Joint Lifetime Financial, Work and Health Decisions: Thrifty and Healthy Enough for the Long Run?*

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Abstract

US individuals are separately admonished for not being healthy enough, and for insufficient savings in both financial and pension assets. However, characterizing joint health, and assets sufficiency becomes more challenging when exposure to death, and sickness risks can be altered through forward-looking health spending and leisure decisions made by agents. We consider such a framework to reassess joint adequacy in health capital, financial and pension wealth. Our benchmark is flexible enough to admit either healthy-and-thrifty, or live-fast-die-young optimal strategies. Nevertheless, observed choices are found to be inconsistent with rational planning. Individuals in the data are not healthy enough, and consequently face a shorter life horizon than expected. Moreover, full insurance, and age-increasing wages would optimally point to more medical expenditures and less leisure to maintain health than currently observed. As a consequence, observed post-retirement income is too low, and financial wealth is depleted too rapidly, leading to a sharp drop in consumption after 65 that is inconsistent with optimizing behavior. Relaxing assumptions on complete health insurance and pension regimes only partially alleviates these discrepancies.

Keywords: Savings Adequacy; Defined Benefits and Contributions Plans; Consumption; Leisure; Health Expenditures; Mortality and Morbidity Risks.

JEL Classification: D91, I12, J22.

1 Introduction

1.1 Motivation and outline

Recent research by Case and Deaton (2015, 2017) highlights a worrisome deterioration in both longevity, and health markers in US individuals, particularly among middle-aged whites.[1] These findings shed further unflattering light on the unhealthy status of many Americans compared to others, and to previous generations.[2] In parallel to insufficiently investing in their own health, US individuals are furthermore admonished for insufficient savings for old age in both their financial, and pension wealth, although somewhat less pessimistic appraisals have also been offered.[3]

Aside from rare exceptions, this literature assesses financial, and pension wealth adequacy conditional on exogenously-determined expected longevity and morbidity expenses. However, making this assessment becomes more challenging when exposure to death, and sickness risks can be altered through conscious health decisions made by agents. For example, current labor/leisure choices affect not only contemporaneous resources, and old-age pension claims, but also future health status. The latter conditions expected exposure to sickness, and death risks, which in turn determine how much to save in financial, and retirement assets. On the one hand, low savings might be justified if agents with high discount rates optimally select unhealthy behavior that shorten the expected life horizon, and thereby reinforce their high discounting of future, over present consumption. On the other hand, low financial and pension wealth might be sub-optimal

[1]Mortality among age 45-54 was falling at about 2% per year in US, and other industrialized economies. Whereas the fall continues elsewhere, Case and Deaton (2015, Fig. 1) shows that this trend is reversed in the US after 1998, and *increases* at 0.5% afterwards. Table 2 identifies a decline in health markers such as self-reported health, ADL difficulties, and risky behaviors over the same period.

[2]National Center for Health Statistics (2012) paints a bleak portrait of risky health status and behavior of US citizens in 2010. For age-adjusted health conditions and risk factors (Tab. 69), 26.7% had high cholesterol, 30% suffered hypertension from which 55.7% had uncontrolled high blood pressure, 68.8% were overweight, and 35.7% were obese. Moreover, 49.1% of adults did not meed federal guidelines regarding physical and aerobic activities (Table 73), 19% were current smokers, while heavy drinking (5 and more drinks a day at least once in the last year) was reported in 32% of male adults. Finally, 22.3% of adults aged 18-64 had no medical insurance (data table for Figure 40), while 14.7% reported delay or nonreceipt of health care in the last year due to costs (data table for Figure 41). See also Solé-Auró et al. (2013) for additional US-international comparisons.

[3]See Hubbard et al. (1994, 1995); Skinner (2007) for insufficient financial wealth, and Devlin-Foltz et al. (2015); Munnell (2013); Rhee and Boivie (2015) regarding pension claims shortcomings. Scholz et al. (2006); Love et al. (2008); Campbell and Weinberg (2015) however argue that whereas certain groups (esp. poorer) of the population under-save for old age, savings may be adequate on average.

if current unhealthy status increases the exposure to future sickness, and its associated high out-of-pocket health expenses.

Understanding how these complex interactions affect agents' health, labor market, and financial decisions and outcomes is essential if one is to gauge the adequacy of savings in *any* asset, be it human, or not. This paper proposes a step in that direction by relying upon a flexible dynamic model to study the joint life cycle determination of work, savings and health-related choices. Importantly, our modeling framework allows for partially diversifiable exposure to death and sickness risks, and admits a wide range of optimal dynamic policies, including healthy-and-thrifty, as well as live-fast-die-young strategies. By resorting to a generalized theoretical framework, we remain *ex-ante* agnostic on the adequacy of these strategies; dynamically-consistent choices ensure that the positioning between these alternatives is determined optimally, and a structural estimation of the model permits an *ex-post* identification of that positioning via a revealed-preferences perspective.

This model is numerically solved, simulated, and estimated structurally. This allows us to perform a fourfold analysis. First, we use the estimated deep parameters to formally test certain key hypotheses. Second, we investigate the effects of current state variables (financial wealth, and health status) on optimal allocations (work/leisure, consumption/savings, health expenditures, and welfare).[4] Third, we simulate the model to compute the optimal life-cycle allocations; these optimal paths are the theoretical metric against which we gauge the adequacy of their empirical counterparts. Fourth, we relax some of the model's key assumption to verify robustness.

Our main findings may be summarized as follows. First, regarding the health production function, our estimated parameters indicate that the null hypotheses of health-independent morbidity and mortality risks, and exogenously set health levels are both rejected, such that agents' decisions can effectively impact how healthy they are and how much they are exposed to sickness and death risks. We also find that the *Long Reach of Childhood* (Case et al., 2005; Smith, 2009; Case and Paxson, 2011) is important; past health levels have strong effects on the productivity of current health investments. Moreover, we find that aging entails larger costs of inaction; both deterministic and

[4]In unreported analysis, we also analyze the separate effects of pension wealth on allocations, and find those to be very similar to the effects of financial wealth, suggesting strong substitutability between retirement, and financial assets with respect to effects on decisions.

stochastic health depreciation rates increase sharply as agents become older. Furthermore, our findings with respect to preferences are consistent with low substitutability between consumption and leisure. We also identify a utilitarian cost of death that is attenuated by leaving positive bequests (*warm glow* benefits). The latter justifies keeping high financial wealth balances at old age to be left to heirs in the case of death.[5]

Second, low substitutability entails that consumption and leisure display similar positive wealth gradients, and negative health gradients. Healthier agents face lower death and sickness risks and optimally choose to save, and work more, and increase pension claims in order to accommodate a longer life horizon. Optimal health spending however is not monotonous. Sufficiently healthy agents cut down spending when health and wealth improve, preferring to substitute in favor of more leisure in the latter case.

Third, our main life cycle results indicate that agents are insufficiently healthy compared to the predictions; life expectancy is therefore too short (79 vs 84 years). Moreover, we find that leisure is insufficient for younger agents, and excessive for elders. With wages peaking at mid-life, fully health-insured agents should rely more on spending and less on leisure to maintain their health capital. A direct consequence of excessive leisure later on is that observed labor income in old age is inadequate given pension claims and accumulated financial wealth. Moreover, consumption, while too high for younger agents, displays sub-optimal declines after age 65. We therefore conclude that observed behavior is not consistent with an optimal forward-looking strategy, even though that metric is sufficiently general to admit a wide range of healthy-and-thrifty, or live-fast-die-young policies.

Fourth, we test the role of some of the model's key assumptions in our findings. First, more generous defined benefit (DB) pension plans in Europe compared to the US which is increasingly relying on defined contribution (DC), have been singled out as potential explanations for worse American health (e.g. Case and Deaton, 2015, p. 15,081). We show that allowing for a DB plan does yield an optimal increase in mid-life leisure, however its effects on health are moderate, and it also predicts insufficient post-retirement wealth compared to the data. Second, we also allow for declining market returns, and potential mismanagement on retirement funds in the aftermath the 2008 Financial Crisis. Our results show that lowering the risky share, and therefore the expected return, on

[5] See also De Nardi et al. (2015); Love et al. (2009) for discussion and empirical evidence on the role of bequests in explaining insufficient post-retirement dissavings.

pension assets forces agents to cut down on leisure, and increase health spending to compensate. The fit however deteriorates as more financial wealth is required to offset the fall in pension wealth. Finally, in light of current uncertainty with regards to Affordable Care Act, we allow for uninsured younger agents, while retaining Medicare for elders. Consistent with findings by Pelgrin and St-Amour (2016), this leads to pre-Medicare health spending cuts, that are only partially offset by more leisure; health status and longevity consequently deteriorate, as required. Unfortunately, so does financial wealth as a shorter life horizon no longer justifies accumulating high levels of assets. We conclude that none of these three assumptions is single-handedly responsible for the discrepancies between optimal and observed decisions.

1.2 Relevant literature

Relatively few researchers study the dynamic determination of health, labor and financial decisions in a comprehensive setting. In light of the technical challenges that are involved, most literature abstracts from endogenizing at least one of the three channels. We innovate by modeling all decisions *jointly*, and in a context where *self-insurance* against death, and sickness risks is possible.

For example, both French (2005), and French and Jones (2011) rely on dynamic life cycle models in order to find whether income taxation, employer-provided health insurance, Medicare, and Social Security have any impact on the retirement decision. Once set, retirement is irreversible, barring any *ex-post* labor income adjustment to changing spending needs. Moreover, whereas wealth accumulation is endogenized, contrary to us, health is modeled as an exogenous stochastic binary variable (bad or good health) and with associated (high or low) health expenditures. More recent work by Capatina (2015) also studies the life cycle of labor and financial choices with exogenous health shocks, but abstracts from pension issues, as well as from endogenous health choices, and self-insurance against health-related risks.

