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Abstract

Why do most individuals claim Social Security benefits before the full retirement age? Claiming benefits early results in a substantial reduction in pension income, yet many people claim as early as possible (age 62) or soon thereafter. We argue that by answering this question, we can make two additional contributions to the literature. First, early claiming is equivalent to low demand for Social Security annuity, thus it offers a unique context for studying the well-known annuity puzzle. Since participation in Social Security is nearly universal, the low demand for this annuity cannot be explained away by market failures. Second, we show that claiming decisions are closely linked to the subjective rate of time preferences and thus can provide a new angle for the identification of this parameter. We provide a quantitative analysis of claiming decisions using a rich structural life-cycle model that matches many important features of the data. We find that the claiming puzzle can be attributed to a combination of three factors: (i) the discrepancy between individuals' subjective valuation of Social Security annuity and its implicit price, (ii) strong bequest motives, (iii) pre-annuitized wealth. We show that if individuals were rewarded for delaying claiming not with additional annuity income but with equivalent (in present value terms) lump-sum payments, the fraction of early claimers would be significantly reduced.

Keywords: Social Security, Retirement, Annuities, Consumption and Saving, Life-Cycle Model

JEL Classification Codes: D91, G11, G22

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1 Introduction

Why do most individuals claim Social Security benefits before the full retirement age? Individuals can claim benefits at any age between 62 and 70. Early claiming (before the full retirement age) results in a permanent reduction in the basic retirement benefits, while late claiming (after the full retirement age) results in a permanent increase. These penalties and rewards can be substantial: for example, for the cohort of individuals born in 1937, claiming at age 62 versus 65 (full retirement age for this cohort) resulted in a 20% reduction in monthly benefits, while claiming at age 70 versus 65 resulted in a more than 30% increase. Yet, among men born between 1936-1938, 67% claimed benefits earlier than the full retirement age.[1]

Our goal in this paper is to investigate the factors affecting individuals' decision about when to claim Social Security benefits. We argue that this question is not only interesting in its own right, but also can offer two additional insights.

First, it provides a particularly interesting setting in which to study the well-known annuity puzzle. This puzzle contrasts the prediction of a standard life-cycle model (people should annuitize a large fraction of their wealth) with empirical evidence (only a few people buy private annuities). The prevalence of early claiming can be considered as another manifestation of this puzzle: choosing the age to claim benefits is equivalent to deciding how much (if any) annuity income to purchase. Every year of delay results in an increase in pension benefits, i.e., additional lifetime annuity income, while the 'price' of this public annuity is one year of foregone benefits.

The (private) annuity puzzle has been, to a significant degree, attributed to market frictions, specifically, adverse selection (Brugiavini, 1993, Finkelstein and Poterba, 2004) and minimum purchase requirements (Pashchenko, 2013). However, since a very small number of people purchase private annuities and the actual magnitude of market frictions is unobservable, it is difficult to quantify to what extent the annuity puzzle is due to these frictions and to what extent it is due to preferences.[2] In contrast, participation in Social Security is compulsory and nearly universal. This gives us an opportunity to re-examine the annuity puzzle in a unique context without frictions common to private markets.[3]

The second insight that can be gained from studying claiming behavior is that it sheds light on the long-standing problem of identification of the subjective rate of time preferences.[4]

[1] Own calculations based on the Health and Retirement Study.

[2] Einav et al. (2010) stress the problem of distinguishing to what extent the observed outcomes in insurance markets are due to adverse selection versus consumers' preferences.

[3] Note that the price of "public" annuity is fixed for each cohort and is independent of the composition of the pool of annuity buyers. Also, as opposed to the private annuity case, people do not have to make a large upfront payment in order to meet the minimum purchase requirement.

[4] In this paper, we refer to the discount factor and the rate of time preferences interchangeably, where

Even though the discount factor is at the core of any intertemporal optimization problem, the question of how to estimate it is not entirely resolved (see Frederick et al., 2002 for an extensive review). This is especially troubling given that, as is well-known from quantitative structural studies, even a small change in the discount factor produces a large impact on economic decisions such as consumption and savings.[5]

Structural and macroeconomic studies typically identify the discount factor from aggregate/average wealth holdings (e.g., Guvenen, 2007, Krueger and Perri, 2005, Storesletten et al., 2004) or from the evolution of median wealth or consumption over the life-cycle (e.g., Cagetti, 2003, Gourinchas and Parker, 2002). The resulting rate of time preference is usually estimated to be rather low, 5% or less. However, studies that explore other features of the data oftentimes conclude that people are much less patient. Deaton (1991) and Carroll (1997) point out that in order to account for such facts as consumption tracking income over part of the life-cycle or a large number of people with few assets, consumers have to be impatient.[6] Several other studies arrive at a similar conclusion while targeting such moments as wealth response to the degree of uncertainty in permanent income (Carroll and Samwick, 1997), wealth holdings of the poor (Lockwood, 2018), or credit card borrowing data (Laibson et al., 2018).[7]

A common approach in structural studies that estimate/calibrate the discount factor is to restrict risk aversion to be equal to the inverse of the intertemporal elasticity of substitution (IES). The key trade-off consumers face in such a setting is between impatience and desire to accumulate precautionary savings (controlled by risk aversion). These two forces push savings in opposite directions and their respective quantitative significance can potentially be identified from wealth profiles over the life-cycle.[8]

In a less restrictive setting, when risk aversion and IES are not tied together (as, for example, in the non-expected utility parametrization suggested by Epstein and Zin, 1989), the observed wealth accumulation profile can be attributed to another trade-off: between aversion to risk and distaste for consumption fluctuations over time. In this case, wealth profiles are not sufficient to pin down the underlying degree of impatience.[9]

the rate of time preferences is equal to the inverse of the discount factor minus one.

[5] For a clear illustration of this point, see Gourinchas and Parker (2002) Figure 5 on page 72, and De Nardi et al. (2016), Figure E3 in the Online Appendix.

[6] The combination of impatience and precautionary savings produces behavior that Carroll (1997) refers to as buffer stock savings.

[7] Carroll and Samwick (1997) estimate the rate of time preferences of around 11%. Lockwood's (2018) benchmark estimate of the discount factor is 0.84 which is equivalent to the rate of time preferences of 19%. Laibson et al. (2018) estimate the discount factor of 0.893 (the rate of time preferences around 12%) in the version of their model with standard (non-hyperbolic) preferences.

[8] See Gourinchas and Parker (2002) and Carroll (1997) for an extensive discussion of this trade-off.

[9] We can use the following simple example to illustrate this. Suppose we observe consumers accumulating

We argue that, in this setting, an important identifying information for the estimation of the rate of time preferences can be obtained from the observed claiming behavior. Specifically, we show that the decision about when to start collecting benefits is very sensitive to the assumed degree of impatience. This happens because, as we discussed earlier, these decisions is equivalent to the purchase of additional Social Security annuity. Since an annuity pays out a fixed income flow for a long period of time, its valuation by individuals crucially depends on their planning horizon and thus on their subjective discount rate.[10]

To investigate claiming behavior (and thus the demand for Social Security annuity), we develop and estimate/calibrate a rich structural life-cycle model that includes both working and retirement periods and has a detailed representation of Social Security rules. Young individuals in the model choose how much to work and to save, as well as when to retire and when to collect benefits (which are not necessarily the same thing). Old individuals choose how quickly to dissave their assets. Our model includes a number of factors previously shown to affect individuals' demand for private annuities, since they can also matter for the claiming decision. This includes uncertain medical and nursing home expenses, bequest motives, means-tested benefits, and pre-annuitized wealth.

The mechanics of our structural model are as follows. Every period after an individual reaches the age of 62, he decides whether or not to claim benefits (if he still didn't do so). The key trade-off in this decision is an immediate increase in available resources versus a higher lifetime pension income starting one year later. The choice between these two alternatives depends on (i) the implicit "price" of the Social Security annuity determined by the schedule of penalties/rewards for early/late claiming, (ii) individual's demand for assets that are not contingent on survival, which is determined by three factors. First, how much annuity income people already have when they claim as early as possible (age 62), i.e., what fraction of their wealth is pre-annuitized. Second, how much wealth they want to leave behind (determined by bequest motives). Third, the exposure of individuals to risks (other than survival risk); most importantly, medical and nursing home expenses.

To estimate the model, we use three datasets: the Health and Retirement Study (HRS), the Medical Expenditure Panel Survey (MEPS), and the Panel Study of Income Dynamics

wealth at a very slow rate. In the standard expected utility case, we can conclude that their discount factor is low, and thus impatience dominates their precautionary motive for saving. In the non-expected utility case (when risk aversion is not tied to IES), such behavior may arise even when consumers are patient but their aversion to intertemporal fluctuations is much stronger than their aversion to risk. The problem of separately identifying intertemporal elasticity of substitution and impatience is also pointed out by Aguiar et al., (2019).

[10] Even though the demand for any annuity (public or private) is informative about the underlying degree of impatience, this parameter is hard to identify from the observed purchase of private annuities due to the small number of participants in this market. For example, among single retirees who are between 65 and 75 years old, only 5% hold life annuities (Pashchenko, 2013).

(PSID). We require our model to fit the data along many dimensions. Specifically, our model can account not only for the dynamics of median wealth over the life-cycle, but also for the dynamics of the bottom and the top 25th percentiles of the wealth distribution. This is important for the identification of preferences parameters, such as risk aversion, intertemporal elasticity of substitution, and bequest motives. Our model is also consistent with the labor force participation and with the average labor income of workers over the life-cycle. Our estimation strategy takes into account the selection into employment, which is particularly important as people start exiting the labor force as they get older. Importantly, our model is consistent with the distribution of individuals by claiming age, which, to the best of our knowledge, represents a new angle in the identification of the discount factor.

The main results from our estimated/calibrated model are as follows. First, claiming behavior provides important identifying information for estimating the discount factor. We show that our model can be made consistent with the observed labor supply and retirement behavior, as well as wealth accumulation and decumulation over the life-cycle for different values of the discount factor. However, in order for the model to *simultaneously* account for all the above mentioned facts and claiming behavior, it should feature a relatively high degree of impatience. Our estimated subjective rate of time preferences is around 4%, which is on the high end of commonly used estimates obtained from targeting average wealth.[11]

Second, we show that, to a significant extent, the observed claiming behavior can be accounted for by the discrepancy between individuals' subjective valuation of Social Security annuity and its implicit price. Put differently, the break-even rate for Social Security annuity (the interest rate which equates its present value to its price) is too low compared to the subjective rate of time preferences. To illustrate this, we change the schedule of penalties/rewards for early/late claiming so that the resulting break-even rate is above the individuals' subjective rate of time preferences. We show that in this case, the fraction of people who delay claiming (and thus buy public annuity) will increase considerably.

Third, we investigate how factors identified in the literature as the most prominent explanations for the annuity puzzle affect claiming decisions. As we discussed earlier, in our context we can abstract from several of these explanations related to information problems and market frictions. In addition, we show that we can also rule out some of the institutional explanations such as the existence of means-tested benefits, which were shown to be important in earlier studies because of the implicit longevity insurance they provide (Butler et al., 2017, Pashchenko, 2013).

