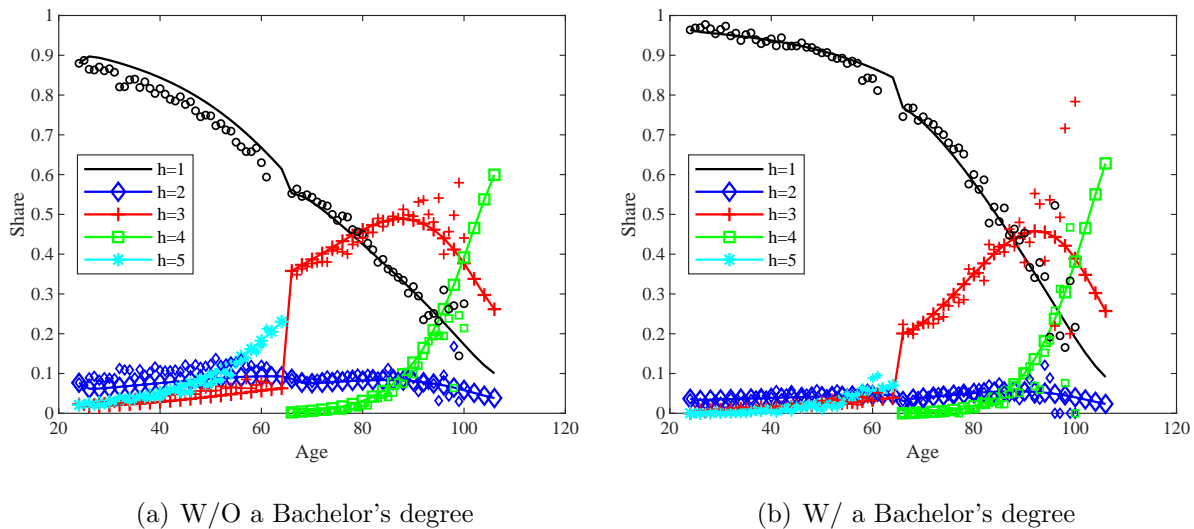
(b) W/ a Bachelor's degree

Figure 12: 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.[23] 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 spend-

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

ing 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 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 3 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. (2019). 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 13 shows our estimated expenditures.[24]

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[24]Not shown in Figure 13 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, $21,520, $319,330, and $896,650.
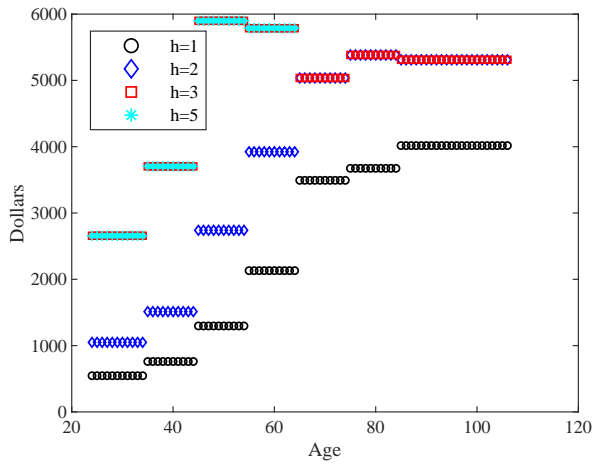
(a) Small
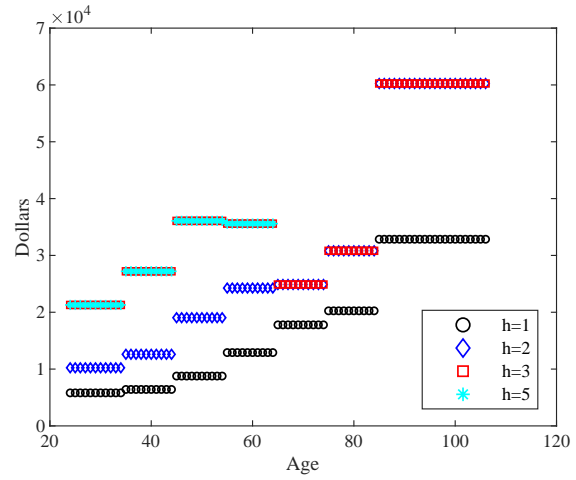
(b) Medium
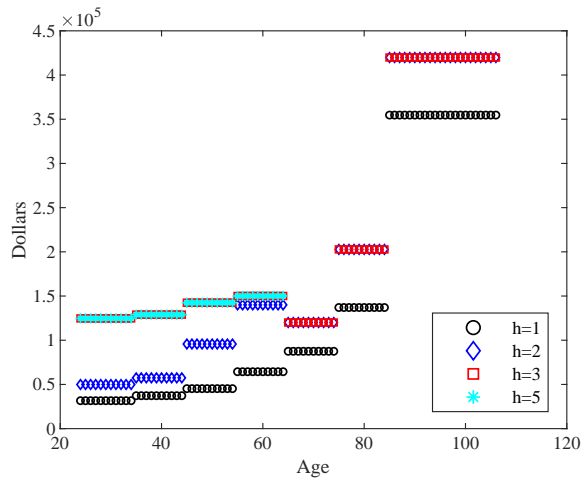
(c) Large

Figure 13: 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

$$w_j = \omega(e, j, h_j) \cdot \eta_j \cdot \min\left\{1, \left(\frac{n_j}{\bar{n}}\right)^\zeta\right\}. \tag{18}$$

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 effect wage profile:

$$\ln\left(\frac{w_{ij}}{\min\left\{1, \left(\frac{n_{ij}}{\bar{n}}\right)^\zeta\right\}}\right) = \sum_{v=1}^{4} \theta_{0v}j^v + \sum_{v=1}^{4} \theta_{1v}e_i j^v + \gamma_i + \varsigma_{ij}, \tag{19}$$

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 14(a) shows the fixed effects estimates.