Fonseca et al. (2013) analyze a life cycle model with endogenous health expenditures, and asset accumulation. As in French and Jones (2011), early retirement is possible but is irreversible, while dynamic leisure/work choices are abstracted from. Galama et al. (2013) construct a continuous time model of health, wealth accumulation, and retirement decisions using the human capital framework developed by Grossman (1972), in order to analyze the effect of health on the decision to retire. However, they abstract from endogenous sickness and death shocks exposure. Similarly, Hokayem and Ziliak (2014) also study labor supply interactions with health-related decisions in the context of the Grossman (1972) model. Similar to us, they allow for leisure time to supplement heath expenses in maintaining depreciable health capital. However, they abstract from long-term consequences of leisure choices on pension wealth, and do not endogenize the effects on the health-related risks exposure.

This paper is also related to recent research by Hugonnier et al. (2013); Pelgrin and St-Amour (2016); Dalgaard and Strulik (2017) who endogenize both health choices, as well as sickness and/or death risks exposure in life cycle decisions. However, the work-leisure decisions are either entirely abstracted from (Hugonnier et al., 2013), or devoid of long-term effects on pension entitlements (Pelgrin and St-Amour, 2016; Dalgaard and Strulik, 2017). Moreover none of these papers focus on savings adequacy.

Also related are Scholz and Seshadri (2012, 2013). Both papers allow for investment, and healthy leisure choices, where the time available for work is exogenously set, conditional on health status. However, whereas mortality risk is diversifiable, health-depreciating sickness shocks are exogenous, and retirement is irreversible, with post-retirement labor participation abstracted from.

The rest of this paper is organized as follows. Section 2 outlines the main features of the theoretical model, with numerical solution methods discussed in Section 3. The main results are outlined in Section 4, with concluding remarks in Section 5.

2 Model

This section characterizes the life cycle allocations problem of an agent facing partially diversifiable mortality and morbidity risks. These decisions concern medical spending, consumption and savings, as well as leisure and work in a setting where health insurance and pension plan characteristics are taken as exogenous. Both health expenditures and leisure improve the depreciable health status which in turn lowers the likelihood of death and sickness. However, leisure entails both present and future costs in terms of foregone current income, and lower anticipated retirement benefits. We first present the dynamics of the two health-related risks. Then, following a discussion of pre- and post-retirement income processes, we describe the budget constraint and agent's preferences.

2.1 Health shocks and status dynamics

In the spirit of Pelgrin and St-Amour (2016), and Hugonnier et al. (2013, 2017) let $t = 0, 1, \ldots, T^M \leq T$ denote the age of an agent, where T^M is the age of death, and T is the maximal longevity. We let $\epsilon_t^k \in \{0, 1\}$ denote mortality ($k = m$) and morbidity ($k = s$) shocks following generalized Bernoulli processes with:

$$\Pr[\epsilon_{t+1}^k = 0 \mid H_t] = \exp[-\lambda^k(H_t)], \tag{1}$$

where $\lambda^k : \mathbb{R}_+ \to \mathbb{R}_{++}$ is a decreasing and convex intensity function of the health level H_t. Hence, healthier agents can partially lower their exposure to morbidity and mortality risks subject to diminishing returns, and incompressible lower bounds. The age of death is the first positive occurrence of the death shock:

$$T^M = \min \{t : \epsilon_t^m = 1\}. \tag{2}$$

Relying on a long tradition in the demand-for-health literature, health is modeled as a depreciable human capital that can be adjusted through health expenditures. We follow recent advances that append healthy leisure, morbidity shocks and time-varying depreciation and productivity to the law of motion:

$$H_{t+1} = \left(1 - \delta_t - \phi_t \epsilon_{t+1}^s\right) H_t + A_t I^g(H_t, I_t, \ell_t). \tag{3}$$

Denoting $\mathbb{I}$ the unit vector, we let $I^g : \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{I} \to \mathbb{R}_+$, define the increasing and concave gross investment function of health status, expenditures I_t, and leisure ℓ_t. The capital depreciates at age-dependent deterministic rate δ_t which is augmented by ϕ_t upon occurrence of sickness. Time-varying depreciation and productivity rates are obtained by letting $\hat{d}_t = g^d \geq 0$ for $d \in \{\delta, \phi, A\}$. This assumption is convenient to ensure that both health maintenance, and sickness become increasingly costly as one ages, although this effect is somewhat mitigated by access to better medical technology in A_t (e.g. OECD, 2015, ch. 8).

2.2 Retirement plans and income processes

We first define $T^R = 65$ as the age at which both public and private retirement benefits can be drawn (henceforth the normal retirement age). For tractability, that age is taken as given and cannot be chosen by the agent. In order to account for the growing trend in elders' participation in the labor market, we do not impose complete and irreversible retirement from work activities after T^R, that is we allow for work $(1 - \ell_t) \in \mathbb{I}, \forall t \in [16, T^M]$.[6] It follows that pre-retirement income is composed of labor income only, whereas post-retirement income is the sum of labor income, and retirement benefits.

We consider two private retirement plans, DC and DB, and one public plan (Social Security). Both private plans have in common that the contributions are calculated as shares of the cumulated labor income. For tractability, we assume that these shares are paid into the retirement fund only up to retirement age. In the DB fund, the cost of those contributions are paid entirely by the employer, whereas the cost is shared between employer and employee in the DC case. While the retirement benefit is non-stochastic in the DB case, it depends on the cumulated portfolio return involving risky assets for the DC plan. Since the majority of US workers with pension plans are under defined contributions schemes,[7] DC plans will be our benchmark assumption, although we will evaluate the effect of DB plans in our robustness analysis in Section 4.4. Finally, Social Security (also known as Primary Insurance Amount, or PIA) is qualitatively similar to the DB plan, with non-stochastic returns, although involving a more complex entitlement formula detailed in Appendix A.

Let $\mathbb{1}_t^R = \mathbb{1}_{t \geq T^R}$ denote the post-retirement age indicator let $r \in \{DC, DB\}$ denote the private retirement plan, and Y_t, Y_t^r respectively denote the income, and private pension income, with w_t the age-dependent annualized wage rate. The income process is

[6] See Bureau of Labor Statistics (2008); Maestas (2010); Toossi (2015) for discussion and evidence of increased old age participation in the labor force. Note that this formulation does not exclude corner solutions in which the agent optimally selects not to work after retirement age, i.e. $\ell_t = 1, t \geq T^R$.

[7] Pension coverage type has evolved from DB to DC plans (Munnell and Perun, 2006; Broadbent et al., 2006). Indeed, Munnell (2013) reports that over the 1983-2013 period, DB shares fell from 62% to 17% of workers with pension coverage, whereas DC shares increased from 12% to 71% over the same period.

characterized by:

$$Y_t = \left[1 - \left(1 - \mathbb{1}_t^R\right) \tau_w^r\right] w_t(1 - \ell_t) + \mathbb{1}_t^R \left(PIA_t + Y_t^r\right), \tag{4}$$

$$Y_t^r = \alpha^r W_t^r, \tag{5}$$

$$W_{t+1}^r = \left[W_t^r + \left(1 - \mathbb{1}_t^R\right) X_t^r\right] R_{t+1}^r, \tag{6}$$

$$X_t^r = \min\left\{\left(\tau_w^r + \tau_f^r\right) w_t(1 - \ell_t), X_{\max}^r\right\}. \tag{7}$$

The specific values of the plan-specific parameters and variables are outlined in Table 1 in Appendix B. Employees can thus work at all ages in (4), but contribute a share τ_w^r to pension plans costs only up to retirement age, where that contribution is $\tau_w^{DC} > 0$ under DC, and is zero under DB. After retirement, they receive the Primary Insurance Amount PIA_t from Social Security, and the private pension income Y_t^r they are entitled to, in addition to any labor income $w_t(1-\ell_t)$ they optimally select. The pension income (5) is an annuity α^r applied on cumulated pension wealth W_t^r, where the latter is calculated in (6) as the contributions X_t^r that are cumulated only up to retirement age. The contributions represent the sum of the worker's and employer's shares $\tau_w^r + \tau_f^r$ of labor income in (7), up to maximal amount $X_{\max}^r$, where the latter is bounded under DC and unbounded under DB. Finally, the portfolio return on pension balances R_{t+1}^r is obtained under the DC plan from investing a share $\omega \in (0, 1)$ in the risky asset with return R_{t+1}^e, and the balance in the risk-free asset with return R_{t+1}^f, whereas the DB plan pays the risk-free return only.

Regarding public pension, the Primary Insurance Amount (PIA) is the Social Security income computed using the (annualized) Average Indexed Monthly Earnings ($AIME$) is defined as:

$$PIA_t = PIA(AIME_t), \tag{8}$$

$$AIME_t(\{\ell_s\}_{s=16}^t) = \frac{1}{t}\sum_{s=16}^{t} w_s(1 - \ell_s). \tag{9}$$

The exact PIA formula follows Social Security rules and is given by (31) in Appendix A.

2.3 Budget constraint

Following Pelgrin and St-Amour (2016), agents can insure against health expenditures through a contract defined by (i) a deductible level $D_t > 0$, (ii) a co-payment rate

$\psi \in (0,1)$ applicable on health expenditures $P_t^I I_t$ above deductible, and (iii) an insurance premium Π_t. The latter is equal to the market premium for young insured agents, and to the Medicare-subsidized premium for elders.

Let $\mathbb{1}^D = \mathbb{1}_{P_t^I I_t \geq D_t}$ denote the deductible reached indicator. The out-of-pocket medical expenditures $OOP_t(I_t)$, and health insurance premia are defined as follows:

$$OOP_t(I_t) = \left(1 - \mathbb{1}^D\right) P_t^I I_t + \mathbb{1}^D \left[D_t + \psi \left(P_t^I I_t - D_t\right)\right], \tag{10}$$

$$\Pi_t = (1 - \mathbb{1}_t^R \pi)\Pi \tag{11}$$

where medical prices and deductibles grow at rate $\hat{x}_t = g^x$, for $x = P, D$ to parallel the growth in medical productivity. The insurance contract in (10) is standard in that the insured agent covers all medical expenditures $P^I I$ up to deductible D, and pays the latter plus a share ψ on expenses above D once the deductible is reached. The premia (11) has agents cover the market premia Π until 65, and the Medicare-subsidized premia $(1-\pi)\Pi$ afterwards.

Given these elements, the law of motion for financial wealth W_t is obtained as:

$$W_{t+1} = \left[W_t + Y_t - C_t - OOP_t - \Pi_t\right] R^f, \tag{12}$$

where C_t is non-medical consumption, pre- and post-retirement income Y_t is given in (4), out-of-pocket health expenditures OOP_t are in (10), and health insurance premia Π_t is given in (11).

