Thrifty and Healthy Enough for the Long Run?[*]

Yannis Mesquida[1] and Pascal St-Amour[1,2,3]

[1]Faculty of Business and Economics (HEC), University of Lausanne

[2]Swiss Finance Institute

[3]CIRANO

July 5, 2016

---

[*] Financial support by the Swiss Finance Institute is gratefully acknowledged. We have benefitted from useful discussions with Raquel Fonseca and Pierre-Carl Michaud.

Abstract

Lifetime financial, work- and health-related decisions made by agents are intertwined with one another. Understanding how these decisions are made is essential to gauge if saving in financial, retirement and human assets is adequate or not. This paper numerically solves, simulates, and structurally estimates a dynamic life cycle model of allocations (consumption/savings, leisure/work and health expenditures), statuses (health, financial and pension wealth) and welfare, allowing for (partially) adjustable exposure to morbidity and mortality risks. Using the simulated life cycle variables as benchmark, our results show that observed choices are not fully consistent with an optimal, forward-looking strategy. Whereas financial savings and pension claims are both adequate, individuals in the data are not healthy enough, and consequently face a shorter horizon than expected. Moreover, full insurance, and age-increasing wages would optimally point to more spending, and less leisure to maintain health than currently observed. As a consequence, observed post-retirement income is too low, and explains a sharp drop in consumption after 65 that is inconsistent with optimizing behavior. Relaxing assumptions on full insurance, and pension regimes only partially alleviates these discrepancies.

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

JEL Classification: E21, I12, J26, J32.

1 Introduction

1.1 Motivation and outline

Agents are required to make complex financial, work-, and health-related decisions throughout their lifetime. A major source of difficulty stems from the fact that these decisions are intertwined with one another (Hugonnier et al., 2013). For example, labor/leisure choices affect not only current resources, but also future pension claims, and health status. The latter conditions exposure to sickness and death risks which in turn affect how much to save in financial assets. Understanding how these lifetime decisions unfold is nonetheless essential if one is to assess the adequacy of savings in *any* asset. Moreover, allowing some degree of substitution and/or complementarity between human, financial and pension wealth levels and instruments is paramount when asking if agents are thrifty and healthy enough.

Regardless of how asset accumulation is measured, the general consensus on savings appears to be not enough of everything: agents save too little in financial wealth (e.g. Hubbard et al., 1994, 1995; Skinner, 2007), in their pension wealth (e.g. Devlin-Foltz et al., 2015; Munnell, 2013; Rhee and Boivie, 2015), and especially not enough in their own health (National Center for Health Statistics, 2012).[1] Whether this assessment is correct or not obviously requires some definition of what is optimal. If we wish to avoid the usual pitfalls of paternalistic views, rules of thumb and horror stories, then, economic theory should be relied upon to determine how much is enough.

The objective of this paper is to propose a step in that direction, and to estimate and rely upon this theoretical metric in order to gauge whether financial and human assets are sufficient or not. Towards that aim, we build upon a dynamic model that has all the features discussed in our earlier example. More precisely, allowing for (partially) endogenous exposure to morbidity and mortality risks, we study the joint life cycle determination of work, financial and health-related choices, fully accounting for the dynamics in financial,

---

[1] 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).

pension, and human health capitals. Importantly, our modeling framework admits a wide range of optimal dynamic policies. For instance, a healthy-and-thrifty policy obtains since the former induces a low discount rate which is conducive to high savings in pension and financial assets, as well as high investing in future health. Conversely, a live-fast and die-young policy is optimal for unhealthy agents facing high mortality risks, and therefore high discount rates, prompting them to favor contemporaneous, over future utility via high current consumption and leisure. Endogenous health ensures that the positioning between these alternatives is determined endogenously.

This model is numerically solved, simulated, and estimated structurally. This allows us to perform a twofold analysis. First, we investigate the effects of current state variables (financial, and pension wealth, as well as health status) on optimal allocations (work/leisure, consumption and health expenditures). Second, we simulate the model to compute the optimal state, and life-cycle allocations. These optimal paths are the theoretical metric against which we gauge their empirical counterparts.

Our main findings with respect to estimated parameters, marginal effects of state variables, and life cycles may be summarized as follows. 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 so-called *Long Reach of Childhood* (Smith, 2009) is important; past health levels have strong effects on the productivity of current health investments. Second, we find that aging entails larger costs of inaction; both deterministic and stochastic health depreciation rates increase sharply with age. Third, our findings with respect to preferences are consistent with relative complementarity between consumption and leisure, as well as a low degree of inter-temporal substitution. We also identify a utilitarian cost of death that is attenuated by a positive motivation for bequest. The latter justifies keeping high financial wealth balances at old age to be left to heirs in the case of death.[2]

Complementarity entails that consumption, and leisure display similar positive wealth gradients, and negative health gradients. Healthier agents face lower death and sickness risks and save, and work more to accomodate a longer life horizon. Optimal health

---

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

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. Otherwise, the health and wealth gradients are positive, and unhealthy agents cut down health expenses, and substitute more leisure when health further deteriorates. We also identify substitutability between financial and pension wealth with the latter having minimal independent effect once the former is accounted for.

Despite confirming pension and financial wealth adequacy, our results indicate that agents are insufficiently healthy and thus face a shorter horizon than optimal (79 vs 84 years). In addition, under full health insurance, and age-increasing wages, health maintenance should be achieved by spending more on health investment, and using less leisure than they actually do. A direct consequence of excessive leisure after mid-life is that elders' total (i.e. retirement plus labor) income is insufficient, forcing a sub-optimal drop in post-retirement consumption. Put differently, observed behavior is *neither* consistent with a live-fast and die-young *nor* with a healthy and thrifty strategy.

We revisit some of the model's key assumption to gauge whether or not they explain our findings. First, allowing for defined a benefit plan does yield an optimal increase in mid-life leisure, however it also predicts healthier and longer-lived agents, contrary to the data. Second, lowering the return on pension assets forces agents to cut down on leisure, and increase health spending. The fit further deteriorates as more financial wealth is required to offset the fall in pension wealth. Third, removing health insurance for younger agents 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 assets. Finally, we allow for potential myopia of agents by replacing the predicted health-dependent with the observed age-dependent death intensity. Again this modification partially explains the differences (e.g. worse health, higher mortality, lower health investment), yet fails to account for all the gaps between the theory and the data. We conclude that none of these assumptions is single-handedly responsible for the discrepancies.

1.2 Relevant literature

Relatively few researchers study the joint dynamic determination of health, labor and financial decisions. French and Jones (2011) build a dynamic programming model that is also structurally estimated using SME in order to find whether employer-provided health insurance, Medicare, and Social Security have any impact on the retirement decision. Their framework includes a complete model of leisure, wealth, retirement, and bequest motive. However, the pension regime is assumed to be a DB plan for every agent. Importantly, contrary to us, health is modeled as an exogenous stochastic binary variable (bad or good health) and health expenditures are also exogenous.

The paper by French (2005) is also based on a dynamic optimization model that is estimated using SME on life cycle moments. Its aim is to evaluate the role of social security and pension taxation as potential explanation for early retirement observed in the data. As for French and Jones (2011), binary health is exogenous and stochastic. Earnings are also stochastic and social security, pension entitlement and spousal income are taken into account. French (2005) focuses on dynamic decisions regarding consumption, hours of work and social security application. Workers are able to reenter the labor force even if they retired early. However, the DC plan is not investigated and neither are endogenous health investment and out-of-pocket expenditures decisions which we address in our setup.

Fonseca et al. (2013) also estimate a life cycle model with endogenous health, asset accumulation and retirement in order to evaluate why health spending and longevity increased in the US from 1965 to 2005. As in French and Jones (2011), early retirement is possible but is irreversible. Earnings are stochastic and follow an exogenous Gaussian process. The model also incorporates health status, health shocks (sickness and death), health insurance, social security, government transfers, spousal earnings, and pension income modeled as a DB plan, with DC retirement abstracted from. The dynamic decisions concern the choice of consumption and health expenditures but abstracts from labor/leisure choices.

Galama et al. (2013) construct a continuous time and structural 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. Interestingly, the retirement decision is completely endogenous. They model DB entitlement, however they do not take into account social security and DC pension.

The focus of Scholz and Seshadri (2013) is similar to French and Jones (2011). The authors investigate the effect of health insurance on retirement decision. However, the model is quite different in that it relies on a health production process with endogenous health expenditures only. Second, they distinguish between working, married, and retired households. Third, they include both mortality and morbidity risks, as well as uncertainty on the earnings process. However, compared to our model, the pension plan is unique and set to DB.

Finally, Samwick and Skinner (2004) rely on an empirical simulation based model with endogenous earnings process and stochastic rate of returns in order to assess whether DC agents are better off than DB ones. They analyze cross sectional data and find that the pension plan type is important in the retirement process. As with us, they argue that it is more important to look at the entire life cycle, and not only the post-retirement period, and claim that any retirement plan difference can be offset by earnings and contribution adjustments throughout the life cycle. However, they do not include labor/leisure choices, and abstract from endogenous health-related risks. The welfare analysis is focused on wealth without evaluating the value function.

