Life Cycle Responses to Health Insurance Status[*]

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Abstract

This paper studies the lifetime effects of exogenous changes in health insurance coverage (e.g. Medicare, PPACA, termination of employer-provided plans) on the dynamic optimal allocation (consumption, leisure, health expenditures), status (health, wealth and survival rates), and welfare. We solve, simulate, and structurally estimate a parsimonious life cycle model with endogenous exposure to morbidity and mortality risks to analyze the impact of young (resp. old) insurance status conditional on old (resp. young) coverage. Our results highlight positive effects of insurance on health, wealth and welfare, as well as mid-life substitution away from healthy leisure in favor of more health expenses, caused by peaking wages, and accelerating health issues.

Keywords— Demand for Health. Endogenous Morbidity and Mortality Risks. Household Finance. Medicare. Simulated Moments Estimation.

JEL classification— D91, G11, I13

1 Introduction

The health insurance status of individuals may change exogenously over the life cycle. For instance, employer-provided insurance often ends at retirement. Moreover, Medicare provides guaranteed and subsidized insurance for elders,[1] whereas the Patient Protection and Affordable Care Act (PPACA, a.k.a. Obamacare) extends other types of health insurance to younger individuals. The purpose of this paper is to analyze the impact of such exogenous, and predictable changes in health insurance for the life cycle allocations (i.e. consumption, health expenditures and leisure), status (wealth, and health), as well as for the welfare of households.

Health insurance coverage at any given period of life likely affects decisions at other periods as well. Indeed, because health can be thought of as a durable good, insurance-induced changes in health status when young do have lifetime consequences on exposure to mortality and morbidity risks (e.g. the *Long Reach of Childhood* effect, Smith, 1999; Case and Paxson, 2011). Moreover, a standard backward induction argument makes it clear that young agents should internalize the effects of being insured or not when old, and its consequences for future health and wealth statuses.

Insurance for health expenditures affects dynamic decisions through two main channels: the budget constraint, and the exposure to morbidity and mortality risks. First, disposable resources are reduced by the amount of the insurance premia. The extent of this income effect depends on the public subsidization through Medicare or PPACA, whereas the financing of these programs through distortionary income taxes affects the leisure/labor supply substitution. Moreover, health insurance lowers the effective price of health care once the deductible level has been reached, making health expenditures relatively less costly compared to other means for adjusting health, such as healthy leisure activities. This change in relative price thus alters the leisure/labor supply substitution and consequently the level of disposable resources.

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[1] See Table 1 for details on Medicare and private insurance coverage and financing.

Second, conditional upon sickness, the out-of-pocket (OOP) medical expenditures are reduced by health insurance, thereby lowering the exposure to future health costs, and mitigating the incentives for maintaining precautionary wealth balances. Furthermore, to the extent that health status determines the capacity to work and the response to treatment, insurance also reduces the incentives for maintaining precautionary health balances. Moreover, the changes in current health expenditures and healthy leisure induced by insurance will impact future health status, and therefore the likelihood of both sickness and death. If better health lowers the probability of morbidity, this again reduces the incentives for maintaining precautionary wealth and health balances, whereas a longer expected lifetime for healthier individuals justifies more savings for old age in both financial and health capitals.

The timing of the coverage is also important for the dynamic allocation. On the one hand, employer-provided coverage that is expected to end at retirement can lead to a pre-retirement acceleration of health expenses and accumulation of the preventive health and wealth stocks. The resulting health improvements alter expected longevity and exposure to future risks, and will in turn affect the inter-temporal allocation for consumption and leisure. On the other hand, post-retirement health insurance such as Medicare makes it possibly optimal to postpone health care until coverage begins which may lead to pre-retirement deterioration in the health status. Again, the resulting changes in wealth and health will alter the dynamic allocation over leisure and consumption via its effects on the budget constraint and the exposure to morbidity and mortality risks.

The previous discussion suggests that (i) the timing of health insurance coverage should affect the allocations *throughout* the life cycle, and (ii) the mechanisms through which these effects take place are non trivial, especially when exposure to morbidity and mortality risks is endogenous. The objective of this paper is to analyze these effects, and to chart their pathways. Understanding how changes in coverage affect the life cycle allocations is important for several reasons. First, from a Public Finance perspective, the resources spent on compulsory coverage programs such as Medicare are substantial, making it the fourth item on the Federal budget in 2011 (see Table 2). Moreover, these resources will expand as PPACA becomes operational and starts imposing health insurance on large, previously uninsured segments of the US population.[2] Since both involve exogenous changes in insurance statuses, identifying the dynamic effects on consumption, wealth, leisure, health expenditures and levels is warranted for policy evaluation purposes. Second, from a normative aspect, imposing market-provided insurance affects endogenous exposure that can also be adjusted through self-insurance. Moral hazard substitution can take place both across instruments (e.g. health expenditures vs healthy leisure vs precautionary health balances) and across time (e.g. less leisure or expenditures now vs more later). Since these substitutions affect exposure to longevity and sickness risks, the net effect of insurance on welfare is not trivially obtained. Moreover, because longevity is altered, indirect effects of health insurance can obtain for other programs such as Social Security. Finally, from a General Equilibrium perspective, we can expect non-trivial Macro effects of the resulting changes on savings and leisure through financial and labor markets.

In order to characterize how health insurance affects life cycle decisions and outcomes, we propose a stochastic life cycle framework constructed around three main building blocks. First, we model health as an adjustable, and depreciable human capital that can be augmented through both health investment (i.e. expenditures) and time (i.e. leisure). The health stock is subject to age-increasing depreciation in order to capture more pressing health problems facing the elders, as well as being subject to stochastic illness shocks that further deplete the health capital. Second, whereas market-provided insurance for health expenditures is exogenously set, we allow for self-insurance against morbidity and mortality risks. More precisely, the likelihood of sickness and of death can be reduced through better health; since the latter is adjustable, morbidity and mortality are thus (partially) endogenous. Third, agents are rational and forward-looking, and

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[2] In 2014, 32 millions (16.7%) nonelderly Americans remained uninsured, with uninsurance varying from 5.1 % (MA) to 18.8% (TX) (Henry J. Kaiser Family Foundation, 2015).

therefore fully internalize the endogenous exposure to sickness and death in their dynamic life cycle decisions.

Conditional upon health insurance status, we numerically solve and simulate the model to recover the life cycle allocations (i.e. consumption, leisure, and investment), statuses (i.e. health and financial wealth), and welfare. These theoretical moments can be contrasted with their empirical counterparts to construct a structural Simulated Moments Estimation (SME) of a subset of the deep parameters. Empirical validity is confirmed by a close match of the predicted and observed life cycles. This performance is remarkable given that the theoretical framework is parsimonious,[3] and that no external forcing processes are appended in the SME. Key to our analysis, the differences in the dynamic allocations and statuses across the insurance and age dimensions can be isolated in order to identify the marginal effects of the health insurance status when young (conditional upon old-age status), and when old (conditional upon young-age status).

Our main findings are threefold. First, our results show that the young insured are noticeably healthier, while durability implies that health remains higher after retirement. Insured elders are also healthier after retirement, but with little evidence of pre-retirement effects. Second, we find that insurance induces a mid-life substitution in leisure and health expenses. In particular, young agents increase hours worked between 45 and 65, and compensate the fall in leisure by more health expenditures over the same period. The insured elders also reduce leisure at mid-life, and postpone health expenditures, and more leisure after retirement only. Despite the increases in health expenses, OOP's remain lower for both young and old insured. This healthy leisure-expenses substitution effect obtains for three reasons. The lower price of health expenditures relative to healthy leisure for insured agents induces a static substitution away from the latter. Moreover the fact that observed wages are highest around mid life, and fall after retirement provides incentives to substitute more work when young in favor of more leisure when old. Finally,

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[3] Indeed, the model is constructed using only six key equations: a law of movement for health, endogenous sickness and death arrival rates, a budget constraint and insurance contract as well as a specification of preferences.

more pressing health issues beginning at mid-life explain why this substitution does not take place earlier.[4]

Our third result is that wealth is higher for the insured agents. Improved health naturally leads to increases in survival rates for both young and old insured. The combination of better longevity, lower exposure to morbidity and OOP risks, and more hours worked implies that wealth is higher for the insured. Consequently, so is welfare, and we find that health insurance is optimal at all ages, except for the young adults. Up to their early-40's, high initial health stocks, low wealth, and low wages make it optimal for the young to self insure through leisure, and health balances rather than through markets. As health-related problems, and wages subsequently start to escalate, lower exposure to OOP risks through market-provided insurance becomes a welcomed alternative to self-insurance.

The rest of the paper proceeds as follows. Following a discussion of the literature in Section 2, we outline the theoretical framework in Section 3. The empirical methods are discussed in Section 4. The iterative and simulation results are presented and discussed in Section 5, before concluding remarks in Section 6. All tables and figures are regrouped in the Appendix.

2 Relevant literature

This paper primarily relates and contributes to the literature on the consequences of morbidity and mortality risks for the life cycle allocations by households (see Table 3 for a classification). In the presence of incomplete or imperfect insurance and asset markets, the effects of sickness risk on medical expenses, and income uncertainty, as well as those of longevity risk cannot be completely hedged away. Consequently, the agents are forced to remain partially exposed and/or adopt costly self-insurance strategies. This literature

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[4] For example, self-reported prevalence of serious illness increases sharply between age groups 18-44, and 45-64, for heart diseases (threefold), cancer and stroke (fourfold) (National Center for Health Statistics, 2012, Tab. 49).

thus analyzes the corresponding consequences for decisions and outcomes related to asset accumulation, medical expenses, labor market supply, as well as the demand for social insurance. Whereas most are treated separately in the literature, this paper innovates by considering all these consequences simultaneously within a unified framework.

First, a vast literature initiated by Kotlikoff (1989) studies consumption decisions in the presence of health-related risks and concludes that prudent agents faced with OOP expenses and labor income uncertainty, as well as the risk of living too long should increase precautionary savings.[5] The empirical evidence is partially supportive of that conjecture; whereas savings by young agents are generally thought to be insufficient, asset decumulation by elders is too slow with respect to standard life cycle predictions.[6] Attempts to rationalize observed behavior emphasize the role of distortions induced by social safety nets. In particular, consumption floors, Social Security, Medicaid and Medicare, all hedge downward risks, and thus reduce precautionary motives, whereas assets-based means testing for some of these policies effectively impose full taxation on wealth beyond a certain threshold.[7] This paper also analyzes the life cycles of asset accumulation in the presence of health-related risks, under various health expenditures insurance regimes (none, private, public), and also emphasizes their influence for precautionary savings for both young and old agents. In contrast, we do allow possible hedging through health-related decisions, rather than impose completely undiversifiable mortality and morbidity risks. Since the agents can reduce their exposure to death and sickness risks, this mitigates the requirement to maintain precautionary savings.

Second and related, two alternative frameworks can be used to study the effects of health-related risks on medical expenses. First, stochastic health expenditures have been

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[5] Examples include Hubbard et al. (1994, 1995); Levin (1995); Palumbo (1999); Dynan et al. (2004); French (2005); Scholz et al. (2006); Hall and Jones (2007); Skinner (2007); Edwards (2008); De Nardi et al. (2009); Fonseca et al. (2013); De Nardi et al. (2010); Ozkan (2011); French and Jones (2011); Scholz and Seshadri (2012); Hugonnier et al. (2013).

[6] See Skinner (2007) for undersavings, and Palumbo (1999); Dynan et al. (2004); De Nardi et al. (2009, 2010) for slow decumulation.

[7] See Hubbard et al. (1994, 1995); Scholz et al. (2006) among others.

modeled as exogenous, and thus tantamount to undiversifiable income shocks.[8] Persistence and predictability of health expenses can be obtained by assuming a Markovian process, and/or correlating these shocks to observable exogenous health and socioeconomic statuses. Second, endogenous health expenditures have been modeled as generating an implicit utilitarian service flow.[9] More explicit approaches, in the spirit of Grossman (1972), model health as a durable good providing implicit utility service flows, whose level can be adjusted through health expenditures.[10] Other alternatives append self-insurance services by allowing health to (partially) reduce morbidity and/or mortality risks.[11] Our modeling choices follow this last strand of endogenous health-related risks literature and emphasize the effects of self-insurance for dynamic allocations.

Third, the consequences of health outcomes for labor revenues have often been modeled by assuming inelastic labor supply, and focusing on their effects on wages, or on the capacity to work.[12] The latter can further be endogenized by allowing for preventive benefits of healthy leisure on health production. Self insurance through leisure then raises moral hazard issues for agents insured through markets who can find it optimal to shirk on preventive measures.[13] We follow the healthy leisure literature and allow for insurance status effects on health prevention decisions. Many researchers also analyze the role of health uncertainty for work decisions on the extensive margin. In particular, this research shows that postponing retirement until Medicare eligibility is optimal when retirement is associated with the loss of employer-provided health insurance benefits.[14] Conversely,

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[8] See for example Hubbard et al. (1995); Rust and Phelan (1997); Palumbo (1999); French (2005); Scholz et al. (2006); Edwards (2008); De Nardi et al. (2009, 2010); French and Jones (2011); Scholz and Seshadri (2013).

[9] Blau and Gilleskie (2008); De Nardi et al. (2010).

[10] Examples include Case and Deaton (2005); Hall and Jones (2007); Yogo (2009); Fonseca et al. (2013); Khwaja (2010); Ozkan (2011); Galama et al. (2013); Scholz and Seshadri (2012, 2013).

[11] Endogenous morbidity and/or mortality risks are studied by Hall and Jones (2007); Ozkan (2011); Scholz and Seshadri (2012, 2013); Hugonnier et al. (2013).

[12] Income effects can be found in Case and Deaton (2005); Fonseca et al. (2013); Khwaja (2010); Scholz and Seshadri (2012), as well as by Hugonnier et al. (2013) who show that the health effects are then isomorphic to those obtained through utilitarian flows.

[13] Ehrlich and Becker (1972); Leibowitz (2004).

[14] Rust and Phelan (1997); Palumbo (1999); Fonseca et al. (2013); French and Jones (2011); Scholz and Seshadri (2013).

retirement can also be accelerated if in poor health, and eligible for early retirement.[15] Although our modeling of leisure choices does allow for non-employment, we abstract from discrete and irreversible retirement decisions.

Fourth, the detrimental consequences of morbidity and mortality risks can also be mitigated through social insurance programs. Positive effects of Medicare for elders have been shown to include better health and longevity,[16] higher utilization rates,[17] but lower exposure to OOP risks,[18] lower precautionary wealth,[19] and higher consumption and leisure.[20] On the other hand, the positive effects of Medicare for younger agents have been much less studied.[21] Our paper attempts to gain further insights on these effects of Medicare on younger generations, and emphasizes previously unstudied effects on the intensive labor margin, while maintaining all the stylized facts associated with elders.

Finally, normative elements associated with Medicare include redistribution from rich to poor. This literature establishes that, although richer households pay more taxes, they also live much longer and consume more health expenditures, rendering Medicare a regressive system from an actuarial point of view.[22] However, a market completion argument paints a more progressive picture through the access to health insurance made possible for poorer households. Finally, the pay-as-you-go nature of Medicare has made it very beneficial for the first cohorts of participating elders, whereas the risk-sharing between healthy young agents and unhealthy retirees has also made it welfare-improving for the latter, yet much less so for the former.[23] Taking into account the distortions induced by the income taxes needed to finance these programs only worsens the burden placed on the working young agents. Although we do not emphasize redistribution

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[15] Wolfe (1985); Bound et al. (2010); Galama et al. (2013).

[16] Lichtenberg (2002); Khwaja (2010); Finkelstein and McKnight (2008); Card et al. (2009); Scholz and Seshadri (2012).

[17] Lichtenberg (2002); Khwaja (2010); Finkelstein (2007); Card et al. (2009).

[18] Khwaja (2010); Finkelstein and McKnight (2008); Scholz and Seshadri (2012); De Nardi et al. (2010).

[19] De Nardi et al. (2010, 2009); Scholz and Seshadri (2012).

[20] Currie and Madrian (1999); French (2005).

[21] Exceptions include Ozkan (2011); Scholz and Seshadri (2012) who describe stockpiling medical expenses until entitlement begins, and reduced precautionary wealth for younger agents.

[22] McClellan and Skinner (2009); Bhattacharya and Lakdawalla (2006); Rettenmaier (2012).

[23] Cutler and Sheiner (2000); McClellan and Skinner (2009); Khwaja (2010); Ozkan (2011); Baicker and Skinner (2011).

between rich and poor, or between healthy and unhealthy, we contribute to the normative literature by providing a separate assessment of the welfare gains of insurance across the age dimension.