The fixed effect 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 effect wage profiles for workers, we set $\omega(e, j, h_j)$ so that the simulated estimates of $\{\theta_{0v}, \theta_{1v}\}_v$ 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 14(b) shows the corrected

| (a) PSID Data (fixed effects) | (b) Model |
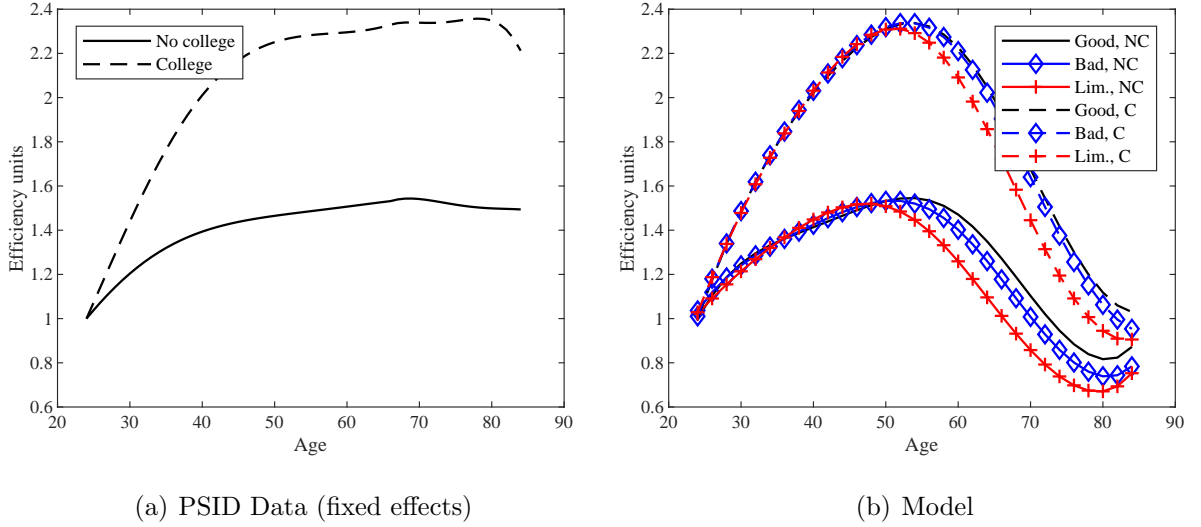
Figure 14: Age Efficiency Profiles

profiles, which are allowed to vary by health. Wages fall steadily after age 55, and the wages for those with work limitations are noticeably 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 $15.8 per hour for those without a Bachelor's degree and $19.4 for those with a Bachelor's degree.

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

$$\gamma_i + \varsigma_{ij} = \eta_{ij} + \varepsilon_{ij} + \varkappa\varepsilon_{ij-1}, \tag{20}$$

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 5 reports the parameters for η_j. The initial distribution of productivity shocks by education and by health is set to match the data distribution of the fixed effects.

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Table 5: Persistence and Variance of the Productivity Shocks

	Non-college	College
Autocorrelation Coefficient	0.933	0.921
Innovation Variance	0.021	0.032

Appendix D: 2050 demographics under different budget balancing approaches

In the "2050 demographics" scenario examined in the main text, we balanced the Social Security budget by reducing benefits. In Table 6 we compare our findings for this exercise (shown in Columns (1)-(3)) to one in which the Social Security budget is balanced through higher taxes. In particular, Columns (4) - (6) of Table 6 repeat the exercises of columns (1) - (3) under the assumption that the Social Security benefit formula remains at its absolute 2012 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.

