Life Cycle Responses to Health Insurance Status*

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Abstract

Health insurance status can change over the life cycle for exogenous reasons (e.g. Medicare for the elders, P-PAC for younger agents, termination of coverage at retirement in employer-provided plans). Durability of the health capital, endogenous mortality and morbidity, as well as backward induction suggests that these changes should affect the dynamic life cycle beyond the period at which they occur. The purpose of this paper is to study these lifetime effects on the optimal allocation (consumption, leisure, health expenditures), and status (health, wealth and survival rates). We analyze the impact of young (resp. old) insurance status conditional on old (resp. young) coverage through the structural estimation of a dynamic model with endogenous death and sickness risks. Our results show that young insurees are healthier, wealthier, consume more health care yet are less exposed to OOP risks, and substitute less (more) leisure before (after) retirement. Old insurees show similar patterns, except for lower precautionary wealth balances. Compulsory health insurances is unambiguously optimal for elders, and for young agents, except early in the life cycle. We draw other implications for public policy such as Medicare and P-PAC.

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1 Introduction

1.1 Motivation and outline

The health insurance status of individuals can change over the life cycle for reasons that are beyond their control. For instance, prior to the introduction of the Patient Protection and Affordable Care Act (P-PAC, a.k.a. Obamacare), Medicare principally provided guaranteed and subsidized insurance for agents over 65. P-PAC extends these provisions to younger individuals. Moreover, employer-provided private insurance often ends at retirement. Introspection suggests that these effects of insurance coverage at any given period of life likely affects decisions at other periods as well. Indeed, because health is a durable good, insurance-induced changes in health status when young will have lifetime consequences on exposition to mortality and morbidity risks (i.e. the so-called *Long Reach of Childhood* effect). Moreover, a standard backward induction argument establishes that young agents must internalize the effects of being insured or not when old, and its consequences for future health statuses and corresponding exposition to the risks of sickness and of dying.

Insurance for health expenditures affects dynamic decisions through the budget constraint via the health expenses, and healthy leisure decisions, and through the insurance premia. It also alters allocations through the changes in the exposition to morbidity and mortality risks induced by the corresponding changes in the health status. First, health insurance naturally lowers the effective relative price of health care. A standard substitution argument induces agents to augment the consumption of health-related services, yet may also lead to moral hazard by fostering a reduction in healthy activities. These adjustments on the expenditures and leisure margins take place both *ex-ante* (e.g. through preventive care), or *ex-post* (e.g. through curative care). For the latter, health insurance thus reduces exposition to out-of-pocket (OOP) expenses conditional upon sickness and lowers the motivations for maintaining high precautionary wealth balances. Second, compulsory participation in insurance plans entails that the agent is poorer by having to pay the insurance premia. Third, any resulting change in health status will alter the conditional probabilities of mortality and morbidity. For instance, better health reduces the risk of future sickness, and again lowers incentives for high precautionary savings. On the other hand, a lower risk of dying for healthier agents encourages savings in order to account for a longer expected lifetime.

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 an acceleration of current expenses and accumulation of the preventive health and wealth stocks. Corresponding improvements in health will alter expected longevity and exposition to future risks 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 (piling up expenses) which may lead to pre-retirement deterioration in the health status. Again, resulting changes in wealth and health will alter the dynamic allocation over leisure and consumption via its effects on the budget constraint and the exposition to morbidity and mortality risks.

The previous discussion suggests (i) that the timing of health insurance coverage should affect the allocations *throughout* the life cycle, and (ii) that the decomposition of such effects in setups where morbidity and mortality risks are partially endogenous is non-trivial. Understanding how changes in coverage affect the life cycle allocations appears to be particularly warranted at a time where a massive change in compulsory coverage is taking place through the P-PAC whereby millions of previously uninsured young Americans will be forced to take insurance.

Towards that aim, we modify a demand–for–health model in the spirit of Grossman (1972)'s human capital framework in order to account for convex adjustment costs, as well as (partially) endogenous sickness and death shocks. The agent selects consumption, leisure and health expenditures to solve a stochastic life cycle optimization, whereby the latter two augment the depreciable health stock, thus reducing morbidity and mortality risks. Time-varying optimal rules and welfare are induced through the finite maximal longevity, as well as the age dependency of (i) the deterministic and stochastic depreciation rates affecting the health capital, (ii) the premia of the health expenditures insurance contracts, and (iii) the wages and Social Security entitlement.

Consistent with evidence that health expenditures insurance contracts — when at all available — are exogenously determined by employment or by the government, the insurance status is taken as given and includes private, and no coverage variants for both younger and older agents, as well as Medicare for elders. This characterization allows us to pinpoint the marginal allocative effects of young (resp. old) agent's health insurance status, by conditioning on that of the old (resp. young) individuals.

The model admits no closed-form solution. It is therefore calibrated, solved numerically by backward iteration for the value function, and simulated forward over a wide population differentiated with respect to initial health and wealth statuses. We iterate that procedure over the parametric space to obtain a structural Simulated Moments Estimation of a subset of the key deep parameters. Both the iterative results and the simulated life patterns with respect to allocations, wealth and health statuses, as well as corresponding expected longevity and survival rates, accurately reproduce a wide range of observed cross-sectional, population, and life cycle moments. Importantly, the differences in this output across the insurance and age dimensions can be isolated in order to gain insights on what are the life-cycle implications of being insured against medical expenses at a particular point in time.

Our main contribution is thus to identify the marginal allocative effects of the health insurance status when young, and when old. First, we find that young insurees are noticeably healthier, and that this effect is stronger if uninsured when old. Moreover, durability implies that health remains higher for some time after coverage ends. Both results suggest that anticipation of end of coverage at retirement leads to high precautionary health balances. Old insurees are also healthier starting at middle age, even if uninsured when young. We therefore find no evidence of optimal stockpiling of expenses in anticipation of post-retirement coverage.

Better health naturally leads to increases in survival rates for both young and old insurees. However, that effect remains moderate. More potent impacts can be found for health investment and OOP expenses. The former are larger for young insurees, especially when coverage ends at retirement. Investment is also higher for old insurees, although smaller in magnitude, suggesting that other means are used to maintain health. In both cases, the exposition to OOP risks is sharply reduced for insurees, despite higher consumption of medical care.

Perhaps the most powerful inter-temporal substitution can be found in healthy leisure decisions. Young insurees find it optimal to reduce leisure when young, and increase it after retirement. This effects stems both from the moral hazard for insurees and the fact that wages fall sharply after retirement, making it optimal to work more when young, and less when old. Old insurees have smaller pre-retirement effects, but clearly take on more leisure after they retire. The combination of more work and less OOP expenses for young insurees leads to much higher *ex-post* wealth when young. Conversely, the combination of more leisure and less exposure to OOP risk entails that old insurees maintain lower *ex-ante* precautionary wealth after they retire.

Finally, we find that health insurance is generally optimal for young insurees, except early on in the life cycle. Up to the mid-30's, high initial health stocks, low wealth, and wages make it optimal for the to self insure through leisure rather than through markets. Conversely, health insurance for the old is always optimal for both young and old agents alike. As health-related problems start to escalate in periods of low labour income, lower exposure to OOP risks is a welcomed alternative to uninsurance.

Regarding public policy implications, our results suggest that allowing for coverage is much more important than determining whether health insurance is privately, or publicly provided. Indeed, our results show little differences whether Medicare is operational or not compred to unsubsidized private markets. In unreported additional testing, we also verify the effects of P-PAC by extending the Medicare provision to younger agents. Again, the results are virtually unchanged compared to privately provided compulsory insurance.

The reason can be traced to the opposing effects of Medicare on the budget constraint. On the one hand Medicare subsidizes the health insurance premia leading to an increase in wealth. On the other, it imposes taxes on labor income that distort the labour-leisure choices. Since coverage parameters (deductibles, co-payments) are otherwise similar, the net effect is minimal. Finally, although clearly optimal from the elders' point of view, it is not entirely clear that it is from the younger agents'. Indeed, self-insurance is potentially optimal early on in the life cycle; imposing a market-based alternative by law is not necessarily optimal from the individual's perspective.

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. Finally, the iterative and simulation results are presented and discussed in Section 5. All tables and figures are regrouped in the Appendix.

2 Relevant literature

This paper primarily relates and contributes to the literature (summarized in Table 3) on the consequences of morbidity and mortality risks for the life cycle allocations by households. In the presence of incomplete or imperfect insurance and asset markets, the effects of sickness risk on medical expenses, nonemployment and wages uncertainty, as well as those of longevity uncertainty on the risk of living too long or too short cannot be completely hedged away. Consequently, the agents are forced to remain partially exposed and/or adopt costly self-insurance strategies. This literature thus analyses the corresponding consequences for decisions and outcomes related to asset accumulation, medical expenses, labour 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[1] and concludes that prudent agents faced with OOP expenses and labour income uncertainty, as well as the risk of living too long should increase precautionary savings (Hubbard et al., 1994, 1995; Levin, 1995; Skinner, 2007; De Nardi et al., 2009). The empirical evidence is partially supportive of that conjecture. On the one hand slow asset deccumulation is indeed observed for elders (Palumbo, 1999; Dynan et al., 2004; De Nardi et al., 2009, 2010). On the other hand, observed savings by young agents are generally thought to be insufficient with respect to standard life cycle predictions (Skinner, 2007). Attempts to rationalize observed behaviour emphasize the role of distortions induced by social safety nets (Hubbard et al., 1994, 1995; Scholz et al., 2006). 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. This paper also analyses 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.

Second, two alternative frameworks can be used to study the effects of health-related risks on medical expenses. First, stochastic health expenditures have been modelled as exogenous, and thus tantamount to undiversifiable income shocks, by 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). 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 modelled as generating an implicit utilitarian service flow by Blau and Gilleskie (2008); De Nardi et al. (2010).