3 Model

This section describes the environment in which finitely-lived risk-averse individuals face endogenous morbidity and mortality risks. The exposure to these risks can be diversified through healthy leisure and medical decisions, as well as through market-provided health insurance. We first discuss the dynamics of these two health-related risks, followed by a description of the budget constraint and the preferences of the agent. Finally, dynamic conditions characterizing the optimal allocation are presented.

Health shocks and health dynamics Let $y \in \mathbb{N}$ denote the calendar year, with $y = 0$ being the reference year, and let $\kappa \in \mathbb{N}_-$ be the birth year of an individual aged $t = y - \kappa = 1, 2, \ldots, T^m \leq T$. Following Hugonnier et al. (2013), we let $\lambda^k : \mathbb{R}_+ \to \mathbb{R}_{++}$ denote an age-invariant, decreasing and convex intensity function of health (H). Health risks $\epsilon^k \in \{0, 1\}$ denote generalized Bernoulli morbidity $(k = s)$ or mortality shocks $(k = m)$, whose probability of occurrence are given as:

$$\Pr\left(\epsilon^k_{t+1} = 1 \mid H_t\right) = 1 - \exp[-\lambda^k(H_t)], \quad k = m, s. \tag{1}$$

Hence, an unhealthy agent faces higher risks of both sickness and death, and is subject to diminishing returns in reducing risk through health improvements. The age at death $T^m \in [0, T]$ is bounded above by T, the maximal biological longevity, and is the first occurrence of the mortality shock:

$$T^m = \min\{t : \epsilon^m_t = 1\}.$$

The health capital is depreciable, and is depleted further upon occurrence of the morbidity shock $\epsilon^s = 1$. It can be adjusted through gross investment $I^g : \mathbb{R}_+ \times \mathbb{R}_+ \times \mathbb{I} \to \mathbb{R}_+$, an increasing, and concave function of health, real investment (I), and leisure $(\ell \in \mathbb{I} \equiv [0,1])$:

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

$$d_t = d_0 \exp[g^d t], \quad d \in \{\delta, \phi\}, \tag{3}$$

$$A_t = A_0 \exp[g^A (t + \kappa)], \tag{4}$$

where g^d are age-specific growth rates of deterministic (δ_t), and stochastic (ϕ_t) depreciation, and where g^A is a year-specific growth rate of the medical technology. The law of motion (2) derives from the health-as-capital specification in the demand-for-health literature (Grossman, 1972), to which are appended morbidity shocks (Hugonnier et al., 2013), as well as age-increasing deterministic δ_t and stochastic depreciation $\phi_t \epsilon^s_{t+1}$. Age-increasing depreciation in (3) captures more pressing health issues for older agents, including the demand for long-term care by elders (Palumbo, 1999). When combined with health-dependent death intensities, it is also convenient for ensuring that life maintenance is getting costlier with age, and induce falling health (Case and Deaton, 2005) as well as increasing mortality rates in endogenous life horizon problems (Ehrlich and Chuma, 1990).[24]

Gross investment in (2) incorporates convex adjustment costs (Ehrlich, 2000; Ehrlich and Chuma, 1990), and healthy leisure inputs (Sickles and Yazbeck, 1998). Diminishing returns and the presence of health in I^g implies path dependency, in that current health issues reflect past behavior, and cannot be completely solved through medical allocations only. The inclusion of leisure in the gross investment function captures non-market inputs in health maintenance (e.g. prevention through physical activities), as well as potential moral hazard issues for agents who can find it optimal to cut down on prevention once

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[24] See Robson and Kaplan (2007) for discussion and alternative models of aging and death.

insured against medical costs (Leibowitz, 2004; Ehrlich and Becker, 1972). The non-negativity constraint for gross investment is standard and prevents agents from selling their own health in markets. Finally, in the spirit of Hall and Jones (2007), the health process also includes exogenous productivity improvement in health production, whereby TFP growth in (4) is determined at the year level $y = t + \kappa$ in order to account for cohort effects that are discussed further below (see Section 5.4.2).

Budget constraint The agent evolves in an incomplete financial markets setup comprising a risk-free asset, and a health expenditures insurance contract; death risk is not insurable through markets but (partially) diversified through gross investments exclusively. Given health prices P_t^I, the health insurance contract is defined by a co-payment rate $\psi \in (0, 1)$ applicable on health expenditures $P_t^I I_t$, a deductible level $D_t > 0$, and an insurance premium $\Pi_t^x \in \{0, \Pi, \Pi^M\}$. The latter is the market premium Π for every insured, or the subsidized premium $\Pi^M = \pi\Pi$ at rate $\pi \in (0, 1)$ for insured elders only when Medicare is operational.

We assume that the health expenditures insurance status $x = (x^y, x^o) \in \{\mathrm{N}, \mathrm{P}, \mathrm{M}\}^2$ for young (x^y) and old (x^o) agents is set exogenously among three alternatives, (N)o insurance, (P)rivate insurance and (M)edicare. Exogenous participation can be rationalized by noting that health insurance is mainly decided upon and provided by employers and/or by government intervention, when the agent is not excluded altogether from health insurance markets because of moral hazard and adverse selection reasons.[25]

Denote by $\mathbb{1}_X = \mathbb{1}_{x=P,M}$ the insured; $\mathbb{1}_M = \mathbb{1}_{x=M}$, the Medicare; $\mathbb{1}_D = \mathbb{1}_{P_t^I I_t > D_t}$, the deductible reached; and $\mathbb{1}_R = \mathbb{1}_{t \geq 65}$ the old age indicators. The out-of-pocket medical expenditures $OOP_t^x(I_t)$, health insurance premia, medical prices, and insurance

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[25] In 2010 over 70% of the employed U.S. population aged 15 and over worked for an employer who offered health plans while more than two-thirds of people aged 18-64 had health insurance provided through either own, or someone else's employer (Janicki, 2013). See also Currie and Madrian (1999); Blau and Gilleskie (2008); McGuire (2011) for incidence and motivations for employer-provided health insurance plans.

deductibles processes are given by:

$$\begin{aligned} OOP_t^x(I_t) &= P_t^I I_t - \mathbb{1}_X \mathbb{1}_D (1-\psi)(P_t^I I_t - D_t), \qquad (5) \\ \Pi_t^x &= \mathbb{1}_X \Pi \left[1 - \mathbb{1}_M \mathbb{1}_R (1-\pi)\right], \\ P_t^I &= P_0^I \exp[g^P(t+\kappa)], \qquad (6) \\ D_t &= D_0 \exp[g^D(t+\kappa)], \qquad (7) \end{aligned}$$

where g^P is the inflation rate of medical prices, and g^D that of the deductibles. As illustrated in Figure 1, the contract (5) is standard whereby the insured agent in plans P and M covers all medical expenditures $P^I I$ up to deductible D and pay a share of expenses ψ afterwards; the uninsured agent in plan N covers all medical expenses. The assumption of identical deductibles and co-payments under plans P and M in (5) is made for tractability, yet is not unrealistic given that Medicare deductibles and typical co-payment are close to those of many private plans values.[26]

Finally, both the health investment prices P_t^I in (6) and deductibles D_t in (7) are time-varying, so as to allow cohort effects that parallel the growth in health production technology A_t in (4). In particular, the medical technology available to an individual aged t years born $\kappa = -30$ years ago is more productive than for an individual with the same age born $\kappa = -50$ years ago, i.e. $A_{t-30} > A_{t-50}, \forall t$. Consequently, agents aged t in cohort $\kappa = -30$ face higher prices, compared to agents of the same age in cohort $\kappa = -50$, i.e. $P^I_{t-30} > P^I_{t-50}$, and also a higher level of deductible, i.e. $D_{t-30} > D_{t-50}$. This additional degree of freedom is useful in gauging the importance of cohort effects by varying κ in the empirical evaluation in Section 5.4.2.

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[26] See Table 1 for Medicare and private insurance comparisons. Medicare coverage for young disabled and Medicaid for poor households are abstracted from for tractability reasons.

Denoting labor income $Y_t^x(\ell_t)$, consumption C_t, and wealth W_t, the income process and budget constraint are given as:

$$\begin{aligned} Y_t^x(\ell_t) &= \mathbb{1}_t^R Y^R + (1 - \mathbb{1}^M \tau) w_t (1 - \ell_t), && (8) \\ W_{t+1} &= \left[W_t + Y_t^x(\ell_t) - C_t - OOP_t^x(I_t) - \Pi_t^x\right] R^f, && (9) \end{aligned}$$

where R^f is the gross risk-free rate of interest. The labor revenues (8) capture the effects of pension income (e.g. Social Security) in Y^R after age 65, the tax effects of Medicare in τ which reduces disposable income for every worker, as well as the age variation in w_t displayed in Figure 2.a. The wealth process (9) highlights the age-, time-, and plan-dependency of disposable resources.

Preferences Let $\beta \in (0, 1)$ be a subjective discount parameter, $U : \mathbb{R}_+ \times \mathbb{I} \to \mathbb{R}_{++}$ denote a monotone increasing and concave instantaneous utility when alive, and $U^m : \mathbb{R} \to \mathbb{R}_-$ an increasing and concave bequest utility function associated with death. Using the mortality shock process (1), and assuming VNM preferences, the within-period utility $\mathcal{U}_t$, with bequest motive is given by:

$$\begin{aligned} \mathcal{U}_t &\equiv U(C_t, \ell_t) + \beta \left(1 - \exp[-\lambda^m(H_t)]\right) U^m(W_{t+1}), \\ &= U(C_t, \ell_t) + [\beta - \beta^m(H_t)]\, U^m(W_{t+1}), \qquad (10) \\ &= \mathcal{U}_t(C_t, \ell_t, I_t, W_t, H_t) \geq 0, \end{aligned}$$

where $\beta^m(H_t) \equiv \beta \exp[-\lambda^m(H_t)] < \beta$ is an endogenous discount factor that increases in health. Preferences (10) combine the flow utility of living, consuming, and taking leisure time, with the expected discounted disutility from dying and leaving bequests. Because individual health is non-transferable, U^m is a function of next-period bequeathed wealth only. In particular, since U is positive, a negative U^m indicates a utility cost of mortality, whereas the marginal utility of bequests $U^m_{W,t+1} \geq 0$ captures "joy-of-giving" elements, i.e. the cost of dying is attenuated by bequeathing larger amounts. However, as outlined in Shepard and Zeckhauser (1984); Rosen (1988); Hugonnier et al. (2013), within-period utility $\mathcal{U}_t$ must remain positive in order to guarantee strict preference for life in endogenous mortality settings. Preferences (10) provide an explicit alternative to implicit models of health valuation $\mathcal{U} = U(C, \ell, H)$, where $\mathcal{U}_H \geq 0$ (see also the discussion of footnote 28 for explicit health-dependent variants). Indeed, since the death intensity is decreasing in health, i.e. $\lambda^m_{H,t} \leq 0$, and because $U^m(W_{t+1})$ is negative and captures a utility cost of death, it follows that

$$\mathcal{U}_{H,t} = \left(\beta \lambda^m_{H,t} \exp[-\lambda^m(H_t)]\right) U^m(W_{t+1}) \geq 0, \tag{11}$$

which ensures positive service flows of health associated with mortality risk reduction. Put differently, health is valuable in part because it reduces the likelihood of death whose utility costs are only partially offset by bequeathed wealth. Observe further from the budget constraint (9), and from (11) that joy-of-giving $U^m_W \geq 0$ also ensures that the model predicts positive cross derivatives of instantaneous utility:

$$\mathcal{U}_{CH,t} = \left(\beta \lambda^m_{H,t} \exp[-\lambda^m(H_t)]\right) U^m_{W,t+1} W_{C,t+1} \geq 0. \tag{12}$$

Put differently, the marginal utility of consumption falls when health deteriorates, consistent with observed findings (Finkelstein et al., 2013).

Next, using the Law of Iterated Expectations, the agent's objective function, denoted $V_t = V^x_t(W_t, H_t)$, solves the constrained maximization problem:

$$\begin{aligned} V_t &= \max_{\{C_t, I_t, \ell_t\}_t^{T^m}} \mathcal{U}_t + \mathrm{E}_t \left\{ \sum_{s=t+1}^{T^m} \beta^{s-t} \, \mathcal{U}_s \mid H_t \right\}, \\ &= \max_{\{C_t, I_t, \ell_t\}_t^{T}} \mathcal{U}_t + \mathrm{E}_t \left\{ \sum_{s=t+1}^{T} \prod_{j=t}^{s-1} \beta^m(H_j) \, \mathcal{U}_s \mid H_t \right\}, \\ &= \max_{C_t, I_t, \ell_t} \mathcal{U}_t + \beta^m(H_t) \mathrm{E}_t \left\{ V_{t+1} \mid H_t \right\}, \end{aligned} \tag{13}$$

subject to the health process (2), and the budget constraint (9). Equation (13) shows that an agent with endogenous stochastic horizon T^m, constant discounting β, and evolving in an incomplete market environment (first line) is isomorphic to an agent with deterministic horizon T, endogenous discounting $\beta^m(H)$, and operating in a complete market setup (second and third lines). Put differently, endogenous mortality risk implies that an unhealthy agent has a shorter expected life horizon and is tantamount to a more impatient individual. As the following discussion makes clear, the forward-looking agent fully internalizes the impact of his leisure and health expenditure decisions on his discounting with respect to future utility flows.

Optimality Letting subscripts denote partial derivatives, the first-order and Envelope conditions for problem (13) reveal that the optimal allocation is characterized by:

$$\begin{aligned} U_{C,t} &= \left(\left[\beta - \beta^m(H_t) \right] U^m_{W,t+1} + \beta^m(H_t) \mathrm{E}_t \left\{ U_{C,t+1} \mid H_t \right\} \right) R^f, && (14) \\ U_{C,t} OOP^x_{I,t} &= \beta^m(H_t) \mathrm{E}_t \left\{ V_{H,t+1} \mid H_t \right\} A_t I^g_{I,t}, && (15) \\ (1 - \mathbb{1}^M \tau) w_t &= \frac{U_{\ell,t}}{U_{C,t}} + \frac{I^g_{\ell,t}}{I^g_{I,t}} OOP^x_{I,t}, && (16) \end{aligned}$$

where the marginal out-of-pocket cost is $OOP^x_{I,t} = P^I_t \left[1 - \mathbb{1}_X \mathbb{1}_D (1 - \psi) \right]$, and where the marginal value of health solves the recursion:

$$\begin{aligned} V_{H,t} = & \overbrace{\beta^m_{H,t} \mathrm{E}_t \left\{ V_{t+1} - U^m_{t+1} \mid H_t \right\}}^{\text{Mortality control value}} + \overbrace{\beta^m(H_t) \mathrm{E}_{H,t} \left\{ V_{t+1} \mid H_t \right\}}^{\text{Morbidity control value}} \\ & + \underbrace{\beta^m(H_t) \mathrm{E}_t \left\{ V_{H,t+1} \left[1 - \delta_t - \phi_t \epsilon^s_{t+1} + A_t I^g_{H,t} \right] \mid H_t \right\}}_{\text{Durability and productive capacity value}}, \end{aligned} \qquad (17)$$

where we have set,

$$\begin{aligned} \mathrm{E}_{H,t} \left\{ V_{t+1} \mid H_t \right\} &= -\lambda^s_{H,t} \exp[-\lambda^s(H_t)] \mathrm{E}_t \left\{ V(W_{t+1}, H^+_{t+1}) - V(W_{t+1}, H^-_{t+1}) \right\} \\ H^+_{t+1} &\equiv (1 - \delta_t) H_t + A_t I^g(H_t, I_t, \ell_t) \\ H^-_{t+1} &\equiv H^+_{t+1} - \phi_t H_t \end{aligned} \qquad (18)$$

is the marginal effect of health on the conditional expectation, and H^+ (resp. H^-) is the health level in the absence (resp. occurrence) of sickness.

The Euler condition (14) equalizes the marginal utility cost of foregone current consumption when savings are increased to the expected discounted marginal benefit of future wealth. The latter is the sum of the positive marginal utility of bequeathed wealth plus the positive marginal utility of future consumption times the rate of return on the safe asset. As health improves, the probability of dying falls, and $\beta^m(H_t)$ increases, thereby shifting weight away from the former in favor of the latter.