This is due to the following distinguishing feature of our approach: we look at the annuity

[11] Note that the effective rate of time preferences in our model is higher since it factors in the survival probability.

puzzle from the perspective of a full life-cycle model, where labor supply, saving, and retirement decisions are endogenized. In contrast, a more common approach in previous studies is to consider annuitization decisions after retirement, where initial wealth and retirement date are exogenously fixed. In such a framework, people can strongly react to changes in the institutional environment (such as means-tested benefits) by purchasing more/less annuities since there are few other margins they can adjust. In the more flexible setting that we consider, people change their behavior over the entire life-cycle, thus their demand for annuities is much less affected.

Overall, we show that the (public) annuity puzzle can be attributed to the combination of the following three factors: i) a relatively high degree of impatience, ii) strong bequest motives and iii) pre-annuitized wealth. Put differently, given the subjective valuation of additional annuity income and the demand for liquid wealth that can be left for bequests, many people consider themselves sufficiently annuitized even when they claim benefits as early as possible.

In the final part of our analysis, we investigate how the above results can inform public policy aimed at increasing the age at which people start collecting pensions. We consider a policy where late claiming is rewarded not with higher pension income but with an equivalent (in present value terms) lump-sum benefits. We show that this policy is very effective at inducing individuals to delay claiming. For example, the percentage of people claiming after the full retirement age increases from 8% in the baseline case to almost 70-80% in the case when lump-sum transfers are offered (the exact number depends on the interest rates used to convert pension income into lump-sum transfers).[12]

In summary, we contribute to the existing literature in several ways. First, we evaluate what factors affect people's decision about when to start collecting pension benefits in a rich structural model that matches the data among many important dimensions. Second, we propose a new strategy for the identification of the subjective rate of time preferences by using the distribution of people by claiming age and by carefully modeling factors that can potentially affect claiming behavior. Finally, we provide a new insight into the well-known annuity puzzle by exploring it in a framework where several previously identified prominent explanations do not apply.

The rest of this paper is organized as follows. Section 2 reviews the related literature. Section 3 discusses the implicit price of Social Security annuity. Section 4 introduces the model, while Section 5 explains our estimation/calibration. The results and conclusion are

[12] This finding is consistent with other studies that show that people prefer lump-sum to annuity options using the results of a natural experiment (Warner and Pleeter, 2001) or specifically designed survey questions (Maurer et al., 2016).

presented in Section 6 and 7, respectively.

2 Literature review

Our paper is related to several strands of literature. First, we belong to a growing literature examining the costs and benefits associated with claiming Social Security at different ages. A common conclusion of these studies is that, in many cases, households can gain from delaying claiming, i.e., the resulting change in the expected present value of retirement income is positive (Coile et al., 2002; Meyer and Reichenstein, 2010; Shoven and Slavov, 2014a and 2014b; Sun and Webb, 2009). Despite these potential gains, many individuals claim benefits as early as possible. In order to understand this puzzle, a number of studies investigate what factors affect the claiming decisions. Hurd et al. (2004) find that individuals with low subjective survival probability tend to claim benefits earlier. Shoven and Slavov (2014a, 2014b) find that there is no strong relationship between early claiming and factors that can potentially affect the gains from delaying, e.g., gender, wealth or marital status. However, the latter study and Venti and Wise (2004) find that individuals with higher education tend to claim benefits later. Goda et al. (2015) use administrative tax data to study whether individuals who claim benefits early are financially constrained. They find that a significant fraction of early claimers have enough assets to delay claiming.

Several studies investigate claiming decisions using a structural life-cycle model. Gustman and Steinmeier (2005) construct a life-cycle model of retirement decisions, allowing for heterogeneity in preferences for leisure and the discount factor. They point out that the standard life-cycle model cannot fully account for the observed claiming behavior. In their later work, Gustman and Steinmeier (2015) show that a richer version of the model with stochastic returns on assets and more flexible labor supply still falls short of capturing a large fraction of individuals claiming as early as possible; however, varying beliefs about the future of Social Security can substantially improve the fit of the model along this dimension.

The second strand of literature we relate to studies the choice individuals make between annuities and lump-sum payouts available in some institutional settings. Warner and Pleeter (2001) investigate this choice offered to some military personnel in the early 1990s. They find that among people eligible for this program most chose lump-sum payouts despite very favorable conversion rate of these payments into annuity streams. Mottola and Utkus (2007) examine a similar choice among participants of large private defined benefit pension plans. They also find that most people prefer to receive their pensions as lump-sum payments. Fitzpatrick (2015) evaluates the results of a natural experiment in Illinois where teachers were given an opportunity to purchase additional pension benefits. She finds that the willingness to pay for this additional pension income was very low. In contrast to these results based on US data, several studies that investigate the lump-sum vs annuity choice in some European pension plans find that most people prefer the annuity option (see Butler and Teppa, 2007, for Switzerland, and Hagen, 2015, for Sweden).

Third, we belong to the literature that studies the annuity puzzle. A standard life-cycle model predicts that people should annuitize all of their wealth (Yaari, 1965). A large literature emerged trying to explain why only few people buy annuities in reality. The lack of willingness to annuitize has been attributed to adverse selection (Mitchell et al., 1999), a large fraction of pre-annuitized wealth in retirees' portfolio (Dushi and Webb, 2004), bequest motives (Lockwood, 2012), uncertain health and medical expenses (Reichling and Smetters, 2015, Turra and Mitchell, 2008), and minimum purchase requirements (Pashchenko, 2013). Two studies show that a structural model featuring several of these explanations can account for the observed annuity demand (Inkman et al., 2011, Pashchenko, 2013). Importantly, in contrast to our approach, all these studies analyze the annuity puzzle in the context of private markets.

More broadly, our paper is related to the literature studying various Social Security reforms (Blandin, 2005, Hong and Rios-Rull, 2007, Kitao, 2014, Laitner and Silverman, 2012). A subset of this literature focuses on policies that can affect Social Security claiming behavior. Maurer et al. (2016) design a survey to investigate whether individuals' decisions when to claim benefits are affected by the option to substitute an increase in pension income with lump-sum benefits. They find a significant increase in the average claiming age in response to this lump-sum option. Imrohoroglu and Kitao (2012) use a general equilibrium framework to compare two Social Security reforms, the first one increases the earliest claiming age by two years while the second one increases the normal retirement age by two years. They find that the second reform has a much larger effect on labor supply and the Social Security budget. Hubener et al. (2016) use a rich model with multi-person households to show that eliminating Social Security survival benefits will differently affect men's and women's claiming and life insurance purchase decisions.

Methodologically, we relate to structural models with uncertainty in health and longevity. This literature is extensive and includes, among others, studies of wealth decumulation after retirement (De Nardi et al., 2010, Ameriks et al., 2019); of health effects over the life-cycle (Capatina, 2015, De Nardi et al., 2018), of general equilibrium effects of various health-related policies (Hansen et al., 2014, Kopecky and Koreshkova, 2014, Pashchenko and Porapakkarm, 2013 and 2016). Our structural model differs from the above mentioned studies in that it combines several important features previously, to the best of our knowledge, not considered together. First, we include endogenous retirement while separating decisions to retire and to claim benefits. Second, we carefully model end-of-life risks by including both medical and nursing home expenses. Third, we use the non-expected utility preferences (the parametrization suggested by Epstein and Zin, 1989) to separate risk aversion from the intertemporal elasticity of substitution, thus emphasizing the problem of identification of the subjective discount factor.

3 Social Security as an annuity: a closer look

Since delaying claiming Social Security benefits is equivalent to buying a (public) annuity, an important question is how much this annuity costs. To impute the price of the Social Security annuity, we use the schedule of penalties and rewards for the cohort born in 1937 as shown in the second row of Table 1.

Consider an individual who is entitled to receive annual benefits b at the full retirement age of 65 and is deciding whether to claim at age 62 or 63. If he claims at 63 he will receive additional lifetime annuity income equal to $0.067b$, but this will cost him $0.8b$ in terms of forgone benefits at age 62. Thus, the price of an additional dollar of this annuity income is equal to $0.8b/0.067b = \$12$. In the same way, an individual who did not claim by age 63 faces a trade-off between further increasing his annuity income by an additional $0.067b$ and claiming right away to receive $0.867b$ in benefits. In this case, he can increase his annuity income at a price of $0.067b/0.867b = \$13$ per one dollar of the extra income stream.

Age	62	63	64	65	66	67	68	69	70
% of full benefits	80%	86.7%	93.3%	100%	106.5%	113%	119.5%	126%	132.5%
Imputed price ($)	12	13	14	15.38	16.38	17.38	18.38	19.38	-

Table 1: First row: Reduction (increase) in benefits for early (late) claiming as a percentage of the benefits received at the full retirement age (1937 cohort). Second row: imputed price of the Social Security annuity.

The second row of Table 1 reports imputed price for each age between 62 and 69. One observation is that the imputed price of the Social Security annuity increases with age. This is not surprising because the incremental increase in annuity income with each additional year of delay is constant ($0.067b$ before the full retirement age and $0.065b$ after that), while the amount of the forgone benefits is increasing.

Next, we compare the imputed price with the actuarially fair annuity price. We compute the actuarially fair price q_m^{AF} of annuity purchased at age m as follows:

$$q_m^{AF} = \sum_{t=m}^{T-1} \frac{\zeta_{t+1|m}}{(1+r)^{t+1-m}},$$

where $\zeta_{t|m}$ is the probability of surviving to age t conditional on being alive at age m, T is the last period of life set to 100 years old, and r is the interest rate. We calculate $\zeta_{t|m}$ using the Social Security cohort life tables for males born in 1940 (the closest cohort to 1937 for which life tables are available). Figure (1) plots the actuarially fair price for three values of the interest rate (1%, 2%, and 3%) alongside the imputed price of the Social Security annuity.

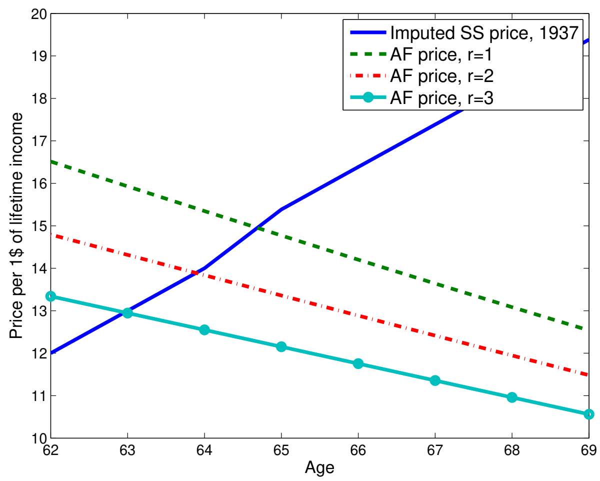

Figure 1: The imputed price of the Social Security annuity vs the actuarially fair annuity prices computed for different interest rates (1%, 2%, and 3%)

As can be seen in Figure 1, for most ages, the prices for the Social Security annuity and the actuarially fair annuity are quite different. For ages 62 and 63, the former is significantly cheaper than the latter even when it is priced based on an interest rate of 3%.[13] However, for ages above 65, private annuity is significantly cheaper than public annuity. This reversal occurs because the price of private annuities decreases with age as older individuals receive a shorter stream of income, while public annuity demonstrates the opposite pattern.