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 discussion in Section 5.

2 Model

This section outlines the life cycle allocations problem of an agent facing partially diversifiable mortality and morbidity risks. These decisions concern consumption (medical and non-medical) 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 foregone current income, and lower future 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) 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:

$$T^M = \min\left\{t : \epsilon_t^m = 1\right\}.$$

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:

$$H_{t+1} = \left(1 - \delta_t - \phi_t \epsilon_{t+1}^s\right) H_t + A_t I^g(H_t, I_t, \ell_t). \tag{2}$$

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.

2.2 Retirement plans and income processes

2.2.1 Retirement plans

We first define $T^R = 65$ as the age at which both public and private retirement benefits can be drawn (henceforth the 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 $(1 - \ell_t) \in \mathbb{I}, \forall t \in [16, T^M]$. 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.[3]

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,[4] DC plans will be our benchmark assumption, although we will evaluate the effect of DB plans in our policy analysis in Section 4.4.1. 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.

2.2.2 Income process

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

---

[3] Note that this formulation does not exclude corner solutions in which the agent optimally selects not to work after retirement age, i.e. $\ell_t = 1, t \geq T^R$.

[4] 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.

income, with w_t the after-tax wage rate. The income process is characterized by:

$$Y_t = \left[1 - \left(1 - \mathbb{1}_t^R\right)\tau_w^r\right] w_t(1-\ell_t) + \mathbb{1}_t^R \left(PIA_t + Y_t^r\right) \tag{3}$$

$$Y_t^r = \alpha^r W_t^r \tag{4}$$

$$W_{t+1}^r = \left[W_t^r + \left(1 - \mathbb{1}_t^R\right) X_t^r\right] R_{t+1}^r \tag{5}$$

$$X_t^r = \min\left\{\left(\tau_w^r + \tau_f^r\right) w_t(1-\ell_t), X_{\max}^r\right\}. \tag{6}$$

The specific values of the plan-specific parameters and variables are outlined in Table 1.

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	$R^f + \omega(R_t^e - R_t^f)$	1

Employees can thus work at all ages in (3), 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 Social Security PIA_t, 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 (4) is an annuity α^r applied on cumulated pension wealth W_t^r, where the latter is calculated in (5) 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 (6), 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 no net return.

Regarding public pension, the Primary Insurance Amount PIA_t is the Social Security income computed using the (annualized) $AIME_t$, where the Average Indexed Monthly

Earnings defined as:

$$
\begin{aligned}
PIA_t &= PIA(AIME_t) \\
AIME_t(\{\ell_s\}_{s=16}^{t}) &= \frac{1}{t}\sum_{s=16}^{t} w_s(1-\ell_s)
\end{aligned}
$$

where the exact PIA formula follows Social Security rules and is given in (21) 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:

$$
\begin{aligned}
OOP_t(I_t) &= \left(1-\mathbb{1}^D\right) P_t^I I_t + \mathbb{1}^D \left[D_t + \psi\left(P_t^I I_t - D_t\right)\right] && (7) \\
\Pi_t &= (1-\mathbb{1}_t^R \pi)\Pi && (8)
\end{aligned}
$$

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 (7) 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 (8) 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:

$$
W_{t+1} = \left[W_t + Y_t - C_t - OOP_t - \Pi_t\right] R^f \qquad (9)
$$

where C_t is non-medical consumption, pre- and post-retirement income Y_t is given in (3), out-of-pocket health expenditures OOP_t are in (7), and health insurance premia Π_t is given in (8).

2.4 Preferences

As shown in Pelgrin and St-Amour (2016), and Hugonnier et al. (2013), 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:

$$\beta^m(H_t) = \beta \exp[-\lambda^m(H_t)] < \beta. \tag{10}$$

Moreover, let the instantaneous utility be defined as:

$$\begin{aligned} \mathcal{U}_t &= U(C_t, \ell_t) + [\beta - \beta^m(H_t)]U^m\left(W_t, Y_t^r\right), \\ &= \mathcal{U}(C_t, \ell_t, W_t, H_t, Y_t^r) \end{aligned} \tag{11}$$

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 $\lambda^m(\cdot)$ is a decreasing function, the healthier agent thus behaves as a more patient individual in (10), and assigns a lower weight on the bequest utility in (11). 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:

$$V_t^r = \max_{C_t, I_t, \ell_t} \mathcal{U}_t + \beta^m(H_t)\mathrm{E}\left[V_{t+1}^r \mid H_t\right] \tag{12}$$

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 (11). The optimization (12) is subject to (i) the Bernoulli distribution (1), (ii) the law of motion for health (2), (iii) the retirement income process (5), and (iv) the budget constraint (9).

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 obtains naturally as a high H induces a low discount rate $\lambda^m(H)$, and high patience $\beta^m(H)$ in (10), which is conducive to high savings in pension and financial assets, as well as high investing in future health. Conversely, a live-fast and 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 observed life cycle strategies are (i) optimal, i.e. consistent with the model, and (ii) best described by either options.

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 $\lambda_t^k(H_t)$, gross investment $I^g(H, I, \ell)$, and the instanteneous utility and bequest functions $U(C, \ell), U^m(W, Y^r)$ as follows:

$$\lambda^m(H) = \lambda_0^m + \lambda_1^m H^{-\xi^m}, \tag{13}$$

$$\lambda^s(H) = \lambda_2^s - \frac{\lambda_2^s - \lambda_0^s}{1 + \lambda_1^s H^{-\xi^s}}, \tag{14}$$

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \tag{15}$$

$$U(C, \ell) = \frac{1}{1-\varepsilon} \left[\mu_c C^{1-\gamma} + \mu_\ell \ell^{1-\gamma}\right]^{\frac{1-\varepsilon}{1-\gamma}}, \tag{16}$$

$$U^m(W, Y^r) = \frac{\mu_m \left(W + \delta^r Y^r\right)^{1-\gamma_m}}{1-\gamma_m} \tag{17}$$

Consistent with the model, the two intensities in (13), and (14) 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 (15) allows for monotone increasing, concave effects of health, expenditures and leisure inputs. The instantaneous utility (16) is specified as a CES to maintain positive utilitarian flows from living. In the spirit of Auerbach and Kotlikoff (1987), we allow for differences in the intra- $(1/\gamma)$ and inter-temporal $(1/\varepsilon)$ elasticities of substitution. The bequest utility function (17) 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 heirs. 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 (12) through a backward iteration:

$$\begin{aligned} V(Z_t) &= \max_{Q_t} \mathcal{U}(Q_t, Z_t) + \beta^m(Z_t)\mathrm{E}\left[V(Z_{t+1}) \mid Z_t\right] \\ \text{s.t.} \quad Z_{t+1} &= Z_{t+1}(Q_t, Z_t, \epsilon_{t+1}), \quad \forall Z_t = Z \in \mathbb{Z}. \end{aligned} \tag{18}$$

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

$$\{Q_t(Z), V_t(Z)\}_{t=16}^{T}, \quad \forall Z \in \mathbb{Z} \tag{19}$$

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

1. The initial state draws (with replacement) from the observed population wealth, health levels at age 15:[5]

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

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

   (a) A trilinear interpolation of the policy functions (19) 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,

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

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

   $$\log(R_{t+1}^e) \sim \text{N.I.D.}(\mu_e, \sigma_e^2)$$

   (d) We use the laws of motion (18) to update the state variables:

   $$Z_{t+1}^{i,n} = Z_{t+1}\left(Q_t^{i,n}, Z_t^{i,n}, \epsilon_{t+1}^{i,n}\right).$$

3.3 Moments and SME estimation

Given the output sequence $\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}$, the theoretical life-cycle $\hat{M}_t$ and unconditional moments $\hat{M}^u$ need to be calculated for the population of living agents only. For that purpose, let $\mathbb{1}_t^{i,n} \in \{1, \text{NaN}\}$ be the alive indicator for agent i, in simulation n, at age t. The life-cycle and unconditional moments are given by:[6]

$$\begin{aligned}\hat{M}_t &= \frac{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}}{\sum_{i=1}^{K_I}\sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}, \\ \hat{M}^u &= \frac{\sum_{t=16}^{T} \hat{M}_t}{T-16}.\end{aligned} \tag{20}$$

---

[5] The initial pension entitlement Y_{15}^r is set at the minimum point on the discretized state space.

[6] In practice we rely on the `nanmean` function in Matlab to avoid factoring in the deaths in computing the moments.

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:

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

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, and the annual mortality rates 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 5 life cycle variables times 12 five-year bins, meaning a total of $K_M = 60$ moments, the Simulated Moments Estimation of Θ^e is clearly over-identified since we estimate 23 deep parameters.

The SME methods require observed life cycle moments on wealth, health, leisure, and out-of-pocket health expenditures. 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 rely on 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. Indeed, 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 total (Consumer Expenditures Survey, CEX) and out-of-pocket medical expenses (Medical Expenditures Survey, MEPS), are the mean expenses per person, conditional upon expenditures.

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 U.S Social Security Administration. However, we fix the DB contribution rate τ_f^{DB} and the DC annuity factor $\alpha^D C$ 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 discussing the role of alternative key assumptions.