[1]Health-related risks effects on savings decisions have been studied by Hubbard et al. (1994, 1995); Palumbo (1999); Dynan et al. (2004); French (2005); Scholz et al. (2006); Hall and Jones (2007); Edwards (2008); De Nardi et al. (2009); Fonseca et al. (2009); De Nardi et al. (2010); Ozkan (2011); French and Jones (2011); Scholz and Seshadri (2012); Hugonnier et al. (2013) among others.

More explicit approaches in the spirit of Grossman (1972) model health as a durable good providing utility services, and that can be adjusted through health expenditures (Case and Deaton, 2005; Hall and Jones, 2007; Yogo, 2009; Fonseca et al., 2009; Khwaja, 2010; Ozkan, 2011; Galama et al., 2012; Scholz and Seshadri, 2012). Following pioneering work by Cropper (1977), other alternatives append self-insurance services by allowing health to (partially) reduce morbidity and mortality risks (Hall and Jones, 2007; Ozkan, 2011; Scholz and Seshadri, 2012; Hugonnier et al., 2013). Our modelling 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 labour revenues have been modelled by assuming inelastic labour supply, and focusing on their effects on wages by Case and Deaton (2005); Fonseca et al. (2009); 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. More explicit approaches study the intensive margin, allowing agents to increase working hours in the presence of high OOP expenses, and thereby reducing the motivation for precautionary savings (Rust and Phelan, 1997; Palumbo, 1999; French and Jones, 2011). Alternatives instead associate illness to work incapacity (Khwaja, 2010; Scholz and Seshadri, 2012). The latter can further be endogenized by allowing for preventive benefits of healthy leisure on health production (Leibowitz, 2004). As discussed by Ehrlich and Becker (1972); Leibowitz (2004), self insurance through leisure then raises moral hazard issues for agents insured through markets who can find it optimal to shirk on preventive measures. We follow the healthy leisure literature and allow for insurance status effects on health prevention decisions. Finally, a large literature analyses the role of health uncertainty for work decisions on the extensive margin. In particular, this literature shows that postponing retirement until Medicare eligibility is optimal when retirement is associated with the loss of employer-provided health insurance benefits (Rust and Phelan, 1997; Palumbo, 1999; Fonseca et al., 2009; French and Jones, 2011). Conversely, retirement can also be accelerated if in poor health, and eligible for early retirement (Wolfe, 1985; Bound et al., 2010; Galama et al., 2012). Although our modelling of leisure choices does allow for nonemployment, we abstract from discrete and irreversible retirement decisions in our analysis.

Finally, 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 (Lichtenberg, 2002; Khwaja, 2010; Finkelstein and McKnight, 2008; Card et al., 2009; Scholz and Seshadri, 2012), higher utilization rates (Lichtenberg, 2002; Khwaja, 2010; Finkelstein, 2007; Card et al., 2009), but lower exposure to OOP risks (Khwaja, 2010; Finkelstein and McKnight, 2008; Scholz and Seshadri, 2012; De Nardi et al., 2010), lower precautionary wealth (De Nardi et al., 2010, 2009; Scholz and Seshadri, 2012) and higher consumption and leisure (Currie and Madrian, 1999; French, 2005). On the other hand, the positive effects of Medicare for younger agents have been much less studied. Exceptions include Ozkan (2011); Scholz and Seshadri (2012) who describe stockpiling medical expenses until entitlement begins, and reduced precautionary wealth for younger agents. Our paper attempts to gain further insights on these effects of Medicare on younger generations, and emphasizes previously unstudied effects on the intensive labour margin, while maintaining all the stylized facts associated with elders. Normative elements associated with Medicare include redistribution from rich to poor (McClellan and Skinner, 2009; Bhattacharya and Lakdawalla, 2006; Rettenmaier, 2012). 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. 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 (Cutler and Sheiner, 2000), 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 (Cutler and Sheiner, 2000; McClellan and Skinner, 2009; Khwaja, 2010; Ozkan, 2011). 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 (Baicker and Skinner, 2011). Although we do not emphasize redistribution between rich and poor, we contribute to the normative literature by providing a separate assessment of the actuarial and market completion costs and benefits to young and elders.

To conclude, the three most related work in terms of methodology are probably Ozkan (2011); Scholz and Seshadri (2012); Hugonnier et al. (2013) who, just like us, focus on life cycle models of endogenous health decisions in an endogenous health-related shocks setting. However, Ozkan (2011); Scholz and Seshadri (2012) both emphasize rich and poor differences in life cycles which we abstract from, and how these differences are affected by Medicare, whereas Hugonnier et al. (2013) focus on portfolio and insurance decisions which we abstract from, and omit discussions of healthy leisure and of social programs. None of these papers consider the effects of exogenous public and private health insurance on the life cycle allocations and welfare between young and old as we do.

3 Model

This section describes the environment in which an agent faces endogenous morbidity and mortality risks whose exposures to can be hedged 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. We close this section by presenting the dynamic conditions that characterize the optimal allocation.

Health dynamics We consider the decisions of a finitely-lived risk-averse individual, confronted with both sickness and death uncertainty. 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 $t = y - \kappa = 1, 2, \ldots, T^m \leq T$. We let $\lambda^k : \mathbb{R}_+ \to \mathbb{R}_{++}$ denote an age-invariant, decreasing and convex intensity function of health (H_t). Health risks $\epsilon^k \in \{0, 1\}$ are a stochastic morbidity ($k = s$) or mortality shock ($k = m$), whose probability of occurrence is 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 risk reduction as health improves. 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 health 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 ($\ell \in \mathbb{I} \equiv [0, 1]$):

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

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

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

where we restrict total depreciation $\delta_t + \phi_t \leq 1$. 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).[2]

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

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 behaviour, and cannot be completely solved through medical allocations. 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 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.

Budget constraint The agent evolves in an incomplete financial markets setup comprising a risk-free asset, with gross rate R^f 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 $\Pi_t^x \in \{\Pi, \Pi^M\}$. The latter is the market premium Π for every insuree, 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 (e.g. Currie and Madrian, 1999; Blau and Gilleskie, 2008; McGuire, 2011).

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 deductibles processes are given by

$$OOP_t^x(I_t) = P_t^I I_t - \mathbb{1}_X \mathbb{1}_D (1-\psi)(P_t^I I_t - D_t), \tag{5}$$

$$\Pi_t^x = \mathbb{1}_X \Pi \left[1 - \mathbb{1}_M \mathbb{1}_R (1-\pi)\right],$$

$$P_t^I = P_0^I \exp[g^P(t+\kappa)], \tag{6}$$

$$D_t = D_0 \exp[g^D(t+\kappa)]. \tag{7}$$

As illustrated in Figure 1, the contract (5) is standard and has the insured agent in plans P and M cover 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, and that subsidization occurs mainly through insurance premia for seniors.[3]

Finally, both the health investment prices in (6) and deductibles in (7) are time-varying, so as to allow cohort effects that parallel the growth in health production technology in (4). In particular, the medical technology available to an individual aged t years born $\kappa = -30$ years ago is more productive than for someone the same age born $\kappa = -50$ years ago, i.e. $A_{t-30} > A_{t-50}, \forall t$. Consequently, agents aged t in cohort $\kappa = -20$ face higher prices, compared to agents of the same age in cohort $\kappa = -50$, i.e. $P_{t-30}^I > P_{t-50}^I$, which in turn also justify a higher level of deductible, i.e. $D_{t-30} > D_{t-50}$.

[3]Medicare coverage for young disabled and Medicaid for poor households are abstracted from for tractability reasons.

This additional degree of freedom will allow us to better gauge the importance of cohort effects by varying κ in the empirical evaluation below.

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

$$Y_t^x(\ell_t) = \mathbb{1}_t^R y^R + (1 - \mathbb{1}^M \tau) w_t (1 - \ell_t), \tag{8}$$

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

where R^f is the gross risk-free rate of interest. The labour revenues (8) capture the effects of pension income (e.g. Social Security) in y^R, the tax effects of Medicare in τ which reduces disposable income for every worker, as well as the age variation in w_t. 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:

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

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 one's own health is non-transferable, U^m is a function of next-period bequeathed wealth only. In particular, a negative U^m indicates a utility cost of mortality, whereas the marginal utility of bequests is positive to capture "joy-of-giving" elements, i.e. the cost of dying is attenuated by bequeathing larger amounts. However, as outlined in Shepard and Zeckhauser (1984) and Rosen (1988), within-period utility $\mathcal{U}_t$ must remain positive in order to guarantee preference for life in endogenous mortality settings. Preferences (10) provide an explicit alternative to implicit models of health valuation $\mathcal{U} = U(C, \ell, H)$. Indeed, since the endogenous subjective discount factor β^m is monotone increasing, and U^m is negative, $\mathcal{U}_{H,t} \geq 0$ ensures positive service flows of health associated with mortality risk reduction.

Next, using the Law of Iterated Expectations, the agent's problem with endogenous stochastic horizon can conveniently be written as a recursive problem with deterministic horizon and endogenous discounting:

$$\begin{aligned} V_t &= \max_{\{C_t, I_t, \ell_t\}_t^{T^m}} \mathcal{U}_t + \mathrm{E}_t \left\{ \sum_{s=t+1}^{T^m} \beta^{s-t}\, \mathcal{U}_s \mid H_t \right\}, \\ &= \max_{\{C_t, I_t, \ell_t\}_t^{T}} \mathcal{U}_t + \mathrm{E}_t \left\{ \sum_{s=t+1}^{T} \prod_{j=t}^{s-1} \beta^m(H_j)\, \mathcal{U}_s \mid H_t \right\}, \\ &= \max_{C_t, I_t, \ell_t} \mathcal{U}_t + \beta^m(H_t) \mathrm{E}_t \left\{ V_{t+1} \mid H_t \right\}, \end{aligned} \tag{11}$$

where $V_t = V_t^x(W_t, H_t)$ is a value function, and where the optimization is subject to the health process (2), and the budget constraint (9). Hence, endogenous mortality risk implies that an unhealthy agent has a shorter expected life horizon and is tantamount to a more impatient individual. However, discounting is not constant but depends on the investment and leisure decisions of the agent.