This comparison reveals that the Social Security annuity is relatively poorly priced for individuals above the full retirement age, which could explain why very few individuals claim after age 65. However, Social Security annuity is very attractive for individuals with average mortality and younger than the full retirement age; thus, making it a puzzle why so many individuals claim as early as possible.[14]

[13] It is important to point out that the private annuity market in the US has a load of around 10% for a person with average mortality as estimated by Mitchell et al. (1999), which increases the gap between the prices of the Social Security annuity and private annuities even further.

[14] Consistent with our finding in this section, Bronshtein et al. (2016) show that individuals who claim benefits early and then buy private annuities or opt for defined benefits annuity are making a financial mistake that can cost them up to $250,000.

4 Baseline Model

4.1 Demographics and preferences

A model period is one year. Individuals enter the model at age 25. Until age R^E individuals make only labor supply and consumption/saving decisions, between ages R^E and R^D individuals also decide whether to start collecting Social Security pension benefits, after age R^D individuals cannot work and only make consumption/saving decisions.

Individuals face health uncertainty: at age t, an agent's health condition h_t can be either good ($h_t = 1$) or bad ($h_t = 0$), where h_t evolves according to an age-dependent Markov process, $\mathcal{H}_t(h_t|h_{t-1})$. Health affects productivity, medical expenses, and survival probability. We denote the probability to survive from period t to $t+1$ as ζ_t^h. Each period an agent faces a stochastic out-of-pocket medical expenditure shock x_t^h which depends on his age and health; we denote the probability distibution of medical shocks as $\mathcal{G}_t(x_t^h)$. Individuals after a certain age are also exposed to the risk of needing long-term care; these shocks arrive with age- and health-dependent probability pn_t^h. An agent who needs to move to a nursing home has to pay an out-of-pocket cost of xn_t.

An individual is endowed with one unit of time that can be used for either leisure or work. Labor supply (l_t) is indivisible: $l_t \in \left\{0, \bar{l}\right\}$. Work brings disutility modeled as a fixed cost of leisure ϕ_w. The leisure of an individual can be represented as $\widetilde{l_t}$ where:

$$\widetilde{l_t} = 1 - l_t - \phi_w \mathbf{1}_{\{l_t>0\}}.$$

Here $\mathbf{1}_{\{.\}}$ is an indicator function equal to one if its argument is true. In addition to consumption and leisure individuals derive utility from leaving bequests.

To separate the risk aversion from the inverse of the intertemporal elasticity of substitution (IES), we incorporate Epstein-Zin preferences in our model (Epstein and Zin, 1989). Specifically, we assume that an individual's utility over streams of consumption (c_t), leisure ($\widetilde{l_t}$), and bequeathed assets in the case of not surviving to the next period (k_{t+1}) can be represented in the following recursive form:

$$U_t = \left[\left(c_t^{\chi}\widetilde{l_t}^{1-\chi}\right)^{1-\gamma} + \beta\left\{\zeta_t^h E_t U_{t+1}^{1-\psi} + (1-\zeta_t^h)\eta\left(k_{t+1}+\phi\right)^{1-\psi}\right\}^{\frac{1-\gamma}{1-\psi}}\right]^{\frac{1}{1-\gamma}}$$

where χ is a parameter determining the relative weight of consumption in the consumption-leisure composite, ψ is the risk-aversion, $1/\gamma$ is the IES, β is the discount factor, η is the strength of the bequest motive, and ϕ is a shift parameter that controls to what extent bequest is a luxury good.[15]

4.1.1 Labor income, taxation, transfers and Social Security

The earnings of an individual are equal to $wz_t^h l_t$, where w is wage and z_t^h is the idiosyncratic productivity that depends on age (t) and health (h_t). All individuals pay an income tax $\mathcal{T}(y_t)$, where taxable income y_t is based on both labor and capital income. Working households also pay a Medicare (τ_{MCR}) payroll tax.

Individuals impoverished due to low earnings or high medical spending receive means-tested transfers T_t^{SI} that guarantee each household a minimum consumption level $\underline{c}$. This safety net is a reduced form representation of existing public transfer programs such as food stamps, Supplemental Security Income, disability insurance, and uncompensated care.

Working individuals pay a Social Security payroll tax (τ_{ss}). The Social Security tax rate for earnings above $\overline{y}_{ss}$ is zero. Social Security benefits $ss(AE, j^R)$ is a concave function of the average lifetime earnings (AE) and the age when the benefits were claimed (j^R). Average earnings evolve as follows:

$$AE_{t+1} = \begin{cases} AE_t + \dfrac{y_t}{35} & ;\ \text{if } t < 60 \\ AE_t + \dfrac{1}{35}\max\{0, y_t - AE_t\} & ;\ \text{otherwise} \end{cases}$$

where

$$y_t = \max\left\{wz_t^h l_t, \overline{y}_{ss}\right\}$$

Note that over the 35-year period from age 25 to 60, AE_t is updated every period, while after age 60 it is updated only if the current earnings exceed the average of previous earnings.[16]

The basic level of Social Security benefits ss^b corresponding to the full retirement age R^F, $ss(AE_t, j^R = R^F)$, is calculated as follows:

$$ss^b = \begin{cases} 0.9AE_t & ;\ \text{if } AE_t < B_1 \\ 0.9B_1 + 0.32(AE_t - B_1) & ;\ \text{if } B_1 \le AE_t < B_2 \\ 0.9B_1 + 0.32(B_2 - B_1) + 0.15(AE_t - B_2) & ;\ \text{if } AE_t \ge B_2, \end{cases} \tag{1}$$

where B_1 and B_2 are the bend points, i.e., the levels of AE_t when the replacement rate changes first from 0.9 to 0.32, then from 0.32 to 0.15. Social Security rules regarding benefits

[15] In this formulation of bequest motive we follow De Nardi (2004) and De Nardi et al. (2010). Note that when $\phi = 0$ bequests become a necessity.

[16] The Social Security benefits are a function of the average earnings of the 35 years with the highest earnings. We use a simplified version of this rule because otherwise we have to keep track of the entire previous earnings history as additional state variables, which makes our computation infeasible.

calculations change for each cohort; we use individuals born in 1936-1938 as our base cohort. The full retirement age (R^F) for our base cohort is 65 years, so we set $R^F = 65$.[17] We set the bend points B_1 to \$6,372 and B_2 to \$38,424 based on the Social Security benefits formula for 2000.[18]

The earliest age an individual can start receiving benefits (R^E) is 62 and the latest age the benefits can be claimed (R^D) is 70. The benefits of early claimers are reduced by 6.7% per year for ages between 62 and 65. Individuals who claim benefits after the full retirement age get their basic benefits increased by 6.5% for every year up to age 70. The full schedule of benefits/rewards for early/late claiming is shown in the first row of Table 1.

Individuals who are younger than the full retirement age, and who receive Social Security benefits but continue to work are subject to a Social Security earning tax t^{earn}.[19] This tax rate is determined as follows:

$$t^{earn} = \begin{cases} 0 & ;\ \text{if } wz_t^h l_t < \$10,080 \\ \min\left\{ ss(AE_t, j^R), \dfrac{wz_t^h l_t - \$10,080}{2} \right\} & ;\ \text{otherwise} \end{cases},$$

i.e., for individuals whose earnings exceed an exempt amount (\$10,080 in 2000), \$1 of benefits is withheld for every \$2 of earnings in excess of the exempt amount. It is important to note that benefits withheld this way are not lost; instead, they go towards increasing the future benefits. More specifically, the Social Security earning tax partially offsets the penalty for early claiming. For example, if an individual has all of his benefits withheld for an entire year, his benefits will be adjusted as if he claimed them one year later. To avoid keeping track of withheld benefits as an additional state variable, we approximate these rules as follows. If more than 50% of an individuals's benefits are withheld due to the earning tax we increase j^R by one year. Otherwise, we do not make any adjustments.[20]

4.1.2 Timing in the model

The timing in the model is as follows. In the beginning of the period, individuals learn their productivity and health status. Based on this information, an individual decides his labor supply (l_t). An individual who is older than age R^E also decides whether to claim

[17] For individuals born in 1936 and 1937 the full retirement age is 65 years, for individuals born in 1938 it is 65 years and 2 months.

[18] These numbers correspond to the annual benefits, they are derived by multiplying the bend points corresponding to monthly benefits by 12.

[19] Starting from 2000, the Social Security earning tax for individuals who reach the full retirement age was abolished.

[20] Our results do not significantly change if we only adjust the claiming age when 100% of benefits are withheld.

Social Security benefits. We denote the claiming decision as i_t^C; $i_t^C = 1$ if an individual claims benefits and $i_t^C = 0$ otherwise. Afterward, the out-of-pocket medical shock (x_t^h) is realized; for individuals older than age R^D the nursing home shock (xn_t) is realized. At the very end of the period, consumption/saving decisions are made. An individual who reaches age R^D and has yet to claim benefits must claim benefits. Individuals after age R^D only make consumption/saving decisions.

4.1.3 Optimization problem

Individuals younger than the earliest claiming age $\left(t < R^E\right)$. The state variables for an individual younger than age R^E at the beginning of each period are capital ($k_t \in \mathbb{K} = R^+ \cup \{0\}$), health ($h_t \in \mathbb{H} = \{0,1\}$), idiosyncratic labor productivity $\left(z_t^h \in \mathbb{Z} = R^+\right)$, average lifetime earnings ($AE_t \in \mathbb{A} = R^+$), and age $\left(t \in \mathbb{T} = \left\{1, 2, ..., R^E - 1\right\}\right)$. We denote the vector of state variables of an individual of age t as $\mathbb{S}_t$: $\mathbb{S}_t = (k_t, h_t, z_t^h, AE_t)$.

The value function of an individual in this age range can be written as follows:

$$V_t(\mathbb{S}_t) = \max_{l_t} \left\{ \sum_{x_t^h} \mathcal{G}_t\left(x_t^h\right) W_t(\mathbb{S}_t; l_t, x_t^h)^{1-\psi} \right\}^{\frac{1}{1-\psi}} \tag{2}$$

where

$$W_t(\mathbb{S}_t; l_t, x_t^h) = \max_{c_t, k_{t+1}} \left\{ \begin{array}{c} \left(c_t^{\chi} \widetilde{l}_t^{1-\chi}\right)^{1-\gamma} + \\ \beta \left[\zeta_t^h E_t\left(V_{t+1}(\mathbb{S}_{t+1})\right)^{1-\psi} + (1-\zeta_t^h)\eta\left(k_{t+1} + \phi\right)^{1-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \end{array} \right\}^{\frac{1}{1-\gamma}} \tag{3}$$

subject to

$$k_t(1+r) + wz_t^h l_t + T_t^{SI} = k_{t+1} + c_t + x_t^h + Tax \tag{4}$$

$$T_t^{SI} = \max\left(0, \underline{c} + x_t^h + Tax - k_t(1+r) - wz_t^h l_t\right) \tag{5}$$

$$Tax = \mathcal{T}\left(y_t^{tax}\right) + \tau_{ss}\min\left(wz_t^h l_t, \overline{y}_{ss}\right) + \tau_{MCR} wz_t^h l_t \tag{6}$$

$$y_t^{tax} = k_t r + wz_t^h l_t \tag{7}$$

The conditional expectation on the right-hand side of Eq.(3) is over z_{t+1}^h and h_{t+1}. Eq.(4) is the budget constraint. Eq.(5) describes the means-tested transfers that provide the minimum consumption guarantee $\underline{c}$. In Eq.(6), the first term is the income tax and the last two terms are payroll taxes. Eq.(7) describes the taxable income.