4.1 Parameters

Calibration set The values and sources for the calibrated parameters Θ^c are shown in Table 5.a (values), and .b (sources). 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 $\lambda^m(H)$ parameters in (13) 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 (14) 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 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 (15) 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 in the sense that not all contemporary health issues may be solved through high expenditures and healthy leisure only.

Turning to preferences in panel 6.c, the CES utility (16) 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 relative complementarity between consumption and leisure.[7] Moreover, we observe an important weight of leisure relative to consumption in the utility function ($\mu_\ell > \mu_C$), as well as a high inter-temporal elasticity of substitution $1/\varepsilon \gg 1$. The estimates of the bequest function (17) suggest a utility cost of death ($\gamma_m > 1$), and realistic relative risk aversion with respect to stochastic financial risk ($\gamma_m = 2.09$). The bequest motive is also found to be non-negligible ($\mu_m > 0$).

Finally, in panel 6.d, 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 ($g^P > g^D > g^A$).

4.2 Optimal allocations

Figure 1 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. Figure 2 plots these variables in the retirement wealth, and health space (W^R, H), where the mean is taken across the age, and financial wealth dimensions, whereas Figure 3 plots these variables in the (W^R, W) space, where the mean is taken across the age, and health dimensions.

First, the optimal consumption in Figure 1.a is monotone increasing in wealth, and decreasing in health. Whereas the wealth effects are as expected, the negative health

---

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

gradient can be explained 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 1.b displays strong similarities with consumption, due to the complementarities that was 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. Observe that the sufficiently healthy and rich agents elect not to work, and take full leisure ($\ell = 1$) instead.

Third, the optimal investment in Figure 1.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 unhealthy individuals. Very unhealthy agents, facing a near unit probability of further sickness and death, thus prefer to cut down on spending, and take full leisure instead when health further deteriorates. This choice is sensible as leisure provides instantaneous utility, whereas spending does not. Finally, as expected, the welfare in Figure 1.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.

Figures 2, and 3 both isolate the effects of retirement wealth on the optimal allocations and on welfare. The retirement wealth gradient is found to be very similar to financial wealth (Fig. 2), yet is moderate once the latter is accounted for (Fig. 3). Indeed, replacing financial, with retirement wealth yields very similar policies in the (W^R, H) space, whereas averaging across health and expressing the policies in (W^R, W) space shows negligible marginal effects of retirement wealth, once financial net worth is accounted for. Again, the substitution away from health spending (panel c) and in favor of leisure (panel b) for wealthier agents is apparent. All in all, this suggests some degree of substitutability between financial and retirement wealth, once health status and age are integrated across.

4.3 Optimal life cycles

To isolate the effects of age, the optimal life cycle trajectories are reported in Figure 4 in Appendix C.2. They are computed as the mean of the simulated paths at a given age using (20). We plot the benchmark simulated allocation (red), along with standard errors (dotted red), and the corresponding observed data (black). 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 4.a illustrates that the secular drop in health levels is accurately reproduced. However, the level is not, indicating that agents in the data are insufficiently healthy compared to the predicted benchmark. Consequently, their exposure to mortality risk (panel b) is too high, and their life horizon is shorter than should be (79.3 years in the data vs 83.9 years predicted).

Moreover, observed spending is less than predicted (panel c), and leisure, while insufficient before mid-life, is excessive afterwards (panel d). Low early wages, that are increasing afterwards means that agents should work less when young, and more starting at mid-life. Complete health insurance coverage suggests that they should also substitute less leisure with more health spending to maintain health; this predicted behavior however is not observed in the data.

Third, despite pension income adequacy (panel e), excessive leisure and insufficient work means that observed total income is insufficient after mid-life (panel f). Consumption is also excessive before mid-life, and clearly below what is optimal after 65 (panel g). Put differently, observed consumption is too flat compared with theoretical predictions; it should optimally be increased in old age to compensate for the flatter leisure. Despite excessive pre-retirement consumption, low observed health spending and pre-retirement leisure entails that observed and optimal financial wealth paths coincide throughout lifetime (panel h). The old-age drop in consumption is therefore attributable to lower labor income, and not to insufficient wealth or pension claims.

4.4 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 (DB) plan. Second, we allow for pontential 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. Fourth, we allow for potential myopia with respect to the endogeneity of death risk exposure. 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.

4.4.1 DB pension plans

As discussed earlier, recent trends have witnessed a fall in DB-type pension plans in favor of DC regimes, prompting us to adopt a defined contribution perspective. Still, defined benefits remain important for many workers, and the model is modified accordingly. The effects on predicted life cycles are reported in Figure 5.

DB plans are often considered to be more generous than their DC counterparts, and this is reflected in much higher pension claims (panel e). The latter encourages DB workers to take an early retirement path (panel d) which results in limited post-retirement improvements in health (panel a), and moderately lower mortality (panel b). Moreover, more mid-life leisure entails that health expenditures can be substituted away (panel c), leading to more pre-retirement financial wealth (panel h). Because pension income is higher, consumption at mid-life can be accelerated (panel g), and causes financial wealth to recede more rapidly after retirement.

4.4.2 Lower return on the pension assets

We have imposed a risky portfolio share $\omega = 60\%$ on DC pension assets. Potential mis-management may result in lower shares which will reduce the rate of return on pension funds, 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 6, and are shown to be very limited.

As expected, lower returns on pension assets results in a decline in pension income (panel e), and post-retirement total income (panel f), forcing the agent to cut down on leisure, and increase hours worked (panel d). The drop in leisure mostly compensated by increased health spending (panel c), such that both health (panel a), and mortality (panel b) remain unaffected. The drop in the value of pension wealth forces the agent to increase financial wealth (panel h), by cutting down consumption (panel g).

4.4.3 Uninsured young agents

Our model assumes full insurance for young and old agents alike. Yet, before PPAC-A becomes fully operational, a sizable share of the US younger population remains uninsured with respect to health risks.[8] To analyze the effects of uninsurance, we modify the model to let young agents face the full price of health expenditures, while allowing for full Medicare coverage for elders. The changes with respect to the initial theoretical predictions are reported in Figure 7.

First, uninsured young agents are unsurprisingly in worse health than insured individuals (panel a), and consequently face a higher mortality risk exposure (panel b). As expected they substitute away from costly health spending (panel c), and in favor of more leisure (panel d) so as to maintain health. As Medicare becomes operational after 65, they reverse these choices by spending more, and cutting down on leisure. The latter is however too late to offset a fall in pension income (panel e), while pre-retirement drop in hours worked results in important cuts in labor revenues (panel f). A shorter expected life span, and higher price of medical expenditures mean that both post-retirement financial wealth (panel h), and consumption (panel g) are reduced.

4.4.4 Myopic health risks

Finally we consider an alternative where agents correctly anticipate the mean death risk at any given age, but are myopic to the possibility of altering that risks through their health decisions. The results in Figure 8 thus replace the theoretical death intensity by $\tilde{\lambda}_t^m$ obtained by projecting the observed death intensities at age t, obtained from the Life Tables on a constant, and on age. Agents are thus myopic in omitting to account for the endogenous dependence of their risk exposure on their own adjustable health, $\lambda_t^m(H_t)$.[9]

---

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

[9] Qualitatively similar results are obtained by replacing the projected mortality rate by the actual rate.

As expected, removing the endogeneity of death risk exposure reduces the attractiveness of spending resources to maintain health. Consequently, both investment (panel c), and leisure (panel d, after age 55) fall sharply, inducing a sharp drop in health level (panel a), and an increased mortality (panel b) compared to our benchmark theoretical model. More work for elders translates to higher total income (panel f), despite a drop in pension revenues (panel e). Finally, a shorter expected lifetime reduces the need to maintain financial wealth balances (panel h), which is sufficiently important as to force a cut in post-retirement consumption (panel g).

5 Discussion

This paper's objective is to assess whether observed life cycle choices by agents with respect to health, leisure/work, and consumption/savings can be rationalized as optimal dynamic policies. In particular, we ask if agents can be considered to be healthy and thrifty enough for the long run. Alternatively, we also inquire whether they optimally select to live fast and die young.

Our modeling strategy evolves around a flexible dynamic optimization framework that can accommodate both hypotheses. In particular, endogenous exposure to future morbidity and mortality risks, as well as future consequences of current leisure choices on future pension entitlement are fully internalized. A key difference with previous studies is that life cycle health-, financial, and work-related choices are thus analyzed *jointly*, rather than separately to assess financial and health adequacy. Moreover, structural estimation of the model ensures a one-to-one mapping between the theory and the empirical assessment.

Based on the previous results, we can hardly conclude that observed choices are consistent with an optimal, forward-looking strategy. Whereas financial savings and pension claims do not appear to be inadequate (i.e. agents are thrifty), individuals in the data are not healthy enough, and consequently face a shorter horizon than expected. Moreover, assuming full insurance would optimally point to more spending, and less leisure to maintain health than currently observed. As a consequence, post-retirement income is too low, and explains a sharp drop in consumption after 65 that is inconsistent with optimizing behavior. Put differently, observed behavior is not consistent with an optimal healthy and thrifty enough strategy. This being said, it is not clear either that they optimally select a live-fast and die-young perspective. One the one hand, they are unhealthy, and short-lived, and consume too much when young compared to the model. However, on the other hand, both accumulated pension and financial wealth appear consistent with the theoretical predictions.