Optimality Letting subscripts denote partial derivatives, the first-order and Envelope conditions for problem (11) reveal that the optimal allocation is characterized by:

$$U_{C,t} = \left(\left[\beta - \beta^m(H_t) \right] U^m_{W,t+1} + \beta^m(H_t) \mathrm{E}_t \left\{ U_{C,t+1} \mid H_t \right\} \right) R^f, \tag{12}$$

$$U_{C,t} OOP^x_{I,t} = \beta^m(H_t) \mathrm{E}_t \left\{ V_{H,t+1} \mid H_t \right\} A_t I^g_{I,t}, \tag{13}$$

$$(1 - \mathbb{1}^M \tau) w_t = \frac{U_{\ell,t}}{U_{C,t}} + \frac{I^g_{\ell,t}}{I^g_{I,t}} OOP^x_{I,t}, \tag{14}$$

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:

$$\begin{aligned} V_{H,t} =& \beta^m_{H,t} \mathrm{E}_t \left\{ V_{t+1} - U^m_{t+1} \mid H_t \right\} + \beta^m(H_t) \mathrm{E}_{H,t} \left\{ V_{t+1} \mid H_t \right\} \\ &+ \beta^m(H_t) \mathrm{E}_t \left\{ V_{H,t+1} \left[1 - \delta_t - \phi_t \epsilon^s_{t+1} + A_t I^g_{H,t}\right] \mid H_t \right\}, \end{aligned} \tag{15}$$

where $\mathrm{E}_{H,t}(\cdot) \equiv \partial \mathrm{E}(\cdot \mid H_t)/\partial H_t$ is the marginal effect of health on the conditional expectation.

The Euler condition (12) 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 favour of the latter.

The Euler equation (13) 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. 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 has been 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 ageing is associated with exogenous increases in productivity A_t, providing additional justification (to age-increasing depreciation) for the higher demand for healthcare observed for elders (e.g. Hall and Jones, 2007; Fonseca et al., 2009).

Equation (14) 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 is lower for the insured thereby making self-insurance through healthy activities less advantageous, once the deductible is covered. The effects of Medicare on the leisure-investment tradeoff are mixed. On the one hand, Medicare taxes reduce the opportunity cost of leisure regardless of age. On the other hand, the lower reduction in marginal out-of-pocket cost after Medicare coverage begins alters the leisure-investment tradeoff, and encourages elders to work more instead.

Finally, the Envelope condition (15) decomposes the marginal value of health into three parts. First, it includes the benefits obtained through the reduction in mortality risk $\beta^m_{H,t} > 0$ times the continuation utility net of bequest utility. Recall that $U^m_{t+1} < 0$ such that 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 for healthier agents is always positive. Second, it includes the marginal value of morbidity risk reduction $\mathrm{E}_{H,t}$. A straightforward argument indicates that this value is positive.[4] Third, 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. Observe that undepreciated health will decline with ageing 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 method we rely upon to estimate the model. The full details are reported in Appendix C. After discussing the choice of functional forms and insurance plans, we introduce the estimation procedure followed by a discussion of the data and estimated parameters.

[4] Conjecture that $V_{H,t} > 0, \forall t$ in (15), in which case $\beta^m(H_t)\mathrm{E}_{H,t}\{V_{t+1} \mid H_t\} > 0$ since health is valuable and the low future health outcome is less likely for healthier agents. 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 (15) then confirms the positive marginal value of health conjecture.

4.1 Functional forms and insurance plans

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

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

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

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \quad \eta_I, \eta_\ell \in (0,1), \tag{18}$$

$$U(C, \ell) = \left[\mu_C C^{1-\gamma} + \mu_\ell \ell^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \quad \mu_C, \mu_\ell \in (0,1), \tag{19}$$

$$U^m(W) = \mu_m \left(\frac{W^{1-\gamma}}{1-\gamma}\right). \tag{20}$$

Equations (16) and (17) both encompass limits to self-insurance as the intensities are bounded below by λ_0^m, and λ_0^s. Morbidity risk is also bounded above by λ_2^s to avoid spiralling 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 (18) ensures diminishing returns to expenditures, leisure and health inputs for gross investment. Next, the Constant Elasticity of Substitution (CES) specification (19) allows for unconditionally positive utility and therefore helps guarantee preference for life over death, $\mathcal{U}_t > 0$ in (10). Conversely, the bequest function (20) is negative for curvature $\gamma > 1$, ensuring that death is costly, whereby the marginal value of bequeathed wealth remains positive.

Next, we consider 5 exogenous insurance plans corresponding to No and Private insurance when young ($1 \leq t < 65$), and No, Private or Medicare when old ($t \geq 65$), and denoted $x = (x_y, x_o) \in \mathbb{X} = \{\text{PM, PP, PN, NM, NN}\}$.[5] The descriptions as well as corresponding expressions for OOP's, premia and income are outlined in Table 4. Plans PM (our benchmark case), and PP encompass full insurance with, and without Medicare.

[5]Plan NP is arguably of limited empirical relevance, and is abstracted from.

Plan PN captures the effects of employment-provided insurance which is terminated at retirement,[6] whereas plans NN and 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. For the latter, the marginal effect of private insurance is obtained by contrasting PP vs PN, whereas that of Medicare obtains from the PM vs PN and NM vs NN comparisons. Finally, the pure budget constraint effects of Medicare are isolated from the coverage effects by imposing full insurance, and computing the difference between plans PM vs PP.

4.2 Simulated method of moments

As in the literature, we proceed with a Simulated Methods of Moments Estimation of our structural model. More precisely, we make use of a quadratic contrast function involving the theoretical (for benchmark case PM) and empirical life cycle moments for the following variables: consumption, leisure and health investment and OOP expenditures, as well as health, wealth and survival rates. For each variable, we rely on 5-year averages between ages 20 to 80 yielding $7 \times 13 = 91$ moments.

In so doing, we solve the model by standard iterative methods. We first select a 20×20 grid for the state and the $30 \times 30 \times 30$ control spaces. Then, for ages $t = T, T-1, \ldots, 0$, the model is solved by backward iteration at each point on the grid. Next, we simulate the life cycles by bilinear interpolation methods. More precisely, we initialize the simulation by taking 400 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 500 trajectories from the initial grid along the optimal path, using the laws of motion (2) and (9) to update the state variables. This

[6]See French and Jones (2011) for an empirical analysis of the effects of employer-provided health insurance on savings and retirement.

procedure is therefore equivalent to simulating 200'000 individual life cycles from which the 5-year moments are computed.

The simulated life cycle moments are conditional upon a given parameter set $\Theta = (\Theta^c, \Theta^e)$ where Θ^c is the calibrated subset for which we have some prior information from the literature and the data, and Θ^e is the estimated parameter subset:

$$\begin{aligned}\Theta^c =&(T, \kappa, \lambda_2^s, \xi^m, \xi^s, P_0^I, g^P, A_0, g^A, \psi, \Pi, \Pi^M, D_0, g^D, \tau, y, R^f, \eta_I, \eta_\ell, \beta, \mu_C, \mu_\ell, \mu_m)\\ \Theta^e =&(\lambda_0^m, \lambda_1^m, \lambda_0^s, \lambda_1^s, \delta_0, g^\delta, \phi_0, g^\phi, \gamma).\end{aligned} \tag{21}$$

The parameter statuses and sources are detailed in Table 6, with values reported in Table 7. First, the maximum age is set at $T = 100$ years, whereas the cohort is set to 1974 to correspond to the median age of 37 in 2011. The intensities parameters $(\lambda_2^s, \xi^m, \xi^s)$ are taken from Hugonnier et al. (2013). Estimates calculated by the National Center of Health Statistics, the Board of Trustees of the Federal HI, and SMI Trust Funds as well as by the Henry J. Kaiser Family Foundation are used for the medical prices, and insurance levels, and growth characteristics $(P_0^I, g^P, A_0, g^A, \psi, \Pi, \Pi^M, D_0, g^D, \tau)$. The average pension benefit y is obtained from the Social Security Administration, whereas the risk-free rate R^f is set from historical data on short-term Treasury Bills. Second, the parameters of the investment function (η_I, η_ℓ), the preferences $(\beta, \mu_C, \mu_\ell, \mu_m)$ are set using the literature whenever possible.

The parameters Θ^e are those estimated from the SME procedure (see Appendix C for details). In short, this procedure miminizes the distance between the simulated and observed life cycle moments for the allocation and status variables. For that purpose, we differ from mainstream practices in our estimation strategy. In particular, standard approaches typically append *ad-hoc* exogenous stochastic processes to the model (e.g. exogenous stochastic health shocks, wages or labor income, ...) that are used to simulate the optimal trajectories. As part of a two-step methodology, these processes are then estimated separately, and the parameters and/or fitted processes substituted back into the model for the simulation phase. The simulation output is then used in the second-step estimation to estimate a (typically small) subset of parameters.

In contrast, we generate the simulation trajectories conditional upon the realization of the morbidity and mortality shocks which are drawn from the *endogenous* intensities given by (1). Put differently, *ad-hoc* processes are neither appended to the model, nor estimated separately in a two-step approach. Rather, we rely on a fully structural, single-step SME estimation framework. Moreover, the set of moments we consider is much larger, and corresponds to the full set of conditional means generated by the model (i.e. optimal controls, state variables, survival rates along the optimal paths). This additional information plays a crucial role in allowing us to identify a much larger subset of deep parameters, for which we have scant prior information, through the estimation.