Table 6: Current and Optimal Policies: 2050 Demographics

	2012 Aggregate SS Spending			2012 SS Rules		
	Current	Optimal 1	Optimal 2	Current	Optimal 1	Optimal 2
Benefit Taxation and Earnings Test	Yes	Yes	No	Yes	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Tax cap / median age-62 AIME	2.18	3.09	3.10	2.18	3.09	3.09
Age-66 benefit (PIA) percentiles (000s)						
10th percentile	21.0	33.9	34.4	28.6	45.9	46.7
median	28.9	33.9	34.8	39.3	45.9	47.0
90th percentile	37.8	33.9	35.1	51.5	45.9	47.4
Benefits relative to age-66 benefit						
age 62	0.74	0.81	0.80	0.74	0.80	0.80
age 70	1.33	1.22	1.23	1.33	1.23	1.23
Benefit claiming						
age 62	1.8%	26.8%	85.4%	3.8%	32.7%	85.4%
age 66	36.8%	99.8%	100.0%	42.2%	99.8%	100.0%
Employment						
age 62	74.4%	69.4%	72.7%	73.3%	65.3%	69.0%
age 70	38.4%	37.8%	40.7%	33.2%	31.4%	35.7%
Aggregate behavior						
employed	73.4%	72.3%	73.1%	72.4%	70.9%	71.9%
hours—employed	0.33	0.33	0.33	0.33	0.33	0.33
earnings ($000s)	97.1	95.9	96.5	96.2	94.5	95.3
assets ($000s)	200.5	205.2	208.8	168.8	173.5	179.5
bequests ($000s)	10.5	10.7	11.2	9.5	9.6	10.3
consumption ($000s)	87.1	86.3	87.3	84.0	82.6	84.1
τ^{ss}	5.0%	4.8%	5.5%	9.0%	8.7%	9.4%
λ_0	25.8%	26.1%	25.8%	25.8%	26.3%	25.8%
Residual government budget (000s)						
revenues	28.5	28.5	28.5	27.6	27.6	27.5
expenses	4.2	4.2	4.2	4.2	4.2	4.2
balance	24.3	24.3	24.3	23.3	23.3	23.3
Internal (annual) rate of return on OAI and DI						
all households	0.48%	0.48%	0.48%	0.43%	0.43%	0.43%
no college degree	0.94%	1.81%	1.69%	0.70%	1.64%	1.55%
college degree	0.25%	-0.31%	-0.25%	0.30%	-0.28%	-0.25%
Consumption equivalent variation						
all households		1.50%	2.22%		1.52%	2.72%
no college degree		1.98%	2.76%		2.04%	3.33%
college degree		0.37%	0.92%		0.29%	1.27%

Appendix E: Robustness to demographic assumptions

In Table 7 we compare economic outcomes under the current Social Security system to those that occur when the payroll tax cap, PIA formula and claiming adjustments are chosen optimally. We consider two model environments. The first environment, shown in columns (1)-(3) differs from the baseline environment in that the processes for health and mortality do not differ by education level. In the second environment, shown in columns (4)-(6), health and education-related differences are removed entirely. All agents face the same mortality and wage risks, and differ only in terms of their wage and mortality realizations. It bears noting that there is no DI in columns (4)-(6), as no one is disabled. Table 7 shows that the optimal policies in these revised environments differ little from their baseline counterparts.

Table 7: Current and Optimal Policies: Alternative Demographic Assumptions

Benefit Taxation and Earnings Test	No Education Differences			No Health or Educational Differences		
	Current	Optimal 1	Optimal 2	Current	Optimal 1	Optimal 2
	Yes	Yes	No	Yes	Yes	No
	(1)	(2)	(3)	(4)	(5)	(6)
Tax cap / median age-62 AIME	2.18	2.81	3.03	2.18	1.89	1.88
Age-66 benefit (PIA) percentiles (000s)						
10th percentile	30.7	42.0	41.6	30.7	42.9	42.3
median	42.1	42.8	42.1	42.1	43.9	42.9
90th percentile	55.1	43.6	42.5	55.1	44.8	43.5
Benefits relative to age-66 benefit						
age 62	0.745	0.796	0.803	0.745	0.776	0.803
age 70	1.320	1.240	1.229	1.320	1.269	1.229
Benefit claiming						
age 62	6.5%	17.8%	81.2%	5.0%	26.4%	100.0%
age 66	73.9%	100.0%	100.0%	67.0%	100.0%	100.0%
Employment						
age 62	69.7%	68.3%	67.5%	82.3%	79.7%	80.4%
age 70	24.6%	21.8%	26.0%	25.1%	22.0%	27.0%
Aggregate behavior						
employed	76.7%	75.9%	76.4%	80.8%	79.8%	80.5%
hours—employed	0.333	0.332	0.332	0.330	0.330	0.330
earnings ($000s)	86.9	86	86.5	88	87.3	88.1
assets ($000s)	123	125.4	130	108.2	112.9	119.5
bequests ($000s)	6.5	6.5	7	5.7	5.9	6.5
consumption ($000s)	72.8	72.1	73.1	72.8	72.4	73.8
τ^{ss}	6.20%	6.13%	6.44%	6.20%	6.34%	6.53%
λ_0	25.80%	26.08%	25.70%	25.80%	25.90%	25.29%
Residual government budget (000s)						
revenues	23.2	23.2	23.2	21.2	21.2	21.2
expenses	3.3	3.3	3.3	2.8	2.8	2.7
balance	19.9	19.9	19.9	18.5	18.5	18.5
Internal (annual) rate of return on OAI and DI						
all households	1.08%	1.08%	1.08%	0.52%	0.51%	0.48%
no college degree	1.50%	1.80%	1.78%			
college degree	0.38%	-0.24%	-0.20%			
Consumption equivalent variation						
all households		0.86%	2.03%		0.65%	2.15%
no college degree		1.05%	2.21%			
college degree		0.05%	1.21%			