2.4 Preferences

As shown in Hugonnier et al. (2013); Pelgrin and St-Amour (2016), the agent's dynamic problem with time-separable VNM preferences, stochastic horizon T^M, and constant discounting $\beta \in (0,1)$ can be rewritten as a deterministic horizon program with health-dependent, endogenous discounting:

$$\beta^m(H_t) = \beta \exp[-\lambda^m(H_t)] < \beta. \tag{13}$$

Moreover, let the instantaneous utility be defined as:

$$\begin{aligned}\mathcal{U}_t &= U(C_t, \ell_t) + [\beta - \beta^m(H_t)]U^m\left(W_t, Y_t^r\right), \\ &= \mathcal{U}(C_t, \ell_t, W_t, H_t, Y_t^r),\end{aligned} \tag{14}$$

where $U : \mathbb{R}_{++} \times \mathbb{I} \to \mathbb{R}_+$ and $U^m : \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_-$ are monotone increasing, and concave instantaneous, and bequest utility functions that satisfy $\mathcal{U} : \mathbb{R}_{++} \times \mathbb{I} \times \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{R}_+ \to \mathbb{R}_+$. Since $\lambda^m(H)$ is a decreasing function, the healthier agent thus behaves as a more patient individual in (13), and assigns a lower weight on the bequest utility in (14). Observe further that, since U^m is increasing and negative, the marginal utility $\mathcal{U}_x \geq 0, x = W, H, Y^r$, ensuring positive instantaneous value to bequeathed wealth and pension entitlement, as well as to health.

Taking current health H_t, wealth W_t, and pension income Y_t^r as given, the agent's dynamic programming problem is:

$$V_t^r = \max_{C_t, I_t, \ell_t} \mathcal{U}_t + \beta^m(H_t)\mathrm{E}\left[V_{t+1}^r \mid H_t\right] \tag{15}$$

where $V_t^r = V(W_t, H_t, Y_t^r) \geq 0$ is the value function, and the period utility $\mathcal{U}_t$ is given in (14). The optimization (15) is subject to the Bernoulli distribution (1), the law of motion for health (3), the retirement income process (6), and the budget constraint (12).

The model admits a wide range of optimal life cycle strategies depending on the structural preference, technological, and distributional parameters. For instance, a healthy-and-thrifty policy naturally obtains since a high H induces a low discount rate $\lambda^m(H)$, and high patience $\beta^m(H)$ in (13), which is conducive to high savings in pension and financial assets, as well as high investing in future health. Conversely, a live-fast-die-young policy can be warranted for unhealthy agents with very high mortality risks, – and therefore high discount rates – and low $\beta^m(H)$, encouraging them to favor contemporaneous, over future utility, via high current consumption and leisure. Importantly, because health is endogenous, the positioning between these various alternatives is determined endogenously. Our empirical strategy is therefore centered on structurally identifying the deep parameters through the data so as to test whether the observed life cycle strategies are consistent with the model.

3 Empirical Methods

This section describes the empirical strategy that we use to solve and estimate the model via a Simulated Moments Estimation (SME). Following the discussion about the functional forms, we outline the iterative and simulation procedures, and present the SM estimator. An overview of the data used in the estimation strategy closes the section.

3.1 Functional forms

We draw from Pelgrin and St-Amour (2016), and Hugonnier et al. (2013) in parametrizing the death and sickness intensity functions $\lambda^k(H_t)$, gross investment $I^g(H, I, \ell)$, and the instanteneous utility and bequest functions $U(C, \ell), U^m(W, Y^r)$ as follows:

$$\lambda^m(H) = \lambda_0^m + \lambda_1^m H^{-\xi^m}, \tag{16}$$

$$\lambda^s(H) = \lambda_2^s - \frac{\lambda_2^s - \lambda_0^s}{1 + \lambda_1^s H^{-\xi^s}}, \tag{17}$$

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \tag{18}$$

$$U(C, \ell) = \left[\mu_c C^{1-\gamma} + \mu_\ell \ell^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \tag{19}$$

$$U^m(W, Y^r) = \frac{\mu_m \left(W + \delta^r Y^r\right)^{1-\gamma_m}}{1-\gamma_m}. \tag{20}$$

Consistent with the model, the two intensities in (16), and (17) are decreasing and convex in health, and bounded below by λ_0^k, whereas λ_1^k determines the endogeneity of sickness and health shocks. The Cobb-Douglas specification for gross investment (18) allows for monotone increasing, concave effects of health, expenditures and leisure inputs. The instantaneous utility (19) is specified as a CES to maintain positive utilitarian flows from living, with $1/\gamma$ capturing the elasticity of substitution.[8] The bequest utility function (20) is negative and reflects a cost of dying for $\gamma_m > 1$; that cost is attenuated by leaving bequests equal to financial wealth plus pension income entitlements for surviving

[8] In the spirit of Auerbach and Kotlikoff (1987), we also experimented with a generalized preferences specification allowing for differences in the intra- $(1/\gamma)$ and inter-temporal $(1/\varepsilon)$ elasticities of substitution:

$$U(C, \ell) = \frac{1}{1-\varepsilon}\left[\mu_c C^{1-\gamma} + \mu_\ell \ell^{1-\gamma}\right]^{\frac{1-\varepsilon}{1-\gamma}}.$$

Our estimation finds very low values for $\varepsilon \approx 0$, suggesting that preferences (19) can safely be assumed.

heirs (*warm glow* benefits). Finally, the gross risky return R_t^e under the DC plan is assumed to be log-normally distributed, with mean μ_e, and variance σ_e^2.

3.2 Iteration and simulation

Let $Z_t = (W_t, H_t, Y_t^r)$ and $Q_t = (C_t, I_t, \ell_t)$ respectively denote the state and control sets at time t, with $Z \in \mathbb{Z}$ representing a given element of the discretized state space. We also let $\epsilon_t = (\epsilon_t^m, \epsilon_t^s, \epsilon_t^e)$ denote the death, sickness and financial shocks. The iterative step consists of solving the program (15) through a backward iteration:

$$V(Z_t) = \max_{Q_t} \mathcal{U}(Q_t, Z_t) + \beta^m(Z_t)\mathrm{E}\left[V(Z_{t+1}) \mid Z_t\right] \tag{21}$$

$$\text{s.t.} \quad Z_{t+1} = Z_{t+1}(Q_t, Z_t, \epsilon_{t+1}), \quad \forall Z_t = Z \in \mathbb{Z}. \tag{22}$$

The output we recover is thus the sequence of age-dependent optimal allocations and value functions on each point in the state space:

$$\{Q_t(Z), V_t(Z)\}_{t=16}^{T}, \quad \forall Z \in \mathbb{Z} \tag{23}$$

Next, we simulate the dynamic optimal paths for agents $i = 1, 2, \ldots, K_I$, and Monte-Carlo replications $n = 1, 2, \ldots, K_N$ as follows:

1. The initial state draws (with replacement) from the observed population wealth, health levels at age 15, where the initial pension entitlement Y_{15}^r is set at the minimum point on the discretized state space:

$$Z_{15}^{i,n} \sim \mathbb{Z}_{15}^{POP}. \tag{24}$$

2. For each year $t = 16, 17, \ldots T$,

   (a) A trilinear interpolation of the policy functions (23) is used to evaluate $Q_t^{i,n}, V_t^{i,n}$ at the contemporary state $Z_t^{i,n}$.

   (b) Death and sickness shocks are endogenously drawn from the generalized Bernoulli,

$$\epsilon_{t+1}^{k,i,n} \sim \{0,1\}^2 \mid \lambda^k(Z_t^{i,n}). \tag{25}$$

(c) Financial shocks are drawn from the log-normal distribution:

$$\log(R^e_{t+1}) \sim \text{N.I.D.}(\mu_e, \sigma_e^2) \tag{26}$$

(d) We use the laws of motion (22) to update the state variables:

$$Z^{i,n}_{t+1} = Z_{t+1}\left(Q^{i,n}_t, Z^{i,n}_t, \epsilon^{i,n}_{t+1}\right). \tag{27}$$

3.3 Moments and SME estimation

Given the output sequence $\left\{Q^{i,n}_t, Z^{i,n}_t\right\}$, the theoretical life-cycle $\hat{M}_t$ and unconditional moments $\hat{M}^u$ need to be calculated for the population of living agents only. In particular, let $\mathbb{1}^{i,n}_t \in \{1, \text{NaN}\}$ be the alive indicator for agent i, in simulation n, at age t. The life-cycle and unconditional moments are given by:

$$\hat{M}_t = \frac{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}^{i,n}_t \left\{Q^{i,n}_t, Z^{i,n}_t\right\}}{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}^{i,n}_t}, \tag{28}$$

$$\hat{M}^u = \frac{\sum_{t=16}^{T} \hat{M}_t}{T-16}. \tag{29}$$

These life-cycle moments can be contrasted with observed ones to construct a Simulated Moments Estimator (SME, e.g. Duffie and Singleton, 1993; Keane and Wolpin, 1994; French, 2005).