4.3 Data

Our empirical strategy requires life cycle data on consumption, leisure, total and out-of-pocket health expenditures, wealth, health status and survival rates. 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. These sources are presented in Table 5.

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 use the National Health Interview Survey (NHIS) to obtain a measure of health. This survey reports ordered qualitative self-reported health status ranging from very poor to excellent that are converted to numerical measures using a linear scale. Survival rates are recovered from the National Vital Statistics System (NVSS). The total and out-of-pocket medical expenses are taken from the Medical Expenditures Survey (MEPS), and are the mean expenses per person, conditional upon expenditures. Next, leisure is the share of time spent not working, and is obtained from the American Time Use Survey (ATUS). Finally, nondurables consumption is taken from the Consumer Expenditures Survey (CEX) as being per-capita total expenditures net of health care and vehicles.

4.4 Parameters

The parameters are presented in Table 7, starting with the calibrated values in Panel (a), and estimated values (standard errors in parentheses) in Panel (b). First, the calibrated morbidity and mortality parameters in Panel (a) show a larger convexity for the former ($\xi^s > \xi^m$), indicative of stronger effects of health in reducing sickness risk, than mortality risk. This is also confirmed by the estimated values for the endogenous intensity components ($\lambda_1^s > \lambda_1^m$) in Panel (b). Moreover, the large calibrated value for λ_2^s is consistent with the absence of limitations in morbidity risk reduction.

Second, the calibrated values for the health investment technology (η_I, η_ℓ) are indicative of an important role of healthy leisure, and of current health status. Equivalently, currently healthy agents engaging in health activities will have much more powerful effects of health care in producing future health. We also witness a positive exogenous trend in healthcare productivity (A_t) that is however less than that observed in health care prices and insurance deductibles ($g^A < g^P, g^D$). Turning to labour income, Panel (b) of Figure 2 shows that real wages display an upward trend over the life cycle up to retirement and fall sharply afterwards. Finally, the preferences parameters are consistent with a 3% annual discount rate, a consumption (leisure) share of $\mu_c = 1/3$ ($\mu_\ell = 2/3$), and a low weight attributed to joy-of-giving in the bequest function ($\mu_m = 2\%$).

Third, regarding the estimated parameters in Panel (b), we find that they are all significant at the 5% level. The depreciation parameters confirm that both deterministic and stochastic depreciations are increasing in age ($g^\delta, g^\phi > 0$). Panel (a) of Figure 2 shows that stochastic morbidity ϕ_t is a strong contributor to total health depreciation rates, and that this contribution becomes larger with age. Equivalently, sickness is much more consequential for elders. Furthermore, 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 compressible ($\lambda_0^s, \lambda_0^m \neq 0$). Unsurprisingly, they also confirm that the incidence of sickness is much more likely than that of death ($\lambda_{0,1}^s > \lambda_{0,1}^s$). Finally, the curvature parameter indicates that the risk aversion with respect to bequeathed wealth is realistic, and that consumption and leisure are mainly complements, with a low elasticity of substitution between the two ($1/\gamma < 1$).

5 Results

This section describes the predicted optimal policies, welfare, and other variables derived from the model. Following a brief discussion of the output obtained from the iterative phase in Section 5.1, we present the results obtained from the simulation phase in Section 5.2, starting first with the population moments followed by the life cycle properties.

5.1 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. As expected, consumption (Panel A), leisure (Panel B), investment (Panel C), are all monotone increasing in wealth. Consumption, leisure and investment are decreasing in health, except for the latter which is increasing at very low health and wealth.

As discussed earlier, a lower risk of dying when health improves is tantamount to lower discounting and induces the healthier agent to increase savings in the face of a longer expected life horizon. Moreover, the lower risk of becoming sick for healthier agents justifies a reduction in both health expenditures, and healthy leisure activities, consistent with findings that the rich and unhealthy spend more on preventive and curative health care (e.g Smith, 1999; Wu, 2003; Barros et al., 2008; Scholz and Seshadri, 2012). However, for the very poor and very unhealthy, the risk of dying is so high that investment is abandoned in favour of other expenses when health deteriorates further.

Finally welfare in Panel D is clearly monotone increasing in both wealth and in health, as expected from the discussion of Envelope condition (15). Observe that concavity is more pronounced with respect to health, as can be anticipated from the diminishing returns in the self-insurance technology (16) and (17), and in the gross investment function (18).

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 and reinstating the life cycle properties.

5.2 Simulation results

5.2.1 Population moments

We compute the population statistics over ages 20–80 $\hat{M}$ and expected life $\hat{S}$ using equations (26) and (27) in the Appendix $\hat{S}$, and then contrast the means for the surviving agents, and for the five health insurance plans (PM, PN, PP, NN and NM). The means are compared with observed moments obtained from data discussed in Table 5.

The close correspondence between observed and predicted moments in Table 8 confirms that the model does quite well in capturing the population features of the data. Investment, consumption, leisure, health and expected longevity are accurately reproduced, while the other variables are reasonably close given the caveats associated with the model and/or data.[7]

Overall, our results confirm that the effects of being insured when young (i.e. contrasting PM vs NM, and PN vs NN) are consistent with a sharp reduction in OOP expenditures. Moreover, both wealth and health levels are noticeably higher for young

[7]Indeed, the model's OOP variables do not take expenses caps into account and thus likely overstates the actual out-of-pocket expenditure. Allowing for expenses caps in the model results in corner solutions in which the agent spends extreme amounts on health expenditures once the deductible has been reached.

insurees, leading to increases in welfare compared to the uninsured. When looking at the effects of health insurance for the elders (i.e. contrasting PM vs PN. NM vs NN, and PP vs PN), we find that OOP's are also lowered, whereas consumption shares of wealth (i.e. $C^s \equiv C/W$) are increased. The net effect is a lower level of wealth, consistent with lower precautionary wealth when insured against health expenditures in old age. Again, welfare is higher for the insured.

The population statistics obtained thus far integrate the simulated survivors' data at all ages and do not reveal how the optimal life cycle is affected. In particular, they remain silent on how the agent's inter-temporal substitution is determined by the insurance plans. We turn to these issues next.

5.2.2 Life-cycle properties

The simulated life cycles are presented in Figures 4–10, and are given as the mean allocations, states, and survival rates at each age across the simulation output, using (24) and (25). To facilitate the discussion, the simulated (corresponding to our benchmark PM case) and observed (when available) levels are reported in Panels A, and B, respectively. The marginal effects of health insurance are computed as the differences of the means across insurance statuses. We report the marginal effects of being insured when young (i.e PM-NM, and PN-NN) in Panels C, and the marginal effects of being insured when old (i.e. PM-PN, NM-NN and PP-PN) in Panels D.

Health status and survival The simulated health statuses in Figure 4.A predict a level, and an optimal decline that are both consistent with those observed for the data in Panel B (see Case and Deaton, 2005; Scholz and Seshadri, 2012; Van Kippersluis et al., 2009, for further evidence and discussion). The optimal level calculated under plan PM however remains somewhat high for the very old, compared to the data which comprises agents who are uninsured at various periods of their lives.

Our results in Panel C and D indicate that insurees are healthier, with larger effects when uninsured at other periods. In particular, the differences in health for the insured young agents in Panel C peak around 50, and fall thereafter, with more effects when the elders' status is uninsurance (PN-NN).[8] The effects of elders' insurance statuses on their health in Panel D are similar in sign and in magnitude, and confirm that old insurees are permanently healthier after 50, and earlier on when the young agent's status is uninsurance (NM-NN). We find no evidence of optimal stockpiling pointing to a decline in health prior to entitlement.

These results highlight the path-dependence of health capital that induces spillover effects of health insurance across age. The durability of the health capital implies that young insurees will also remain healthier than otherwise for some time after they lose insurance at old age. On the other hand, the Cobb-Douglas technology in (18) implies that the marginal productivity of health investment increases in health, making it optimal for young uninsured to build up their health stock prior to old age coverage, and its associated high expenses (see below). Finally, we observe the same marginal effects whether elders' insurance is provided through Medicare (PM-PN), or through private insurers (PP-PN). This suggests that the budget constraint effect of Medicare is limited once we net out the coverage effect.

The predicted optimal decline in the health status induces a corresponding simulated fall in the survival rates in Figure 5.A. Both the decline and the level are again consistent with those in the data (Panel B), even though the concavity is under-estimated, possibly because of our assumption of age-independent death intensity parameters in (16). Unsurprisingly, the better health for young insurees entails a better survival in Panel C, particularly then the elder's status is uninsurance. Similarly, healthier insured elders enjoy a longer expected lifetime after retirement, and earlier on when uninsured as young. In both cases, the gains in longevity remain moderate. Again, the differences

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

in the marginal effects between Medicare and privately provided insurance, are also insignificant.

Health expenditures and healthy leisure The simulated health dynamics both induce and result from investment and healthy leisure decisions made over the life cycle. First, in Figure 6.A, both the level, and the upward trend of observed investment are accurately matched. The model however under-predicts the level of expenditures for the very old. In Panel C, the insured young agents invest more, especially around middle age. Again, the effects are strongest when the elders' status is uninsured. The results of Panel D show that the insured elders invest more at middle age and after, except in cases involving PN. When the private coverage ends at retirement, agents find it optimal to raise investment before age 65 more than they would if coverage was expected to continue. Again we find little evidence of optimal stockpiling in NM vs NN with no reduction in investment prior to Medicare coverage. Interestingly, the differences in health investment become minimal after 75, indicating that insurees rely on other means than health expenditures to adjust their health status (see the discussion on leisure below).