A fair concern is whether our underlying assumptions stand behind the model's inability to fully reproduce the data. To address this question, 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. Relaxing the pension plan hypothesis only partially improves the results. Whereas the model predicts that leisure should increase after mid-life, health spending is lower for DB agents. However, both effects offset one another with respect to health maintenance such that DB agents are similarly healthy, and long-living than 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, 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.

Third, before PPAC-A 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. First, 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.

Finally, we also considered potential myopia with respect to mortality risks by replacing the death endogenous intensity with an age-increasing, but health-independent version, such that agents correctly expect their death exposure on average, but fail to internalize the positive impacts of healthy choices on longevity. Again this modification holds some promises, yet is insufficient to account for all the differences between predicted, and observed behavior. In particular, as we remove the longevity value of better health, predicted health deteriorates strongly via lower expenses and leisure. Moreover, post-retirement consumption is pro-factually much lower, but results from counter-factual drops in financial wealth for elders.

Overall, we conclude that the discrepancies between the data and the optimal allocation cannot be solely attributed to excessive assumptions related to pension, or health insurance regime, nor through those regarding the forward-looking aptitudes of agents. Other alternative explanations include real estate which has been omitted from the analysis. Higher post-retirement leisure could be explained by more liquid wealth incorporated in house value, allowing less work for elders. A shorter life horizon induced by unhealthy behavior could also be rationalized by more bequest utility from bequeathed housing wealth. 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. Finally, we have allowed for age-dependent variation in human capital depreciation, and consequences of illness. An alternative could be to also allow for independent age variation in death and sickness risk exposures, in addition to that induced by falling health. Age-increasing incidence could reduce the attractivity of investing in one's health and could help reconciling the model with the data. We leave these and other potential explanations on the research agenda.

References

Arias, Elizabeth (2014) 'United States life tables, 2010.' *National Vital Statistics Report* 63(7), 1–63

Auerbach, Alan J., and Laurence J. Kotlikoff (1987) *Dynamic fiscal policy.* (Cambridge; New York and Melbourne:)

Broadbent, John, Michael Palumbo, and Elizabeth Woodman (2006) 'The shift from defined benefit to defined contribution pension plans - implications for asset allocation and risk management.' Technical Report, Working Group on Institutional Investors, Global Savings and Asset Allocation established by the Committee on the Global Financial System, December

Bureau of Labor Statistics (2011) 'Highlights of womens earnings in 2010.' Report 1031, U.S. Department of Labor, July

Chen, Kai, and Mary Hardy (2010) 'Trade-off between benefits and guarantees: A DB underpin pension plan case.' Working Paper E-2010-09-008, School of Economics at Peking University, September

Deloitte (2009) 'Defined contribution / 401(k) fee study.' Report, Investment Company Institute, June

_ (2014) 'Annual defined contribution benchmarking survey.' Report, International Foundation of Employee Benefits Plans

DeNardi, Mariacristina, Eric French, and John Bailey Jones (2015) 'Savings after retirement: A survey.' NBER Working Paper 21268, National Bureau of Economic Research

Devlin-Foltz, Sebastian, Alice M. Henriques, and John Sabelhaus (2015) 'The evolution of retirement wealth.' Finance and Economics Discussion Series 2015-009, Board of Governors of the Federal Reserve System

Duffie, Darrell, and Kenneth J Singleton (1993) 'Simulated Moments Estimation of Markov Models of Asset Prices.' *Econometrica* 61(4), 929–52

EBSA (2013) 'What you should know about your retirement.' Booklet, U.S. Department of Labor, Employee Benefits Security Administration

Federal Reserve Bank of St-Louis 'Federal Reserve Economic Data (FRED).' `http://research.stlouisfed.org/fred2/`

Fonseca, Raquel, Pierre-Carl Michaud, Arie Kapteyn, and Titus Galama (2013) 'Accounting for the Rise of Health Spending and Longevity.' IZA Discussion Papers 7622, Institute for the Study of Labor (IZA)

Forman, John Barry (2000) ‘Public pensions: Choosing betwee defined benefits and defined contribution plans.’ *Law Review of Michigan State University* 1, 187–213. Tax Law Symposium

French, Eric (2005) ‘The Effects of Health, Wealth, and Wages on Labour Supply and Retirement Behaviour.’ *Review of Economic Studies* 72(2), 395–427

French, Eric, and John B. Jones (2011) ‘The Effects of Health Insurance and Self-Insurance on Retirement Behavior.’ *Econometrica* 79(3), 693–732

French, Kenneth ‘U.S. research returns data library.’ `http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/index.html`

Fronstin, Paul, and Ruth Helman (2013) ‘Views on employment-based health benefits: Findings from the 2013 health and voluntary workplace benefits survey.’ Notes 12, Employee Benefit Research Institute, December

Galama, Titus, Arie Kapteyn, Raquel Fonseca, and Pierre-Carl Michaud (2013) ‘A health production model with endogenous retirement.’ *Health Economics* 22(8), 883–902

Grossman, Michael (1972) ‘On the concept of health capital and the demand for health.’ *Journal of Political Economy* 80(2), 223–255

Henry J. Kaiser Family Foundation (2011a) *Employer Health Benefits: 2011 Annual Survey* (Menlo Park CA)

_ (2011b) ‘Medicare at a glance.’ Medicare Policy Fact Sheet, Menlo Park CA, November

_ (2015) ‘Key facts about the uninsured population.’ `http://kff.org/uninsured/fact-sheet/key-facts-about-the-uninsured-population/`

Hubbard, R. Glenn, Jonathan Skinner, and Stephen P. Zeldes (1994) ‘Expanding the life-cycle model: Precautionary saving and public policy.’ *American Economic Review* 84(2), 174–79

_ (1995) ‘Precautionary saving and social insurance.’ *Journal of Political Economy* 103(2), 360 – 399

Hugonnier, Julien, Florian Pelgrin, and Pascal St-Amour (2013) ‘Health and (Other) Asset Holdings.’ *Review of Economic Studies* 80(2), 663–710

ICI (2013) ‘401(k) plan asset allocation, account balances and loan activities in 2012.’ ICI Research Perspective, Investment Company Institute

_ (2014) ‘Investment company factbook.’ ICI Research Perspective, Investment Company Institute

IRS (2009) ‘Internal revenue bulletin.’ Technical Report 2009-50, Internal Revenue Service

_ (2010) ‘Internal revenue bulletin.’ Technical Report 2010-49, Internal Revenue Service

Keane, Michael, and Kenneth Wolpin (1994) ‘The Solution and Estimation of Discrete Choice Dynamic Programming Models by Simulation and Interpolation: Monte Carlo Evidence.’ *The Review of Economics and Statistics* 76(4), 648–72

Love, David A., Michael G. Palumbo, and Paul A. Smith (2009) ‘The trajectory of wealth in retirement.’ *Journal of Public Economics* 93(1-2), 191 – 208

McIsaac, Chris (2013) ‘How America saves.’ Report, The Vanguard Group

Medicare.gov ‘Medicare costs at a glance.’ `http://www.medicare.gov/your-medicare-costs/costs-at-a-glance/costs-at-glance.html`

Munnell, Alicia H. (2013) ‘401 (k)/ira holdings in 2013: An update from the SCF.’ Briefs IB-14-15, Center for Retirement Research, September

Munnell, Alicia H., and Pamela Perun (2006) ‘An update on private pensions.’ Briefs IB-50, Center for Retirement Research, August

National Center for Health Statistics (2012) *Health, United States, 2011: With Special Feature on Socioeconomic Status and Health* (Hyattsville, MD: United States Department of Health and Human Services. Centers for Disease Controls and Prevention)

Pang, Gaobo, and Mark J. Warshawsky (2013) ‘Retirement Savings Adequacy of US Workers.’ Working Paper 2263379, SSRN

Pelgrin, Florian, and Pascal St-Amour (2016) ‘Life cycle responses to health insurance status.’ *Journal of Health Economics.* Forthcoming

Rhee, Nari, and Ilana Boivie (2015) ‘The continuing retirement savings crisis.’ NIRS Research Report, National Institute on Retirement Security, March

Samwick, Andrew, and Jonathan Skinner (2004) ‘How Will 401(k) Pension Plans Affect Retirement Income?’ *American Economic Review* 94(1), 329–343

Scholz, John Karl, and Ananth Seshadri (2013) ‘Health Insurance and Retirement Decisions.’ *Michigan Retirement Research Center Research Paper*

Skinner, Jonathan (2007) ‘Are you sure you’re saving enough for retirement?’ *Journal of Economic Perspectives* 21(3), 59 – 80

Smith, James P. (2009) ‘The impact of childhood health on adult labor market outcomes.’ *Review of Economics and Statistics* 91(3), 478–489

SSA (2010) ‘Facts and figures about social security’

_ (2011) ‘Fast facts and figures about social security’

The Boards Of Trustees, Federal HI and SMI Trust Funds (2012) ‘The 2012 annual report of the boards of trustees of the federal hospital insurance and federal supplementary medical insurance trust funds.’ Annual report, Washington DC

A Social Security

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

$$\begin{aligned} PIA_t = \min \{ & \alpha_1^{PIA} \min \left(AIME_t, Cap_1^{AIME} \right) + \\ & \alpha_2^{PIA} \max \left[0, \min \left(AIME_t - Cap_1^{AIME}, Cap_2^{AIME} - Cap_1^{AIME} \right) \right] + \\ & \qquad \alpha_3^{PIA} \max \left(0, AIME_t - Cap_2^{AIME} \right), PIA^{max} \} \end{aligned} \tag{21}$$

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}:

$$AIME_t = \frac{1}{T^E \tau_f^{DB}} Y_t^{DB} \tag{22}$$

such that (21) becomes:

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

where we set $T^E = 49$, and $\tau_f^{DB} = 0.014$ in AIME (22).