For that purpose, define $\Theta = (\Theta^e, \Theta^c)$ the estimated and calibrated parameter set. Let $\hat{M}(\Theta) = \{\hat{M}_t(\Theta)\} \in \mathbb{R}^{K_M}$ denote the collection of theoretical life cycle moments of interest, and M denote the corresponding observed moments. For a given weighting matrix $\Omega \in \mathbb{R}^{K_M \times K_M}$, the SME estimation of the structural parameters Θ^e is:

$$\hat{\Theta}^e = \underset{\Theta^e}{\text{argmin}} \left[\hat{M}(\Theta) - M\right]' \Omega \left[\hat{M}(\Theta) - M\right]. \tag{30}$$

The calibrated and estimated parameters are discussed in further details below. We compute the theoretical life cycle moments for health, wealth, leisure, out-of-pocket expenditures over 5-year intervals for ages between 20–80. The corresponding observed moments are discussed below and refer to the US population for the years 2010 and 2011. By using 4 life cycle variables times 12 five-year bins, meaning a total of $K_M = 48$

moments, the Simulated Moments Estimation of Θ^e is over-identified since we estimate 23 deep parameters.[9]

The SME methods require observed life cycle moments on the four previously mentioned variables. Ideally, a single panel database regrouping all these variables would be used. Unfortunately, to the best of our knowledge, such a database does not exist. Hence, we follow Pelgrin and St-Amour (2016) and rely on various well-known panels that are representative of the American population. These sources are presented in Table 4. First, for financial wealth, we use the Survey of Consumer Finances (SCF). Our measure for financial wealth includes assets (stocks, bonds, banking accounts, ...). Second, leisure is the share of time spent not working, and is taken from the American Time Use Survey (ATUS). Third, we use the National Health Interview Survey (NHIS) to get a measure of health. This survey includes ordered qualitative self-reported health status ranging from very poor to excellent that are converted to numerical measures using a linear scale. Fourth, the out-of-pocket medical expenses (Medical Expenditures Survey, MEPS), are the mean expenses per person, conditional upon expenditures. The MEPS data set is also relied upon for hourly wages. As shown in Figure 1, wages display significant age variation and are peaking around mid-life. Fifth, the probability of dying (National Vital Statistics Reports, Life Table for the Total US population) is defined as the ratio of number of persons who died between age t and t+1 over those who reached age t.

Finally, the retirement plans also require administrative and statistical information on retirement income in order to parametrize the Social Security, DB, and DC formulas (e.g Average Monthly Index Earnings thresholds, DC annuity factor). To compute social security benefits, we use 2010 and 2011 data from the US Social Security Administration. We fix the DB contribution rate τ_f^{DB} and the DC annuity factor α^{DC} by averaging different literature sources since no survey exist on these parameters.

4 Results

We first discuss the estimated parameters, followed by a presentation of the output obtained from the iteration and simulation phases. We close this section by reviewing the role of alternative key assumptions.

[9]Our results are also robust to using the age-dependent mortality rates as additional moments, i.e. using 60 instead of 48 moments.

4.1 Parameters

Calibration set The values and sources for the calibrated parameters Θ^c are shown in Table 5. These parameter values were selected relying on data, official figures, and literature as much as possible. The remaining free parameters concern the range and dimension of the state, and control spaces, and were calibrated through an extensive trial and error procedure.

Estimation set The estimated parameters Θ^e are reported in Table 6, with standard errors in parentheses. The latter indicate that all the parameters in Θ^e are precisely estimated, and have the correct expected signs. In panel 6.a, the mortality intensity parameters in (16) confirm that the endowed death intensity λ_0^m is low. The weight and curvature parameters with respect to health indicate that death risk is diversifiable ($\lambda_1^m, \xi^m \neq 0$). Next, the sickness intensity process in (17) unsurprisingly reveals a much higher exposure to sickness than to death risk ($\lambda^s(H_t) > \lambda^m(H_t), \forall H_t$). Moreover, the parameters are consistent with endogenous morbidity exposure ($\lambda_1^s, \xi^s \neq 0$), as well as with a high endowed intensity, and the absence of bounds on sickness risk exposure ($\lambda_0^s, \lambda_2^s \gg 0$).

In panel 6.b, the deterministic depreciation δ_t is non-trivial, and age-increasing. Conditional upon sickness, the incremental depreciation that is suffered by the agent is found to be consequential ($\phi_t > \delta_t$), and more age-dependent than its deterministic counterpart ($g^\phi > g^\delta$). All in all, this suggests that the health capital falls rapidly in the absence of constant maintenance, that the sickness process we identify is associated with severe, rather than benign illness, and whose consequences are much more detrimental for elders, than for young agents. The gross investment function (18) that we estimate is indicative of medical technological progress ($g^A > 0$), and of positive, diminishing marginal products of investment and leisure in maintaining health ($\eta_I, \eta_\ell \in (0,1)$). Moreover, the large marginal effect of health in the gross investment ($\eta_H \equiv 1 - \eta_I - \eta_\ell > 0$) suggests path dependence, i.e. Long Reach of Childhood effects, in the sense that not all contemporary health issues may be solved through high expenditures and healthy leisure only. In panel 6.c, the growth in medical productivity that we identify ($g^A > 0$) is paralleled with medical prices inflation ($g^P > 0$), that is accompanied by a corresponding increase in deductibles ($g^D > 0$). Observe that medical prices augment more rapidly than both medical technology and deductibles ($g^P > g^D > g^A$).

Turning to preferences in panel 6.d, the CES utility (19) that we estimate is characterized by low intra-temporal elasticity of substitution between leisure and consumption ($1/\gamma \ll 1$) that is consistent with known estimates of Frisch elasticity, and indicative of low substitutability between consumption and leisure.[10] Moreover, we observe an important weight of leisure relative to consumption in the utility function ($\mu_\ell > \mu_C$). The estimates of the bequest function (20) suggest a utility cost of death, and realistic relative risk aversion with respect to stochastic financial risk ($\gamma_m = 2.09 > 1$). The bequest motive is also found to be non-negligible ($\mu_m > 0$).

4.2 Optimal allocations in function of wealth, and health

Figure 2 in Appendix C.1 plots the mean optimal consumption (panel a), leisure (panel b), health investment (panel c), and welfare (panel d) in function of financial wealth (W), and health (H), where the mean is taken across the age, and retirement wealth dimensions.[11]

First, the optimal consumption in Figure 2.a is monotone increasing in wealth, and decreasing in health. Whereas the wealth effects are as expected, the negative health gradient can be explained from equation (13) by the lower discounting for healthier agents who prefer to consume less, and save more at a given wealth level, in order to account for a longer life horizon. Second, the optimal leisure choice in Figure 2.b displays strong similarities with consumption, due to the low substitutability that were previously estimated ($1/\gamma \ll 1$). Again, it is unsurprisingly increasing in financial wealth, and decreasing in health, where the latter obtains because healthy agents face lower death, and sickness risks exposure and can select to work more when health improves. In addition, longer expected lifetime for healthier agents warrants more work to invest in retirement claims. Observe that non-participation on the labor market is possible, with the unhealthy and sufficiently rich agents electing not to work, and take full leisure ($\ell = 1$) instead.

[10] See Auerbach and Kotlikoff (1987, pp. 51-52) among others.

[11] In unreported additional analysis, we also computed the marginal effects of pension wealth W^r on the optimal allocations. Those effects were found to be very similar to that of financial wealth, as well as limited, once the latter is accounted for, suggesting substitutability between pension, and financial capital.

Third, the optimal investment in Figure 2.c is non-monotone in both wealth and health. Sufficiently healthy agents tend to substitute away from health spending, and in favor of leisure when wealth increases; otherwise, the wealth gradient of spending is positive for the unhealthy. Moreover, health spending falls in health for sufficiently healthy agents, but increases for the very unhealthy individuals. Facing a near unit probability of further sickness and death, these agents prefer to cut down on spending, and take full leisure instead when health further deteriorates. This choice is sensible; while both can increase future health, leisure provides instantaneous utility, whereas spending does not. Finally, as expected, the welfare in Figure 2.d is monotone increasing in both financial wealth and health. Note that the strong convexities in the adjustment costs of gross investment $I^g(H, I, \ell)$, and of risk exposure $\lambda^k(H)$ entails that the curvature is more pronounced with respect to H, than W.

4.3 Optimal life cycles

To isolate the effects of age, the optimal life cycle trajectories are illustrated in Figure 3, in Appendix C.2. They are computed as the mean of the simulated paths at a given age using (28). We plot the benchmark simulated allocation (solid red) with 95% confidence intervals (dotted red), along with the corresponding observed data (black).[12] Overall, these results confirm that our benchmark model performs well in reproducing the shape of the life cycle paths, with some notable exceptions.

Indeed, panel 3.a shows that whereas the secular drop in health levels is accurately reproduced, the level is not, with agents in the data being insufficiently healthy compared to the predicted benchmark. Consequently, their exposure to mortality risk is too high (panel b), and their observed longevity (79.3 years) is 4.6 years shorter than predicted. Panels c, and d indicate that the observed unhealthy status is caused by young agents' health spending, and leisure that are both insufficient compared to the benchmark. Long Reach of Childhood effects ensure that these discrepancies at younger age have a long-lasting impact on health of elders that cannot be completely offset by additional healthy spending or leisure after retirement.

[12]The confidence interval were computed through the estimated parameter, and associated covariance matrix, and evaluated at mean health, pension, and financial wealth at each age.

Moreover, the model predicts that agents should work more when their wages are highest around mid-life (see Figure 1). To avoid detrimental effects on health, complete health insurance coverage suggests that they should also compensate less leisure with more health spending;[13] this predicted behavior however is not observed in the data. Whereas the post-retirement drop in wages does warrant a reduction in hours worked, the observed increase in leisure is excessive, and old agents work less than they should (panel d).[14] Consequently, old-age total income (i.e. pension plus work) is too low (panel f), despite pension claims adequacy (panel e).

Consistent with insufficient savings assessments, we also witness excessive consumption for young agents, followed by a sharp drop after retirement that are both inconsistent with optimal planning (panel g). Sub-optimal drops in post-retirement consumption have also been identified by others.[15] In our setting, contemporaneous consumption should be increased throughout the lifetime since optimal depletion of the health stock induces more discounting of future utility (see Figure 2.a). Finally, despite pre-retirement adequacy, a longer predicted horizon, relatively important bequest motive, as well as more labor income jointly entail that financial wealth should be decumulated more slowly after retirement than it actually is (panel h).

Overall, we conclude that observed behaviors are not consistent with optimal planning, even though the theoretical metric we rely upon admits a wide range of policies. Whereas pension and financial assets accumulation does not appear inadequate,[16] the agents' observed health, and longevity are sub-optimal. Moreover, the mix between leisure, and health spending in at odds with the incentives provided by full insurance, and the life cycle of wages. Finally, as for others, the model does not warrant the observed excessive consumption when young, and the sharp drop after retirement.

[13] See Pelgrin and St-Amour (2016) for similar effects. From a different perspective, other research has shown positive effects of health insurance on labor supply. Currie and Madrian (1999); Madrian (2007) provide evidence of employer-provided health insurance effects in delaying retirement age. Garthwaite et al. (2014) identify "employment lock" effects whereby search for employment as provider of health insurance is increased when public health insurance programs are terminated.