Individuals older than the earliest claiming age but younger than the latest claiming age $\left(R^E \le t < R^D\right)$ and who has yet to claim benefits. An individual in this age range has to decide whether to claim Social Security benefits or not. His value function can be written as follows:

$$V_t(\mathbb{S}_t) = \max_{l_t, i_t^C} \left\{ \sum_{x_t^h} \mathcal{G}_t\left(x_t^h\right) W_t^E(\mathbb{S}_t; l_t, i_t^C, x_t^h)^{1-\psi} \right\}^{\frac{1}{1-\psi}} \tag{8}$$

$$W_t^E(\mathbb{S}_t; l_t, i_t^C = 0, x_t^h) = \max_{c_t, k_{t+1}} \left\{ \begin{array}{c} \left(c_t^{\chi} \tilde{l}_t^{1-\chi}\right)^{1-\gamma} + \\ \beta \left[\zeta_t^h E_t \left(V_{t+1}(\mathbb{S}_{t+1})\right)^{1-\psi} + (1-\zeta_t^h)\eta\left(k_{t+1}+\phi\right)^{1-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \end{array} \right\}^{\frac{1}{1-\gamma}}$$

$$W_t^E(\mathbb{S}_t; l_t, i_t^C = 1, x_t^h) = \max_{c_t, k_{t+1}} \left\{ \begin{array}{c} \left(c_t^{\chi} \tilde{l}_t^{1-\chi}\right)^{1-\gamma} + \\ \beta \left[\zeta_t^h E_t \left(V_{t+1}^C(\mathbb{S}_{t+1}, j^R)\right)^{1-\psi} + (1-\zeta_t^h)\eta\left(k_{t+1}+\phi\right)^{1-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \end{array} \right\}^{\frac{1}{1-\gamma}}$$

subject to

$$k_t(1+r) + wz_t^h l_t + ss(AE_t, t)\mathbf{1}_{\{i_t^C=1\}} + T_t^{SI} = k_{t+1} + c_t + x_t^h + Tax \tag{9}$$

$$T_t^{SI} = \max\left(0, \underline{c} + x_t^h + Tax - k_t(1+r) - wz_t^h l_t - ss(AE_t, t)\mathbf{1}_{\{i_t^C=1\}}\right)$$

$$Tax = \mathcal{T}\left(y_t^{tax}\right) + \tau_{ss}\min\left(wz_t^h l_t, \overline{y}_{ss}\right) + \tau_{MCR} wz_t^h l_t + t^{earn}\mathbf{1}_{\{t<R^F, i_t^C=1, l_t=\bar{l}\}} \tag{10}$$

$$y_t^{tax} = k_t r + wz_t^h l_t + ss(AE_t, t)\mathbf{1}_{\{i_t^C=1\}}$$

$$j^R = \begin{cases} t & ;\ \text{if } t^{earn} < 0.5ss(AE_t, t) \\ t+1 & ;\ \text{otherwise} \end{cases} \tag{11}$$

Note that the interim value function W_t^E takes different forms depending on whether an individual claims benefits or not; in the former case, there will be another state variable next period: age at which he begins collecting benefits. Eq.(9) includes Social Security benefits $ss(AE_t, t)$ for individuals who choose to collect benefits in the current period (i.e., $i_t^C = 1$).

Eq.(10) includes a Social Security earning tax for individuals who are younger than the full retirement age and who claimed benefits but continue working. Eq.(11) allows the claiming age to be increased by one year for working individuals who claimed in the current period and had most of their benefits withheld by the Social Security earning tax.

Individuals older than the earliest claiming age but younger than the latest claiming age $\left(R^E \leq t < R^D\right)$ and who already claimed benefits. An individual in this category has an additional state variable j^R, the age at which he started collecting benefits. The value function of an individual in this category can be written as follows:

$$V_t^C(\mathbb{S}_t, j^R) = \max_{l_t} \left\{ \sum_{x_t^h} \mathcal{G}_t\left(x_t^h\right) W_t^C(\mathbb{S}_t, j^R; l_t, x_t^h)^{1-\psi} \right\}^{\frac{1}{1-\psi}} \tag{12}$$

$$W_t^C(\mathbb{S}_t, j^R; l_t, x_t^h) = \max_{c_t, k_{t+1}} \left\{ \begin{array}{c} \left(c_t^{\chi} \widetilde{l}_t^{1-\chi}\right)^{1-\gamma} + \\ \beta \left[\zeta_t^h E_t \left(V_{t+1}^C(\mathbb{S}_{t+1}, \widetilde{j}^R)\right)^{1-\psi} + (1-\zeta_t^h)\eta\left(k_{t+1}+\phi\right)^{1-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \end{array} \right\}^{\frac{1}{1-\gamma}}$$

subject to

$$k_t(1+r) + wz_t^h l_t + ss(AE_t, j^R) + T_t^{SI} = k_{t+1} + c_t + x_t^h + Tax \tag{13}$$

$$T_t^{SI} = \max\left(0, \underline{c} + x_t^h + Tax - k_t(1+r) - wz_t^h l_t - ss(AE_t, j^R)\right)$$

$$Tax = \mathcal{T}\left(y_t^{tax}\right) + \tau_{ss}\min\left(wz_t^h l_t, \overline{y}_{ss}\right) + \tau_{MCR} wz_t^h l_t + t^{earn}\mathbf{1}_{\{t<R^F, i_t^C=1, l_t=\bar{l}\}}$$

$$y_t^{tax} = k_t r + wz_t^h l_t + ss(AE_t, j^R) \tag{14}$$

$$\widetilde{j^R} = \begin{cases} j^R & ;\ \text{if } t^{earn} < 0.5ss(AE_t, j^R) \\ j^R + 1 & ;\ \text{otherwise} \end{cases} \tag{15}$$

Note that the age at which an individual first claimed benefits $\left(j^R\right)$ affects his pension income $ss(AE_t, j^R)$ but this age is increased if he is subject to the Social Security earning tax and most of his benefits are withheld by the tax (Eq.15).

Individuals after age R^D. An individual older than age R^D only makes consumption-saving decisions and his state variables are capital (k_t), health (h_t), average lifetime earnings ($AE \in \mathbb{A} = R^+$), age when he first claimed benefits ($j^R \in \mathbb{J} = \{R^E, ..., R^D\}$), and age ($t$). Denote the vector of state variables as $\mathbb{S}_t^R = (k_t, h_t, x_t^h, AE, j^R)$. The value function of an individual in this age range can be written as follows:

$$V_t^R(\mathbb{S}_t^R) = \left\{ \sum_{x_t} \sum_{xn_t} \mathcal{G}_t \left(x_t^h\right) pn_t^h W_t^R(\mathbb{S}_t^R; x_t^h, xn_t)^{1-\psi} \right\}^{\frac{1}{1-\psi}}$$

where

$$W_t^R(\mathbb{S}_t^R; x_t^h, xn_t) = \max_{c_t, k_{t+1}} \left\{ \begin{array}{c} \left(c_t^{\chi} \tilde{l}_t^{1-\chi}\right)^{1-\gamma} + \\ \beta \left[\zeta_t^h E_t \left(V_{t+1}^R(\mathbb{S}_{t+1}^R)\right)^{1-\psi} + (1-\zeta_t^h)\eta \left(k_{t+1} + \phi\right)^{1-\psi}\right]^{\frac{1-\gamma}{1-\psi}} \end{array} \right\}^{\frac{1}{1-\gamma}} \tag{16}$$

subject to:

$$k_t (1+r) + ss(AE, j^R) + T_t^{SI} = k_{t+1} + c_t + \mathcal{T}\left(y_t^{tax}\right) + x_t^h + xn_t$$

$$T_t^{SI} = \max\left(0, \underline{c} + \mathcal{T}\left(y_t^{tax}\right) + x_t^h + xn_t - k_t (1+r) - ss(AE, j^R)\right)$$

$$y_t^{tax} = k_t r + ss(AE, j^R)$$

Note that the interim value function W_t^R is conditional on the realization of the out-of-pocket medical spending shock x_t^h and the nursing home shock xn_t.

5 Data and calibration

5.1 Data and sample selection

An ideal dataset for our study would be a representative panel that tracks individuals over the entire life-cycle and includes information on labor supply, labor income, savings, medical spending, and Social Security claiming behavior. However, a dataset like this does not exist for the US, so we combine information from the three datasets: the Medical Expenditure Panel Survey (MEPS), the Health and Retirement Study (HRS) and the Panel Study of Income Dynamics (PSID). In all three datasets, we select a sample of male individuals. We use 2002 as the base year, and all level variables are normalized to the base year using the

Consumer Price Index (CPI).

The MEPS is a nationally representative survey of households with a particular focus on medical usage and health insurance variables. It contains individuals of all ages but age is top-coded at 85. The MEPS has a short panel dimension: each individual is observed for at most two years. Medical spending reported in the MEPS is cross-checked with insurers and providers which improves its accuracy.[21] We use the MEPS to construct data moments related to medical spending (except for nursing home spending), health, labor income, and employment.[22] We use fourteen waves of the MEPS from 1999 to 2012. We construct a sample of male individuals who are at least 20 years old. That includes 80,984 individuals (or 152,308 individual-year observations).

The HRS is a nationally representative sample of individuals over the age of 50. We use the RAND Version P of this dataset to construct moments related to claiming behavior and nursing home costs. When constructing claiming behavior moments, we use males born around 1937 as our base cohort. We choose this cohort because we need to consider individuals who (i) face similar rules regarding early/late claiming benefit adjustments, (ii) are entirely retired (or older than 70) by the last wave of the HRS we consider. To increase the number of observations, we use a window of 3 years, i.e., we consider all males born in years 1936-1938, which leaves us with 864 individuals. To construct moments related to nursing home costs, we use a larger sample by pooling waves 2002-2012 of the HRS. We use a sample of individuals older than 70 who do not have missing information on nursing home use, health or age. This leaves us with 8,546 individuals (or 35,487 individual-year observations).

The PSID is a national representative panel survey of individuals and their families. It started in 1968 on an annual basis and from 1997 it is administered biennially. We use the PSID to construct data moments related to wealth accumulation.

5.2 Demographics and preferences

In the model, agents are born at age 25 and can live to a maximum age of 99. For survival probabilities, we use the cohort life table for men born in 1940 provided by the Social Security Administration.[23] To adjust conditional survival probabilities ζ_t^h for differences in health, we follow Attanasio et al. (2011). Specifically, we use the HRS to estimate the difference

[21] Pashchenko and Porapakkarm (2016a) provide more details on the MEPS dataset.