Second, the increase in out-of-pocket expenditures in Figure 7.A is consistent with the data. The level is somewhat over-estimated, possibly because our model abstracts from limitations such as expenses caps. The insurance effects in Panels C and D are clearly consistent with a decrease in exposure to OOP costs, despite an increase in utilization for insurees. We find little evidence of differences based on private versus public insurance in generating this fall in OOP exposure.

Third, the leisure paths in Figure 8.A display strong similarities with observed patterns; they are initially low, followed by a sharp increase when wages fall after age 60 (see Figure 2, Panel b), consistent with observed behavior (e.g. Rust and Phelan, 1997). Our results in Panels C are indicative of moral hazard effects of health insurance. Indeed, young insurees tend to reduce leisure when young, and postpone it up to middle age. Insured elders in Panel D do not reduce leisure when young, but also increase it after middle age. This increase is particularly important when very old and acts as an alternative to medical expenses to maintain health status.

Wealth, and welfare First, the simulated wealth dynamics in Figure 9.A coincide very well with the data in Panel B. In particular, the model replicates the asset accumulation when young, a peak occurring around retirement, followed by post-retirement dissavings.[9] The insured young agents in Panel C clearly are wealthier than the uninsured. This result highlights the effects of both lower exposure to OOP expenses and lower levels of leisure in generating higher *ex-post* wealth for younger agents. Observe that this effect is larger and more long-lasting when the agent is also insured when old (PM vs NM). This can be explained by the lower level of leisure after middle age in Figure 8.C. Conversely, in Panel D, the insured elders have lower wealth than the uninsured after middle age. This result is related again to the expected lower exposure to OOP expenses for old insurees which reduces the need to build up *ex-ante* precautionary wealth reserves, as well as the higher level of leisure compared to the uninsured. Observe again that the effect is stronger when Medicare is involved (NM vs NN). The subsidization of insurance premia further reduces the need to build up wealth reserves to cover insurance when employment is reduced after retirement.

Finally, the combination of single-peaked wealth, falling health and survival rates implies that welfare in Figure 10.A is also increasing up to retirement, and slowly falling thereafter. 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. The plots in Panel C reveal that insurance for the young agents is sub-optimal up to the early 30's when wealth and wages are low, and health problems

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

are scant, and optimal afterwards, consistent with the non-insurance data.[10] Conversely, Panel D reveals that insurance for the elders is always optimal. The optimality of the Medicare programs is also clearly apparent with plans PM and NM yielding the highest welfare.

5.2.3 Discussion: Life cycle effects of Medicare

Our results have a number of implications for the life cycle responses to Medicare. First, our findings are consistent with Medicare and private insurance being close substitutes. Indeed, the comparisons of the PM–PN and PP–PN paths in Panels D reveal very similar marginal effects of the insurance status for elders, whether that insurance is provided through Medicare, or through private markets.

Second and related, the pure budget constraint effects of Medicare, as isolated in Panels.D (PM vs PP), was found to be moderate, indicating that Medicare affects the life cycle mostly through its effect on coverage to otherwise uninsured elders (see also McClellan and Skinner, 2009, for a similar conclusion from a different perspective). Taxes on labor revenues tend to reduce disposable income when young, and distort labour-leisure choices throughout the life cycle. However, the Medicare tax rate is low ($\tau = 1.45\%$), and the subsidy of health insurance premia after 65 is tantamount to a compensating lump-sum transfer, and increases wealth after retirement. The modest net effects indicate that current taxes and future subsidies apparently offset one another, thereby casting some doubt on the hypothesis that Medicare entitlement is positive financial net worth.

This close substitution is also confirmed by unreported additional testing, whereby we incorporate Plan MM in order to analyse the effects of the Patient Protection and Affordable Care Act (P-PAC aka Obamacare), and where the Medicare provisions are extended to agents under 65.[11] Our results again suggest that these budget constraint

[10]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.

[11]The full MM results are available upon request from the corresponding author.

effects are very moderate, such that results under plans PM and MM are indistinguishable from one another.

Third, the effects of Medicare coverage for otherwise uninsured agents is much more significant, and is consistent with those outlined by the empirical literature. In particular, the model reproduces noticeably better health and moderately better survival (Lichtenberg, 2002; Khwaja, 2010; Finkelstein and McKnight, 2008; Card et al., 2009; Scholz and Seshadri, 2012), as well as more investment (Lichtenberg, 2002; Khwaja, 2010; Finkelstein, 2007; Card et al., 2009), yet lower OOP's (Khwaja, 2010; Finkelstein and McKnight, 2008; Scholz and Seshadri, 2012; De Nardi et al., 2010), as well as lower precautionary wealth (De Nardi et al., 2010, 2009; Scholz and Seshadri, 2012), and more leisure (Currie and Madrian, 1999; French, 2005).

Fourth, the pre-retirement effects of Medicare take the form of better health around middle age. This result is explained by the durability of the health capital. Because the marginal product of health investment and leisure increases in the health status, agents find it optimal to build up health in anticipation of when they will need it most, i.e. after retirement. This increase is achieved through more investment and leisure around middle age, and therefore speaks against the stockpiling hypothesis. On the other hand, our results also highlight lower precautionary wealth around middle age when post-retirement exposure to OOP risks is covered by Medicare. This is achieved through more leisure and consumption prior to entitlement.

Finally, our findings confirm that exclusion from health insurance market becomes very detrimental at middle age, but not for younger adults who may still prefer to remain uninsured when wealth is low, the health stock is high and health problems are scant. In contrast, health insurance for elders is always optimal. Universal eligibility of insurance, whether via Medicare or private markets, might therefore not be Pareto improving. Also, Medicare was found to be welfare improving at the individual level, with the effects on welfare accruing through the budget constraint being positive, but dwarfed compared to those incurred through market completion. This however does not imply dynamic

Pareto optimality from society's point of view. Indeed, our bequest weight is low, such that our agents have limited concern for the future generations who end up paying part of the current costs of Medicare. Moreover, the general-equilibrium efficiency costs of tax-financed Medicare have not been addressed in our model and could turn out to be quite important.

References

Arias, Elizabeth (2010) 'United States life tables, 2006.' *National Vital Statistics Report* 58(21), 1–40

Baicker, Katherine, and Jonathan S. Skinner (2011) 'Health care spending growth and the future of U.S. tax rates.' Working paper 16772, National Bureau of Economic Research, Cambridge, MA, February

Barros, Pedro Pita, Matilde P. Machado, and Anna Sanz-de Galdeano (2008) 'Moral hazard and the demand for health services: A matching estimator approach.' *Journal of Health Economics* 27(4), 1006 – 1025

Bhattacharya, Jay, and Darius Lakdawalla (2006) 'Does Medicare benefit the poor?' *Journal of Public Economics* 90, 277–292

Blau, David M., and Donna B. Gilleskie (2008) 'The role of employee health insurance in the employment behavior of older men.' *International Economic Review* 49(2), 475–514

Bound, John, Todd Stinebrickner, and Timothy Waidmann (2010) 'Health, economic resources and the work decisions of older men.' *Journal of Econometrics* 156(1), 106 – 129

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

Card, David, Carlos Dobkin, and Nicole Maestas (2009) 'Does Medicare save lives?' *Quarterly Journal of Economics* 124(2), 597–636

Cardon, James H., and Igal Hendel (2001) 'Asymmetric information in health insurance: Evidence from the national medical expenditure survey.' *RAND Journal of Economics* 32(3), 408 – 427

Case, Anne, and Angus Deaton (2005) 'Broken down by work and sex: How our health declines.' In *Analyses in the Economics of Aging,* ed. David A. Wise (Chicago: University of Chicago Press) chapter 6, pp. 185 – 205

Cropper, M. L. (1977) 'Health, investment in health, and occupational choice.' *Journal of Political Economy* 85(6), pp. 1273–1294

Currie, Janet, and Brigitte C. Madrian (1999) 'Health, health insurance and the labor market.' In *Handbook of Labor Economics,* ed. Orley Ashenfelter and David Card, vol. 3 (Elsevier Science, North-Holland) chapter 50, pp. 3310–3416

Cutler, David M., and Louise Sheiner (2000) 'Generational aspects of medicare.' *The American Economic Review* 90(2), pp. 303–307

De Nardi, Mariacristina, Eric French, and John Bailey Jones (2009) 'Life expectancy and old age savings.' *American Economic Review* 99(2), 110–115

_ (2010) 'Why do the elderly save? the role of medical expenses.' *Journal of Political Economy* 118(1), 39–75

Dynan, Karen E., Jonathan Skinner, and Stephen P. Zeldes (2004) 'Do the rich save more?.' *Journal of Political Economy* 112(2), 397 – 444

Edwards, Ryan D. (2008) 'Health risk and portfolio choice.' *Journal of Business and Economic Statistics* 26(4), 472–485

Ehrlich, Isaac (2000) 'Uncertain lifetime, life protection and the value of life saving.' *Journal of Health Economics* 19(3), 341–367

Ehrlich, Isaac, and Gary S. Becker (1972) 'Market insurance, self-insurance, and self-protection.' *Journal of Political Economy* 80(4), pp. 623–648

Ehrlich, Isaac, and Hiroyuki Chuma (1990) 'A model of the demand for longevity and the value of life extension.' *Journal of Political Economy* 98(4), 761–782

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

Finkelstein, Amy (2007) 'The aggregate effects of health insurance: Evidence from the introduction of Medicare.' *Quarterly Journal of Economics* 122(1), 1 – 37

Finkelstein, Amy, and Robin McKnight (2008) 'What did Medicare do? the initial impact of Medicare on mortality and out of pocket medical spending.' *Journal of Public Economics* 92(7), 1644–1668