The Euler equation (15) equates the current marginal utility cost of out-of-pocket health expenditures to the expected future marginal benefit of the additional health procured by investment. Being uninsured ($\mathbb{1}_X = 0$) clearly raises the effective price of investment ($OOP_I = P^I$) and therefore the current marginal OOP cost of health expenditures, thereby lowering their attractiveness. Moreover, as Figure 1 makes clear, the marginal OOP cost of health expenditures is kinked at the deductible for insured agents, and encourages them to spend more once the deductible D_t is reached. Medicare also implies that $OOP^x_{I,t}$ is age-dependent as young uninsured agents become covered at age 65, encouraging them to postpone health expenditures until coverage begins. Observe furthermore from (4) that aging is accompanied by exogenous increases in productivity A_t, providing additional justification (to age-increasing depreciation) for the higher demand for health care observed for elders (e.g. Hall and Jones, 2007; Fonseca et al., 2013).

Equation (16) is a static optimality condition that equates the marginal cost of leisure (i.e. after-tax wages) to its marginal benefit. The latter is the sum of the marginal rate of substitution between leisure and consumption plus the marginal reduction in out-of-pocket expenditures made possible by resorting to leisure instead of investment to improve health. Moral hazard can arise because this additional benefit of leisure in terms of OOP reduction is lower for the insured ($\mathbb{1}_X = 1$) thereby making self-insurance through healthy activities less advantageous, once the deductible is covered ($\mathbb{1}_D = 1$). The effects of Medicare on the leisure-investment trade-off are mixed. On the one hand, Medicare taxes reduce the opportunity cost of leisure regardless of age. On the other hand, the reduction in marginal out-of-pocket cost after Medicare coverage begins alters the leisure-investment trade-off, and encourages elders to work more instead.

Finally, the Envelope condition (17) decomposes the marginal value of health into three parts. The first right-hand side term includes the benefits obtained through the reduction in mortality risk $\beta^m_{H,t} > 0$ times the continuation utility net of bequest utility. Since $U^m_{t+1} < 0$, the increased expected benefit of surviving for healthier agents is augmented by a lower expected utility cost associated with dying, thereby ensuring that the marginal value of lower mortality risk for healthier agents is always positive. The second right-hand side term includes the marginal value of morbidity risk reduction $\mathrm{E}_{H,t}$. A straightforward argument indicates that this value is positive.[27] In the third component, durability and productive capacity also implies that the marginal value of health captures the expected future marginal value of the undepreciated health stock, plus the marginal product of health in the gross investment technology. This last value clearly establishes that health expenditures are an investment, and that health is a capital, and not a consumption good, consistent with the health-as-capital literature.[28]

As equations (17) and (18) also make clear, imposing exogenous mortality ($\lambda^m_H = \beta^m_H = 0$), exogenous morbidity ($\lambda^s_H = 0$), and path independent gross investment ($I^g_H = 0$) restrict the marginal value of health to its (lower) durability value only. The optimality conditions (15) and (16) show that exogeneity and path independence thus reduce the

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[27] Conjecture that $V_{H,t} > 0, \forall t$ in (17), in which case $\beta^m(H_t)\mathrm{E}_{H,t}\{V_{t+1} \mid H_t\} > 0$ in (18) since health is valuable and the low future health outcome is less likely for healthier agents ($\lambda^s_{H,t} \leq 0$). Observing that $\beta^m_{H,t} > 0$, and $U^m(W_{t+1}) < 0$, while $\delta_t + \phi_t < 1$ and $I^g_{H,t} \geq 0$ and solving forward (17) then confirms the positive marginal value of health conjecture.

[28] Note that Grossman (1972, p. 291), while emphasizing the capital nature of health, does not rule out health providing direct utility services, i.e. $U(C, H)$. Direct utilitarian flows of health are further discussed in Finkelstein et al. (2009, 2013) who focus on how health affects the marginal utility of consumption. For completeness, we also experimented with a variant of preferences (22) allowing for explicit utility for health:

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

The results we obtained being qualitatively similar, but empirically worse, we select the simpler health-independent formulation $\mu_\ell = 1 - \mu_C$. From the discussion of (10), it follows that all instantaneous utilitarian flows of health can be traced to its longevity benefits.

attractiveness of investing in health through expenditures and through healthy leisure. Note finally that undepreciated health will decline with aging as the depreciation rates δ_t, ϕ_t become large. Increasing depreciation plus finite lives and non bequeathable health then make it increasingly costly to maintain the health capital for the elders.

4 Empirical strategy

This section outlines the empirical methods that we rely upon to solve and estimate the model. The presence of autonomous time variation in wages, productivity, prices, and deductibles, combined with kinked OOP costs schedule, and, especially, the endogenous discounting induced by health-dependent mortality risk imply that analytical solutions are unattainable and numerical approaches must be relied upon to solve the model.[29] After discussing the choice of functional forms and insurance plans, we introduce the iterative, and simulation procedures from which the Simulated Moments Estimation is obtained.[30] We close the section by an overview of the data used in the estimation.

4.1 Functional forms and insurance plans

First, in order to complete the parametrization the model in Section 3, we consider decreasing convex intensities, a CRS gross investment function, as well as CES and CRRA

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[29] See also Hugonnier et al. (2013) for discussion and quasi-closed form solutions based on perturbation methods for endogenous discounting models with complete markets and linear OOP schedules.

[30] A more detailed technical appendix outlining the empirical procedure is available upon request.

utility functions:

$$\lambda^m(H) = \lambda_0^m + \lambda_1^m H^{-\xi^m}, \tag{19}$$

$$\lambda^s(H) = \lambda_2^s - \frac{\lambda_2^s - \lambda_0^s}{1 + \lambda_1^s H^{-\xi^s}}, \tag{20}$$

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \quad \eta_I, \eta_\ell \in (0,1), \tag{21}$$

$$U(C, \ell) = \left[\mu_C C^{1-\gamma} + (1-\mu_C)\ell^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \quad \mu_C \in (0,1), \tag{22}$$

$$U^m(W) = \mu_m \frac{W^{1-\gamma}}{1-\gamma}. \tag{23}$$

Equations (19) and (20) both encompass limits to self-insurance as the intensities are bounded below by $\lambda_0^k = \lim_{H\to\infty} \lambda^k(H)$, whereas exogeneity of the morbidity and mortality risks is obtained by imposing the restrictions $\lambda_1^k = 0$ or $\xi^k = 0, k = m, s$. Morbidity risk is also bounded above by $\lambda_2^s = \lim_{H\to 0} \lambda^s(H)$ to avoid spiraling optimal paths where health falls, inducing more sickness, and further depreciation and certain subsequent sickness and death (see Hugonnier et al., 2013, for discussion). The Cobb-Douglas technology (21) ensures diminishing returns to expenditures, leisure and health inputs for gross investment, whereas the Constant Elasticity of Substitution (CES) specification (22) allows for unconditionally positive utility and therefore helps guarantee preference for life over death, $\mathcal{U}_t > 0$ in (10). Conversely, the bequest function (23) is negative when the curvature parameter γ is greater than one, ensuring that death is costly, whereby the marginal value of bequeathed wealth remains positive.

Next, we consider four exogenous insurance plans corresponding to No and Private insurance when young ($1 \leq t < 65$), and No, and Medicare when old ($t \geq 65$), and denoted $x = (x_y, x_o) \in \mathbb{X} = \{\text{PM, PN, NM, NN}\}$.[31] The descriptions as well as corresponding expressions for OOP's, premia and income are outlined in Table 4. Plan PM (our benchmark case) encompasses full insurance. Plan PN captures the effects of employment-provided insurance which is terminated at retirement, whereas plans NN and

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[31] Plan NP is arguably of limited empirical relevance, and is abstracted from. Plan PP was also considered with results qualitatively similar to those under plan PM.

NM illustrate the effects of market failures leading to exclusion from health insurance. This classification allows for a convenient identification of the marginal effects of (i) young agents insurance status conditional on the elders insurance status (by contrasting PM vs NM, and PN vs NN), as well as those of the (ii) elders' insurance status conditional on young insurance status (by contrasting PM vs PN and NM vs NN).

4.2 Iteration

The iterative step consists in solving the model numerically by backward induction via a Value Function Iteration approach. Let $Z = (H, W) \in \mathbb{Z}$, denote the discretized state space of dimension K_Z, $\epsilon = (\epsilon^s, \epsilon^m) \in \{0, 1\}^2$, the health shocks, and $Q = (C, I, \ell) \in \mathbb{Q}$, the discretized control space of dimension K_Q. For a given cohort $\kappa \in \mathbb{N}_-$, and for each insurance plan $x \in \mathbb{X} = \{\text{PM, PN, NM, NN}\}$, the Value Function Iteration consists of iterating recursively over ages $t = T, T-1, \ldots, 1$ in order to solve:

$$\begin{aligned} V_t^x(Z) &= \max_{\{Q_t \in \mathbb{Q}\}} \mathcal{U}(Q_t, Z) + \beta^m(Z) \mathrm{E}_t \left\{ V_{t+1}^x(Z_{t+1}) \mid Z \right\}, \\ \text{s.t. } Z_{t+1} &= Z_{t+1}(Q_t, Z, \epsilon_{t+1}) \end{aligned} \tag{24}$$

at each state $Z \in \mathbb{Z}$. Contrary to standard backward iterative procedures, the model is solved for all periods in order to account for the time variation in health productivity, wages and prices, as well as for the Long Reach of Childhood effects.[32]

The age- and plan-specific allocations, and welfare are obtained as:

$$\{Q_t^x(Z), V_t^x(Z)\}_{t=1}^T, \quad \forall Z \in \mathbb{Z}, x \in \mathbb{X}, \tag{25}$$

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[32] In particular, whereas Contraction Mapping Theorem ensures rapid convergence for sufficiently concave and discounted dynamic problems with time-independent forcing processes, our processes for wages, depreciation, prices, deductibles, and productivity, are all time-dependent over the entire life cycle. In addition, the simulation discussed below draws the initial wealth and health statuses from the observed population at age 16. For all these reasons, the iteration process must be solved backward from maximal terminal age $T = 100$ to initial age 16.

and are used in the simulation phase.[33]

4.3 Simulation

The iteration phase in (24) is performed over a pre-determined state space $\mathbb{Z}$. In order to compute the optimal solutions along the optimal path, it is necessary to simulate the model forward by using the allocation (25) in conjunction with the shocks ϵ generated from the endogenous intensities in (1) and the laws of motion for Z in (2) and (9). Specifically, for each simulated agent $i = 1, 2, \ldots, K_I$ and Monte-Carlo replication $n = 1, 2, \ldots, K_N$ we use the following steps for the adult population aged 16 and over:

1. We initialize the state using draws taken (with replacement) from the observed population wealth and health levels at age 16:

$$Z_{16}^{i,n} \sim \mathbb{Z}_{16}^{POP}.$$

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

    (a) Optimal rules $Q_t^{i,n}$ and value function $V_t^{i,n}$ are computed using a bilinear interpolation of the policy functions (25) that were obtained in the iterative phase, and are evaluated at the state $Z_t^{i,n}$.

    (b) Mortality and morbidity 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) State variables are updated,

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

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[33] To facilitate exposition, we henceforth drop the explicit dependence of variables on plan x from the notation.

The output sequence $\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}$, is the one along the optimal path over ages $t = 16, \ldots, T$, and can be used to compute both the life cycle and the unconditional statistics across surviving agents. In particular, let $\mathbb{1}_t^{i,n} \in \{1, \mathrm{NaN}\}$ be the alive indicator for agent i, in simulation n, at age t. The theoretical life cycle moment $\hat{M}_t$ for allocation, welfare, and state, and the survival rate $\hat{S}_t$ is given at each age t by integrating over surviving agents and simulation replications:

$$\begin{aligned} \hat{M}_t &= \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n} \left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}}{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}, \\ \hat{S}_t &= \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}{K_I K_N}. \end{aligned} \tag{26}$$

Similarly, the corresponding unconditional moments $\hat{M}$ for allocation, welfare, state and life expectation $\hat{S}$ are obtained by integrating the life cycle moments and survival rate over age for the adult population:

$$\hat{M} = \frac{\sum_{t=16}^{T} \hat{M}_t}{T - 16}, \tag{27}$$

$$\hat{S} = \sum_{t=16}^{T} \hat{S}_t. \tag{28}$$

These theoretical moments can be contrasted with the empirical moments in order to estimate the model.

4.4 Calibration and estimation strategy

The previous iteration and simulation phases are performed conditional upon a given parameter set $\Theta = (\Theta^c, \Theta^e)$ where Θ^c denotes the calibrated parameters subset, and Θ^e is the estimated parameters subset:

$$\begin{aligned} \Theta^c &= (T, \kappa, \lambda_2^s, \xi^m, \xi^s, P_0^I, g^P, A_0, g^A, \psi, \Pi, \Pi^M, D_0, g^D, \tau, Y^R, R^f, \eta_I, \eta_\ell, \beta, \mu_C, \mu_\ell, \mu_m) \\ \Theta^e &= (\lambda_0^m, \lambda_1^m, \lambda_0^s, \lambda_1^s, \delta_0, g^\delta, \phi_0, g^\phi, \gamma). \end{aligned}$$

The values for the calibrated parameter Θ^c are identified via the literature whenever possible, and through an extensive trial and error process.[34] The estimated parameters Θ^e are those for which we have scant prior information, namely the parameters of the intensity processes $\lambda^k(H)$, as well as the deterministic and stochastic depreciation processes (δ_t, ϕ_t). The coefficient of relative risk aversion γ is also included in the estimation set as further check of the model. The parameters in Θ^e are identified through an SME estimator. In particular, let $\hat{\mathbf{M}}(\Theta) \in \mathbb{R}^{K_M}$ be the collection of theoretical life cycle moments $\{\hat{M}_t\}$ given in (26), $\mathbf{M} \in \mathbb{R}^{K_M}$ be the corresponding observed moments, and $\Omega \in \mathbb{R}^{K_M \times K_M}$ be a weighting matrix. The Simulated Moments Estimation (SME) of Θ^e is given as:

$$\hat{\Theta}^e = \underset{\Theta^e}{\operatorname{argmin}}[\hat{\mathbf{M}}(\Theta) - \mathbf{M}]'\Omega[\hat{\mathbf{M}}(\Theta) - \mathbf{M}]. \tag{29}$$

In practice, the theoretical life cycles moments $\hat{\mathbf{M}}(\Theta)$ in (29) are computed over 5-year intervals between the age of 25 and 80, and involve out-of-pocket expenditures, leisure, wealth, and health for our benchmark insurance case PM (Private when young, Medicare when old).[35] The corresponding empirical moments $\mathbf{M}$ are taken from various widely-used health and socio-economic surveys corresponding to the American population for years 2010 and 2011, and are discussed in further details below. The SME of $\hat{\Theta}^e$ in (29) is consequently over-identified with a total of 48 moments (i.e. 4 life cycles ×12 five-year bins) that are used to identify 9 structural parameters.

Our estimation strategy differs from traditional practices in structural estimation of life-cycle models. To see this, redefine the parameter set as $\Theta = (\Theta^c, \Theta^e_1, \Theta^e_2)$. As Table 5

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[34] In particular, the search for calibrated values Θ^c proceeded in parallel with that for starting values Θ^e_0 for the estimation algorithm. Before proceeding with the estimation phase, all the parameters in (Θ^c, Θ^e_0) were systematically varied, with iteration and simulation phases performed in order to check for consistency with theory and empirical facts, as well as convergence, and local optima. Once sufficiently good results were obtained, we then proceeded with the final estimation phase using Θ^c as calibrated value, and Θ^e_0 as staring values. We also relied on Simulated Annealing algorithms that are well-known for robustness to local optima.

[35] More precisely, we initialize the simulation by taking $K_I = 100$ draws (without replacement) from the observed distribution over health and wealth at age 16, such that this sample is representative of the general population at the beginning of adult age. We then simulate $K_N = 500$ trajectories from the initial grid along the optimal path. This procedure is therefore equivalent to simulating 50'000 individual life cycles from which the 5-year moments are computed.

makes clear, both traditional and our methods fix a calibrated subset Θ^c. However, traditional methods separately estimate a subset of forcing processes (e.g. exogenous stochastic health shocks, wages or labor income, ...) in a first stage to identify $\hat{\Theta}_1^e$, as well as characterize the distribution of exogenous stochastic processes $\hat{\sigma}_1$. The first-stage parameter subset $\hat{\Theta}_1^e$ is relied upon to solve the model by iteration, whereas the distribution parameters $\hat{\sigma}_1$ are then used in the simulation phase. The remaining subset $\hat{\Theta}_2^e$ is estimated in the second stage, conditional upon $\hat{\Theta}_1^e, \hat{\sigma}_1$. In contrast, our single-step approach abstracts from first-stage estimation, and fully embodies all distributional parameters of the endogenous stochastic processes in Θ^e. It follows that $\hat{\Theta}^e$ requires neither outside estimation of forcing processes, nor any ad-hoc characterization of distributional processes.