[14] Maestas (2010) notes that 'unretirement', i.e. agents returning to work after retirement, has been growing in popularity, and is mainly associated with forward-looking planning, rather than insufficient *ex-post* resources.

[15] See Hamermesh (1984); Hurd and Rohwedder (2005); Haider and Stephens (2007); Battistin et al. (2009); Aguila et al. (2011) for further evidence and discussion of the Retirement Consumption Puzzle.

[16] See also Scholz et al. (2006); Love et al. (2008); Campbell and Weinberg (2015) for additional evidence of financial and pension adequacy.

4.4 Robustness checks: Alternative specifications

We now analyze the effects of relaxing several key assumptions in the theoretical model in order to verify how the empirical performance can be affected. First, we replace our DC assumption with one where individuals are covered by a defined benefit plan. Second, we allow for potential mis-management of pension funds by altering the risk-return mix on the pension assets' portfolio. Third, we account for the fact that many young agents remain uninsured with respect to health spending. Keeping the deep parameters constant, the model is solved and simulated again for each alternative. In Appendix C.3, we plot the observed X_t (black), benchmark $\hat{X}_t$ (red) and alternative $\tilde{X}_t$ (blue) life cycles.

DB pension plans As discussed in footnote 7, DB-type pension plans have been phased out in favor of DC regimes, prompting us to adopt a defined contribution regime as our benchmark. Still, defined benefits remain important for many workers, and the model is modified accordingly. The effects on predicted life cycles are reported in Figure 4.

DB plans are often considered to be more generous than their DC counterparts (see Table 1). This is apparent in pension claims (panel e), and encourages DB workers to take an "early retirement" path, i.e. augment leisure starting at mid-life, and reduce pre-retirement income (panels d, f). The increase in leisure entails that mid-life health expenditures can be substituted away (panel c), without distinct effects on health levels or mortality (panels a, b). Because pension income is higher (panels e, f), both the mid-life consumption, and asset decumulation can be accelerated (panels g, h).

We find that allowing for DB, instead of our benchmark DC pension plan has no effect on fit with respect to health levels and mortality. However, the fit is deteriorated for all other variables. Our base assumption regarding defined contribution pension plans therefore cannot be identified as the main cause for the gap between observed, and predicted behavior in Figure 3.

Lower return on the pension assets Consistent with practice (see Table 2), we have set a risky portfolio share $\omega = 60\%$ on DC pension assets. Potential mis-management of retirement funds may however result in lower risky shares which will reduce the expected rate of return on pension assets, and therefore the post-retirement pension claims. For that purpose, we reduce ω to 30%. The effects on predicted life cycles are reported in Figure 5, and are shown to be very limited.

As expected, lower returns on pension assets results in a sharp decline in pension income (panel e). To compensate, agents must reduce post-retirement leisure (panel d), and work more to limit the fall in total income (panel f). Moreover, lower leisure is met by substituting additional health spending (panel c) in order to maintain health levels, and mortality (panel a, b). A final effect of lower pension claims entails that agents must increase financial reserves by lowering consumption, and slowing down asset decumulation in old age (panels g, h).

Overall, the effects of allowing for pension mismanagement are very limited for most life cycles, with some deterioration observed in pension, and financial wealth (panels e, h). The discrepancies between observed, and prescribed allocations in Figure 3 are apparently not uniquely caused by low rates of return on pension assets.

Uninsured young agents Our model assumes full insurance for young and old agents alike. Yet, before ACA becomes fully operational, a sizable share of the US younger population remains uninsured with respect to health risks.[17] To analyze the effects of uninsurance, we modify the model to let young agents pay the entire price of health expenditures, while retaining full Medicare coverage for elders. The changes with respect to the initial theoretical predictions are reported in Figure 6.

As identified by Pelgrin and St-Amour (2016), a key effect of age-determined access to health insurance is to induce inter-temporal substitution between leisure, and health spending as health maintenance instruments. In panels c, and d, uninsured young agents thus cut down on spending before retirement, and augment it sharply when Medicare becomes operational. To compensate, they augment leisure when young, and reduce it after retirement. Despite this inter-temporal substitution, pre-retirement health is worse (panel a), leading to an increase in mortality (panel b). Moreover, less work when young leads to lower pension claims (panel e), which are offset by additional post-retirement work to maintain income (panel f). Higher exposure to OOP costs for uninsured agents when health issues become important at mid-life, combined with a shorter horizon induce

[17]An estimated 32 millions (16.7%) nonelderly Americans remained uninsured in 2014 (Henry J. Kaiser Family Foundation, 2015).

a more rapid wealth depletion after age 50 (panel h). Lower financial resources in turn leads to lower consumption when old, that are closer to observed levels (panel g).

With respect to fit, we conclude that the alternative model with uninsured young agents better reproduces observed health levels, and mortality (panels a, b), as well as post-retirement consumption (panel g). However, the fit is deteriorated with respect to post-retirement health spending, leisure, pension, and total income and wealth (panels c, d, e, f, h). The differences between observed, and optimal life cycles in Figure 3 are therefore robust to accounting for uninsurance among pre-Medicare young agents.

5 Conclusion

This paper's objective is to assess whether agents' observed life cycle choices with respect to health, leisure/work, and consumption/savings can be rationalized as optimal decisions to a flexible dynamic problem. Contrary to most previous studies, the life cycle health-, financial-, and work-related choices are analyzed jointly, rather than separately. Importantly, this analysis is performed in a setting where exposure to future morbidity and mortality risks, as well as future consequences of current leisure choices on future pension entitlement are fully internalized. Moreover, a structural estimation of the model ensures a close mapping between the theory and the empirical assessment.

Based on the empirical results, we could hardly conclude that observed choices are fully consistent with an optimal, forward-looking strategy. Individuals in the data are not healthy enough, and consequently face a shorter life horizon than expected, whereas post-retirement wealth falls too rapidly. Moreover, assuming full insurance would optimally point towards more spending, and less leisure to maintain health than currently observed. As a consequence, total post-retirement income (pension plus work) is too low, which combined with insufficient wealth, explains a sharp drop in consumption after 65 that is inconsistent with optimizing behavior. Although the model admits a wide range of strategies (e.g. healthy-and-thrifty, or live-fast-die-young policies), the structural estimation suggests that the theoretical assets and health targets are not met, and that the optimal mix between consumption, leisure and health is not attained; we therefore concur with concerns separately voiced by others that the observed behavior is not consistent with agents being thrifty and healthy enough for the long run.

A fair issue is whether our underlying assumptions stand behind the model's inability to fully reproduce the data. To address this concern, we relaxed several key hypotheses. First, to account for a sizable (although receding) share of the population covered by defined benefit pension plans, we allowed for DB regimes instead of our assumed defined contribution plan. Changing the pension plan hypothesis only partially improves the results. Whereas the model predicts that leisure should pro-factually increase after mid-life, health spending is lower for DB agents; both effects offset one another with respect to health maintenance such that DB agents are similarly healthy, and long-living compared to their DC counterparts. Moreover, the predicted consumption, and financial wealth life cycles diverge further from the observed values.

Second, to account for potential mismanagement of pension fund leading to lower rates of return on asset holdings, we reduced the portfolio share on risky assets. Since the latter pay a positive risk premia, this results in cutting down the value of pension claims. However, the effects on health levels and mortality are negligible, whereas investment increases, and leisure falls counter-factually. Moreover, the effects on income, consumption, and wealth are weak, leading to no improvement in model performance.

Finally, before ACA becomes operational, important shares of young US population remain uninsured for health expenses. Replacing our full insurance hypothesis by a no insurance for younger and Medicare-covered insurance for elders also provides partial improvement, with much more potent effects on health-related variables. As expected, predicted health falls sharply, and mortality rates increase and become closer to those observed in the data. However, uninsured young agents also substitute away from spending and in favor of more leisure, leading to a deterioration of performance on both fronts. Moreover, post-retirement wealth falls sharply because of the shorter expected lifetime, leading to further inconsistencies.

Overall, we conclude that the discrepancies between the data and the optimal allocation cannot be solely attributed to unrealistic assumptions related to pension or health insurance regime. Other alternative explanations include real estate which has been omitted from the analysis (e.g. Yogo, 2016, for inclusion of housing). Higher post-retirement leisure could be explained by more liquid wealth capitalized in house value, allowing less work for elders. A shorter life horizon induced by unhealthy behavior could also be rationalized by more warm glow effects from bequeathed housing wealth compensating the utility cost of death. A further alternative could be limitations preventing elders' participation in the labor market. For instance fiscal, means-testing or Social Security penalties on post-retirement labor income, or employers' reluctance to hire elders could explain excessive leisure for elders. We leave these and other potential explanations on the research agenda.

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A Social Security

Given the Average Indexed Monthly Earnings $AIME_t$, the Social Security income is obtained as:

$$PIA_t = \min\left\{\alpha_1^{PIA}\min\left(AIME_t, Cap_1^{AIME}\right) + \alpha_2^{PIA}\max\left[0, \min\left(AIME_t - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME}\right)\right] + \alpha_3^{PIA}\max\left(0, AIME_t - Cap_2^{AIME}\right), PIA^{max}\right\} \quad (31)$$

Note that in order to reduce the dimension of the state space, the Social Security income can also be expressed as a function of Y_t^{DB}:

$$AIME_t = \frac{1}{T^E\tau_f^{DB}}Y_t^{DB} \quad (32)$$

such that (31) becomes:

$$PIA_t = \min\left\{\alpha_1^{PIA}\min\left(\frac{Y_t^{DB}}{t\times\tau_f^{DB}}, Cap_1^{AIME}\right) + \alpha_2^{PIA}\max\left[0, \min\left(\frac{Y_t^{DB}}{t\times\tau_f^{DB}} - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME}\right)\right] + \alpha_3^{PIA}\max\left(0, \frac{Y_t^{DB}}{t\times\tau_f^{DB}} - Cap_2^{AIME}\right), PIA^{max}\right\} \quad (33)$$

where we set $T^E = 49$, and $\tau_f^{DB} = 0.015$ in AIME (32).