Fonseca, Raquel, Pierre-Carl Michaud, Titus Galama, and Arie Kapteyn (2009) 'On the rise of health spending and longevity.' Discussion paper 4622, IZA Institute for the Study of Labor, Bonn, December

French, Eric (2005) 'The effects of health, wealth, and wages on labour supply and retirement behaviour.' *Review of Economic Studies* 72(2), 395–427

French, Eric, and John Bailey Jones (2011) 'The effects of health insurance and self-insurance on retirement behavior.' *Econometrica* 79(3), 693–732

Galama, Titus, Arie Kapteyn, Raquel Fonseca, and Pierre-Carl Michaud (2012) 'A health production model with endogenous retirement.' *Health Economics* pp. n/a–n/a

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

Hall, Robert E., and Charles I. Jones (2007) 'The value of life and the rise in health spending.' *Quarterly Journal of Economics* 122(1), 39–72

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

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

_ (2012) 'State health facts.' `http://www.statehealthfacts.org`

Hubbard, R. Glenn, Jonathan Skinner, and Stephen P. Zeldes (1994) 'Expanding the life-cycle model: Precautionary saving and public policy.' *American Economic Review* 84(2), 174 – 179

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

Hugonnier, Julien, Florian Pelgrin, and Pascal St-Amour (2013) 'Health and (other) asset holdings.' *The Review of Economic Studies* 80(2), 663–710

Khwaja, Ahmed W. (2010) 'Estimating willingness to pay for Medicare using a dynamic life-cycle model of demand for health insurance.' *Journal of Econometrics* 156(1), 130 – 147

Kotlikoff, Laurence J. (1989) 'Health expenditures and precautionary savings.' In *What determines savings?,* ed. Laurence J. Kotlikoff (Cambridge, Mass. and London: MIT Press) pp. 141 – 162

Leibowitz, Arleen A. (2004) 'The demand for health and health concerns after 30 years.' *Journal of Health Economics* 23(4), 663 – 671

Levin, Laurence (1995) 'Demand for health insurance and precautionary motives for savings among the elderly.' *Journal of Public Economics* 57(3), 337 – 367

Lichtenberg, Frank R. (2002) 'The effects of Medicare on health care uilization and outcomes.' In *Frontiers in Health Policy Research,* ed. Allan M. Garber, vol. 5 MIT Press Cambridge MA pp. 27–52

McClellan, Mark, and Jonathan S. Skinner (2009) 'The incidence of Medicare.' *Journal of Public Economics* 90, 257–276

McGuire, Thomas G. (2011) 'Chapter five - demand for health insurance.' In *Handbook of Health Economics,* ed. Thomas G. Mcguire Mark V. Pauly and Pedro P. Barros, vol. 2 of *Handbook of Health Economics* (Elsevier) pp. 317 – 396

McWilliams, J. Michael, Ellen Meara, Alan M. Zaslavsky, and John Z. Ayanian (2007) ‘Use of health services by previously uninsured Medicare beneficiaries.’ *New England Journal of Medicine* 357(2), 143–153

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

National Center for Health Statistics (2011) ‘Summary health statistics for the U.S. population, 2010.’ National Health Interview Survey 251, United States Department of Health and Human Services. Centers for Disease Controls and Prevention., Hyattsville, MD, December

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

OASDI Board of Trustees (2012) ‘The 2012 annual report of the board of trustees of the federal old-age and survivors insurance and federal disability insurance trust funds.’ Annual report 73-947, U.S. Social Security Administration, Washington DC, April

Ozkan, Serdar (2011) ‘Income inequality and health care expenditures over the life cycle.’ Manuscript, Federal Reserve Board

Palumbo, Michael G. (1999) ‘Uncertain medical expenses and precautionary saving near the end of the life cycle.’ *Review of Economic Studies* 66(2), 395–421

Rettenmaier, Andrew J. (2012) ‘The distribution of lifetime medicare benefits, taxes and premiums: Evidence from individual level data.’ *Journal of Public Economics* 96(9–10), 760 – 772

Robson, Arthur J., and Hillard S. Kaplan (2007) ‘Why do we die? economics, biology, and aging.’ *American Economic Review* 97(2), 492 – 495

Rosen, Sherwin (1988) 'The value of changes in life expectancy.' *Journal of Risk and Uncertainty* 1(3), 285–304

Rust, John, and Christopher Phelan (1997) 'How Social Security and Medicare affect retirement behavior in a world of incomplete markets.' *Econometrica* 65(4), 781–831

Scholz, John Karl, Ananth Seshadri, and Surachai Khitatrakun (2006) 'Are Americans saving optimally for retirement?' *Journal of Political Economy* 114(4), pp. 607–643

Scholz, John Karl, and Ananth Seshadri (2012) 'Health and wealth in a life cycle model.' Manuscript, Department of Economics University of Wisconsin-Madison, August

Shepard, Donald S., and Richard J. Zeckhauser (1984) 'Survival versus consumption.' *Management Science* 30(4), 423–439

Sickles, Robin C., and Abdo Yazbeck (1998) 'On the dynamics of demand for leisure and the production of health.' *Journal of Business and Economic Statistics* 16(2), 187–197

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

Smith, James P. (1999) 'Healthy bodies and thick wallets: The dual relation between health and economic status.' *Journal of Economic Perspective* 13(2), 145–166

Social Security Administration 'Average monthly social security benefit for a retired worker.' `http://ssa-custhelp.ssa.gov/app/answers/detail/a_id/13/~/average-monthly-social-security-benefit-for-a-retired-worker`

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

U.S. Census Bureau (2011a) 'Age and sex composition: 2010.' Census Briefs, U.S. Department of Commerce, Washington, DC 20233, May

— (2011b) *Statistical Abstract of the United States, 2012,* 131 ed. (Washington DC)

Van Kippersluis, Hans, Tom Van Ourti, Owen O'Donnell, and Eddy van Doorslaer (2009) 'Health and income across the life cycle and generations in Europe.' *Journal of Health Economics* 28, 818–830

Wolfe, John R (1985) 'A model of declining health and retirement.' *Journal of Political Economy* 93(6), 1258–1267

Wu, Stephen (2003) 'Sickness and preventive medical behavior.' *Journal of Health Economics* 22(4), 675 – 689

Wunder, Christoph, Andrea Wiencierz, Johannes Schwarze, and Helmut Kuchenhoff (2013) 'Well-being over the life span: Semiparametric evidence from British and German longitudinal data.' *Review of Economics and Statistics* 95(1), 154 – 167

Yogo, Motohiro (2009) 'Portfolio choice in retirement: Health risk and the demand for annuities, housing, and risky assets.' NBER Working Paper 15307, National Bureau Of Economic Research, September

A Tables

Table 1: Medicare summary

Part	Covers	Taxes	Co-payment	Deductibles (Y)	Premia (M)
A	Inpatient care	2.9% payroll	20%	$1,156	
B	Outpatient care	Gen. revenues	20%	$140	$99.90
D	Drugs	Gen. revenues	25%	$310	$39.36

Notes: Sources: 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.

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.	Leisure	Retire.	Leisure in health	Mortal.	Morbid.
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)	✓							
Fonseca et al. (2009)	✓	✓	✓		✓			
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. (2012)	✓	✓	✓		✓			
Hugonnier et al. (2013)	✓	✓	✓				✓	✓
This paper	✓	✓	✓	✓		✓	✓	✓

Table 4: Insurance plans, net effects and restrictions

(a) Statuses and net effects

Status: young	Status: old			Net effects
	Insured		Uninsured	
	Medicare	Private		
Insured				
- Private	PM	PP	PN	Insured old
Uninsured	NM		NN	Insured old
Net effects	Insured young		Insured young	

(b) OOP's, premia, and income

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

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: Data sources

Variables	Data (2010, 2011), and explanations
W	Survey of Consumer Finances (SCF), Federal Reserve Bank. Financial assets held.
H	National Health Interview Survey (NHIS), Center for Disease Control. Self-reported health status (phstat) where Poor=0.10, Fair=0.825, Good=1.55, Very good=2.275, Excellent=3.0.
S	National Vital Statistics System (NVSS), Center for Disease Control. Survival rates
I	Medical Expenditures Survey (MEPS), Agency for Health Research and Quality. Total health services mean expenses per person with expense and distribution of expenses by source of payment.
OOP	Medical Expenditures Survey (MEPS), Agency for Health Research and Quality. Out-of-pocket health services mean expenses per person with expense and distribution of expenses by source of payment.
ℓ	American Time Use Survey (ATUS), Bureau of Labor Statistics. Share of usual hours not worked per week, 1-uhrsworkt/40
C	Consumer Expenditures Survey (CEX), Bureau of Labor Statistics. Non-durables consumption, net of health expenditures and vehicle purchases = 4*(totex4pq - healthpq - vehicle)

Table 6: Parameter statuses and sources

Parameters	Status/sources
T, κ	Life tables, Arias (2010). Median age, U.S. Census Bureau (2011a, Tab. 2, p. 4).
λ_2^s, ξ^s, ξ^m	Hugonnier et al. (2013, Tab. 2)
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. The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
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	Average monthly Social Security benefit for a retired worker Social Security Administration (n.d.).
w_t	Median usual weekly earnings of full-time wage and salary workers by selected characteristics, 2010 annual averages Bureau of Labor Statistics (2011, Tab 1)
η_I, η_ℓ	Free parameters
β, μ_C, μ_ℓ, μ_m,	Various literature, and French and Jones (2011), De Nardi et al. (2009)
λ_0^m, λ_1^m, λ_0^s, λ_1^s	Estimated
δ_0, g^δ, ϕ_0, g^ϕ	Estimated
γ	Estimated