B Tables

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
70	538	524	526	508	524
75	596	580	596	566	584.5
80	684	668	675	649	669
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
$\delta^r = 0.5$ 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 (HRGW31X), 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}	0.014	τ_f^{DC}	0.05	τ_w^{DC}	0.06		
α^a	0.067	δ^r	0.5	$X_{\max}^{DC}$	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

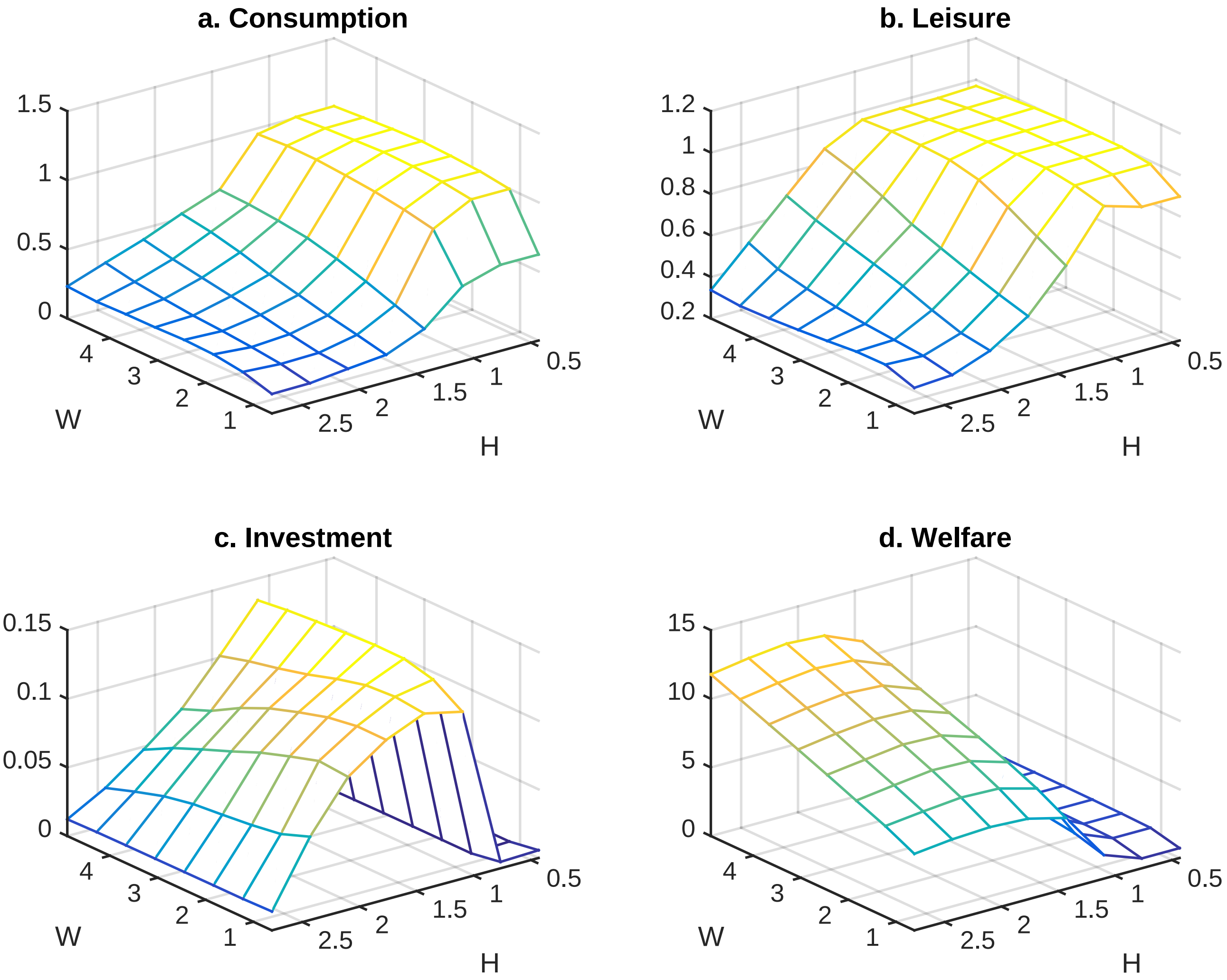
Parameters	Sources and explanations
T, κ	Life tables, Arias (2014). Median age, Bureau of Labor Statistics (2011, Tab. 2, p. 4).
β	Various literature
P_0^I	National Center for Health Statistics (2012, Tab. 126), CPI and annual percent change for all items, selected items and medical care components, 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)
$\alpha_1^{PIA}, \alpha_2^{PIA}, \alpha_3^{PIA}, PIA^{max}$	SSA (2010, 2011)
$Cap_1^{AIME}, Cap_2^{AIME}$	SSA (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 (13), (14)							
λ_0^m	0.0003	λ_1^m	3.7702			ξ_m	9.3898
	(0.0000)		(0.0087)				(0.0051)
λ_0^s	1.7193	λ_1^s	4.1696	λ_2^s	89.8946	ξ_s	7.0050
	(0.0061)		(0.0115)		(0.0002)		(0.0080)
b. Health production (2), (15)							
δ_0	0.0267	g^δ	0.0171	ϕ_0	0.0974	g^ϕ	0.0269
	(0.0001)		(0.0001)		(0.0005)		(0.0001)
A_0	2.1727	g^A	0.0039	η_I	0.2732	η_ℓ	0.4666
	(0.0048)		(0.0000)		(0.0080)		(0.0018)
c. Preferences (16), (17)							
γ	5.1795	μ_c	0.0493	μ_ℓ	0.1979	ε	0.0002
	(0.0167)		(0.0002)		(0.0060)		(0.0000)
γ_m	2.0876	μ_m	0.6518				
	(0.0088)		(0.0024)				
d. Deductibles and medical prices (7), (8)							
D_0	0.0104	g^D	0.0059	g^P	0.0063		
	(0.0000)		(0.0000)		(0.0000)		

C Figures

C.1 Optimal allocations


a. Consumption

b. Leisure

c. Investment

d. Welfare

Figure 1: Allocations and welfare in (W, H)