[22] The MEPS dose not contain information on nursing home spending because it only samples the non-institutionalized population and thus excludes nursing home residents.

[23] The Social Security Administration publishes cohort life tables by ten-year intervals, i.e., for individuals born in 1930,1940, etc. We use the cohort born in 1940 since it is the closest to our base cohort's birth year (1937).

in survival probabilities between people in good and bad health.[24] We first estimate the survival probability as a function of a cubic polynomial of age, using a probit model for each health status. We then compute the *survival premium* - the difference between the estimated survival probabilities of healthy and unhealthy males for each age. From the Social Security Administration cohort life tables, we know the average survival probability of males. From the MEPS, we can estimate the fraction of people in each health category for each age. Using this information, we can recover the survival probabilities of healthy and unhealthy people for each age.

We set the consumption share in the utility function (χ) to 0.5 to facilitate matching the employment profile. This number is within the range estimated by French (2005).[25] We set the labor supply of those who choose to work ($\bar{l}$) to 0.4. We define a person as employed if he earns at least $2,678 per year in base year dollars (this corresponds to working at least 10 hours per week and earning the minimum wage of $5.15 per hour). The fixed leisure cost of work ϕ_w is calibrated to match the age profile of employment.

A common approach in structural life-cycle and macroeconomic models is to use the discount factor β to match wealth accumulation over the life-cycle or the aggregate wealth to income ratio. This approach is justified by the fact that saving decisions of individuals are very responsive to the discount factor. However, the studies that use wealth accumulation decisions to identify the discount factor usually abstract from Social Security claiming decisions.[26] In our model, the decision to claim Social Security benefits is endogenous and we show that it is strongly affected by the value of the discount factor. Consequently, we adjust the discount factor to match the percentage of people claiming benefits at the earliest possible age (62). The resulting β is 0.962, which is equivalent to the rate of time preferences of 3.95%. In Section 6.1, we discuss our identification of the discount factor in more detail.

Since in our calibration strategy the discount factor is used to match the claiming behavior, we are left with four parameters to match wealth profiles over the life-cycle: the intertemporal elasticity of substitution ($IES = 1/\gamma$), the risk aversion (ψ), the strength of the bequest motive (η) and the degree to which bequest is a luxury good (ϕ). The risk aversion and the IES affect wealth accumulation over the working stage of the life-cycle; we set the risk aversion to 4 and 1/IES to 1.5 (IES equals to around 0.67). It is important to note

[24] We define health categories based on self-reported health status in the HRS. We classify individuals as being healthy or in good health if they report having *excellent*, *very good*, or *good* health. Meanwhile, we classify those reporting *fair* or *poor* health as being unhealthy or in bad health. We follow the same classification when defining health status in the MEPS data. (See Section 5.3.)

[25] Given we have indivisible labor supply, we cannot pin down this parameter using a moment in the data.

[26] Gustman and Steinmeier (2005 and 2015) are an exception; they allow for endogenous claiming decisions but still use wealth profiles to identify the discount factor. They show that a model with the discount factor identified this way falls short of replicating the claiming decisions observed in the data.

that to match the wealth accumulation profile, we need to set the risk aversion relatively high and make it significantly different from 1/IES. The risk aversion by itself has limited power to affect wealth accumulation if it is equal to the inverse of the IES, because even though higher risk aversion results in a stronger precautionary motive, it also implies a lower IES. Low IES increases preferences for a flatter consumption profile and thus flattens the wealth accumulation profile. To break apart this relationship, we need to distinguish the risk aversion from the inverse of the IES.[27]

After the first half of the life-cycle, bequest motives start having a stronger impact on wealth dynamics. The bequest function that we use implies bequests are a luxury good, i.e., the bequest motives become operational only when individuals' assets are above a certain threshold, in which case the amount of assets they allocate to bequests is determined by the marginal propensity to bequeath (MPB). The threshold and the MPB can be expressed as functions of the parameters η and ϕ in a simple two-period consumption-savings model (see De Nardi et al. (2010) and Pashchenko (2013) for more details). We adjust the threshold to match the wealth profiles of individuals in the bottom 25th percentile of the wealth distribution and we adjust the MPB to match the profiles for the median and the 75th percentile. The resulting numbers are \$3,605 for the threshold and 0.969 for the MPB.[28]

5.3 Health, medical expense and nursing home shocks

To construct our health measure, we use self-reported health status in the MEPS. In the MEPS an individual's self-reported health status is coded as 1 for excellent, 2 for very good, 3 for good, 4 for fair and 5 for poor. Individuals in the MEPS are interviewed five times over a two-year period and the question about health is asked in every interview round. We classify a person as being in bad health if his average health score over that year is greater than 3.

To construct the age-dependent health transition matrix, we first compute the transition matrices for ages 30, 40,...,70. In each case, we use a sample within a 10-year age bracket. For example, to construct the transition matrix for age 40, we pool individuals between ages 35 and 44. We then construct the health transition matrix for all the remaining ages by using polynomial degree two approximation.

Medical expenses in our model correspond to the out-of-pocket medical expenditures in the MEPS dataset. In our calibration, the medical expense shock is approximated by a 3-state discrete health- and age-dependent stochastic process. For each age and health status, these three states correspond to the average out-of-pocket medical expenses for three groups:

[27] See Pashchenko and Porapakkarm (2019) for a detailed discussion of this issue.
[28] The corresponding values of η and ϕ are 2.4^{11} and $115,000$, respectively.

those with out-of-pocket medical spending below the 50th, between the 50th and 95th, and above the 95th percentile, respectively.[29]

We estimate the risk of incurring a nursing home shock (pn_t^h) from the HRS as follows. First, we compute the probabilities of entering a nursing home for selected ages: 67, 72, 77, 82, 87, and 95. In each case, we use a sample within a 5-year age bracket. That is, we compute the percentage of individuals who report staying in a nursing home in each interview round for the following age groups: 65-69, 70-74, 75-79, 80-84, 85-89, and older than 90. Since the HRS is a biennnial survey, we convert these numbers into annual probabilities under the assumption that the probability to stay in a nursing home over the two-year interval is equal to the product of the annual probabilities. We then extrapolate the probability to stay in a nursing home at other ages using polynomial degree three approximation. We do this separately for healthy and unhealthy males. The HRS also reports the number of nights for all nursing home stays. To compute the average nursing home costs, we multiply the number of nights by the average daily rate for a semiprivate room in a nursing home, which was \$158.26 in 2003 according to Metlife (2003).[30]

5.4 Taxes and government transfers

We parameterize the tax function $\mathcal{T}(y)$ following Gouveia and Strauss (1994):

$$\mathcal{T}(y) = a_0 \left[y - \left(y^{-a_1} + a_2 \right)^{-1/a_1} \right]$$

As in Gouveia and Strauss (1994), we set a_0 and a_1 to 0.258 and 0.768, respectively. We set the parameter a_2 to 0.616 following Pashchenko and Porapakkarm (2013).

The Medicare, Social Security and consumption tax rates were set to 2.9 percent, 12.4 percent and 5.67 percent, respectively. The maximum taxable income for Social Security ($\overline{y}_{ss}$) is set to \$76,200 (corresponding to year 2000).

When calibrating the minimum consumption floor $\underline{c}$, we use the fact that this safety net has a significant effect on the labor supply of individuals with low assets, such as the young.

[29] The MEPS tends to underestimate aggregate medical expenditures (Pashchenko and Porapakkarm, 2016b). The ratio of aggregate medical spending in the National Health Expenditure Account (NHEA) divided by aggregate medical spending in the MEPS for people younger and older than 65 years old constitute 1.6 and 1.9, respectively. These numbers were computed by averaging over the years 2002, 2004, 2006, 2008, and 2010 (the years when NHEA provides aggregate statistics by age). The larger discrepancy for the older group is due to the fact that the MEPS does not include nursing home expenditures. To bring aggregate medical expenses computed from the MEPS in line with the corresponding statistics in the NHEA, we multiply our estimated medical expenses by 1.60. We use this number for both people younger and old than 65 years old because we explicitly account for nursing home spending in our model.

[30] The MetLife Market Survey of Nursing Home and Home Care Costs, August 2003 is available at http://www.lifestyleinsurance.com/media/2003%20NHHC%20Market%20survey.pdf

We set the minimum consumption floor to \$3,500 to match the employment rate among individuals in the age group 30-34 years old. Our estimate of the consumption floor is in line with other models with medical expense shocks that consider the entire life-cycle (e.g. Capatina, 2015).

5.5 Labor productivity process

We specify the individual productivity as following:

$$z_t^h = \lambda_t^h \exp(v_t) \exp(\xi) \tag{17}$$

where λ_t^h is the deterministic component that depends on age and health; while the stochastic component consists of the persistent shock v_t and a fixed productivity type ξ:

$$v_t = \rho v_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{18}$$

$$\xi \sim N(0, \sigma_\xi^2)$$

For the persistent shock v_t, we set ρ to 0.98 and σ_ε^2 to 0.02 following the incomplete market literature (Storesletten et al., 2004; Hubbard et al., 1994; French, 2005). We set the variance of the fixed productivity type (σ_ξ^2) to 0.242 as in Storesletten et al. (2004). In our computation, we discretize the shock processes using 9 gridpoints for v_t and 2 gridpoints for ξ. To construct the distribution of individuals just entering the model, we draw v_1 in Eq.(18) from the $N(0, 0.352^2)$ distribution following Heathcote et al. (2010).

To estimate the deterministic part of productivity λ_t^h, we need to account for the fact that we only observe labor income of workers and we do not know the potential labor income of non-workers. These two groups are not the same because there is a selection into employment. To avoid the selection bias, we adapt the method developed by French (2005). We first estimate the average labor income profiles from the MEPS dataset for all workers. Conditional on other parameters of the model, we then guess λ_t^h in Eq.(17) and feed the resulting productivity into our model. After solving and simulating the model, we compute the average labor income profile of workers in our model and compare it with the data. We update our guess of λ_t^h and reiterate until the labor income and the employment profiles in the model match those in the data.

We set the wage rate w such that the level of average earnings in our model is the same as in the data. The model parametrization is summarized in Table 5 in Appendix A.

5.6 Baseline model performance

Figure (2) compares the employment profile (left panel) and the average labor income of workers (right panel) in the data and in the model. The model closely tracks the data. The average labor income profiles and employment profiles were targeted in our calibration by adjusting the exogenous productivity (λ_t^h), the disutility from work parameter (ϕ_W) and the consumption floor ($\underline{c}$).

The left panel of Figure (3) shows that our calibration strategy of adjusting the risk aversion, IES, and the bequest function parameters allows us to capture the wealth profiles for the bottom 25th percentile, median and top 25th percentile of the empirical wealth distribution. The right panel of Figure (3) compares the claiming behavior in our model with that of the cohort born between 1936-1938 in the data. In our calibration, we target the percentage of individuals who start collecting Social Security benefits as early as possible (at age 62) but the model is able to capture the overall pattern of claiming for other ages as well.