Table 7: Parameter values

(a) Calibrated parameters

parameter	value	parameter	value	parameter	value	parameter	value
T	100	κ	-37				
ξ^m	2.5	λ_2^s	50	ξ^s	4.9		
A_0	1.5	g^A	0.004	η_I	0.20	η_ℓ	0.40
ψ	0.200	Π	0.0413	Π^M	0.0167		
P_0^I	1.8522	g^P	0.008	D_0	0.0100	g^D	0.008
y^R	0.1476	τ	0.0145	R^f	1.04		
β	0.9656	μ_c	0.3333	μ_ℓ	0.6667	μ_m	0.0200
$W_{\min}$	0.05	$W_{\max}$	4	$H_{\min}$	0.1	$H_{\max}$	3
$C_{\min}$	0.05	$C_{\max}$	1	$I_{\min}$	0	$I_{\max}$	1
$\ell_{\min}$	0.05	$\ell_{\max}$	1				
K_W	10	K_H	10	K_Y	30		

(b) Estimated parameters

parameter	value	(standard error)	parameter	value	(standard error)
δ_0	0.0166	(0.0072)	g^δ	0.0154	(0.0062)
ϕ_0	0.0658	(0.0215)	g^ϕ	0.0157	(0.0046)
λ_{m0}	0.0061	(0.0020)	λ_{m1}	0.0091	(0.0044)
λ_{s0}	0.2621	(0.1347)	λ_{s1}	5.1022	(1.2468)
γ	3.4005	(1.4523)			

Notes: See Table 6 for description of parameter status and sources. Estimated parameters based on SME estimator (28).

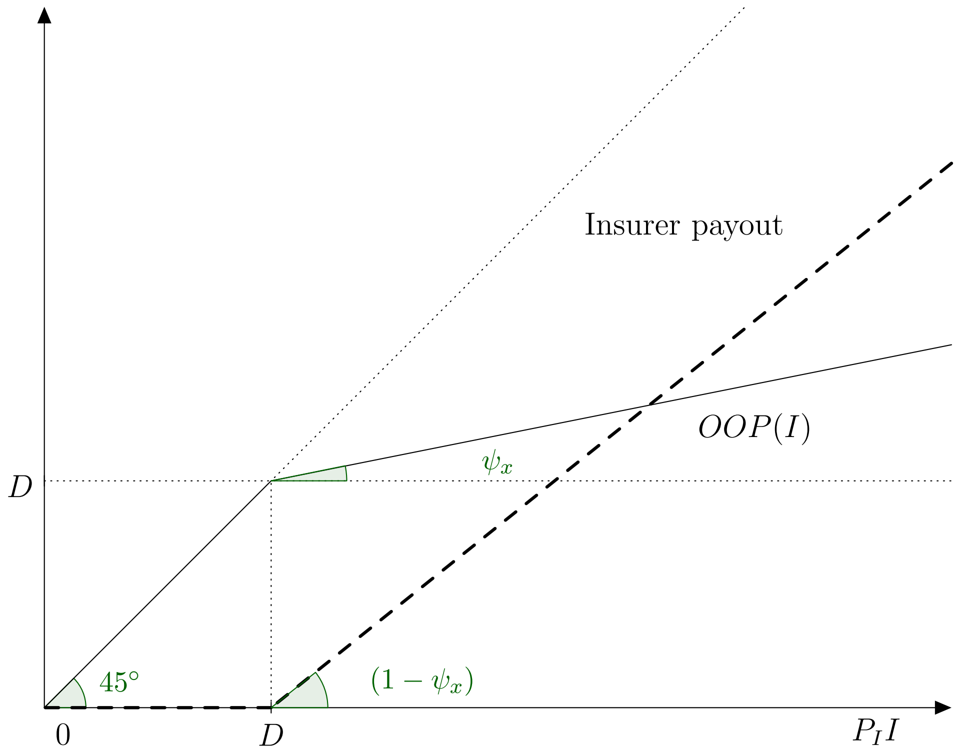
Table 8: Data and simulated population moments (age 20–80)

Series	Data	Simulated PM	PN	PP	NN	NM
I	0.0305	0.0345	0.0345	0.0345	0.0345	0.0345
OOP^*	0.0069	0.0214	0.0218	0.0218	0.0629	0.0457
C^*	0.1353	0.1892	0.1966	0.1941	0.1850	0.1899
ℓ	0.3774	0.3046	0.3187	0.3124	0.3064	0.3166
W^*	2.2112	1.4067	1.6260	1.5884	1.1401	1.1015
H	2.0863	2.5366	2.5400	2.5372	2.5066	2.5243
$\hat{S}^\dagger$	77.9000	78.8929	78.8684	78.8360	78.7351	78.8229
V	NaN	8.9054	8.7184	8.8215	8.2932	8.5916

Notes: Population statistics computed using (24)–(27). *: in 100,000\$, ^{s}: in shares of financial wealth, †: in years.

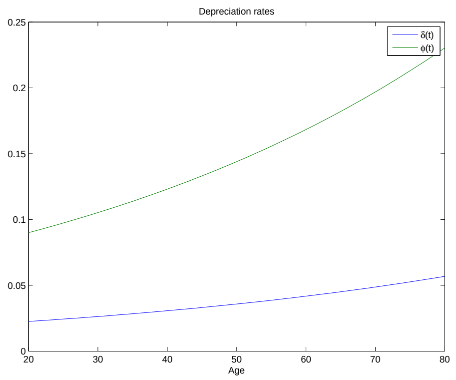
B Figures

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

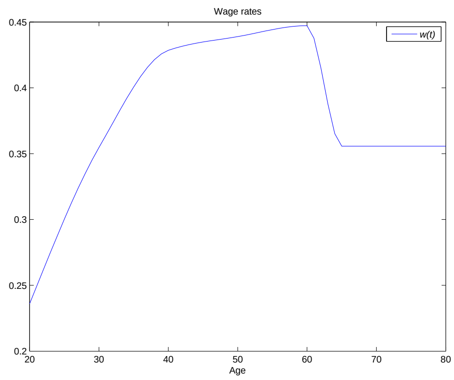


Notes: Solid line: Out-of-pocket expenditures (5) for deductible D and co-payment rate ψ as function of health expenditures $P_I I$. Dashed line: Insurance payout by insurer.