4.5 Data

Our empirical strategy requires life cycle data on leisure, out-of-pocket health expenditures, wealth, and health status.[36] Ideally, a single panel data-base regrouping all these variables would be used. Unfortunately, to the best of our knowledge, such a data-base does not exist. We therefore rely on various well-known panels that are representative of the American population at a given point in time. These sources are presented in Appendix C, with the corresponding data reported in Table 6.

First, for wealth, we use the Survey of Consumer Finances (SCF). Our measure for financial wealth includes assets (stocks, bonds, banking accounts, IRA accounts ...) either directly, and indirectly held (e.g. through pension funds). Next, we rely on the Medical Expenditures Survey (MEPS) to obtain the health status, wages, total, and out-of-pocket health expenditures. The MEPS survey reports qualitative self-reported health

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[36] We also solve for health investment, but do not include it in the SME procedure. Comparable health investment data refers to the quantity consumption and utilization rates of health services, and is more difficult to measure than OOP's, and is therefore abstracted from the empirical evaluation. In the spirit of out-of-sample validation, we nonetheless use a quantity proxy defined as mean expenses divided by the medical price index in assessing the model's life cycle performance (see Figure 6.a).

status ranging from very poor to excellent that are converted to numerical measures using a linear scale.

Finally, consistent with the income equation (8), healthy leisure is the amount of time spent not working, and is obtained from the American Time Use Survey (ATUS). One could reasonably argue that only a limited share, say $\chi \in (0,1)$, of total leisure time, say $L_t = 1 - N_t$, is actually spent on healthy leisure activities, i.e. $\ell_t = \chi L_t$ while the rest is engaged in non-healthy leisure (e.g. couch potatoes). This is inconsequential for our approach since substituting in the Cobb-Douglas technology (21) and using the TFP process (4) reveals that effective gross investment is now $A_t I_t^g = \tilde{A}_t I_t^{\eta_I} L_t^{\eta_\ell} H_t^{1-\eta_I-\eta_\ell}$, where $\tilde{A}_t \equiv A_t \chi^{\eta_\ell} = \tilde{A}_0 \exp[g^A(t+\kappa)]$ is the effective TFP. Since the initial technology $\tilde{A}_0$ is a calibrated free parameter, it implicitly encompasses the effective healthy leisure share.[37]

5 Results

Following a brief discussion of the estimated and calibrated parameters, we present the output obtained from the iterative phase, followed by the results obtained from the simulation phase. A final section addresses additional validity checks, and robustness issues.

5.1 Parameters

The estimated and calibrated values (panel a) and calibration sources (panel b) for some of the main parameters of interest are displayed in Table 7, whereas the remaining calibrated parameters are presented in Table 8. The standard errors are reported in parentheses (omitted) for the parameters that are estimated (calibrated). The estimation results confirm that all our structural estimates Θ^e are significant at the 5% level.

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[37] If we would willing to ascribe healthy leisure to health-related care (ATUS t010301), self-care (ATUS t010399), and walking, exercising and playing with animals (ATUS t020602), then the healthy activities could be estimated to represent $\chi = 4.3\%$ of total leisure time. This low estimate does not account for the share of sleeping and eating time that can be associated with healthy leisure, and is more difficult to establish. For these reasons, we select the agnostic approach of implicitly incorporating κ in the TFP parameter $\tilde{A}_0 \equiv A_0 \chi^{\eta_\ell}$.

First, regarding the mortality (19), and the morbidity (20) intensities, our estimated parameters warrant the conjecture that both mortality and morbidity are endogenous ($\lambda_1^s, \lambda_1^m \neq 0$), and that both risks are not fully diversifiable ($\lambda_0^s, \lambda_0^m \neq 0$).[38] Unsurprisingly, they also confirm that the incidence of sickness is much more likely than that of death ($\lambda^s(H_t) > \lambda^m(H_t), \forall H_t$), whereas the large calibrated value for λ_2^s is consistent with the absence of limitations in morbidity risk reduction. Finally, both the calibrated curvature (ξ^k), and the estimated endogenous (λ_1^k) parameters are consistent with more potent effects of better health in reducing sickness than death risk ($\lambda_H^s(H_t) > \lambda_H^m(H_t), \forall H_t$).

Second, the depreciation parameters confirm that both deterministic and stochastic depreciations (3) are positive ($\delta_0, \phi_0 > 0$), and are increasing in age ($g^\delta, g^\phi > 0$). Figure 2.b shows that stochastic morbidity ϕ_t is a strong determinant of total health depreciation rates, and that sickness is much more consequential for elders. We also witness a positive exogenous trend in healthcare productivity (4) that is however less than that observed in Table 8 with respect to health care prices and insurance deductibles ($0 < g^A < g^P, g^D$). Furthermore, the calibrated values η_I, η_ℓ for the health investment technology (21) are indicative of an important role of healthy leisure, and of current health status in the gross investment function.

Third, the preferences parameters in (22) and (23) are realistic.[39] The parameters are consistent with a consumption (leisure) share of $\mu_C = 1/3$ ($\mu_\ell = 2/3$), and a low weight $\mu_m = 2\%$ attributed to joy-of-giving in the bequest function. The estimated curvature parameter indicates that consumption and leisure are mainly complements, with a low

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[38] Endogenous morbidity risk is identified in Smith (2005, 2007) who highlights the role of current health as predictor of future health events. Endogenous mortality is found by Benjamins et al. (2004), as well as by Hurd and McGarry (1995); Hurd et al. (2001) who document the positive link between self-reported health status, and survival probabilities, as well as the one between subjective and objective mortality risk. Finally, although the setting is quite different, Hugonnier et al. (2013) structurally estimate, test and confirm the endogeneity of mortality and morbidity risks.

[39] A consumption share of one-third is standard in the Macro literature (e.g. Kydland, 1995, p. 148). A low elasticity of substitution for CES preferences is also identified by Auerbach and Kotlikoff (1987, pp. 51-52), both with respect to inter- and intra-temporal substitution. The admissible range for the curvature γ is usually between zero and ten (e.g. Mehra and Prescott, 1985; Brav et al., 2002). Finally, low bequest motives have also been identified in the literature (e.g. French and Jones, 2011; De Nardi et al., 2009).

elasticity of substitution between the two ($1/\gamma < 1$), and that the risk aversion with respect to bequeathed wealth is reasonable.

5.2 Iterative results

Figure 3 displays the optimal allocations, as well as the welfare functions of the predetermined health and wealth state. For that purpose, we compute the mean values between ages 60–65, under benchmark plan PM. Our results confirm that consumption, leisure, and out-of-pocket expenses are all generally decreasing in health, with some exceptions at very high, and at very low health and wealth levels. First, as discussed earlier, a lower risk of dying when health improves is tantamount to lower discounting and encourages the healthier agent to reduce consumption and increase savings in the face of a longer expected life horizon (Fig. 3.a).

Moreover, the health dynamics (2) entail that better current health increases expected future health which, when combined with the lower risk of becoming sick, justifies a substitution away from both healthy leisure activities (Fig. 3.b), and from health expenditures (Fig. 3.c) for healthier agents. However, for the very poor and very unhealthy, the risk of dying becomes high enough that investment is abandoned in favor of other expenses when health deteriorates further.

As expected, both consumption and leisure are increasing in wealth. Investment however is not monotone in wealth; it first increases for the unhealthy, and then falls in wealth in favor of more leisure when sufficiently healthy. Finally welfare is clearly monotone increasing in both wealth and health (Fig. 3.d), as can be expected from the discussion of Envelope condition (17). Observe that concavity is more pronounced with respect to health, as could be anticipated from the diminishing returns in the self-insurance technology (19) and (20), and in the gross investment function (21).

5.3 Simulation results

The previous results are obtained over a given state space, and at a given period in the life cycle. In what follows we calculate the age-dependent policies along the simulated optimal path, thereby fully endogenizing the evolution in the health and wealth statuses. We start by integrating along the age dimension in order to compute the unconditional moments. This is followed by an analysis of the age-dependent statistics.

5.3.1 Unconditional moments

We first compute the unconditional statistics (27) for the surviving agents over ages 25–80, as well as the expected lifetime (28). This exercise is repeated for the four health insurance plans (PM, PN, NN and NM).[40] Comparing the simulated with the observed moments in Table 9.a confirms that the model does quite well in capturing the age-independent features of the data. Indeed, leisure, wealth, health and expected longevity are all accurately reproduced. Out-of-pocket expenses are somewhat over-estimated, likely because of the absence of expenditure caps in the model.

Overall, our results provide evidence that being insured when young (i.e. contrasting PM vs NM and PN vs NN), as well as when old (i.e. contrasting PM vs PN and NM vs NN) entails important decreases in out-of-pocket expenditures, as well as a substitution away from healthy leisure. Both wealth, and health levels increase (especially for the younger insured), with the latter inducing a longer expected lifetime. As a result, being insured is welfare-improving when analyzed across the age domain.

The unconditional moments also make it possible to calculate the elasticity of total health spending $P_t^I I_t$ with respect to the marginal out-of-pocket price. Following Aron-Dine et al. (2013), we can compute the arc elasticity associated with variations in the

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[40] More precisely, using the calibrated and estimated parameters for our benchmark case PM, we recalculate the iterative and simulation output for each of the three other insurance plans using the specifications in Table 4.b, and from which the life cycles, and the unconditional moments are computed. Ideally, separate estimations would have been performed for each of the four alternative cases. However, data limitations (noticeably the fact that plans PN or NN are not observed) imposes a unique estimation relying on the most prevalent case – plan PM – and a counter-factual exercise relying on the same set of estimated parameters.

co-payment rate ψ as the percentage change in total health spending resulting from a percentage change in the co-payment rate.[41] The elasticity estimates that are reported in Table 9.b compare favorably with the ones obtained under the RAND Health Insurance Experiment.[42] As expected, the elasticity is higher when observed over longer periods.

5.3.2 Life-cycle properties

The simulated life cycles are presented in Figures 4–9, and are given as the mean allocations, and states at each age across the simulation output, using (26). To facilitate the discussion, the observed (red line, when available) and the simulated (blue line) levels are reported in panels a, where the simulation corresponds to our benchmark PM case. The confidence intervals fully integrate parametric uncertainty, and are computed from the estimated variance-covariance of the parameters, using the delta method, and are plotted as the dotted blue lines.[43] We also report the marginal effects of being insured when young (i.e PM-NM, and PN-NN) in panels b, and the marginal effects of being insured when old (i.e. PM-PN, and NM-NN in panels c.

The simulated health statuses in Figure 4.a predict levels, as well as an optimal decline that are consistent with those observed for the data.[44] Our results in panel b indicate that young insured agents are healthier, starting at mid-life. The effects are long-lasting because of the persistence in the health dynamic process (2).[45] The results in panel c are consistent with some degree of stockpiling whereby young uninsured agents who will be

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[41] For insurance status $x \in (x_1, x_2)$, and corresponding expenses $M_1 = M(x_1), M_2 = M(x_2)$, the arc elasticity is computed by evaluating the percentage change in M with respect to mean benchmark $0.5(M_1 + M_2)$ divided by the percentage change in marginal OOP cost, i.e. the relative change in price from no insurance to insurance is $-0.8 = -(1 - \psi)$. The percentage change in expenses M is obtained by varying the insurance status from partial insurance (i.e. NM, PN), or no (i.e. NN) insurance, to our benchmark full insurance (i.e. PM).

[42] Accepted estimates from the RAND study are -0.20 (Keeler and Rolph, 1988). Aron-Dine et al. (2013, Tab. 4.A, p. 214) report estimates varying between -0.49, and -0.09.

[43] The uncertainty associated with the simulation phase is omitted from the reported confidence intervals since that variance can be driven to arbitrarily low values by increasing the number of simulations.

[44] See Case and Deaton (2005); Scholz and Seshadri (2012); Van Kippersluis et al. (2009) for further evidence and discussion of observed health evolution.

[45] See also McWilliams et al. (2007) for medical evidence that previously insured young agents have better morbidity conditions after age 65.

insured when old (NM-NN) optimally choose to let health run down just before retirement and substitute better health when old and insured.[46]

Second, the levels and life-cycle increases in out-of-pocket expenditures displayed in Figure 5.a are consistent with those observed in the data, despite being numerically (but not statistically) higher than observed values. Both panels b and c indicate a sharp reduction in OOP's for the insured, with little evidence of pre- or post-coverage effects.[47] Third, for reasons discussed in footnote 36, we do not include investment in our list of moments to match. Nonetheless, the health investment life cycle in Figure 6.a shows a lifetime increase which is consistent with patterns observed in the proxy of real medical expenditures (right-hand scale), as well as with other proxies, such as the number of medical visits. In panel b, being insured when young induces a mid-life increase in health-care consumption that terminates at retirement, but with little spillovers afterwards. Similarly, panel c shows an increase in investment after entitlement begins for the insured elders, but no pre-retirement effects.[48]

Fourth, the observed life cycle of leisure in Figure 7.a is also reproduced quite well by the model. Panel b shows that young insured prefer to reduce their healthy leisure, especially at mid-life when wages are at their highest levels, before falling sharply after retirement (see Figure 2.a). Similarly, insured elders in panel c substitute less leisure at mid life in favor of more later on, after wages have fallen.[49]

Fifth, wealth life cycles are also reproduced very accurately by the model in Figure 8.a, with optimal accumulation when young and dissaving after retirement.[50] We saw that being insured when young reduces exposure to OOP expenditures and induces a reduction

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[46] Stockpiling prior to Medicare coverage has been identified by Ozkan (2011); Scholz and Seshadri (2012). Health improving effects, and moderate increases in longevity for elders under Medicare have been also identified by Lichtenberg (2002); Khwaja (2010); Finkelstein and McKnight (2008); Card et al. (2009); Scholz and Seshadri (2012).

[47] Significant reduction in OOP exposure under Medicare has been identified by Khwaja (2010); Finkelstein and McKnight (2008); Scholz and Seshadri (2012); De Nardi et al. (2010).

[48] Lichtenberg (2002); Finkelstein (2007); Card et al. (2009) also present evidence of increased consumption of health care for old insured.

[49] Empirical analyses of Medicare's effects on elders' leisure choices also are indicative of more leisure after retirement (Currie and Madrian, 1999; French, 2005).

[50] See also De Nardi et al. (2010, 2009); Dynan et al. (2004) for discussion and evidence of asset decumulation in old age.

in healthy leisure time, i.e. an increase in labor supply. Furthermore, the increase in health levels discussed earlier leads to longer expected life horizon (Table 9). All elements concur to increase the optimal wealth levels in panel b. The effect of better longevity also justifies building up more wealth balances when young for insured elders in panel c.

Finally, since welfare is monotone increasing in both health and wealth (Figure 3.d), it displays a similar inverted U shape as the latter in Figure 9.a, peaking at age 65 before falling under the combined influence of diminishing health and wealth afterwards.[51] In panels b and c, longer expected lifetime, better health and wealth, as well as reduced exposure to morbidity and OOP risks justify why being insured is unambiguously welfare increasing after mid life, especially when uninsured in the other periods. The absence of clear welfare gains prior to age 40 is consistent with the larger incidence of uninsurance among younger cohorts,[52] and is explained by the low wages (Figure 2.a), the relatively high endowed health level (Figure 4.a), and therefore low morbidity rates, and the low accumulated wealth (Figure 8.a) which all contribute to raise the marginal cost of insurance premia.

5.4 Additional validity and robustness

5.4.1 Reduced-form tests

The results presented thus far have highlighted the model's remarkable ability to track unconditional moments (including expected lifetime), as well as the life cycle properties of the agents' allocations and statuses. Additional gauging of the model's performance can be drawn from the reduced-form implications. Clearly, data limitations imply that not all the predictions can be tested (e.g., universal access to Medicare precludes the testing of the insurance effects on elders). Nonetheless, certain implications of the model

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[51] Recent evidence for similar inverted-U shape for welfare can be found for German and British panel data by Wunder et al. (2013, Fig. 4) who document an increase up to age 65 associated with increasing financial resources, followed by a fall associated with declining health.

[52] The percentage of people without health insurance falls from 31.4% for ages 25–34 to 15.7% for ages 45–54 (National Center for Health Statistics, 2011, Tab. 141). See also Cardon and Hendel (2001) for evidence of uninsurance among younger cohorts.

regarding the demand for health by younger agents can be assessed in order to provide additional validity checks.