6 Results

This section is organized as follows. We start by illustrating the role of the discount factor in individuals' decision regarding at what age to claim Social Security benefits. We then extend this discussion by showing the effect of the break-even rate of the Social Security annuity in claiming decisions. Next, we consider how factors previously shown to be important for decisions to annuitize through private markets affect claiming behavior or, equivalently, the demand for Social Security annuity. Finally, we consider a policy experiment where we allow individuals who delay claiming to receive the resulting increase in their pension income as lump-sum benefits.

6.1 The role of the discount factor

To illustrate the role of the discount factor in claiming decisions, in this section we consider two alternative versions of the model. In the first version, the discount factor is fixed at 0.95 which is lower than the baseline value of 0.962. In the second version, we set the discount factor to a higher value of 0.97. In each case, we recalibrate our model until we match the wealth and employment profiles in the data.

Figure (4) shows that for each of the alternative discount factors, the model parameters can be adjusted to match the employment and wealth profiles in the data. However, as shown in Figure (5), these two versions of the model fail to account for the observed Social

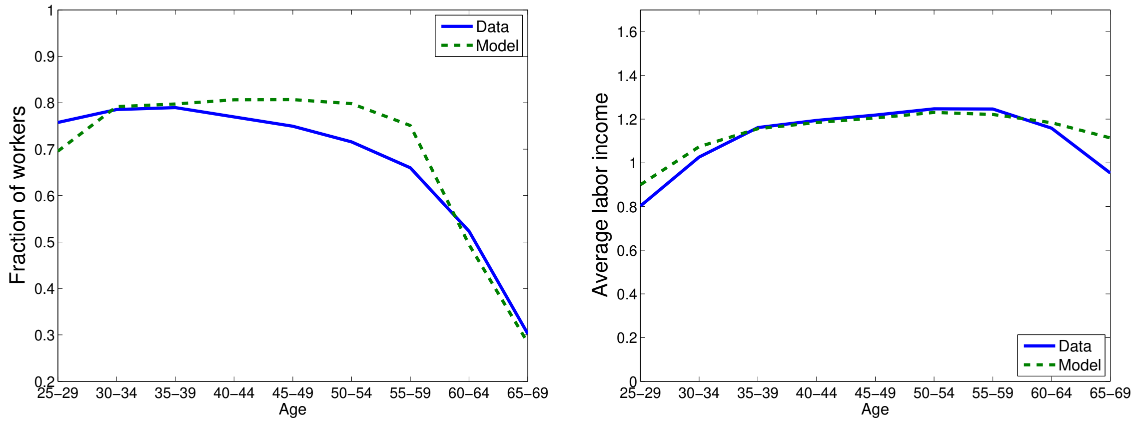

Figure 2: Left panel: fraction of workers by age. Right panel: average income among workers by age. All level variables are normalized by average income.

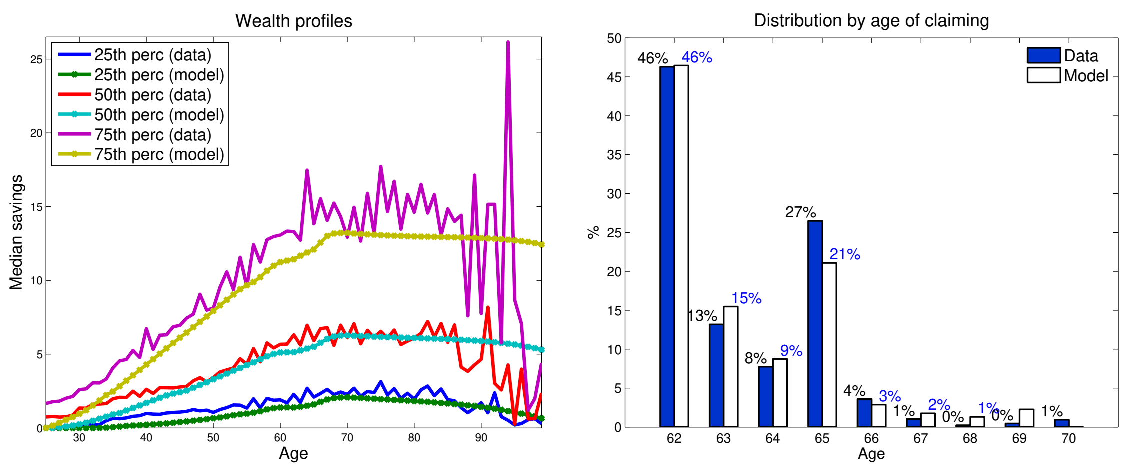

Figure 3: Left panel: wealth profiles by age. Right panel: distribution by claiming age. All level variables are normalized by average income.

Security claiming behavior, especially for the percentage of individuals claiming at age 62. In particular, the model with the low discount factor produces too many people claiming at age 62 (57% in the alternative model versus 46% in the baseline), while in the model with the high discount factor too few people claim at age 62 (24% in the alternative model versus 46% in the baseline).

The intuition behind why the discount factor plays a key role in accounting for claiming behavior is as follows. Individuals who delay claiming are 'purchasing' Social Security annuity, i.e., they forgo current benefits to increase the future stream of income. The subjective valuation of this extra stream of income depends crucially on the discount factor. If the

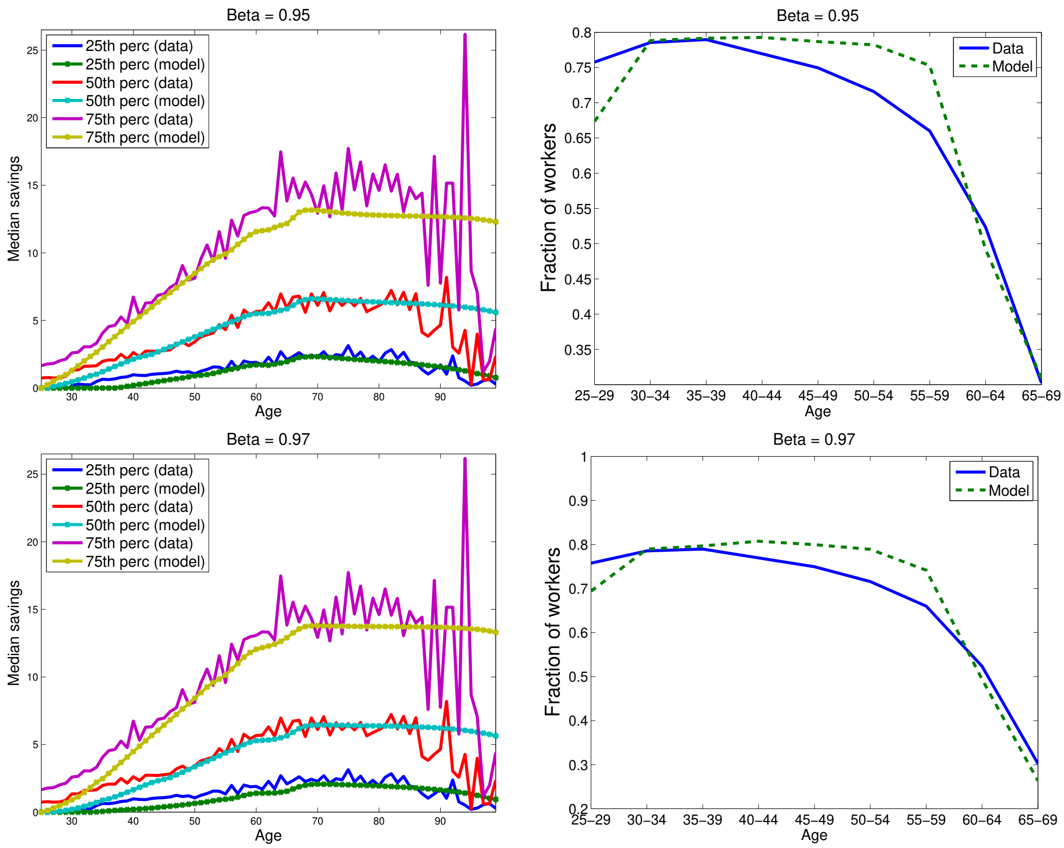

Figure 4: Wealth and employment profiles in the two versions of the model. Top panel: the discount factor is lower than in the baseline (0.95). Bottom panel: the discount factor is higher than in the baseline (0.97). All level variables are normalized by average income.

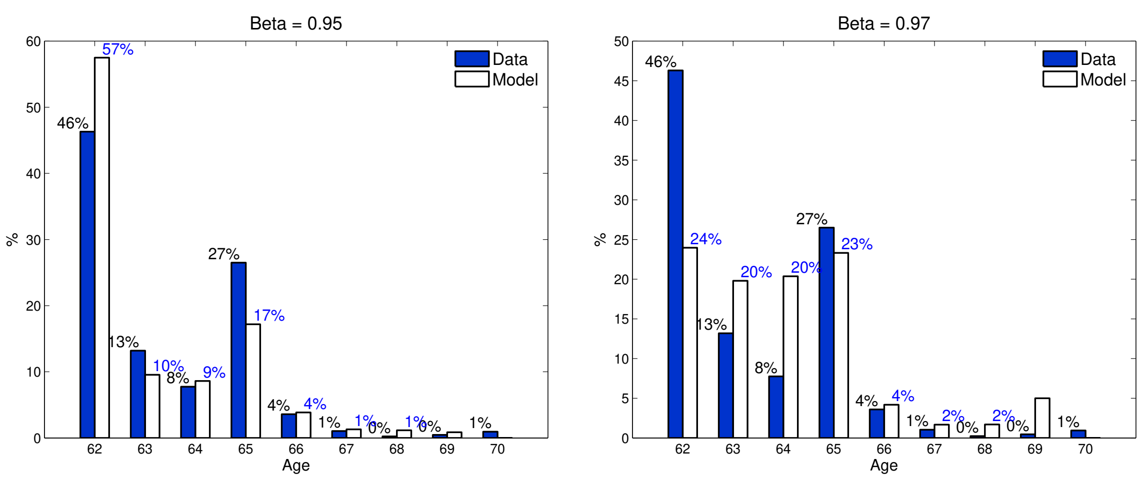

Figure 5: Distribution by claiming age in the two versions of the model. Left panel: the discount factor is lower than in the baseline (0.95). Right panel: the discount factor is higher than in the baseline (0.97)

discount factor is low, this stream of income is valued less and individuals choose to forgo this annuity by claiming as early as possible.

It is important to note that our results suggest that individuals' subjective valuation of the additional pension income is lower than the "price" of the Social Security annuity. In the next section, we show how the demand for public annuity depends on its implied price.

6.2 The role of the break-even rate

Our goal in this section is to study the effect of the Social Security annuity break-even rate on the demand for this annuity. The break-even rate is defined as the interest rate that equates the present value of the stream of lifetime income to its price for an individual with average mortality.

In the following set of experiments, we readjust the schedule of penalties/rewards for early/late claiming so that the price of Social Security annuity is actuarially fair for an individual with average mortality for different break-even rates. Specifically, we consider two break-even rates: 2% and 5%. The first rate is below the subjective rate of time preferences estimates in our model (around 4%), while the second one is above it. Rows 2 and 3 of Table 2 display the resulting adjustments to Social Security benefits. We explain the details of the computation of these adjustments in Appendix B.