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

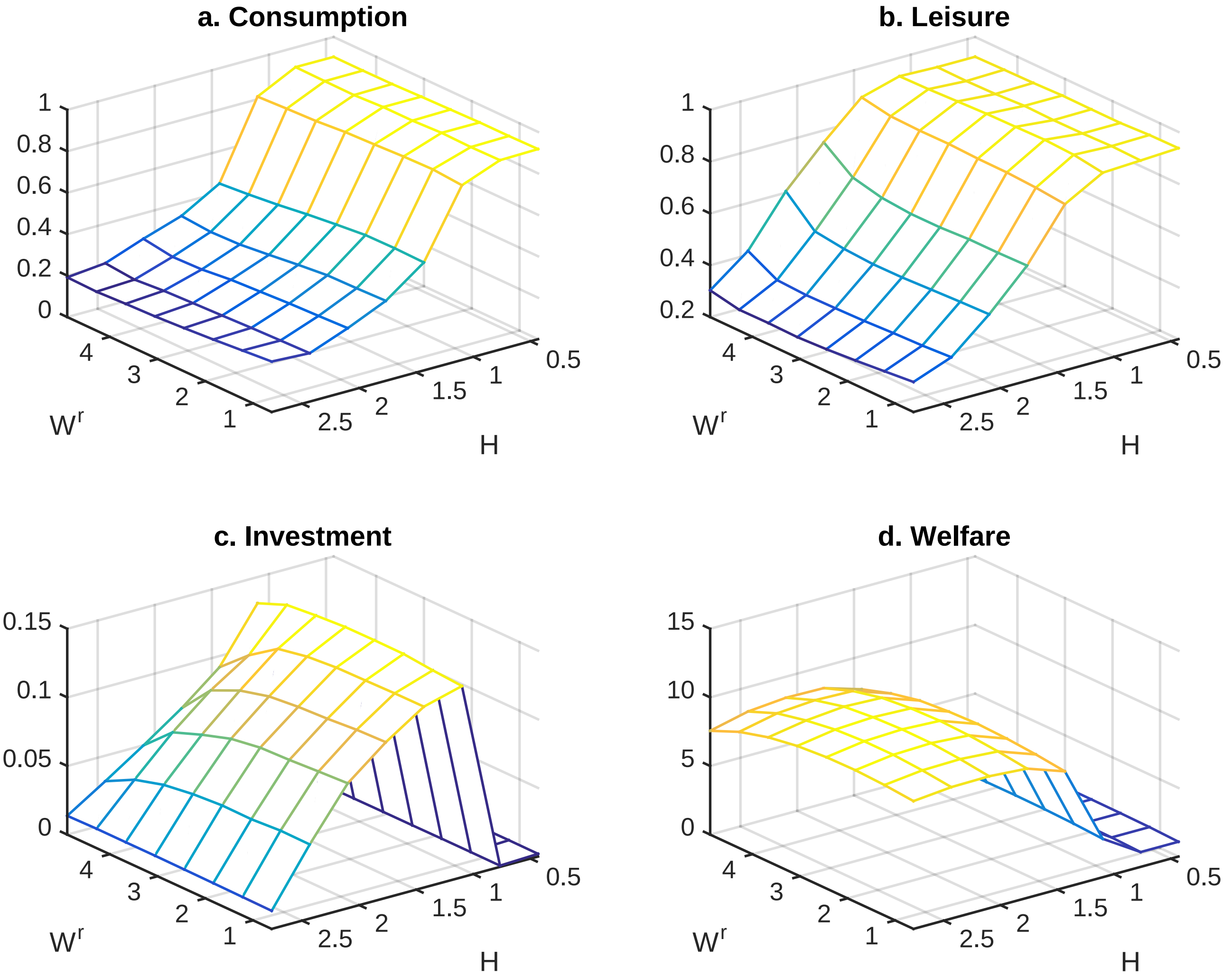


Figure 2: Allocations and welfare in (W^r, H)

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

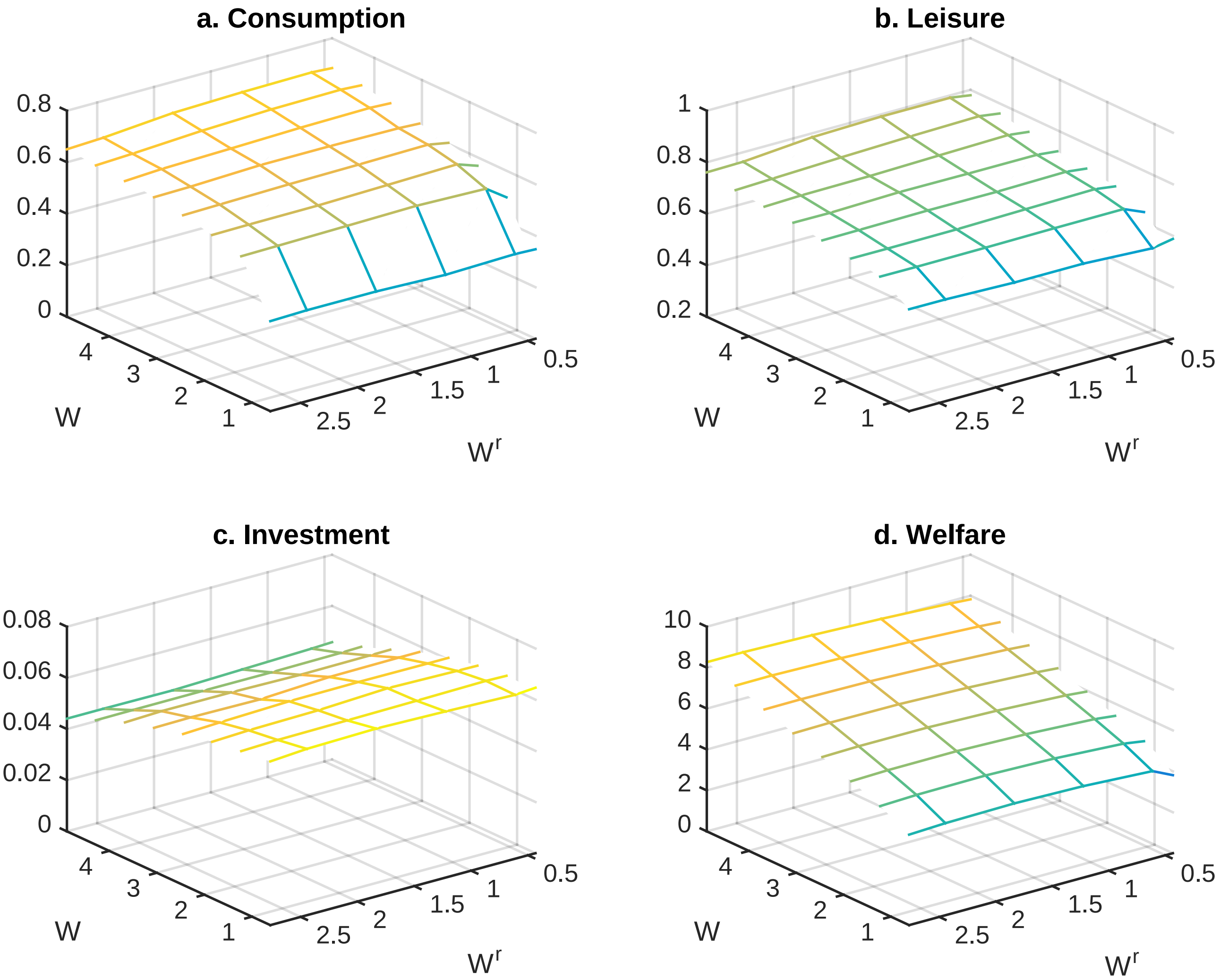


Figure 3: Allocations and welfare in (W, W^r)

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

C.2 Optimal life cycles

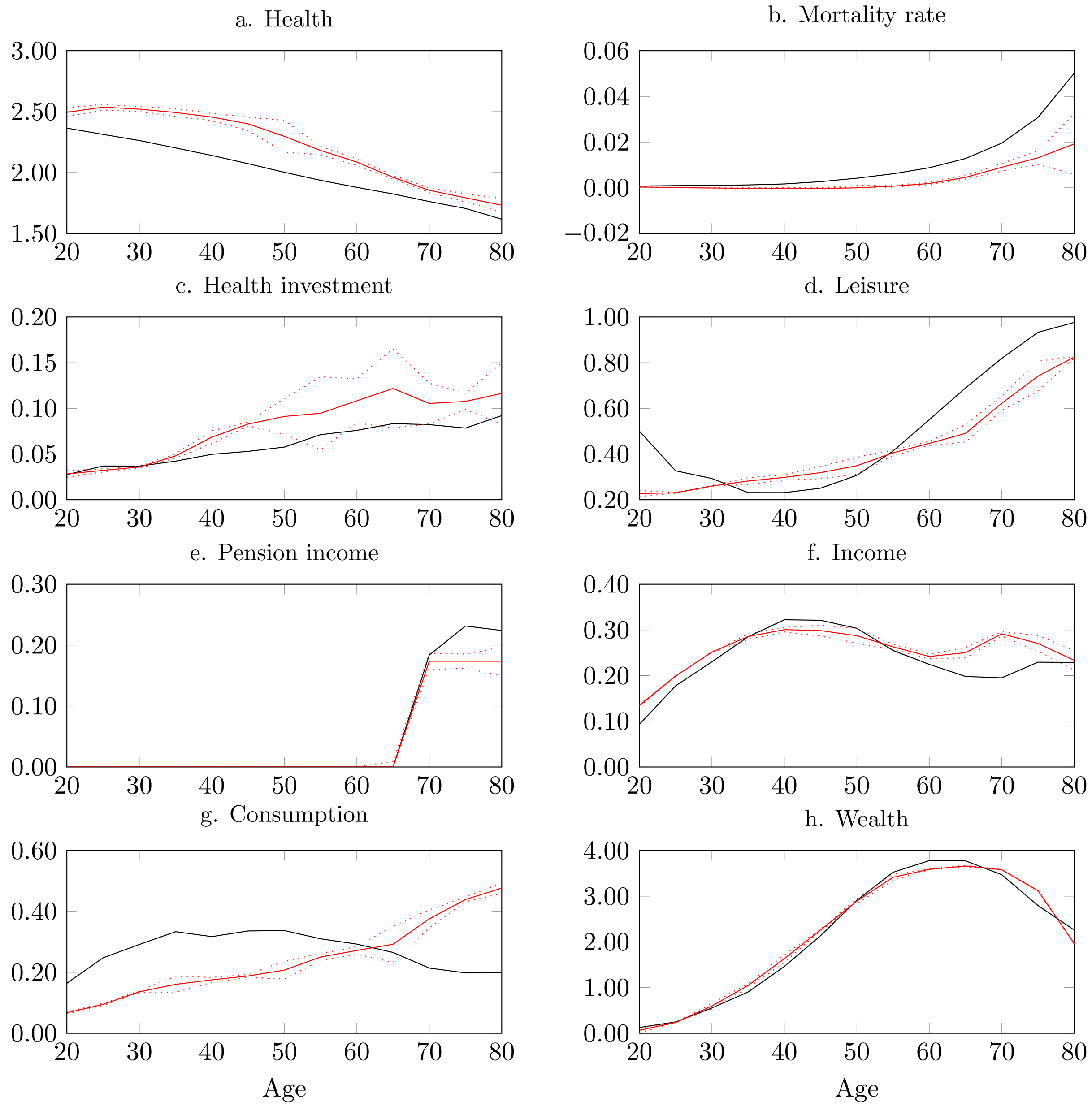
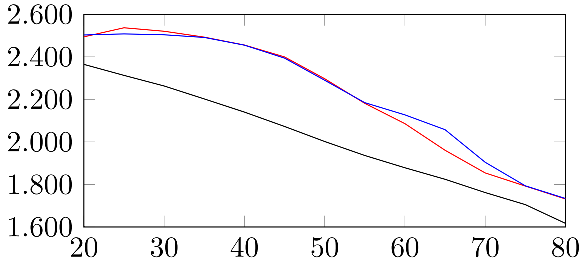