B Tables

Table 1: Pension plan-specific rules

plan r	DC (benchmark)	DB
τ_w^r	τ_w^{DC}	0
τ_f^r	τ_f^{DC}	τ_f^{DB}
α^r	α^{DC}	1
$X_{\max}^r$	$X_{\max}^{DC}$	∞
R_t^r	$R_t^f + \omega(R_t^e - R_t^f)$	R_t^f

Notes: Pension plans restrictions for total income (4), pension income (5), pension wealth (6), and contributions cap (7).

Table 2: Asset Allocation and percentage share invested in equities for DC plans

% of 401(k) in equities	Age 20's	Age 60's	Average
0	0.9	0.16	0.0
(0,20]	0.1	0.8	0.1
(20,40]	0.2	0.14	0.3
(40,60]	0.5	0.26	0.5
(60,80]	0.19	0.16	0.7
(80,100]	0.64	0.20	0.9
Average	0.74	0.48	0.6

Notes: Equities include equity funds, company stock, and the equity portion of balanced fund. Funds include mutual funds, bank collective trusts, life insurance separate accounts, and any pooled investment product invested primarily in the security indicated. Source: Tabulations from EBRI/ICI Participant-Directed Retirement Plan Data Collection Project (ICI, 2013).

Table 3: Joint Survivor Annuity for a \$100'000 investment in 2010-2011

100% Joint Survivor Monthly Annuity for \$100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	494	480	481	465	480.0
70	538	524	526	508	524.0
75	596	580	596	566	584.5
80	684	668	675	649	669.0

50% Joint Survivor Monthly Annuity for \$100'000 invested					
Age	01.01.2010	01.07.2010	01.01.2011	01.07.2011	Average
65	575	559	555	538	556.75
70	643	627	623	609	625.5
75	734	717	713	699	715.75
80	870	851	846	829	849.0
$\delta^r = 0.5$ and $\alpha^a = 12 \times \$556.75/\$100'000 = 0.067$					

Notes: Sources: www.immediateannuities.com/annuity-shopper/as-archive.html

Table 4: Data sources

Variables	Data, and explanations
W_t	Survey of Consumer Finance (SCF) data (Summary extract data set, 2010, rscfp2010.dta, corresponding to data used in the Federal Reserve Bulletin). Because the model abstract from durables and housing, wealth is defined as financial wealth (fin).
W_t^{DC}	Survey of Consumer Finance (SCF, 2010). DC account is the sum of any households pension account except IRA/Keogh accounts included in the financial wealth.
H_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Health is defined as respondent's self-reported health status (RTHLTH31), and categorized by age. The original polytomous data is converted to numerical values using a linear scale where Poor=0.10, Fair=0.825, Good=1.55, Very good=2.275, Excellent=3.0.
$P_t^I I_t$	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Total health expenditures are defined as total health care (TOTEXP11).
OOP_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Out-of-pocket health expenditures are defined as total health care paid by self/family (TOTSLF11).
ℓ_t	American Time Use Survey (ATUS), Bureau of Labor Statistics (2010 Activity file). Leisure is defined as the share of usual hours not worked per week, (1-uhrsworkt/40) where codes 9999 (NIU) and 9995 (variable hours) were set to 1.
C_t	Consumer Expenditures Survey (CEX) data, Bureau of Labor Statistics (2011 interview file). Consumption is defined as adjusted total expenditures last quarter (totex4pq) from which we subtract health care (healthpq) and vehicles (cartknpw+cartupq+othvehpq), with quarterly data in converted to annual values.
Y_t	Current Population Survey (CPS, 2010), Bureau of Labor Statistics. The annual income is the weekly total income times 52 weeks computed using both full and part-time (less than 35h of work per week) households, respectively weighted, for each age group.
w_t	Medical Expenditures Panel Survey (MEPS), Agency for Health Research and Quality, 2010, RD 3/1 data. Wages are hourly wage (HRWG31X), with inapplicable values converted to missing, and converted to an annual basis through a 40-hours per week and 52 weeks conversion.
$\lambda^m(t)$	Probability of dying between age t and $t+1$, National Vital Statistics Reports, Life Table for the Total US population, 2010 (Arias, 2014, Tab. 1).

Table 5: Calibrated parameters values and sources

(a) Values

Param.	Value	Param.	Value	Param.	Value	Param.	Value
T	100.0	κ	-37.0	β	0.9656	P_0^I	1.8522
ψ	0.20	Π	0.0413	Π_M	0.0167	τ	0.0145
R^f	1.0408	R^e	1.0709	σ^e	0.187	ω^e	0.6
τ_f^{DB}	0.015	τ_f^{DC}	0.05	τ_w^{DC}	0.06		
α^a	0.067	δ^r	7.4839	$X_{\max}^{DC}$	0.49		
α_1^{PIA}	0.9	α_2^{PIA}	0.32	α_3^{PIA}	0.35		
Cap_1^{AIME}	0.0755	Cap_2^{AIME}	0.4552	$PIA^{\max}$	0.2356		
$W_{\min}$	0.05	$W_{\max}$	5.0	$H_{\min}$	0.1	$H_{\max}$	3.0
$C_{\min}$	0.05	$C_{\max}$	1.0	$\ell_{\min}$	0.0	$\ell_{\max}$	1.0
$I_{\min}$	0.1	$I_{\max}$	1.0	K_Z	10^3	K_Q	10^3

(b) Sources

Parameters	Sources and explanations
T, κ	Life tables, Arias (2014). Median age, Bureau of Labor Statistics (2011, Tab. 2, p. 4).
β	Various literature
P_0^I	National Center for Health Statistics (2012, Tab. 126), CPI and annual percent change for all items, selected items and medical care components, 2010. The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
ψ, Π, Π_M, τ	Henry J. Kaiser Family Foundation (2011a,b); Medicare.gov (n.d.). The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
R^f, R^e, σ^e	Federal Reserve Bank of St-Louis (n.d.); French (n.d.)
ω^e	Table 2 and ICI (2014, p. 132)
τ_f^{DB}	Various literature, Chen and Hardy (2010), Forman (2000), Fronstin and Helman (2013), Pang and Warshawsky (2013)
τ_f^{DC}, τ_w^{DC}	Deloitte (2014, p. 6), Deloitte (2009, p. 12), and McIsaac (2013, p. 5)
α^a, δ^r	Table 3 and EBSA (2013)
X_{max}^{DC}	IRS (2009, 2010)
$\alpha_1^{PIA}, \alpha_2^{PIA}, \alpha_3^{PIA}, PIA^{max}$	Social Security Administration (2010, 2011)
$Cap_1^{AIME}, Cap_2^{AIME}$	Social Security Administration (2010, 2011)

Table 6: Estimated parameter values

Param.	Value (std. err)	Param.	Value (std. err)	Param.	Value (std. err)	Param.	Value (std. err)
			a. Sickness and death intensities (16), (17)				
λ_0^m	0.0003	λ_1^m	3.7864			ξ_m	9.4301
	(0.0000)		(0.0950)				(0.1502)
λ_0^s	1.7267	λ_1^s	4.1875	λ_2^s	90.2806	ξ_s	7.0351
	(0.0395)		(0.1190)		(0.0152)		(0.1794)
			b. Health production (3), (18)				
δ_0	0.0268	g^δ	0.0172	ϕ_0	0.0973	g^ϕ	0.0265
	(0.0006)		(0.0006)		(0.0025)		(0.0007)
A_0	2.1820	g^A	0.0039	η_I	0.2744	η_ℓ	0.4554
	(0.0733)		(0.0000)		(0.0100)		(0.0063)
			c. Deductibles and medical prices (10), (11)				
D_0	0.0104	g^D	0.0059	g^P	0.0063		
	(0.0001)		(0.0001)		(0.0002)		
			d. Preferences (19), (20)				
γ	5.2017	μ_c	0.0495	μ_ℓ	0.1987		
	(0.1198)		(0.0010)		(0.0035)		
γ_m	2.0966	μ_m	0.6546				
	(0.0295)		(0.0135)				

C Figures

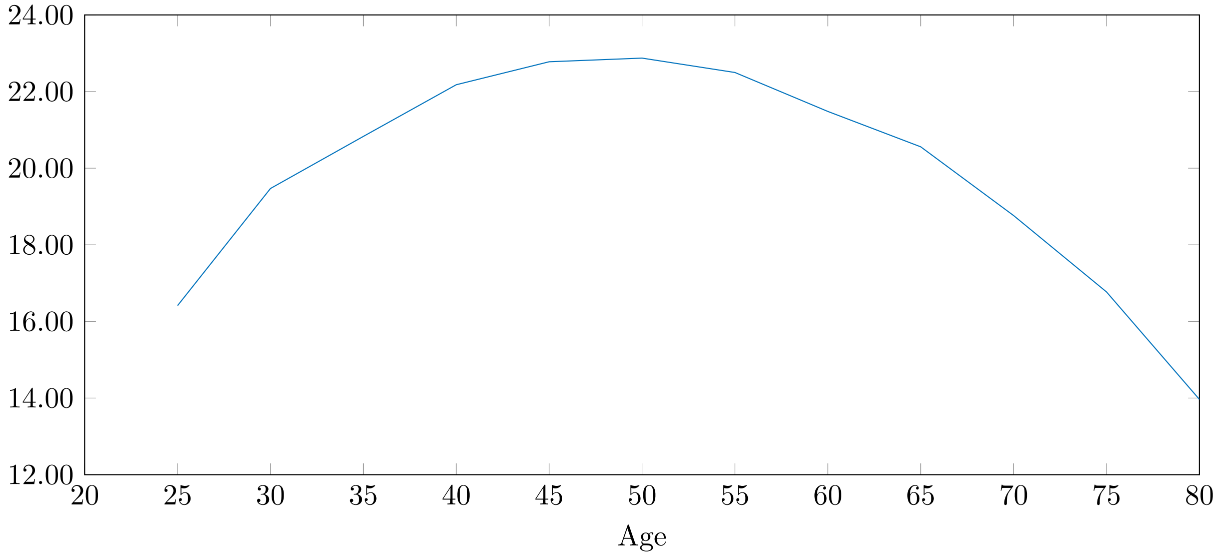

Figure 1: Mean hourly wages

Notes: In 2010 dollars. Data sources: Medical Expenditures Panel Survey (See Table 4 for details).