Figure (6) shows the distribution by claiming age of individuals in these experiments. As we can see in the left panel of the figure, when the break-even rate is below the subjective rate of time preferences, more people would claim at age 62, i.e., the demand for Social Security annuity would be lower than in the baseline economy. In contrast, when the break-even rate is above the subjective rate of time preferences (right panel of the figure), the demand for this annuity significantly increases. The percentage of people claiming as early as possible decreases from 46% to 31%, and the percentage of individuals claiming after the full retirement age increases from 8% to 39%. Thus, changing the way the Social Security annuity is priced can lead to a significant delay in claiming, but for this to occur the break-even rate for this annuity should be above the individuals' rate of time preferences.

Age	62	63	64	65	66	67	68	69	70
Actual	80%	86.7%	93.3%	100%	106.5%	113%	119.5%	126%	132.5%
<u>Counterfactuals:</u>									
$r = 2\%$	81.6%	87.2%	93.3%	100%	107.5%	115.8%	125.2%	135.6%	147.5%
$r = 5\%$	76.6%	83.5%	91.3%	100%	109.8%	120.9%	133.4%	147.7%	164%

Table 2: The counterfactual percentages of full benefits for early/late claiming that result from actuarially fair pricing of the Social Security annuity for different break-even rates.

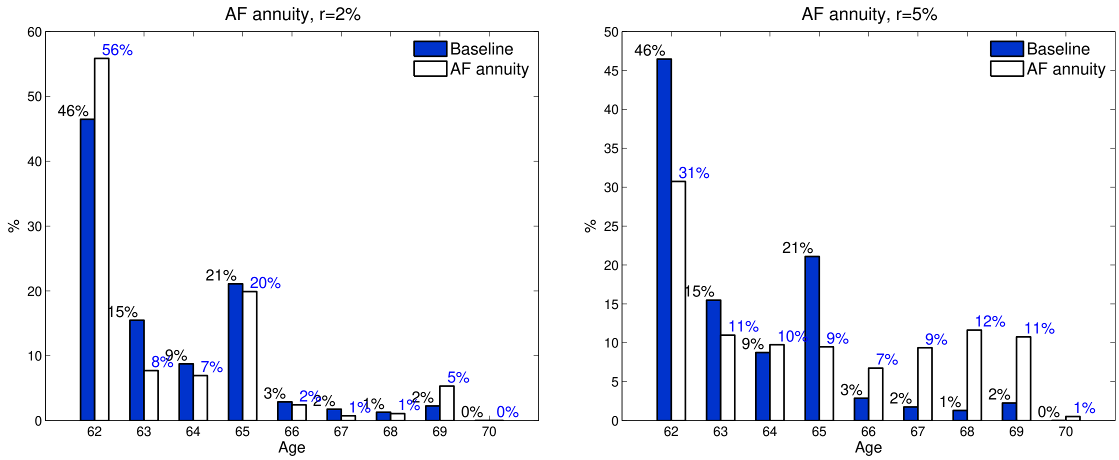

Figure 6: Distribution by claiming age in two versions of the model where the Social Security annuity is priced actuarially fair. Left panel: the price is based on an interest rate of 2%. Right panel: the price is based on an interest rate of 5%.

6.3 The role of various impediments to private annuitization

In this section, we consider claiming decisions in the context of the well-known annuity puzzle. The unwillingness of people to purchase private annuities has been attributed to the following factors: market frictions (adverse selection and minimum purchase requirements), medical spending, means-tested benefits, pre-annuitized wealth, and bequest motives. Since, as we discussed earlier, the first explanation does not apply in our context, in this section we provide quantitative analysis of the effect of the remaining impediments to private annuitization on claiming decisions.

Medical spending Davidoff et al. (2005) show theoretically that uncertain medical expenses can affect demand for annuities and the direction of this effect depends on the timing of the risk: medical spending risk early in life can decrease demand for annuities while late in life it can produce the opposite effect. To understand the effect of uncertain medical expenses on demand for Social Security annuity, we consider an experiment where both medical and nursing home shocks are set to zero.

Panel (a) in Figure (7) and the second column in Table 3 illustrate the results of this experiment. Notice that the percentage of individuals claiming as early as possible increases (from 46% in the baseline to 53%), in other words, without medical expenses there is even less demand for Social Security annuity.

This decrease in demand happens because medical spending increases quickly with age, i.e., medical risk is concentrated late in life. Thus, when an individual survives until very old age (an insurable event for annuities) this likely coincides with a situation where an

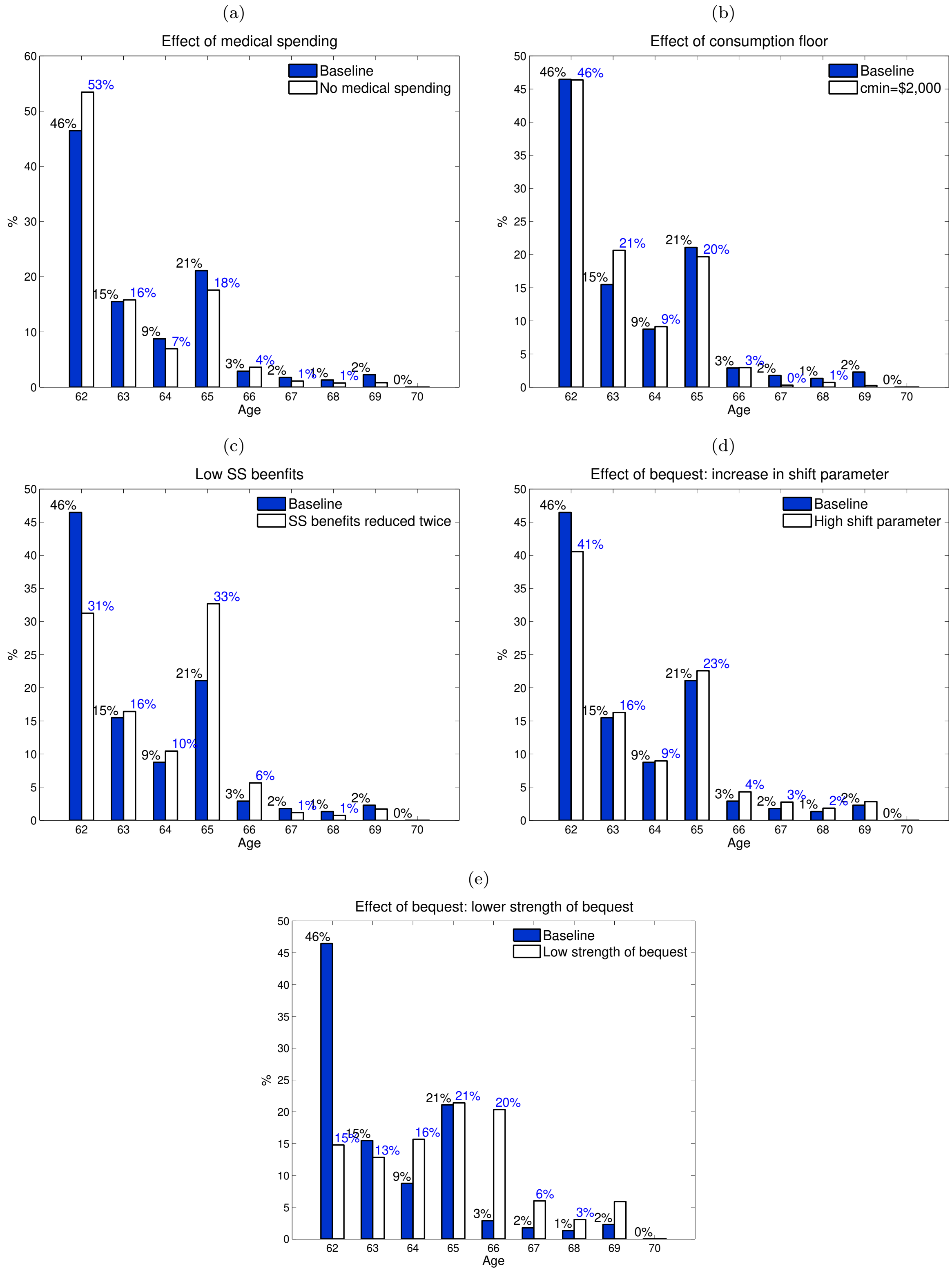

Figure 7: Distribution by claiming age in the baseline vs counterfactuals

individual faces high medical or nursing home spending. This complementarity makes Social Security annuity more valuable in the presence of medical spending.

Claiming	Baseline	No medical shocks	Low $\overline{c}$	Low Social Security benefits	High bequest threshold	Low bequest strength
Early (62-64)	71%	76%	76%	58%	66%	43%
Full retirement age (65)	21%	18%	20%	33%	23%	21%
Late (66-70)	8%	6%	4%	9%	12%	35%

Table 3: Percentage of individuals claiming early, late and at the full retirement age in the baseline vs counterfactuals.

Means-tested benefits Means-tested benefits can decrease the demand for private annuities because they de facto represent annuity-like income for individuals who outlive their assets and thus crowd-out demand for private longevity insurance (Butler et al., 2017, Pashchenko, 2013). In our model, means-tested benefits are modeled as the consumption minimum floor that is set to \$3,500 in the baseline calibration. To understand the importance of this public program in determining claiming behavior, we consider an experiment where the consumption floor is decreased to \$2,000, and its results are displayed in the Panel (b) of Figure (7) and the third column of Table 3.

Lowering the consumption floor does not have an effect on the percentage of individuals claiming as early as possible but more people start claiming at age 63 and less after the full retirement age. Note that since we are considering a full life-cycle model, the means-tested programs matter not only for decisions to annuitize but also for labor supply and savings decisions early in life. Individuals facing a less generous consumption floor work and save more and arrive at the retirement stage with more assets, they can also afford to retire earlier which explains a small shift towards early claiming. This experiment shows the importance of taking the early stage of life into account when considering the effect of public insurance programs on late-life decisions. Individuals who face less generous public support adjust their behavior over the working stage of the life-cycle and this can have more of an impact on their demand for public annuities than the change in the insurance arrangements per se.

Pre-annuitized wealth Even individuals who claim Social Security benefits as early as possible are entitled to a stream of life-time income, i.e., they already have part of their lifetime wealth annuitized. One reason behind the reluctance to delay claiming can be that the fraction of this pre-annuitized wealth is already high and individuals do not want to increase it any further.

To understand the role of this factor in claiming decisions, we consider an experiment where we scale down the Social Security program. Specifically, we assume that individuals pay half as much payroll tax (6.2% as opposed to 12.4%) and receive half the benefits, i.e., the basic benefits ss^b in Eq.(1) are multiplied by 0.5.

Panel (c) in Figure (7) and the forth column in Table 3 illustrate the results of this experiment. There is a noticeable decline in the number of early claimers: the percentage of people claiming before the full retirement age decreases from 71% (baseline) to 58%. Thus, once individuals are entitled to lower annuity income at age 62 they are more interested in acquiring additional lifelong income by delaying claiming.