For that purpose, consider the following reduced-form implementation for younger agents $i = 1, N$, and age $t \in (20, 64)$ with respect to leisure:

$$\begin{aligned}\ell_{i,t} =& \gamma_1^\ell H_{i,t} + \gamma_2^\ell H_{i,t}^2 + \gamma_3^\ell W_{i,t} + \gamma_4^\ell \left(W_{i,t} \times H_{i,t}\right) + \gamma_5^\ell \mathbb{1}_{i,t}^X + \gamma_6^\ell \left(\mathbb{1}_{i,t}^X \times t\right) \\ &+ \mathbf{X}_{i,t}\beta^\ell + \epsilon_{i,t}^\ell\end{aligned} \tag{30}$$

and with respect to OOP's:

$$\begin{aligned}OOP_{i,t} =& \gamma_1^O H_{i,t} + \gamma_2^O H_{i,t}^2 + \gamma_3^O W_{i,t} + \gamma_4^O \left(W_{i,t} \times H_{i,t}\right) + \gamma_5^O \mathbb{1}_{i,t}^X + \gamma_6^I \left(\mathbb{1}_{i,t}^X \times t\right) \\ &+ \mathbf{X}_{i,t}\beta^O + \epsilon_{i,t}^I,\end{aligned} \tag{31}$$

where as before $\mathbb{1}_{i,t}^X$ is the insured status, and where $\mathbf{X}_{it}$ are the additional controls. The main testable predictions concerning leisure and OOP's obtained thus far are that (i) both are decreasing and convex in health, (ii) leisure is increasing in wealth, and OOP's are increasing at low health levels, and (iii) leisure is lower for the insured at mid-life, while OOP's are lower, but increase at mid-life. These theoretical results concerning the shape of the optimal leisure and investment functions, as well as those predicting the effects of the insurance status imply sign restrictions on the γ^ℓ, γ^O parameters that are summarized in Table 10.a.

We can test these sign restrictions using the MEPS data base which contains the leisure, OOP and health series (see Appendix C; in the absence of a wealth variable in MEPS, it is proxied by the education level). The results in Table 10.b confirm that all the sign restrictions implied by the model are verified. This favorable performance, combined with the capacity in reproducing the life cycles, indicates that the model is well suited for capturing a large subset of the salient features of the data.

5.4.2 Robustness to the cohort effects

The results obtained thus far fully account for the heterogeneity in the life cycles stemming from heterogeneous initial health and wealth statuses, and from the idiosyncratic exposure to morbidity and mortality shocks. However, for tractability reasons, we have assumed homogeneous preferences, technology, and cohort. In particular, the latter implies that the agents who are alive at any given point in time all have the same age in our simulated populations. This is admittedly restrictive in that we abstract from the overlapping generational structure of actual populations. Put differently, focusing on a single cohort (which is replicated a large number of times in the simulation) entails that cohort effects are not entirely accounted for in our simulation strategy. For example, elders in the current population presumably have access to the same medical technology than their contemporary younger fellow citizens. However, they likely had access to a lower level of medical technology when younger, resulting in different optimal life cycle allocations across cohorts.

In order to better understand how these cohort effects may influence our results, we recompute the full iterative and simulation output for the PM benchmark case, taking as given the estimated parameters, but changing the cohort indicators κ. Inspecting the medical TFP (4), the medical prices (6), and the deductibles (7) processes reveals how the life cycle allocations should be altered. In Figure 10, we plot our benchmark life cycles for $\kappa = -37$ (blue line), along with those corresponding to a younger cohort $\kappa = -32$ (green line), and to an older cohort $\kappa = -42$ (black line). Our results show (i) remarkable qualitative robustness to changing the cohort, and (ii) marginal cohort effects that are consistent with intuition. Since younger (older) cohorts have access to better (worse) health technology, they achieve better (worse) health levels in panel a. Moreover, the combination of higher prices and deductibles explain why they must also spend more on OOP expenditures (panel b). Better health technology further allows the younger cohort to take on less leisure (panel c). Finally, longer expected horizon explains why the younger cohort need to maintain higher post-retirement wealth balances in panel d.

5.4.3 Robustness to heterogeneity: Education

`[To be completed]`

6 Conclusion

Introspection, empirical and theoretical analyzes all suggest that health insurance status should affect dynamic allocations and outcomes (i) significantly, and (ii) across periods of time. Indeed, health expenditures and healthy leisure decisions are conditioned by the effective price of health expenditures, which in turn depends on the insurance status. The dynamic health-related allocations affect the evolution of health statuses, and therefore the exposure to morbidity and mortality risks throughout the life cycle. Sickness and death risks also condition the evolution of financial wealth, as a precautionary balance against both high OOP expenditures and against high longevity. Moreover, backward induction reveals that being insured when old should affect the allocations when young, whereas the persistence of health processes imply that health-related decisions when young and insured will have long-lasting effects that need to be accounted for.

This paper proposes a (relatively) simple model that is capable of keeping track of these complex mechanisms. This framework relies on three fundamental hypotheses. First, we follow a long tradition in Health Economics in modeling health as a depreciable, and adjustable human capital in order to account for persistence. Second, exposure to morbidity and mortality risks can be (partially) adjusted through health investment and leisure decisions. This allows us to account for self-insurance, as well as for substitution, both in the inter-temporal domain, and among the various health-maintenance instruments. Third, agents are not myopic, but are forward looking in their dynamic decisions, thereby fully accounting for backward induction elements. We solve, simulate and estimate this model under a benchmark case for insurance status. This exercise reveals remarkable consistency with respect to observed unconditional and life cycle moments. Importantly, by varying the health insurance status when young (conditional on old status), and when old (conditional on young status), we are able to identify the marginal effects on the allocations, statuses, and welfare.

Three main results stand out with respect to life cycle effects of insurance statuses. First, young insured agents are healthier, and remain so after retirement due to durability of the health capital. Old insured agents are also healthier, but with limited pre-retirement effects. Second, healthy leisure and expenses are substitutes; leisure is lower and expenses are higher at mid-life for insured agents due to peaking wages, lower marginal OOP costs, and escalating health issues. Third, improved longevity for healthier agents, more work, and lower exposure to OOP's all concur to increase wealth for insured agents. Finally, our results show that the conjunction of lower health expenses risk exposure, more longevity, better health and larger wealth balances imply that health insurance is unambiguously welfare increasing starting at mid-life. Before that age, high endowed health, low wages and low accumulated financial resources means that self-insurance remains a valid alternative to market-provided insurance. Note that welfare improvements of health insurance does not imply dynamic Pareto optimality from society's point of view. Indeed, our bequest motive is low, such that our agents have limited concern for the future generations who end up paying part of the current costs of public insurance schemes such as Medicare or PPACA. Moreover, the general-equilibrium efficiency costs of tax-financed insurance schemes have not been addressed in our model and could turn out to be quite important.

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A Tables

Table 1: Medicare and private insurance summary

Items	Taxes	Co-payment	Deductibles (Y)	Premia (Y)
		(a) Medicare		
A- Inpatient care	2.9% payroll	20%	\$1,156	
B- Outpatient care	Gen. revenues	20%	\$140	\$1,199
D- Drugs	Gen. revenues	25%	\$310	\$472
		(b) Private		
Total premium				\$4,940
Employee contrib.				\$1,021
Co-pay doctor visits		22.82\$/visit	\$1,025	
General med. expenses		18.8%		

Notes: Sources: (a) Medicare: Henry J. Kaiser Family Foundation (2012); Medicare.gov (n.d.); OASDI Board of Trustees (2012). Part A payroll taxes shared equally between employers and employees. Parts B and D financed 25% out of premia, 75% out of general tax revenues. When applicable, deductible and premia are averages based on taxable income. (b) Private: MEPS (2010a,b, Tab. I.C.1, I.C.2, I.F.2, I.F.5, I.F.6). Average total single premium per enrolled employee, private-sector establishments that offer health insurance. Average total employee contribution, individual deductible, and co-payment for an office visit to a physician, per enrolled employee for single coverage at private-sector establishments that offer health insurance.

Table 2: Federal Budget Outlays, 2011

Item	Budget (B$)	Share (%)
National Defense	768.2	20.1
Social Security	748.4	19.6
Income Security	622.7	16.3
Medicare	494.3	12.9
Health	387.6	10.2
Education	115.1	3.0
⋮	⋮	⋮
Total	3818.1	100.0

Notes: Sources: U.S. Census Bureau (2011b, Tab. 473, p. 312), Federal Budget Outlays by Detailed Function.

Table 3: Literature classification

	Endogenous:							
Author(s)	Savings	Health expend.	Health prod.	Labor leisure	Retirement	Leisure in health prod.	Mortality risk	Morbidity risk
Cropper (1977)	✓	✓	✓				✓	✓
Hubbard et al. (1995)	✓							
Rust and Phelan (1997)				✓	✓			
Palumbo (1999)	✓							
French (2005)	✓			✓	✓			
Case and Deaton (2005)	✓	✓	✓					
Scholz et al. (2006)	✓							
Hall and Jones (2007)	✓	✓	✓				✓	
Blau and Gilleskie (2008)		✓		✓			✓	✓
Edwards (2008)	✓							
De Nardi et al. (2009)	✓							
Yogo (2009)	✓	✓	✓					
Khwaja (2010)		✓	✓			✓		
De Nardi et al. (2010)	✓	✓						
Ozkan (2011)	✓	✓	✓				✓	✓
French and Jones (2011)	✓			✓	✓			
Scholz and Seshadri (2012)	✓	✓	✓			✓	✓	
Galama et al. (2013)	✓	✓	✓		✓			
Fonseca et al. (2013)	✓	✓	✓		✓			
Scholz and Seshadri (2013)	✓	✓	✓		✓	✓		
Hugonnier et al. (2013)	✓	✓	✓				✓	✓
This paper	✓	✓	✓	✓		✓	✓	✓

Table 4: Insurance plans, net effects and restrictions

(a) Statuses and net effects

	Status: old		
Status: young	Insured	Uninsured	Net effects
Insured	PM	PN	Insured old
Uninsured	NM	NN	
Net effects	Insured young		

(b) OOP's, premia, and income

plan x	$OOP_t^x(I_t)$	Π_t^x	$Y_t^x(\ell_t)$
PM	$P_t^I I_t - \mathbb{1}_D(1-\psi)(P_t^I I_t - D_t)$	$\Pi\left[1-\mathbb{1}_R(1-\pi)\right]$	$\mathbb{1}_R Y^R + (1-\tau)w_t(1-\ell_t)$
PN	$P_t^I I_t - (1-\mathbb{1}_R)\mathbb{1}_D(1-\psi)(P_t^I I_t - D_t)$	$(1-\mathbb{1}_R)\Pi$	$\mathbb{1}_R Y^R + w_t(1-\ell_t)$
NM	$P_t^I I_t - \mathbb{1}_R\mathbb{1}_D(1-\psi)(P_t^I I_t - D_t)$	$\mathbb{1}_R\Pi\pi$	$\mathbb{1}_R Y^R + (1-\tau)w_t(1-\ell_t)$
NN	$P_t^I I_t$	0	$\mathbb{1}_R Y^R + w_t(1-\ell_t)$

Notes: Insurance plans: (N)o insurance, (P)rivate insurance, and (M)edicare. Indicators: $\mathbb{1}_X = \mathbb{1}_{x=P,M}$ (Insured), $\mathbb{1}_M = \mathbb{1}_{x=M}$ (Medicare), $\mathbb{1}_D = \mathbb{1}_{P_t^I I_t > D_t}$ (Deductible reached), $\mathbb{1}_R = \mathbb{1}_{t \geq 65}$ (Retired).

Table 5: Differences in estimation strategies

Step	Traditional	This paper
Calibration	Θ^c	Θ^c
Estimation (1^{st} stage)	$\hat{\Theta}_1^e, \hat{\sigma}_1$	—
Iteration	$\left\{Q_t(Z) \mid \Theta^c, \hat{\Theta}_1^e, \Theta_2^e\right\}$	$\{Q_t(Z) \mid \Theta^c, \Theta^e\}$
Simulation	$\left\{Q_t, Z_t \mid \Theta^c, \hat{\Theta}_1^e, \Theta_2^e, \hat{\sigma}_1\right\}$	$\{Q_t, Z_t \mid \Theta^c, \Theta^e\}$
Estimation (2^{nd} stage)	$\hat{\Theta}_2^e \mid \hat{\Theta}_1^e, \hat{\sigma}_1$	$\hat{\Theta}^e = \left(\hat{\Theta}_1^e, \hat{\Theta}_2^e\right)$

Notes: Main differences in structural estimation of life-cycle models. Calibrated and estimated parameters $\Theta = (\Theta^c, \Theta^e) = (\Theta^c, \Theta_1^e, \Theta_2^e)$.

Table 6: Observed life cycle moments

Age group	(1) Obs.	(1) Wealth†	(2) Obs.	(2) Health†	(3) Obs.	(3) Wages‡	(4) Obs.	(4) Total exp.	(5) Obs.	(5) OOP†	(6) Obs.	(6) Leisure†
25	2025	20 688 $	2256	2.2443	1472	16.41 $	2267	3 019 $	2267	383 $	959	25.0%
30	2650	41 035 $	2247	2.1903	1511	19.94 $	2255	3 028 $	2255	494 $	1241	23.0%
35	2665	65 192 $	2124	2.1162	1418	22.06 $	2130	3 194 $	2130	463 $	1340	24.9%
40	3245	136 949 $	2141	2.0325	1394	22.85 $	2148	3 362 $	2148	520 $	1335	23.5%
45	3560	188 164 $	2173	2.0102	1357	22.89 $	2177	3 599 $	2177	600 $	1288	19.2%
50	3900	299 499 $	2219	1.9596	1349	23.16 $	2223	5 774 $	2223	733 $	1202	24.9%
55	3805	378 413 $	1992	1.8924	1138	22.94 $	1994	6 534 $	1994	1 020 $	1102	32.8%
60	3005	451 300 $	1645	1.9128	703	22.54 $	1645	8 250 $	1645	1 084 $	946	53.1%
65	2210	444 551 $	1304	1.9563	308	20.97 $	1305	8 764 $	1305	1 094 $	744	76.6%
70	1530	315 671 $	919	1.9092	117	17.81 $	919	8 672 $	919	1 034 $	591	87.9%
75	1150	296 924 $	717	1.8082	62	18.54 $	718	10 512 $	718	1 200 $	456	94.3%
80	920	225 900 $	514	1.7899	17	13.97 $	516	9 319 $	516	1 227 $	379	97.6%
All	32410	224 065 $	25436	2.0856	12291	20.09 $	25501	4 892 $	25501	691 $	13260	44.0%
Source	SCF		MEPS		MEPS		MEPS		MEPS		ATUS	

Notes: See Appendix C for data sources. †, (resp. ‡): Used in SME estimation as observed moment (resp. observed forcing process). Age group defined from base age, e.g. group 35 is from age $t \in [35, 40)$. The estimation relies on a $1.0e^{-5}$ scaling applied to all nominal variables (wealth, OOP, wages, total expenditures).

Table 7: Key parameters values and sources

(a) Estimated and calibrated parameter values

Mortality (19)			
λ_0^m	λ_1^m		ξ^m
0.0061 (0.0019)	0.0076 (0.0023)		2.5
Morbidity (20)			
λ_0^s	λ_1^s	λ_2^s	ξ^s
0.3276 (0.1587)	4.3071 (1.3721)	50.0	4.9
Depreciation (3)			
δ_0	g^δ	ϕ_0	g^ϕ
0.0197 (0.0064)	0.0147 (0.0051)	0.0582 (0.0284)	0.0104 (0.0048)
TFP (4) and gross investment (21)			
A_0	g^A	η_I	η_ℓ
1.5	0.004	0.20	0.40
Preferences (10), (22) , (23)			
μ_C	μ_M	β	γ
0.33	0.02	0.9656	4.6785 (1.3851)

(b) Calibrated parameters sources

$\xi^m, \lambda_2^s, \xi^s$	Hugonnier et al. (2013, Tab. 2, p. 688)
η_I, η_ℓ	Free parameters
A_0, g^A	Free parameter, The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
β, μ_C, μ_m	Backus et al. (1995, Tab. 11.3, p. 338), French and Jones (2011, Tab. IV, p. 713)

Notes: Standard errors reported in parentheses (omitted) for estimated (calibrated) parameters. Estimated parameters based on SME estimator (29).