C.1 Optimal allocations

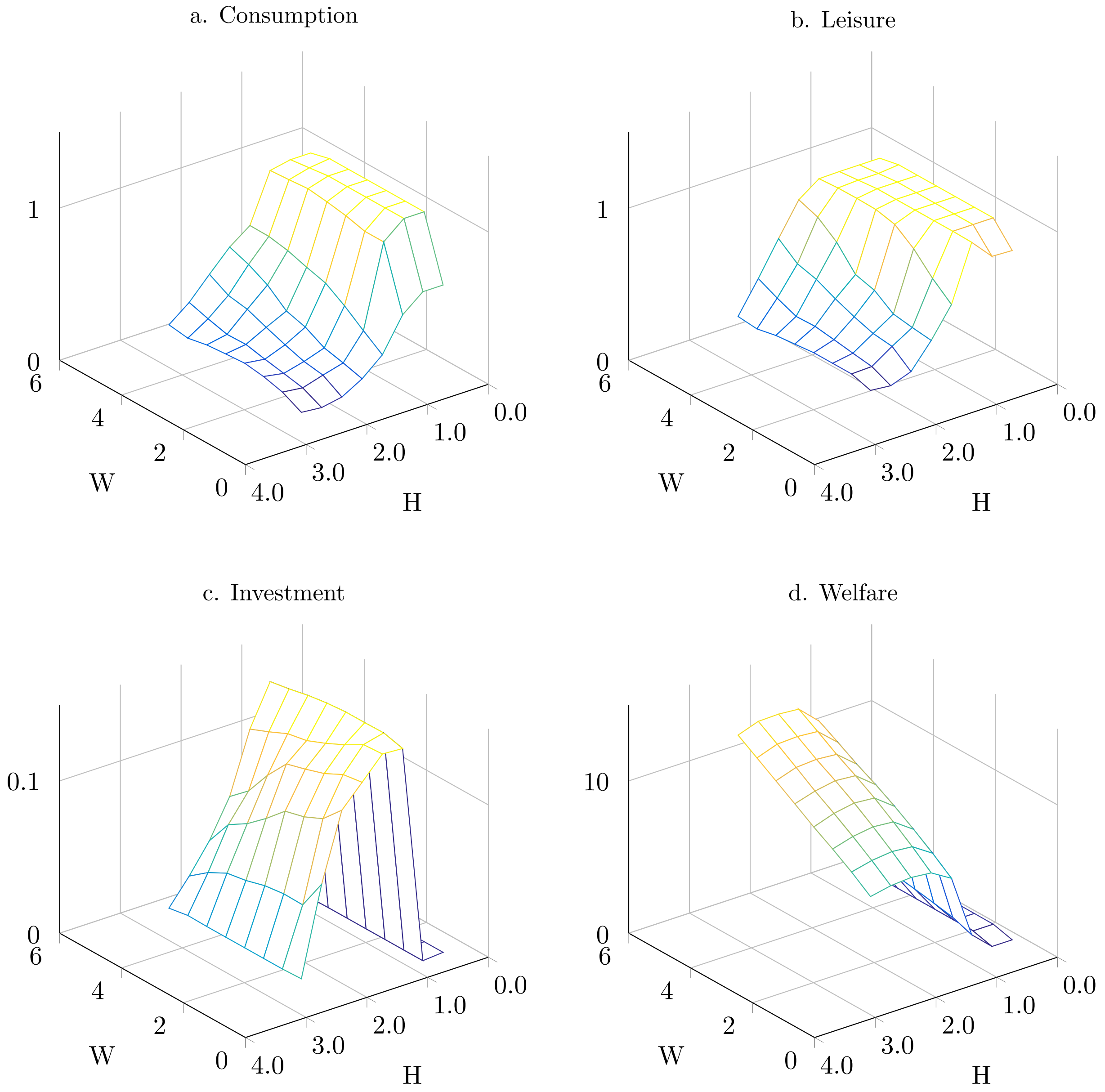

Figure 2: Allocations and welfare in (W, H)

Notes: Mean of optimal allocations and welfare across levels of pension wealth, and between ages 20–80.

C.2 Observed and optimal life cycles

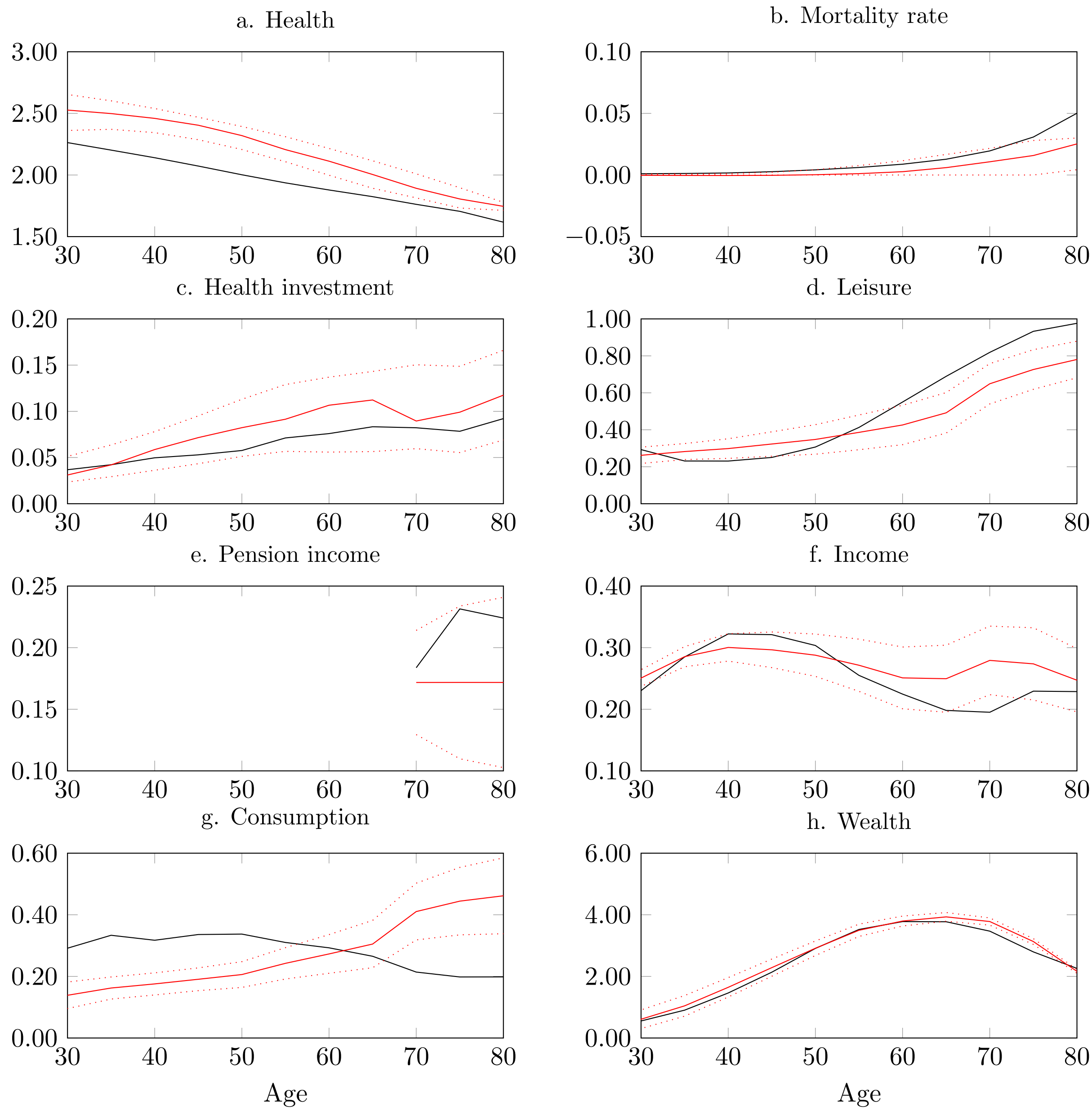

Figure 3: Observed and optimal life cycle allocations (benchmark model)

Notes: Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line. Nominal values in panels e–h are reported in \$100,000 units.