Bequest motives A key feature of an annuity is that it only pays out in states where an individual is alive; this can be a serious drawback for an individual who cares about the state when he is not alive because he has bequest motives. To understand how this mechanism affects claiming decisions, we consider two experiments with weaker bequest motives. In the first experiment, we increase the bequest threshold (i.e., the level of assets above which bequest motive is operational) from the baseline level of $3,600 to $6,000 while keeping the MPB unchanged. In the second experiment, we decrease the MPB from the baseline level of 0.97 to 0.95 while keeping the threshold unchanged. Note that in the first experiment, the bequest motive affects a smaller group of people who are relatively rich; while in the second experiment, the bequest motive is weaker but it is operational at a similar level of assets as in the baseline.

The results of these experiments are presented in Panels (d) and (e) of Figure (7) and the fifth and sixth columns of Table 3. Note that in both cases, the demand for public annuity increases but the effect is significantly more pronounced in the case with lower MPB: the percentage of people claiming before the full retirement age decreases from 71% (baseline) to 66% in the first experiment and to 43% in the second one. Moreover, in the second case the percentage of individuals claiming as early as possible declines by almost two thirds to 15%. Thus, bequest motive represents a quantitatively important factor in explaining low demand for Social Security annuity.

6.4 Policy implications: lump-sum option

Our results in the previous subsections show that individuals are not willing to acquire extra public annuity by delaying claiming because they discount the future at a relatively high rate, have strong bequest motives, and are already well-annuitized, i.e., they have substantial annuity income even if they claim at the earliest possible age. One policy implication of these findings is that to incentivize individuals to claim later, it is important to account for this unwillingness to annuitize and offer alternative rewards for delaying claiming. One alternative is to substitute the increase in future pension with lump-sum transfers. Specifically, in the current environment, individuals who delay claiming are offered additional lifetime annuity; instead, they could be offered a lump-sum transfer equivalent to the present discounted value of this annuity.

To understand the quantitative implications of this policy, we consider an experiment where an individual who is entitled to the basic retirement benefits of b at age 65 and who claims at age m is offered a lump-sum transfer LS_m instead of additional flows of pension income. These transfers are determined as follows:

$$LS_m = \begin{cases} \sum_{t=m}^{T-1} \frac{\zeta_{t+1|m} 0.067b}{(1+r)^{t+1-m}} & ; \text{ if } m = 63, 64 \\ \sum_{t=m}^{T-1} \frac{\zeta_{t+1|m} 0.065b}{(1+r)^{t+1-m}} & ; \text{ if } m = 65, .., 70 \end{cases}$$

Note that the difference in transfers for individuals below and above the full retirement age arises because the accrual in extra pension income for each year of delay is higher for the former group than for the latter one ($0.067b$ vs $0.065b$).

The left panel of Figure (8) and the second column of Table 4 display the results of this experiment when the interest rate used to convert pension income into lump-sum benefits is set to 2%, which is the same value as in our baseline calibration. This policy option results in a large change in the pattern of claiming behavior: the percentage of individuals claiming as early as possible drops from 46% in the baseline to only 3%, at the same time the percentage claiming as late as possible (age 70) increases from almost zero to 25%. Overall, the percentage of individuals claiming before the full retirement age decreases from 71% in the baseline to 11%, and the percentage claiming after the full retirement age increases from 8% in the baseline to 83%. This illustrates that individuals value the lump-sum option significantly more than an increase in future pension benefits and are willing to delay claiming if this option is offered. Note that this result is consistent with the findings of Maurer et al. (2016) who using survey responses to a specifically designed set of questions find that individuals would be willing to delay claiming if they were offered a lump-sum option.

It is worth emphasizing that when the increase in pension benefits is converted into lump-sum transfers the interest rate plays an important role; i.e., the higher the interest rate, the lower the computed present discounted value of pension income and, thus, the smaller the lump-sum benefits. To check the sensitivity of this policy to the assumed interest rate, we consider a case with a higher interest rate. As discussed in Section 6.2, the interest rate of

2% is below the rate of time preferences in our model (which is around 4%) and this matters for individuals' valuation of the annuity income. We next compute the lump-sum benefits using an interest rate of 5%.

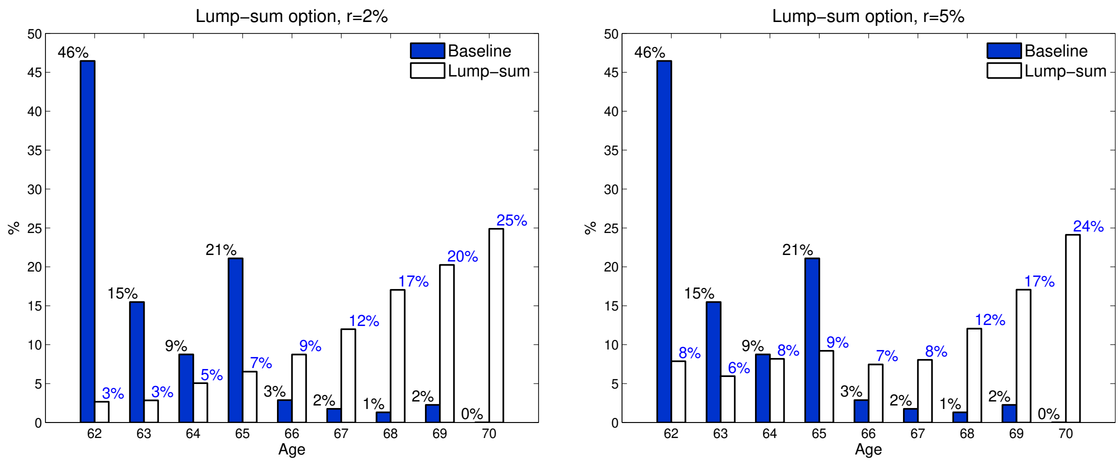

Figure 8: Distribution by claiming age when the lump-sum option is offered. Left panel: the lump-sum transfers are based on an interest rate of 2%. Right panel: the lump-sum transfers are based on an interest rate of 5%.

Claiming	Baseline	$r = 2\%$	$r = 5\%$
Early (62-64)	71%	11%	22%
Full retirement age (65)	21%	7%	9%
Late (66-70)	8%	83%	69%

Table 4: The effects of offering lump-sum benefits on claiming decisions.

The right panel of Figure (8) and the third column of Table 4 show the resulting claiming behavior. Compared with the case of a 2% interest rate, more people claim before the full retirement age (22% vs 11%) and fewer after that age (69% vs 83%). However, the pattern of claiming is still remarkably different from the baseline case because most people prefer to collect benefits after the full retirement age. This suggests that even if annuity income is converted to lump-sum benefits at a high interest rate, this policy provides much stronger incentives to delay claiming than an increase in pension income.

7 Conclusion

In this paper, we construct a rich structural model with heterogeneous agents in order to analyze individuals' decisions about when to claim Social Security benefits. An important fact from the data is that despite relatively large increases in pension benefits for those who delay claiming, most individuals claim before the full retirement age.

We show that answering this question has broader implications than just a better understanding of decisions to retire and collect pension benefits. First, it offers a unique context to study the well-known annuity puzzle. Delaying claiming is equivalent to purchasing additional annuity income because individuals forgo benefits for one year to get a higher lifetime stream of benefits in the future; thus, the prevalence of early claiming is equivalent to low demand for Social Security annuity. Since the participation in Social Security is compulsory and nearly universal, low demand for this annuity cannot be explained away by information asymmetries and market failures.

Second, claiming decisions can provide additional identifying information for the estimation of the subjective rate of time preferences. Annuities represent a lifelong constant income flow and their valuation by individuals crucially depend on their personal discount factor; thus the demand for Social Security annuity can be informative about the underlying degree of impatience.

We show that claiming decisions are very responsive to the subjective rate of time preferences. Several versions of our calibrated model are consistent with the observed labor supply and savings decisions over the life-cycle, but to simultaneously account for these facts and claiming behavior our model has to feature a relatively low discount factor. Put differently, the unwillingness of individuals to annuitize can be partly attributed to the fact that the present value of the extra annuity income obtained by delaying claiming is too low conditional on their rate of time preferences. We also show that if individuals were instead offered an actuarially fair annuity with a break-even rate that exceeds their rate of time preferences, substantially more people would delay claiming.

Overall, we show that the (public) annuity puzzle can be largely attributed to a combination of three factors: relatively high degree of impatience, strong bequest motives and pre-annuitized wealth. In other words, given individuals' subjective valuation of additional annuity income gained from delaying claiming and their preferences for liquid wealth that can be left for bequests, they consider themselves sufficiently annuitized even when they claim as early as possible (age 62). In contrast to earlier studies, we find that means-tested transfers have a limited impact on the demand for Social Security annuity. Less generous public transfers make individuals more vulnerable to the risk of outliving their assets, which can potentially increase their annuity demand. However, they insure this risk by accumulating more resources starting early in life rather than by acquiring more public annuities.

Our policy analysis shows that rewarding individuals for delaying claiming with lump-sum benefits is substantially more effective than offering them additional pension income.

Individuals value the additional resources obtained by postponing claiming but they strongly prefer the additional funds immediately as opposed to spreading them out over their remaining lifetime.

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Appendix

A Summary of the parametrization of the baseline model

Parameter name	Notation	Value	
Parameters set outside the model			Source
Consumption share	$\varkappa$	0.5	French (2005)
Labor supply	$\bar{l}$	0.4	
Tax function parameters	a_0	0.258	Gouveia and Strauss (1994)
	a_1	0.768	”
	a_2	0.616	Pashchenko and Porapakkarm (2013)
Labor productivity			
- Persistence parameter	ρ	0.98	Storesletten, et al. (2000)
- Variance of innovations	σ_ε^2	0.02	”
- Fixed effect	σ_ξ^2	0.24	”
Parameters used to match some targets			Target
Discount factor	β	0.962	% claiming at age 62
Risk aversion	ψ	4	Wealth accumulation before 60
1/IES	γ	1.5	”
Bequest parameters			
- MPB	-	0.97	Wealth profile after 60 for p50 and p75
- Bequest threshold	-	\$3,600	Wealth profile after 60 for p25
Consumption floor	$\underline{c}$	\$3,500	% employment among 30-34
Wage rate	w	1.55	average earnings
Fixed costs of work	ϕ_w	0.255	employment profiles (healthy)

Table 5: Parameters of the model.

B Actuarially fair adjustments to Social Security benefits

In this section, we explain how the adjustments to Social Security benefits for early/late claiming reported in Table 2 are computed. Denote the adjustments for age 62 as x_{62}, for age 63 as x_{63}, etc. As in the actual schedule of benefits and rewards, we set x_{65} to 1, i.e., individuals who claim at age 65 get full benefits. In order for the underlying price of the Social Security annuity to be actuarially fair, these adjustments have to satisfy the following:

$$q_t^{AF} = \frac{x_t}{x_{t+1} - x_t}, \qquad t = 62, ..., 69$$

where q_t^{AF} is the actuarially fair price for the annuity at age t. This represents a system of 8 equations which can be solved for x_t because $x_{65} = 1$.