Table 8: Other calibrated parameter values and sources

(a) Calibrated values

parameter	value	parameter	value	parameter	value	parameter	value
T	100	κ	-37				
ψ	0.200	Π	0.0413	Π^M	0.0167		
P_0^I	1.6504	g^P	0.0064	D_0	0.0100	g^D	0.0064
Y^R	0.1476	τ	0.0145	R^f	1.04		
$W_{\min}$	0.05	$W_{\max}$	5	$H_{\min}$	0.1	$H_{\max}$	3
$C_{\min}$	0.05	$C_{\max}$	1	$I_{\min}$	0.01	$I_{\max}$	0.10
$\ell_{\min}$	0.10	$\ell_{\max}$	1				
K_Z	(30×30)	K_Q	$(30 \times 30 \times 30)$	K_I	100	K_N	500

(b) Sources

T, κ	Life tables, Arias (2015). Median age, U.S. Census Bureau (2011a, Tab. 2, p. 4).
P_0^I, g^P	National Center for Health Statistics (2012), Tab 126, CPI and annual percent change for all items, selected items and medical care components, 2010.
ψ, Π, Π_M, τ D, g^D	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	Federal Reserve Bank of St-Louis (n.d.).
Y^R	Average monthly Social Security benefit for a retired worker Social Security Administration (n.d.).

Notes: The state space parameters $(W_{\min}, W_{\max}, H_{\min}, H_{\max}, K_Z)$, as well as the control space parameters $(C_{\min}, C_{\max}, I_{\min}, I_{\max}, \ell_{\min}, \ell_{\max}, K_Q)$ are set as free parameters.

Table 9: Unconditional moments and elasticity estimates (age 25–80)

(a) Data and simulated unconditional moments

		Simulated			
Series	Data	PM	PN	NN	NM
Out-of-pocket, OOP^*	0.0069	0.0092	0.0103	0.0145	0.0134
Leisure, ℓ	0.4397	0.4231	0.4268	0.4339	0.4324
Wealth, W^*	2.2406	2.1854	2.1444	1.5192	1.6199
Health, H	2.0856	2.0839	2.0841	2.0631	2.0646
Survival, $S^\dagger$	77.9	77.95	78.05	77.49	77.55
Welfare, V	NaN	9.6096	9.5483	8.7592	9.0598

(b) Elasticity estimates

Case	Measure	Elasticity
Insurance when young	NM-PM	-0.3087
Insurance when old	PN-PM	-0.2237
Insurance lifetime	NN-PM	-0.6606

Notes: (a) Unconditional statistics computed using (26)–(28). *: in 100,000\$ †: in years. (b) Arc price elasticity of relative changes in total spending from full to co-payment rate ψ on total demand for health $P^I I$.

Table 10: Reduced-form restrictions and estimates

(a) Reduced-form sign restrictions

Prediction	Figure	Reduced-form tests
(a) Leisure		
Decreasing in health	Fig. 3.b	$\gamma_1^\ell < 0$
Convex in health	Fig. 3.b	$\gamma_2^\ell > 0$
Increasing in wealth	Fig. 3.b	$\gamma_3^\ell > 0, \gamma_4^\ell = 0$
Lower for insured at mid-life	Fig. 7.b	$\gamma_5^\ell = 0, \gamma_6^\ell < 0$
(b) OOP		
Decreasing in health	Fig. 3.c	$\gamma_1^O < 0$
Convex in health	Fig. 3.c	$\gamma_2^O > 0$
Incr. (decr.) in wealth at low (high) health	Fig. 3.c	$\gamma_3^O > 0, \gamma_4^O < 0$
Lower for insured, higher at mid-life	Fig. 6.b	$\gamma_5^O < 0, \gamma_6^O > 0$

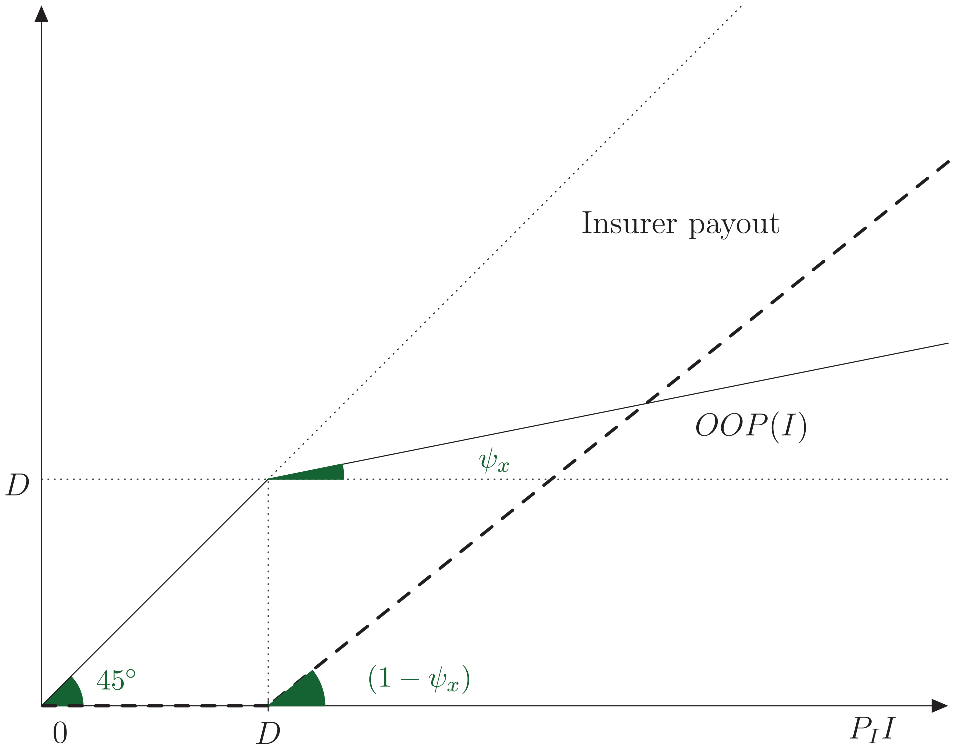
(b) Reduced-form estimates

	(1) leisure	(2) oop
1. health	-0.0351^{**}	-0.00424^{***}
	(0.0151)	(0.000931)
2. health_sq	0.00646^{**}	0.00104^{***}
	(0.00305)	(0.000188)
3. educ	0.00420^{**}	0.000583^{***}
	(0.00176)	(0.000108)
4. educ_health	0.000363	-0.000144^{***}
	(0.000825)	(0.0000506)
5. insured	0.0339^{*}	-0.00232^{**}
	(0.0173)	(0.00106)
6. insured_age	-0.00209^{***}	0.0000749^{***}
	(0.000444)	(0.0000272)
R^2	0.139	0.067
F	141.4	63.52
Observations	11378	11506

Notes: (a) Theoretical sign restrictions for reduced-form model (30), (31). (b) Younger agents aged 20–64. Data sources: MEPS, described in Appendix C. With constant, age, wage, family size, gender, race, and marital status controls included. Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

B Figures

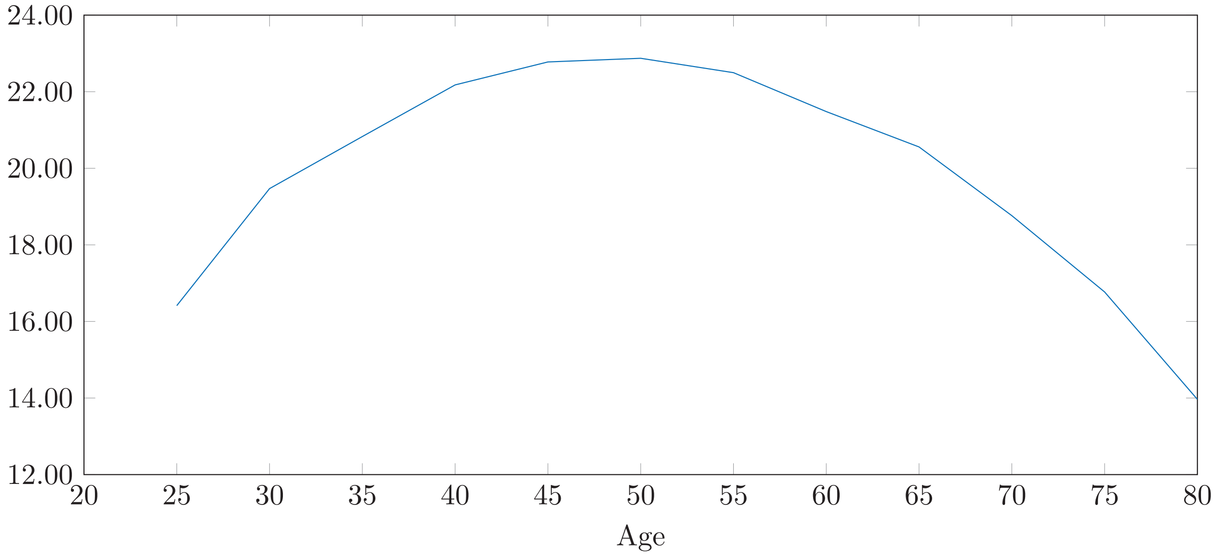
Figure 1: Out-of-pocket health expenditures and insurer payouts



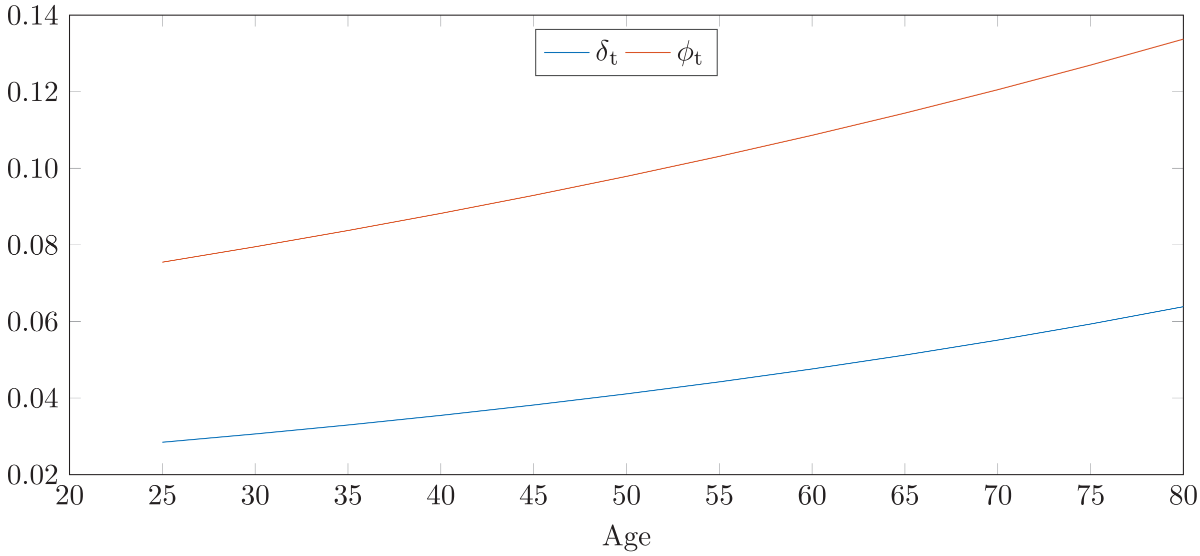
Notes: Solid line: Out-of-pocket expenditures (5) for deductible D and co-payment rate ψ as function of health expenditures $P_I I$. Dashed line: Insurance payout by insurer.

Figure 2: Wages and depreciation rates

(a) Mean hourly wage ($)

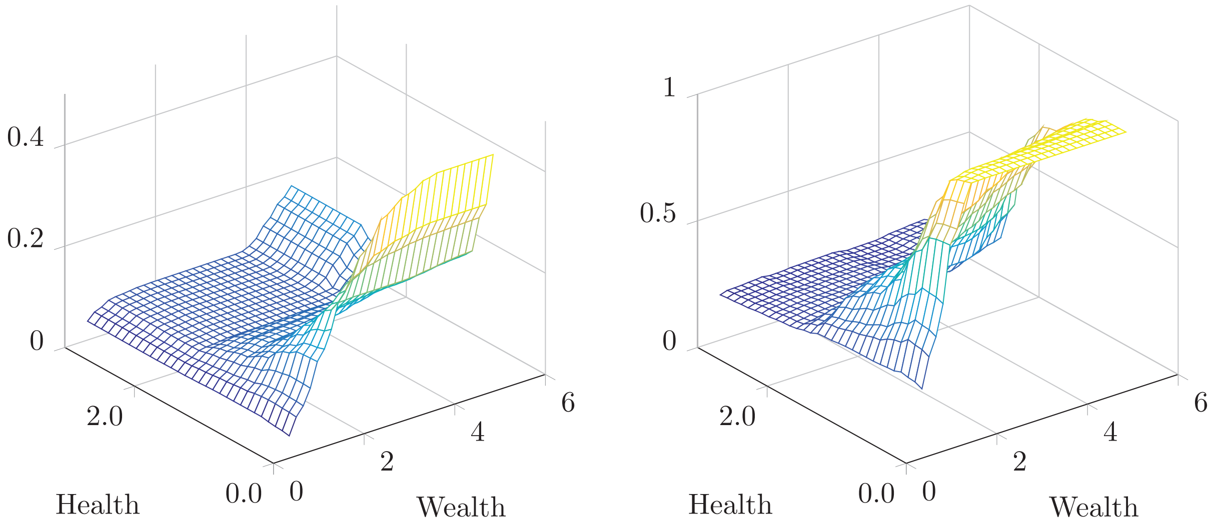


(b) Depreciation



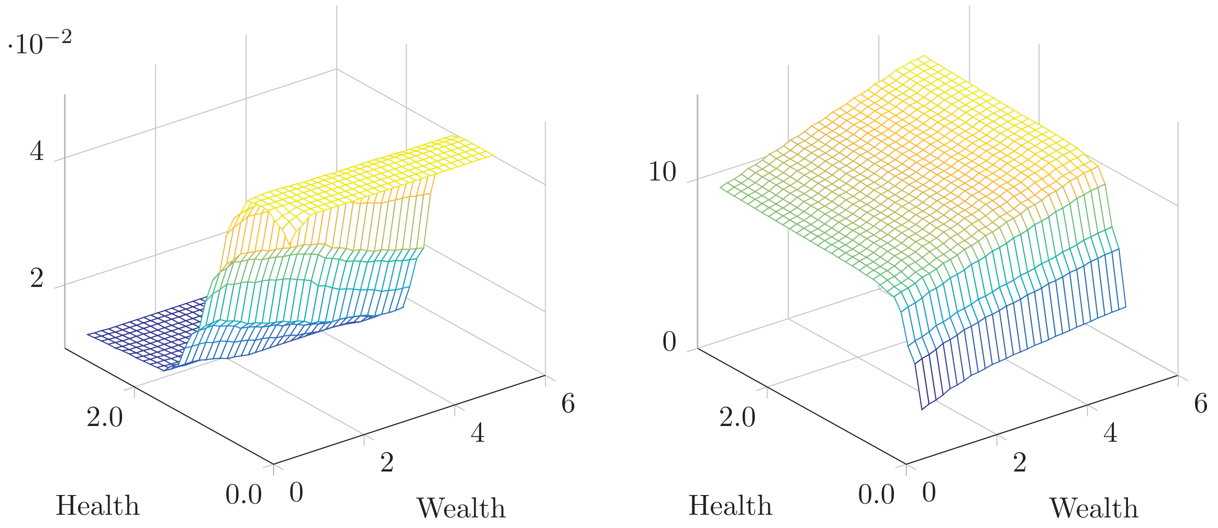
Notes: (a) Mean hourly wages (in $, column 3 of Table 6). (b) Deterministic (δ_t), and stochastic (ϕ_t) depreciation rates, at estimated parameters in Table 7.a.