C.3 Alternative model assumptions

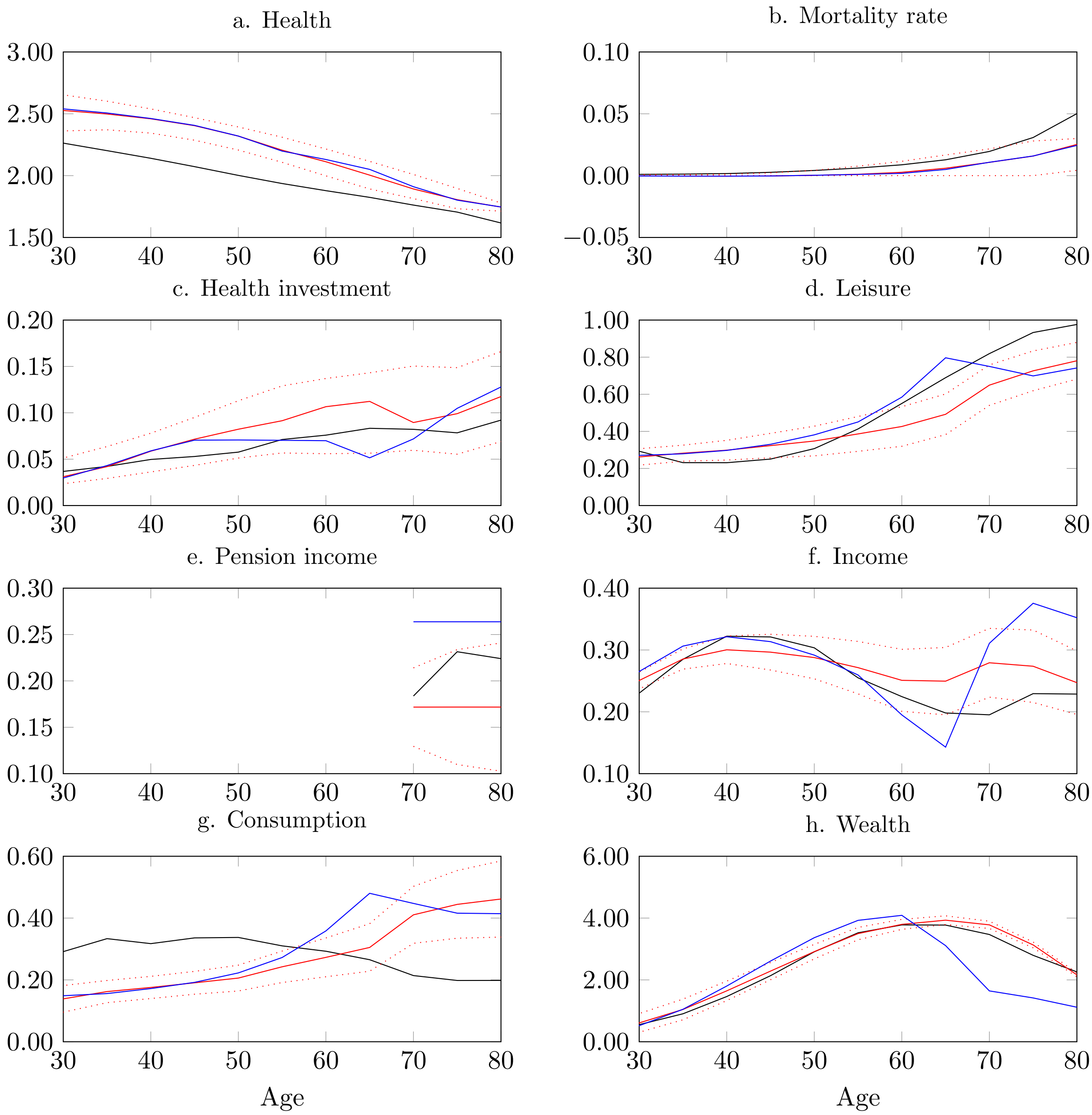

Figure 4: Defined benefit pension plan

Notes: The alternative is obtained by using the Defined Benefit plan outlined in Table 1. Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line; alternative: solid blue line (—). Nominal values in panels e–h are reported in $100,000 units.

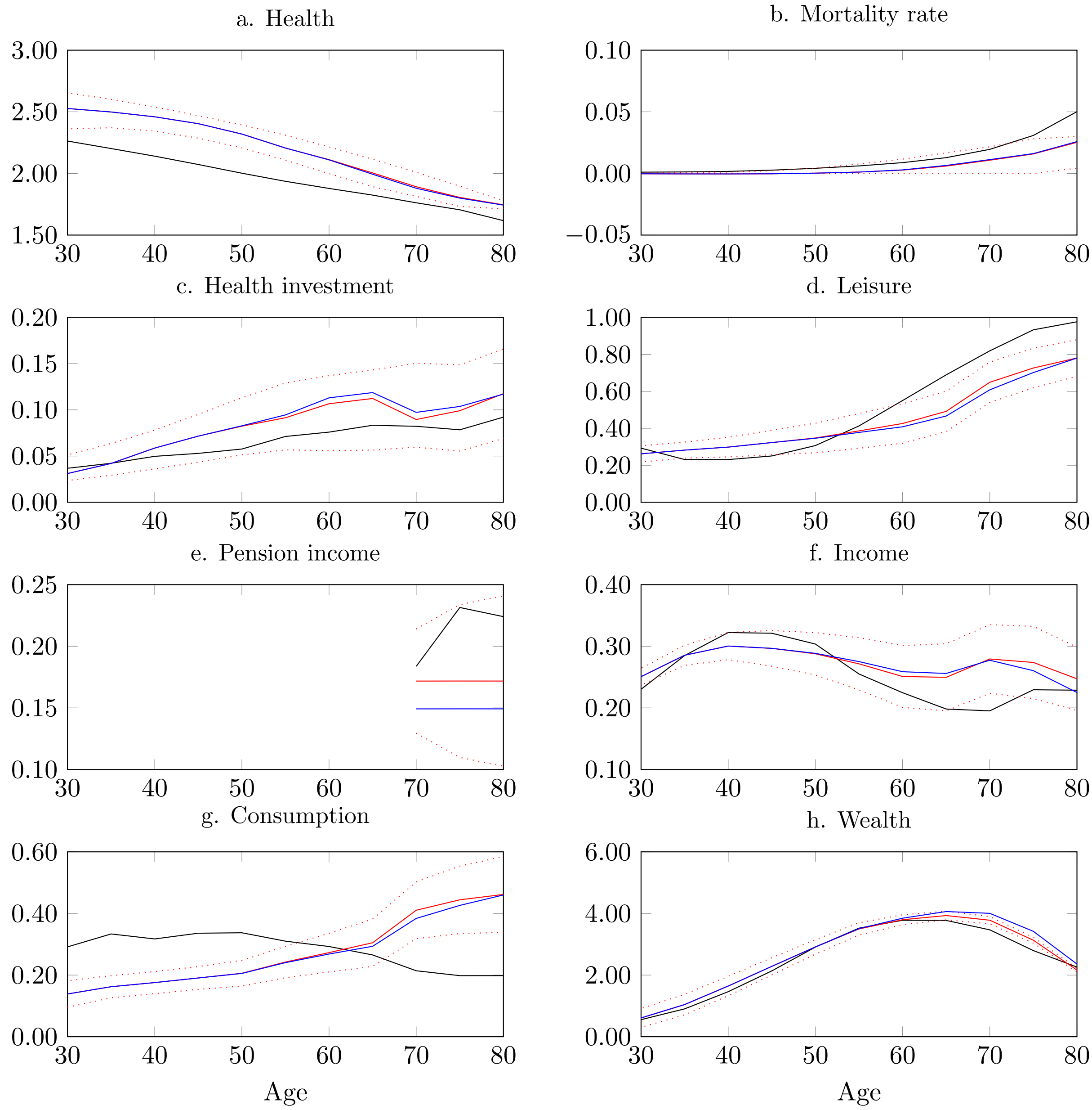

Figure 5: Low risky share

Notes: The alternative is obtained by lowering the risky share of the pension fund portfolio $\tilde{\omega} = 0.5\omega$. Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line; alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.

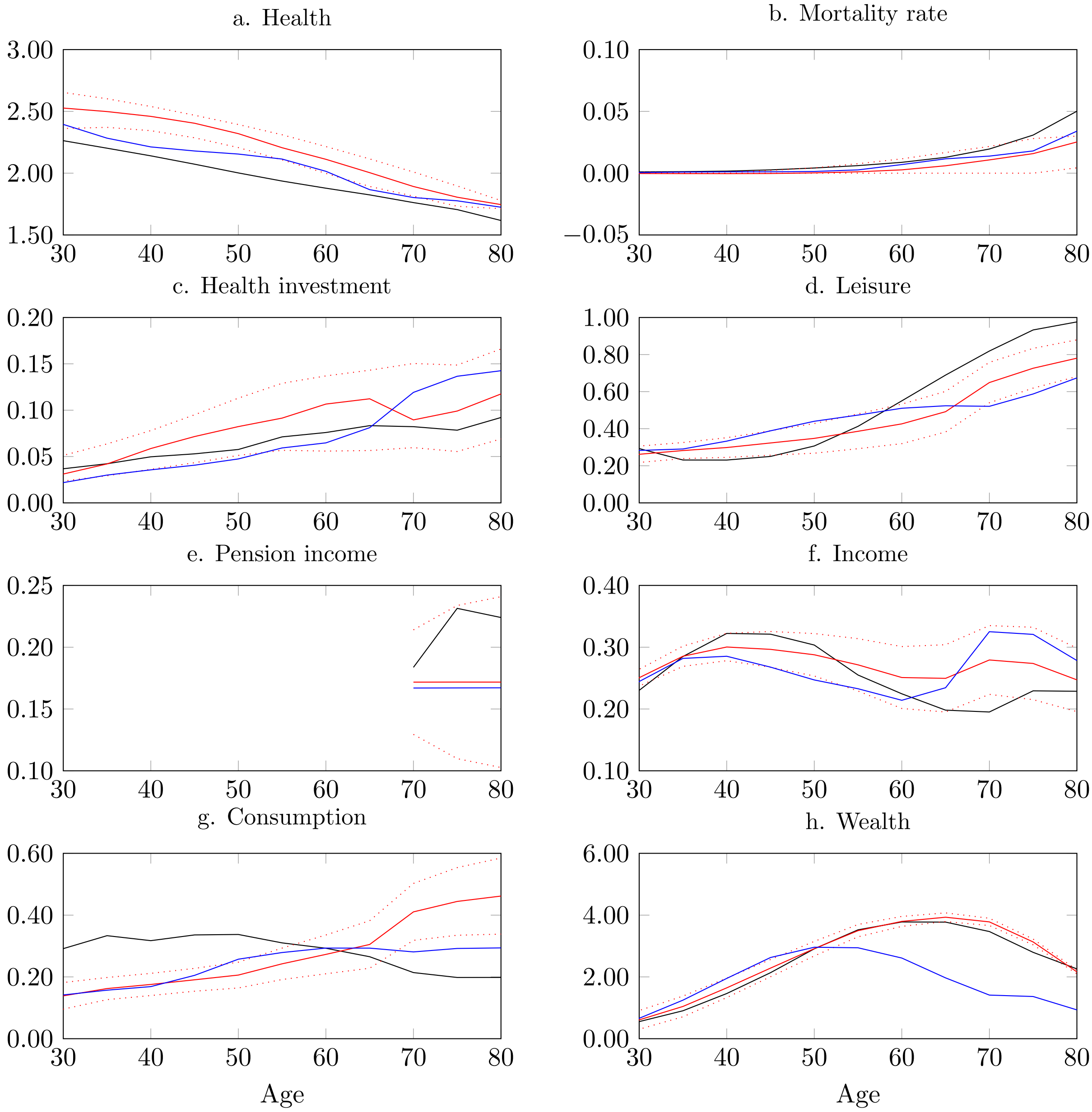

Figure 6: Uninsured young agents

Notes: The alternative is obtained by removing the health insurance for young agents, while retaining Medicare coverage after 65, i.e. $O\tilde{O}P_t(I_t) = (1 - \mathbb{1}_t^R)P_t^I I_t + \mathbb{1}_t^R OOP_t(I_t)$. Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line; alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.