Figure 4: Life cycle allocations

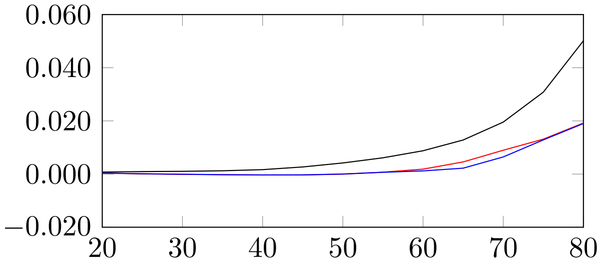
Notes: Data: solid black line (—); benchmark: solid red line (—); 95% confidence intervals: dotted red line. Nominal values in panels d–h are reported in $100,000 units.

C.3 Alternative model assumptions

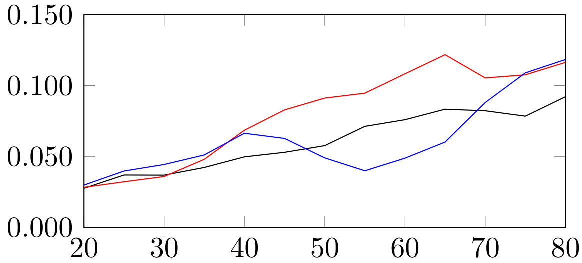
a. Health



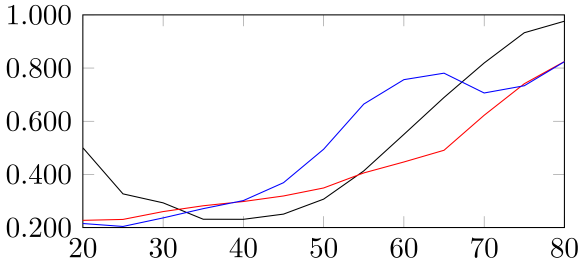
b. Mortality rate



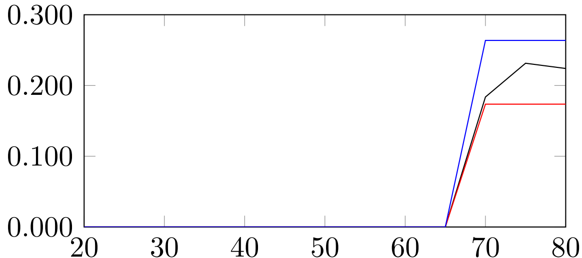
c. Health investment



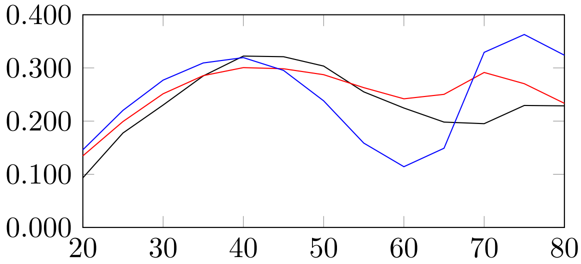
d. Leisure



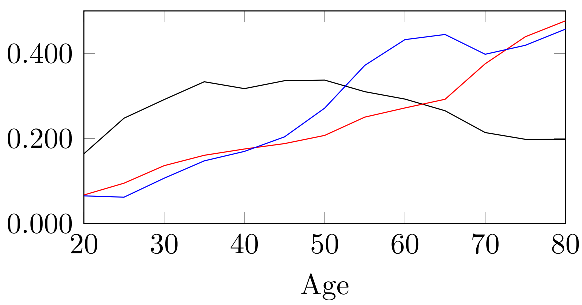
e. Pension income



f. Income



g. Consumption



h. Wealth

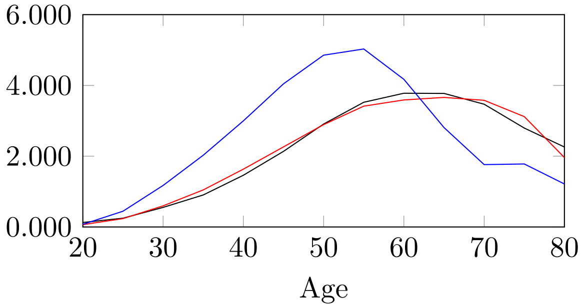


Figure 5: Defined benefit

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

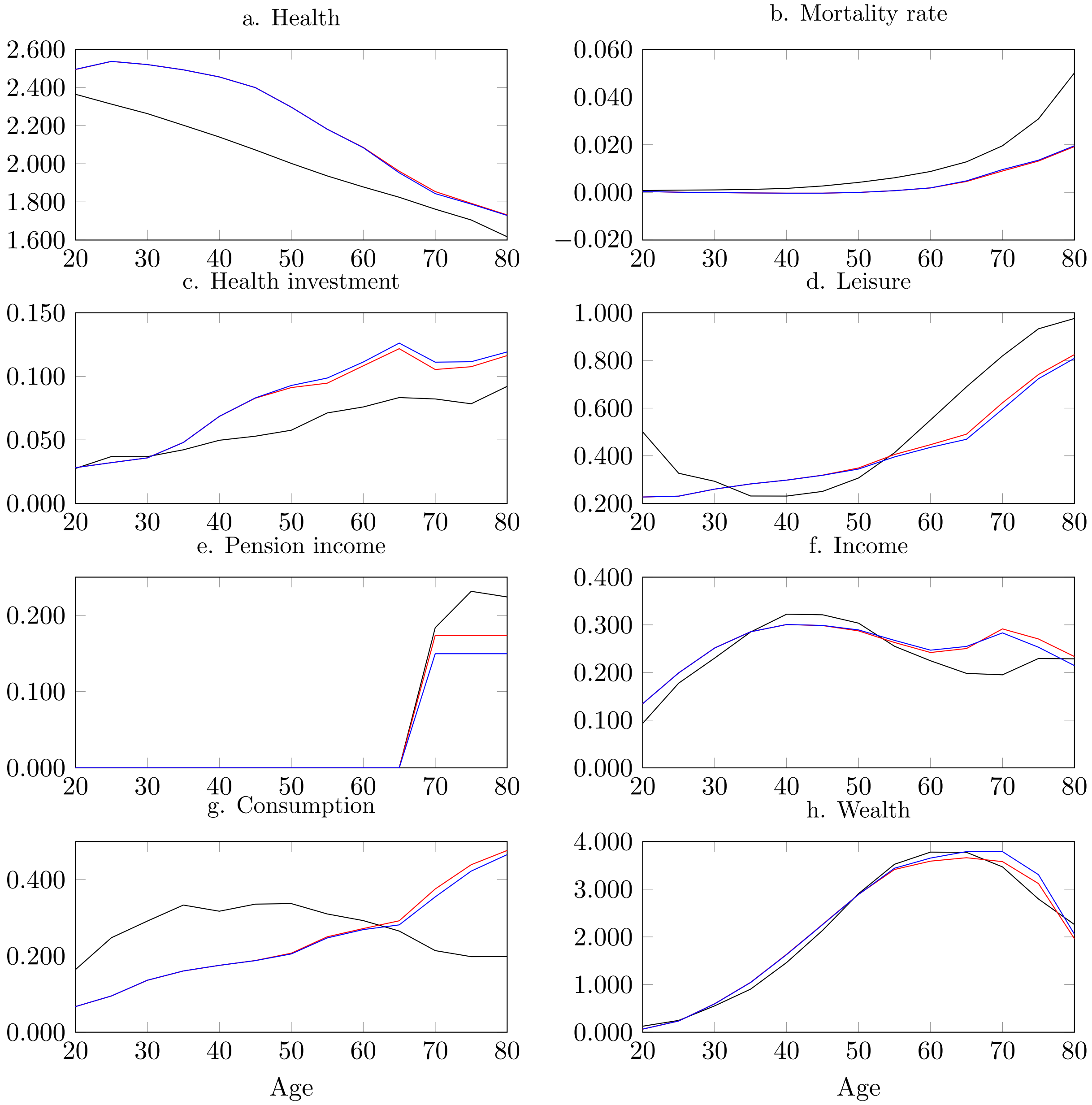
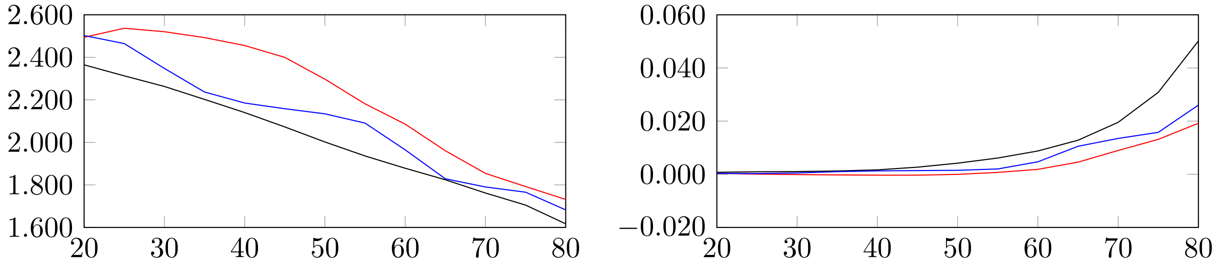
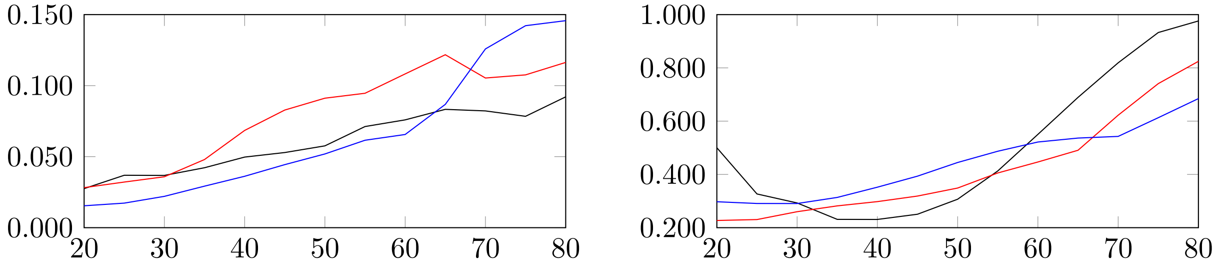