Figure 3: Iteration results



(a) Consumption

(b) Leisure



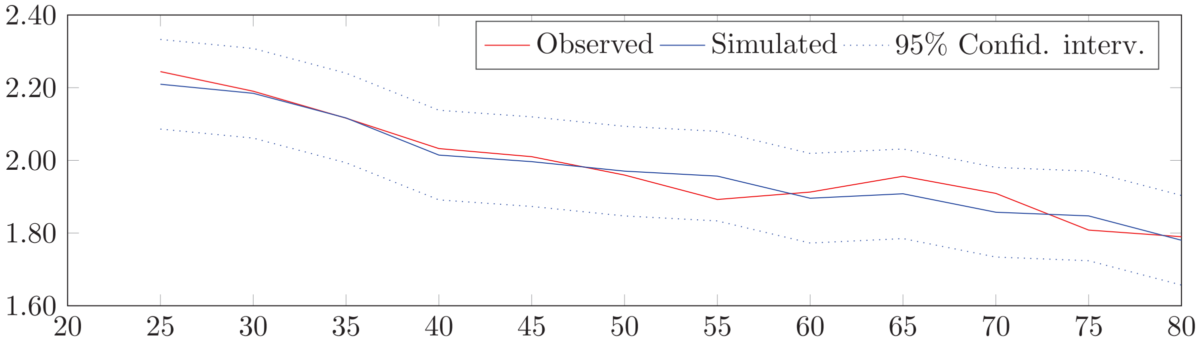
(c) OOP

(d) Welfare

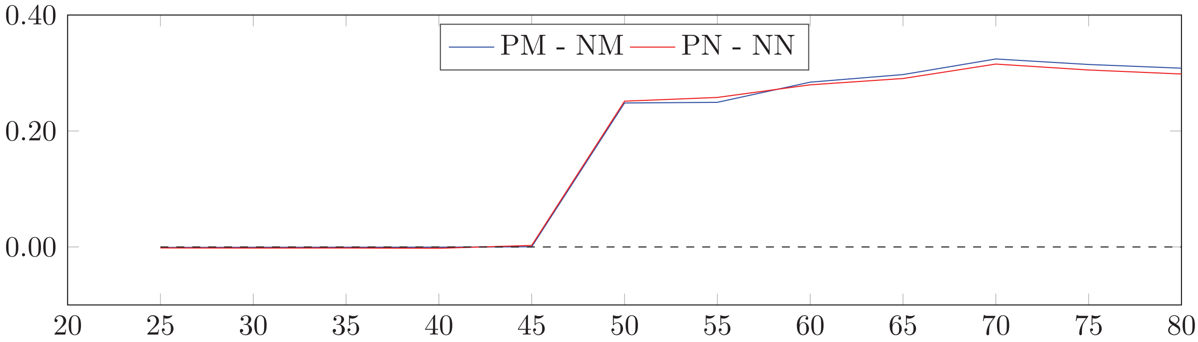
Notes: Optimal allocations and welfare (25) calculated between ages 60-65, under benchmark plan PM.

Figure 4: Life cycle health

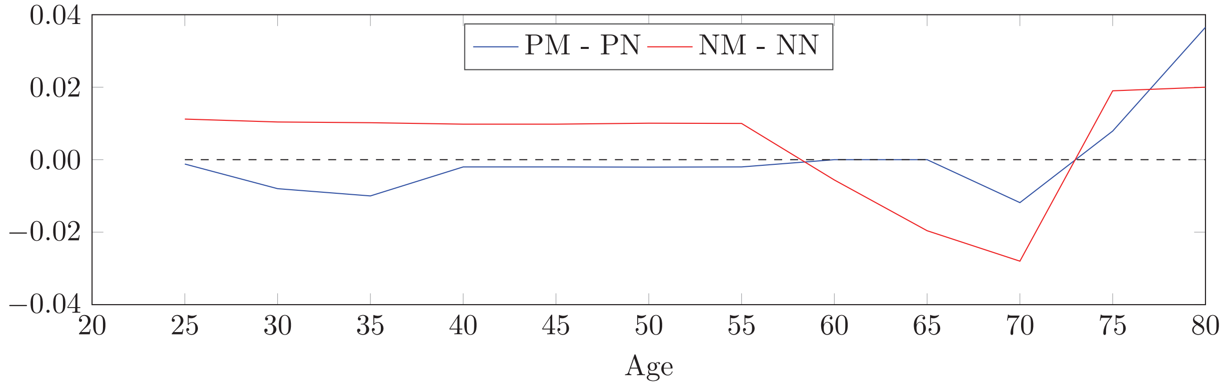
(a) Observed and simulated health



(b) Effects insured young



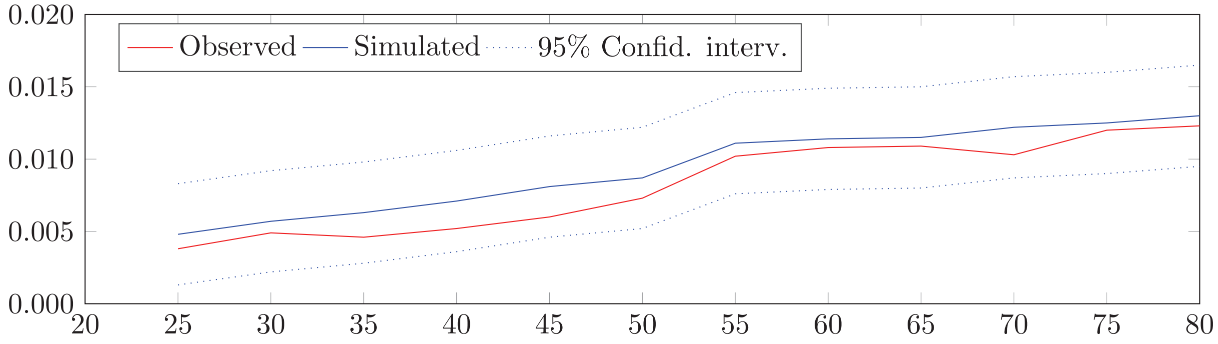
(c) Effects insured old



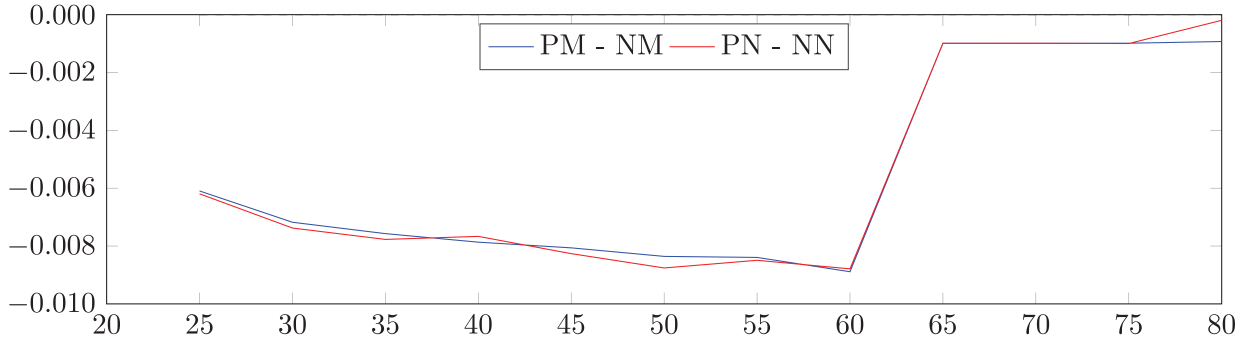
Notes: (a) Mean simulated life cycle (26) for health status H_t (solid blue line), corresponding observed values (solid red line, data in Table 6, col. 2), and 95% confidence intervals (dotted blue lines); health units described in Appendix C. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 5: Life cycle out-of-pocket health expenditures

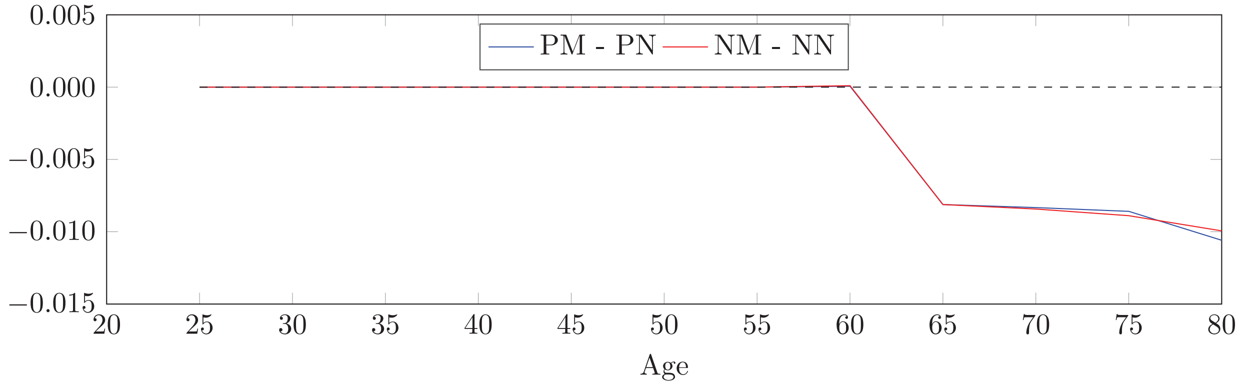
(a) Observed and simulated OOP



(b) Effects insured young



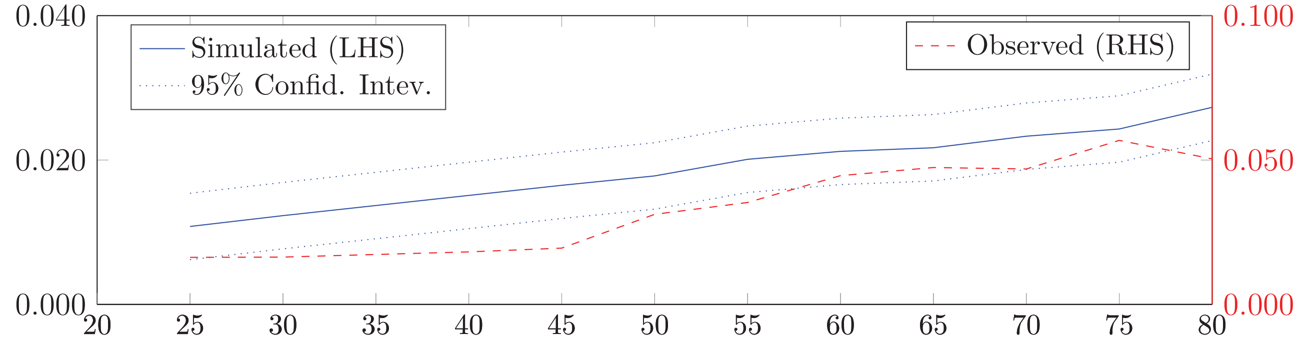
(c) Effects insured old



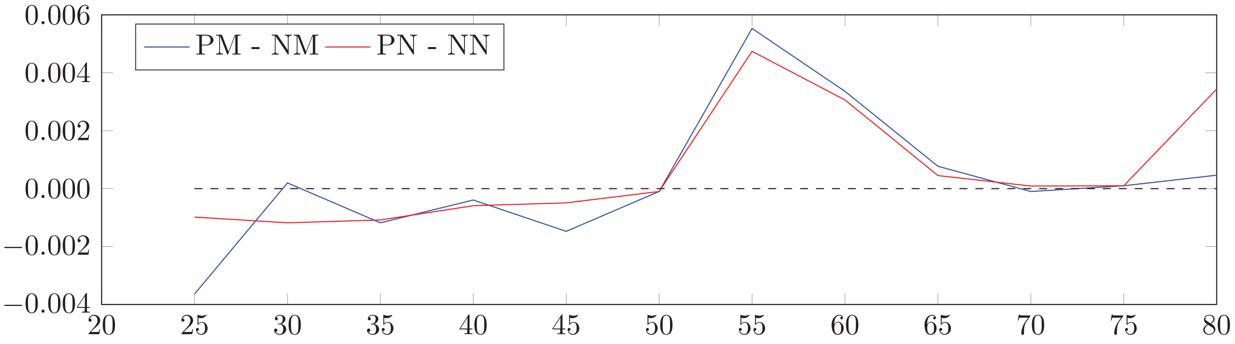
Notes: (a) Mean simulated life cycle (26) for out-of-pocket health expenditures OOP_t (solid blue line), corresponding observed values (solid red line, data in Table 6 col. 5), and 95% confidence intervals (dotted blue lines); units measured in \$100'000. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 6: Life cycle health investment

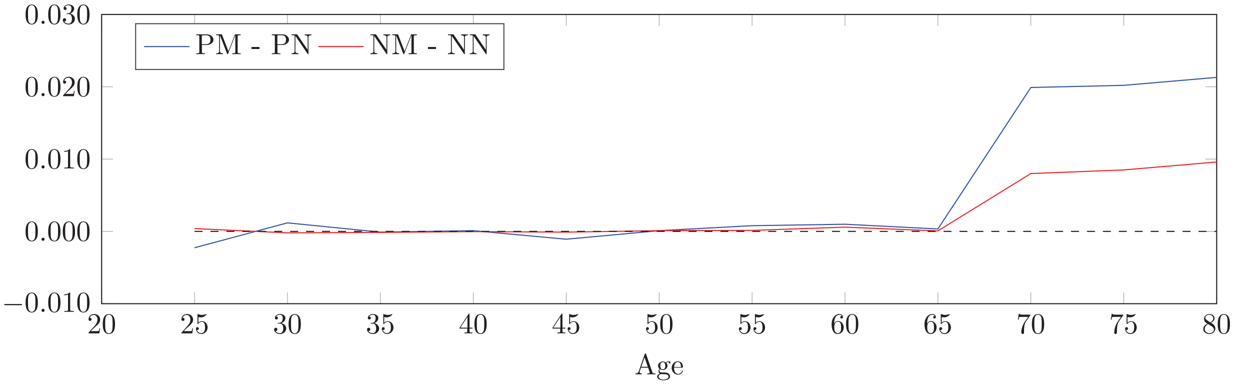
(a) Observed and simulated investment



(b) Effects insured young



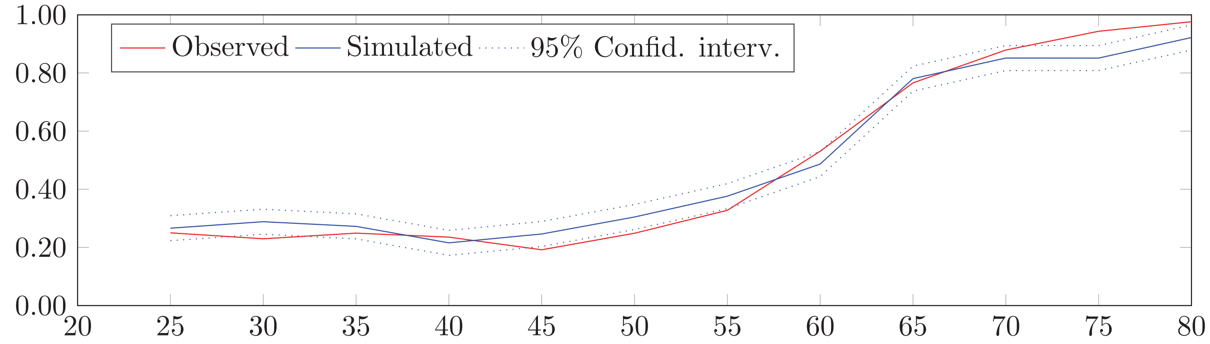
(c) Effects insured old



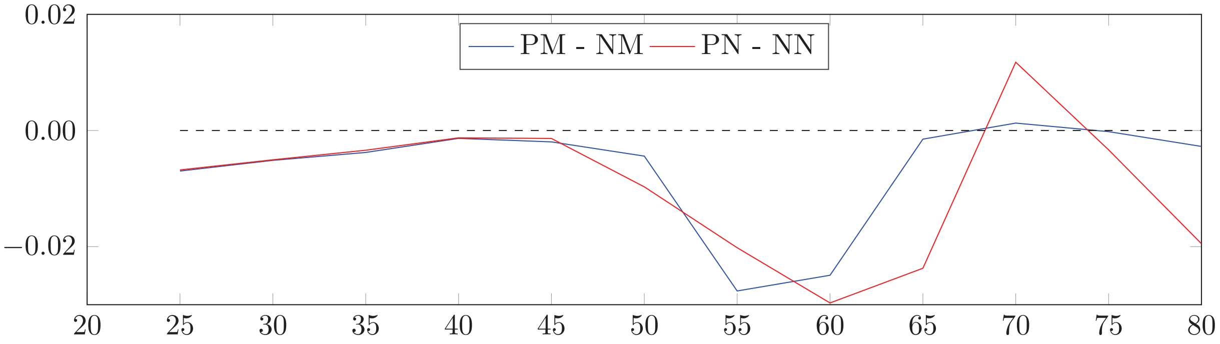
Notes: (a) Mean simulated life cycle (26) for health investment I_t (LHS scale, solid blue line), corresponding observed values (LHS scale, dotted red line), and 95% confidence intervals (dotted blue lines); observed units (RHS scale, dashed red line) correspond to real expenses, i.e. total health expenses, data in Table 6 col. 4, divided by medical prices P_t^I calculated using parameters in Table 8.a. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 7: Life cycle healthy leisure