Figure 6: Low risky share

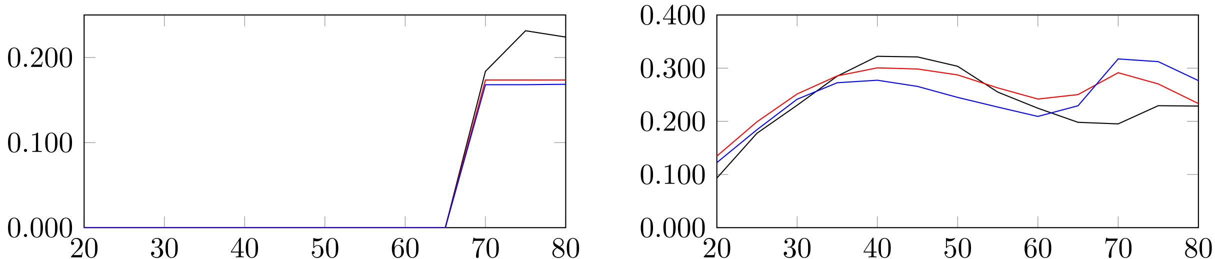
Notes: The alternative is obtained by lowering the risky share of the pension fund portfolio $\tilde{\omega} = 0.5\omega$. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.


a. Health

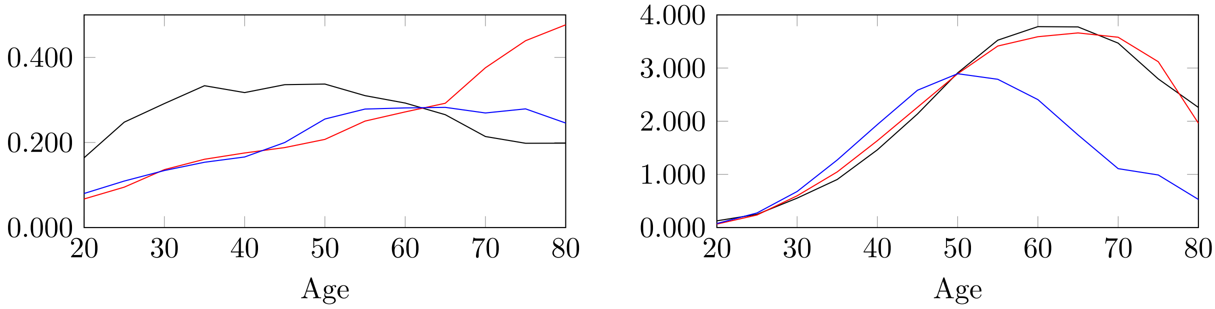
b. Mortality rate


c. Health investment

d. Leisure


e. Pension income

f. Income


g. Consumption

h. Wealth

Figure 7: Uninsured young agents

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

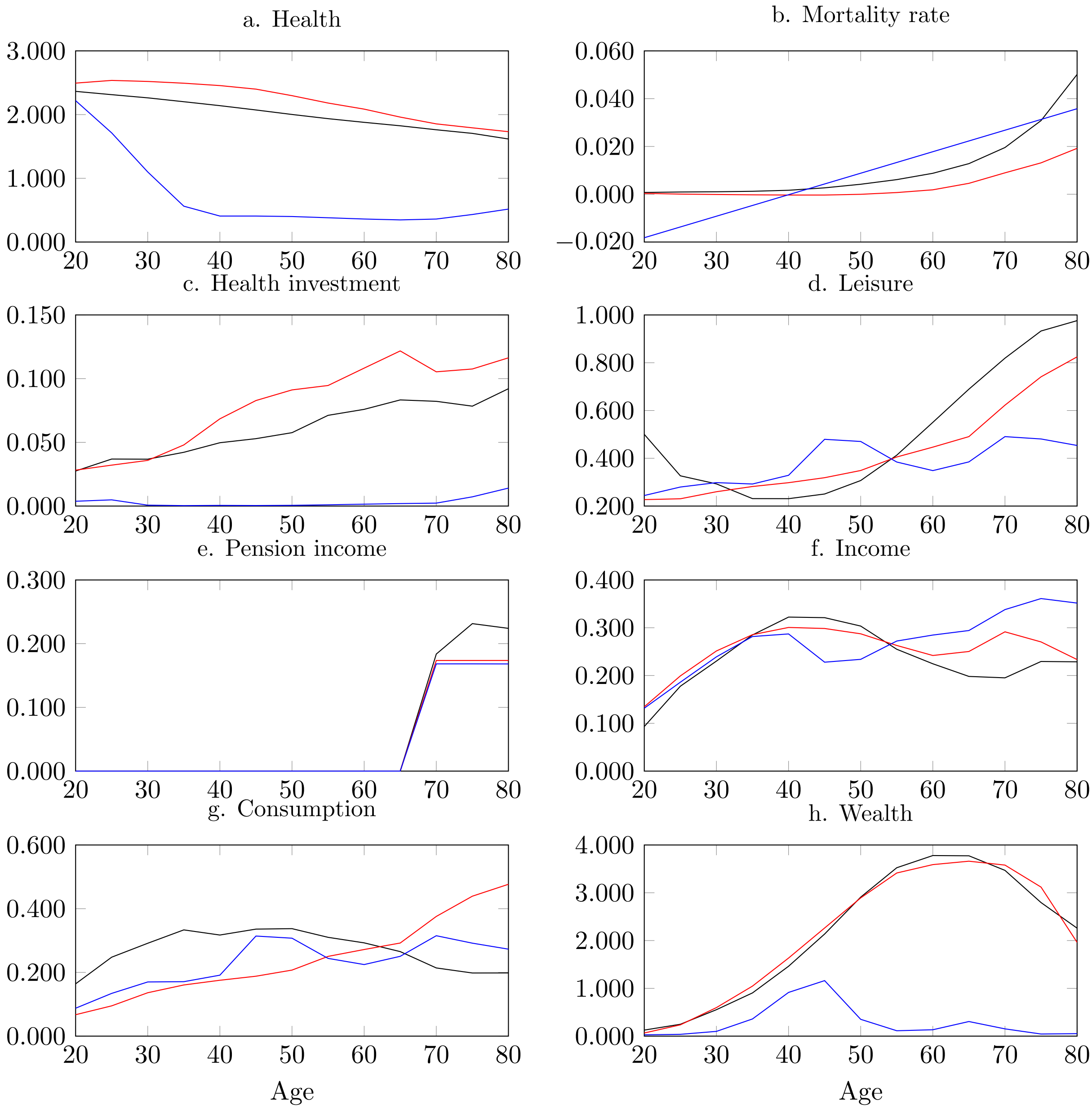


Figure 8: Myopic health risks

Notes: The alternative is obtained by replacing predicted $\hat{\lambda}^m(H_t)$, by the projected, and health-independent death intensity $\tilde{\lambda}^m = \tilde{\lambda}_0^m + \tilde{\lambda}_1^m \times t$, the the projection is based on a OLS estimate using actual death intensities. Data: solid black line (—); benchmark: solid red line (—); alternative: solid blue line (—). Nominal values in panels e–h are reported in \$100,000 units.