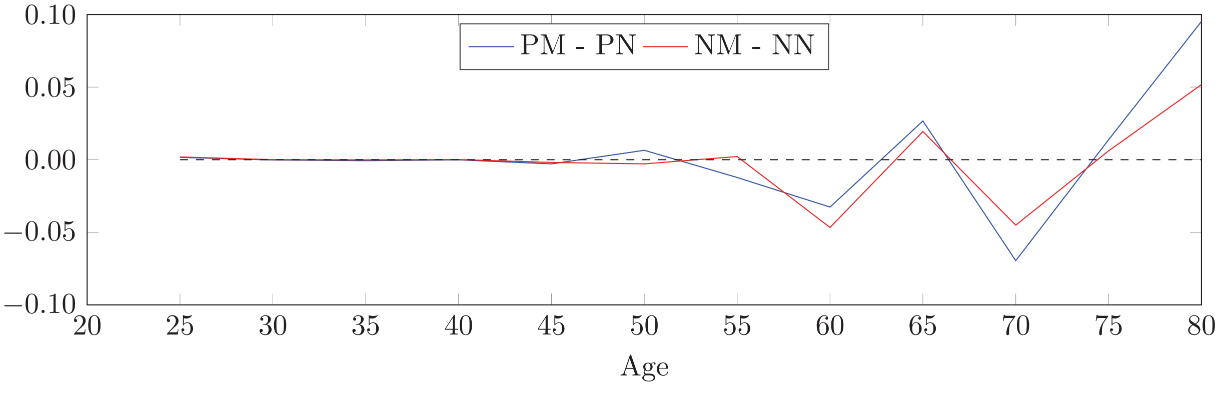
(a) Observed and simulated leisure



(b) Effects insured young



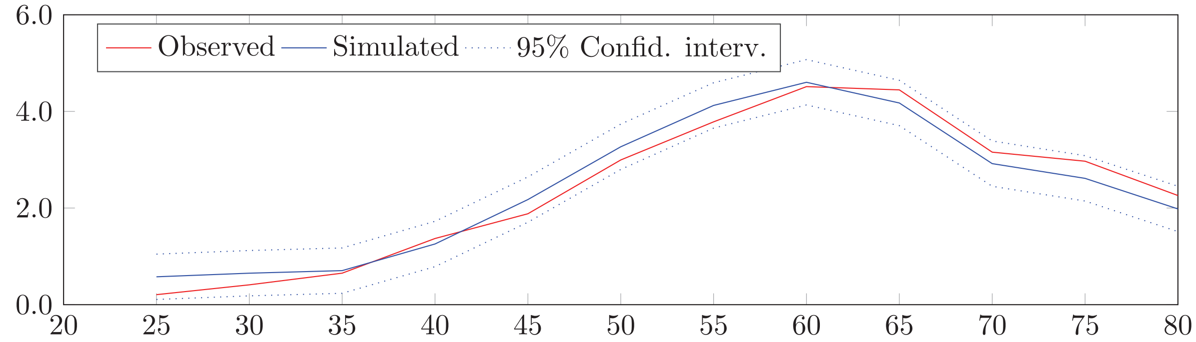
(c) Effects insured old



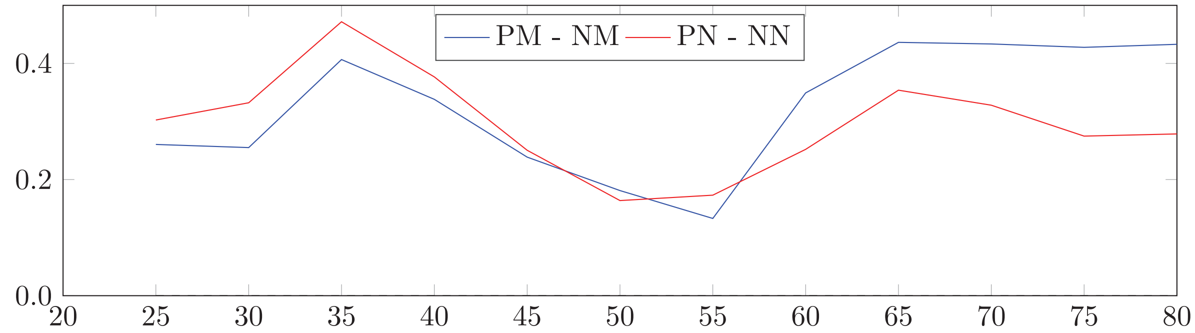
Notes: (a) Mean simulated life cycle (26) for leisure ℓ_t (solid blue line), corresponding observed values (solid red line, data in Table 6 col. 6), and 95% confidence intervals (dotted blue lines); units measured in shares of total available time. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 8: Life cycle wealth

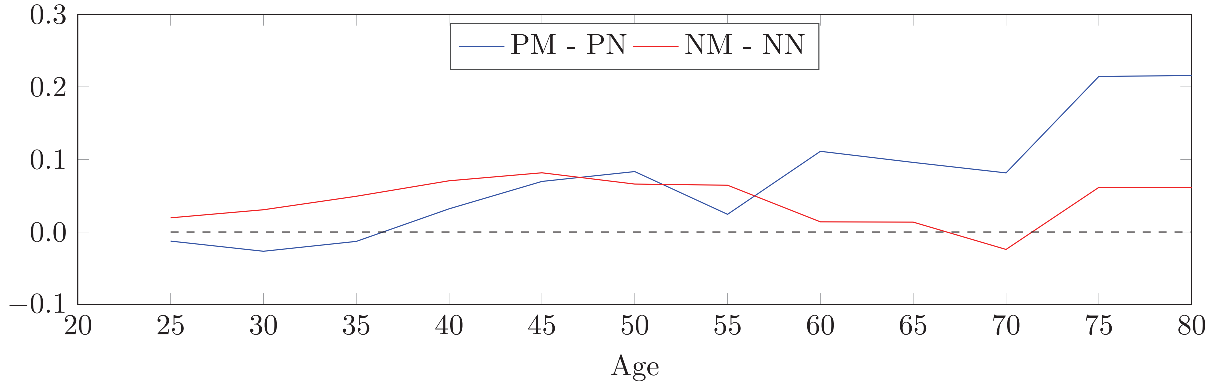
(a) Observed and simulated wealth



(b) Effects insured young



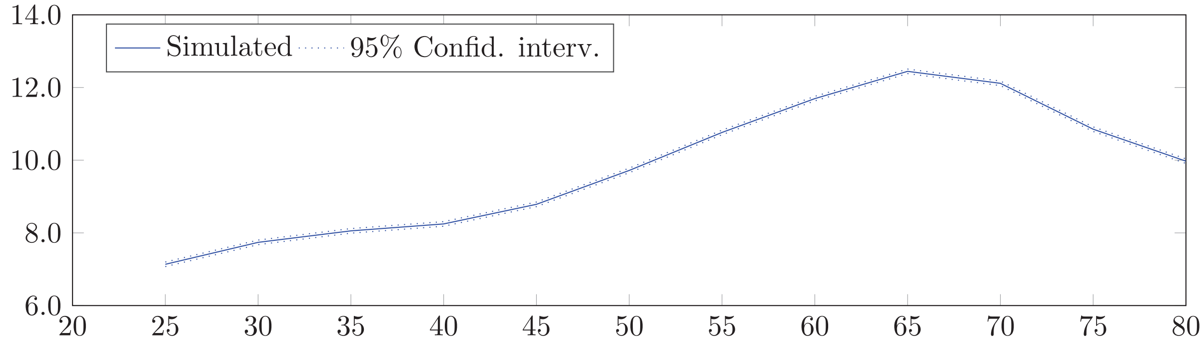
(c) Effects insured old



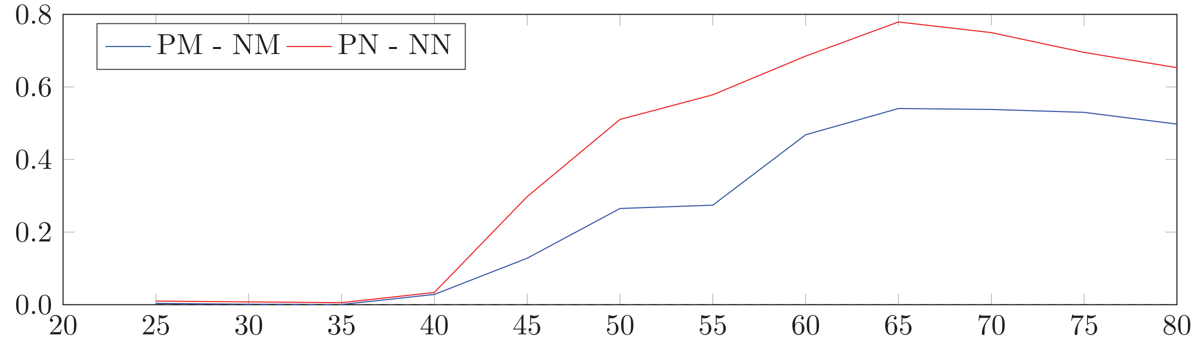
Notes: (a) Mean simulated life cycle (26) for financial wealth W_t (solid blue line), corresponding observed values (solid red line, data in Table 6 col. 1), and 95% confidence intervals (dotted blue lines); units measured in \$100’000. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 9: Life cycle welfare

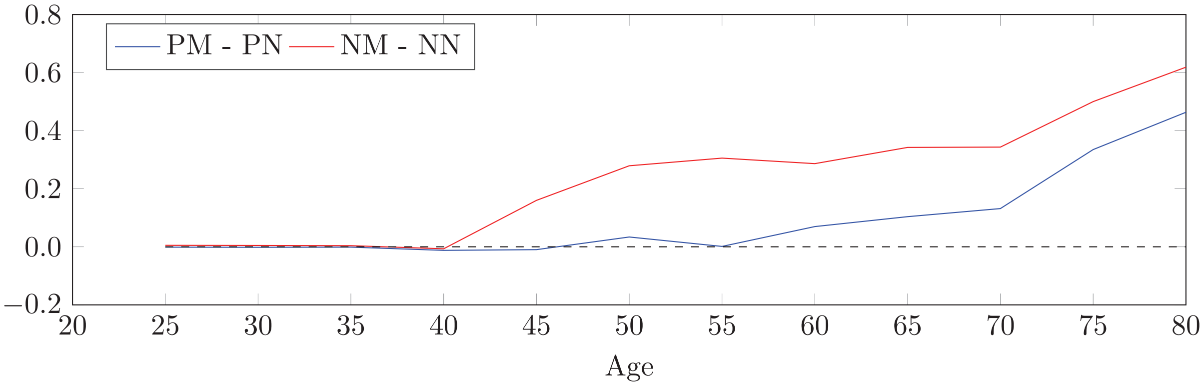
(a) Observed and simulated welfare



(b) Effects insured young

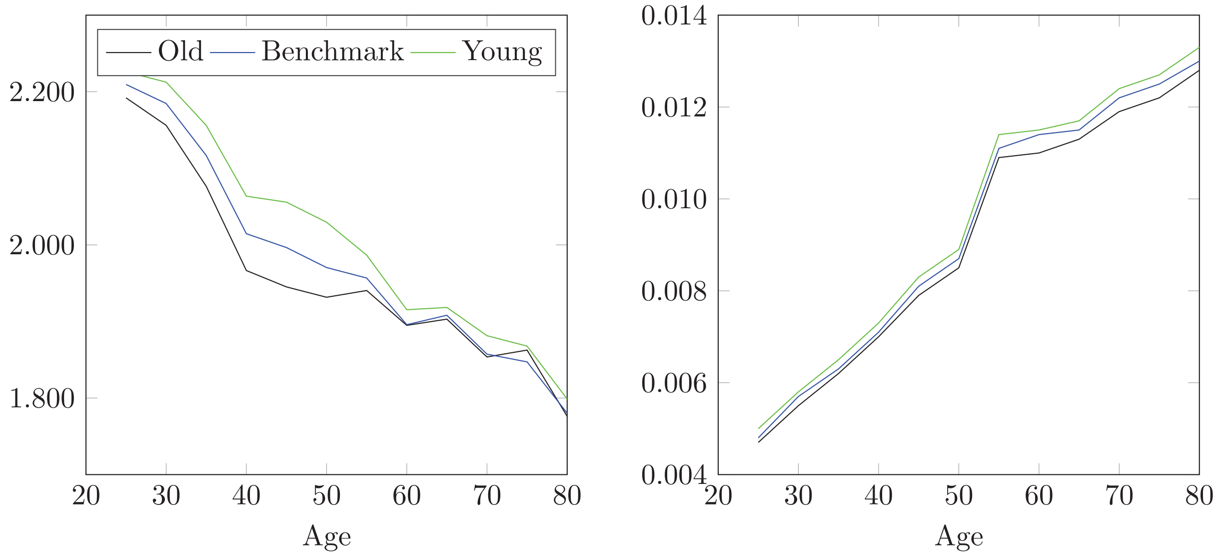


(c) Effects insured old



Notes: (a) Mean simulated life cycle (26) for welfare V_t (solid blue line), (no corresponding observed values), and 95% confidence intervals (dotted blue lines); units are not defined. (b) and (c) are differences in the means of the simulated variables across insurance plans.

Figure 10: Cohort effects

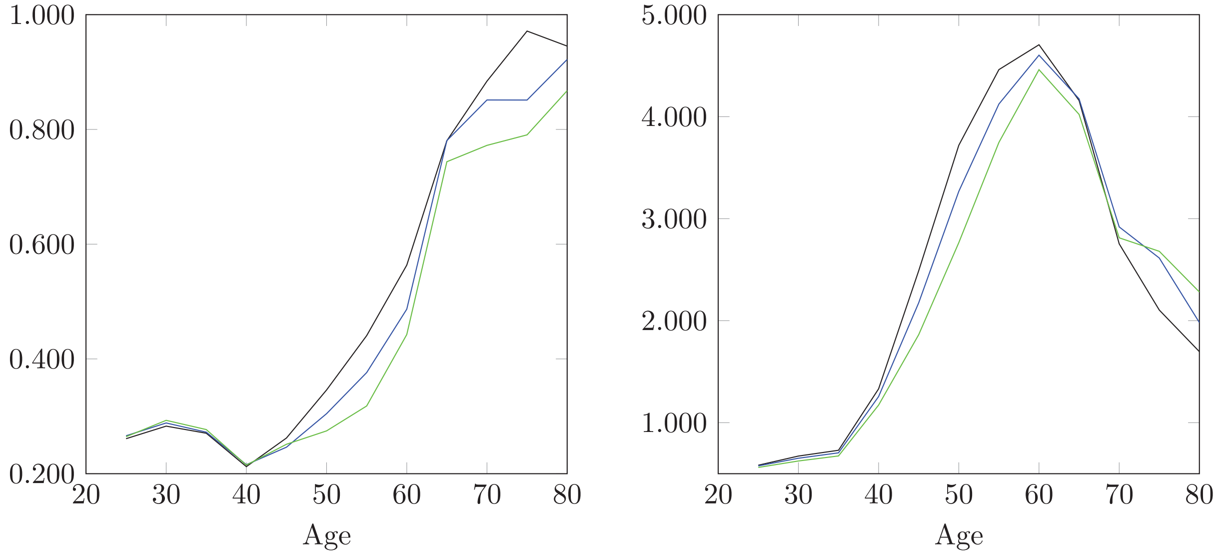


(a) Health

(b) OOP

(c) Leisure

(d) Wealth



Notes: Solid black line: $\kappa = -42$ (old cohort). Solid blue line: $\kappa = -37$ (benchmark). Solid green line: $\kappa = -32$ (young cohort).

C Data sources

This section describes in greater details how the observed life cycle data was collected. In the absence of a unique panel incorporating all the required variables, the data was obtained for the years 2010, and 2011 from various sources: SCF, MEPS, ATUS (main moments used in estimation), as well as CEX and NVSS (additional moments). Unless stated otherwise, data limitations force us to define the observational unit as the household for expenditures and assets data, and the survey respondent for age and health components. We do not distinguish along dimensions (e.g gender, race, . . .) other than those explicitly stated. The observed life cycle moments are reproduced in Table 6, and correspond to 5-year averages between age groups 25–80. All reported moments rely on appropriate analytical weights.

C.1 Main moments used in SME estimation

Wealth W_t We rely on the 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). The original SCF-2010 data is obtainable from the FRB Board of Governors SCF website.

Health H_t We use 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.

Out-of-pocket health expenditures OOP_t We use 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).

Leisure ℓ_t We use 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.2 Additional moments

Wages w_t We use 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.

Total health expenditures $P_t^I I_t$ We use 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).

Consumption c_t We use 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.

Life expectation S We resort to estimates from the National Vital Statistics System (NVSS), Center for Disease Control. We use the age-0 expectation of life for total population (i.e. all origin and gender), year 2011 (Arias, 2015, Tab. A, p. 3).