Figure 2: Depreciation rates and wages



(a) Depreciation



(b) Wages

Figure 3: Iteration results

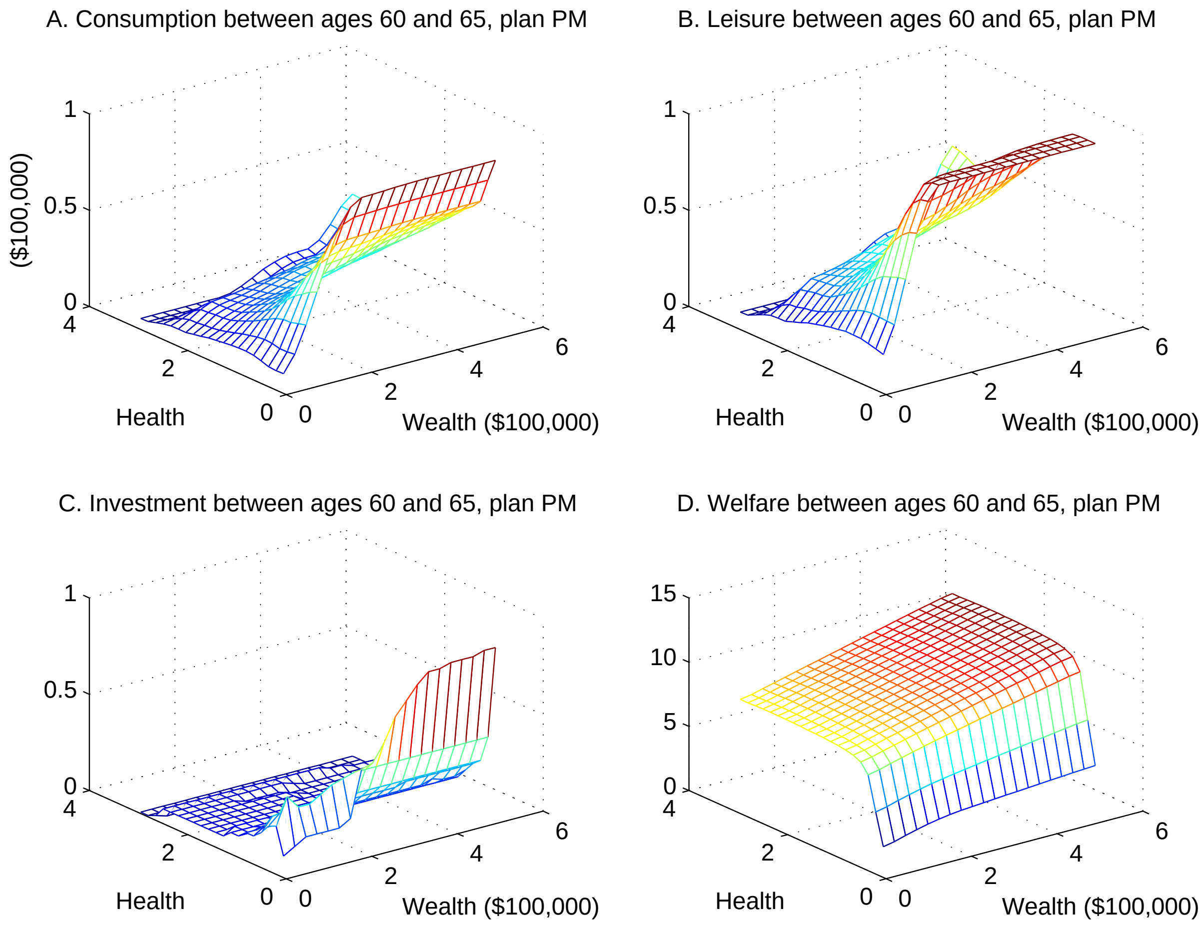


Figure 4: Simulated life cycle health

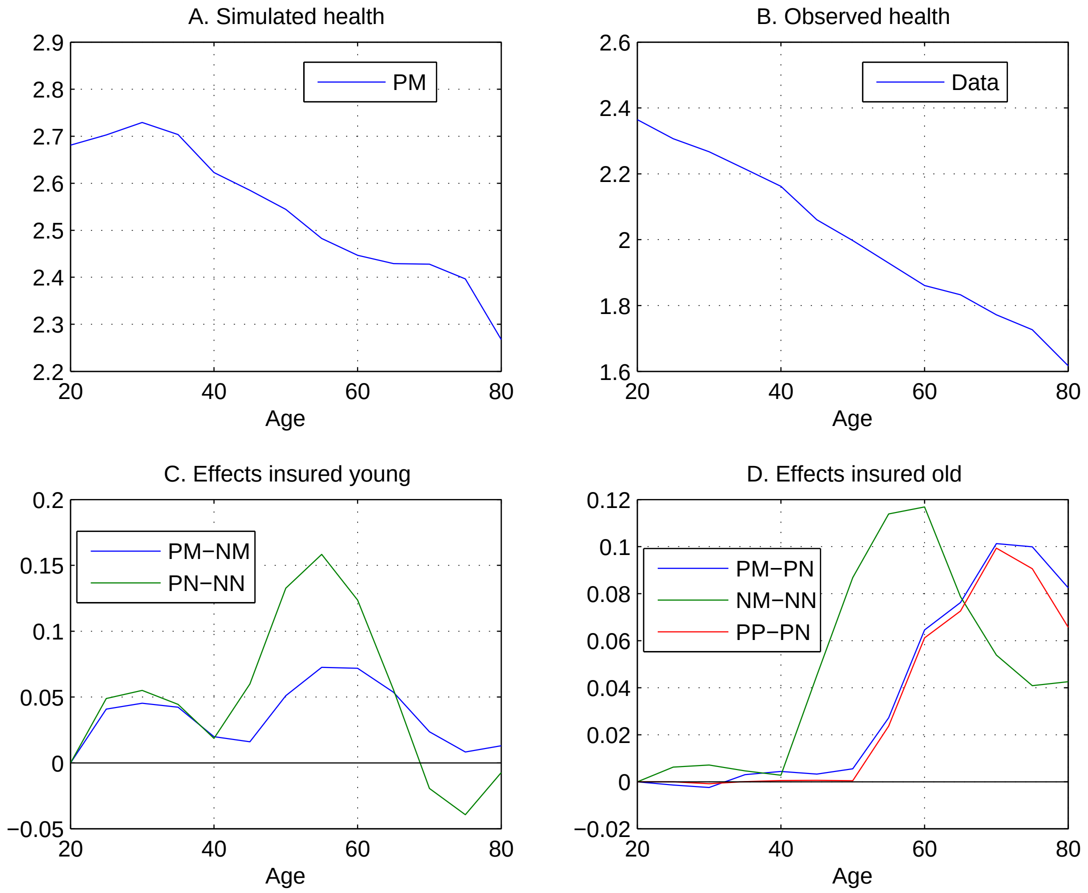


Figure 5: Simulated life cycle survival rate

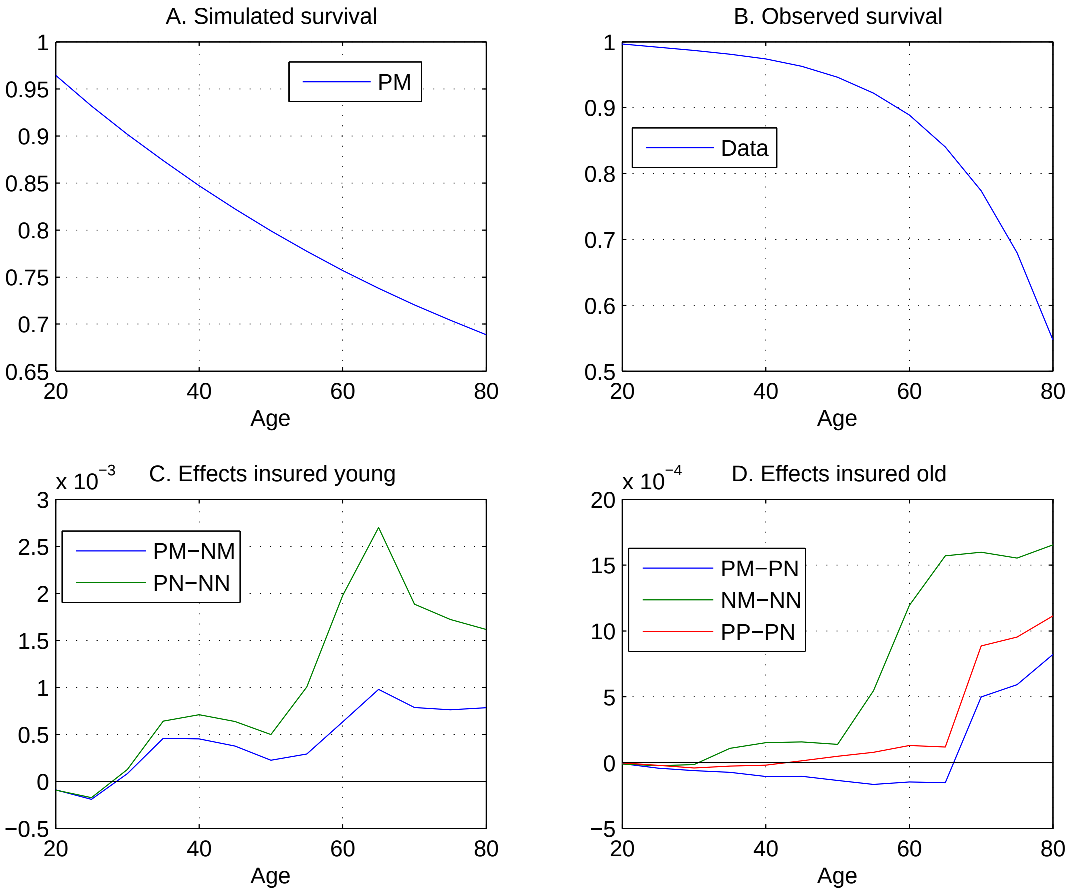


Figure 6: Simulated life cycle health investment

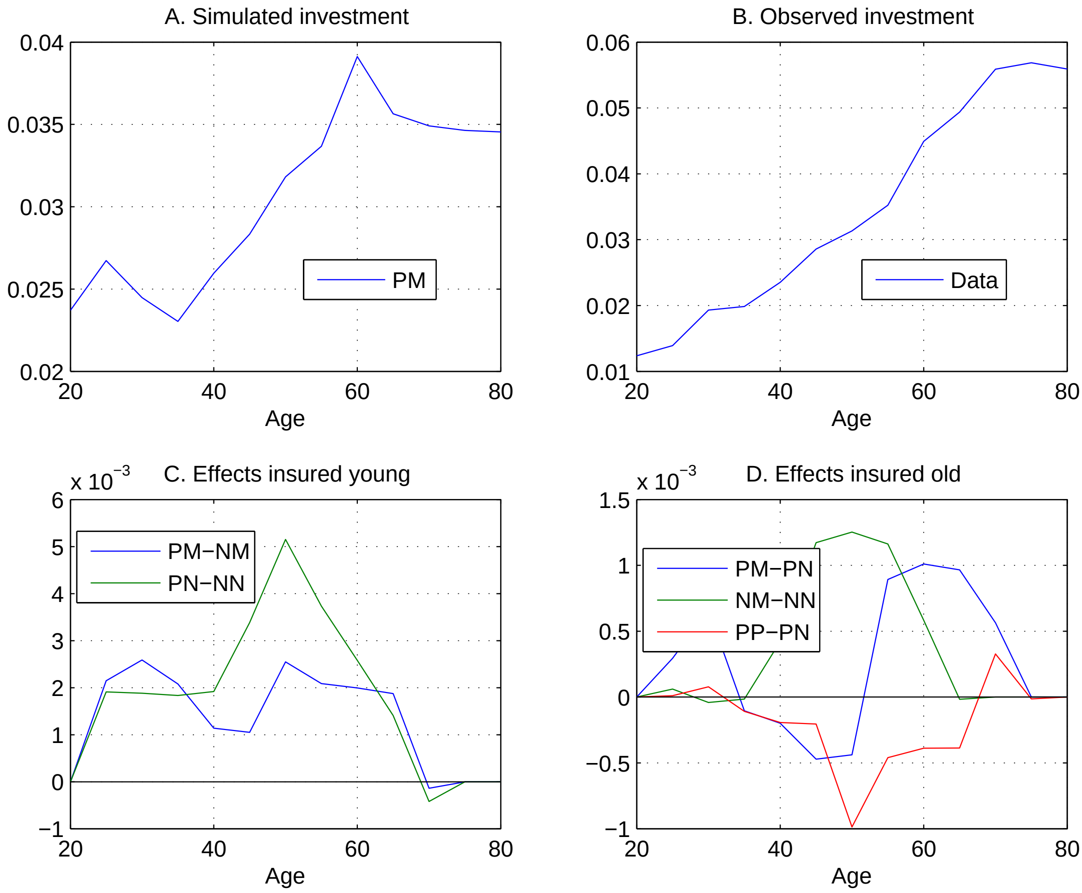


Figure 7: Simulated life cycle out-of-pocket health expenditures

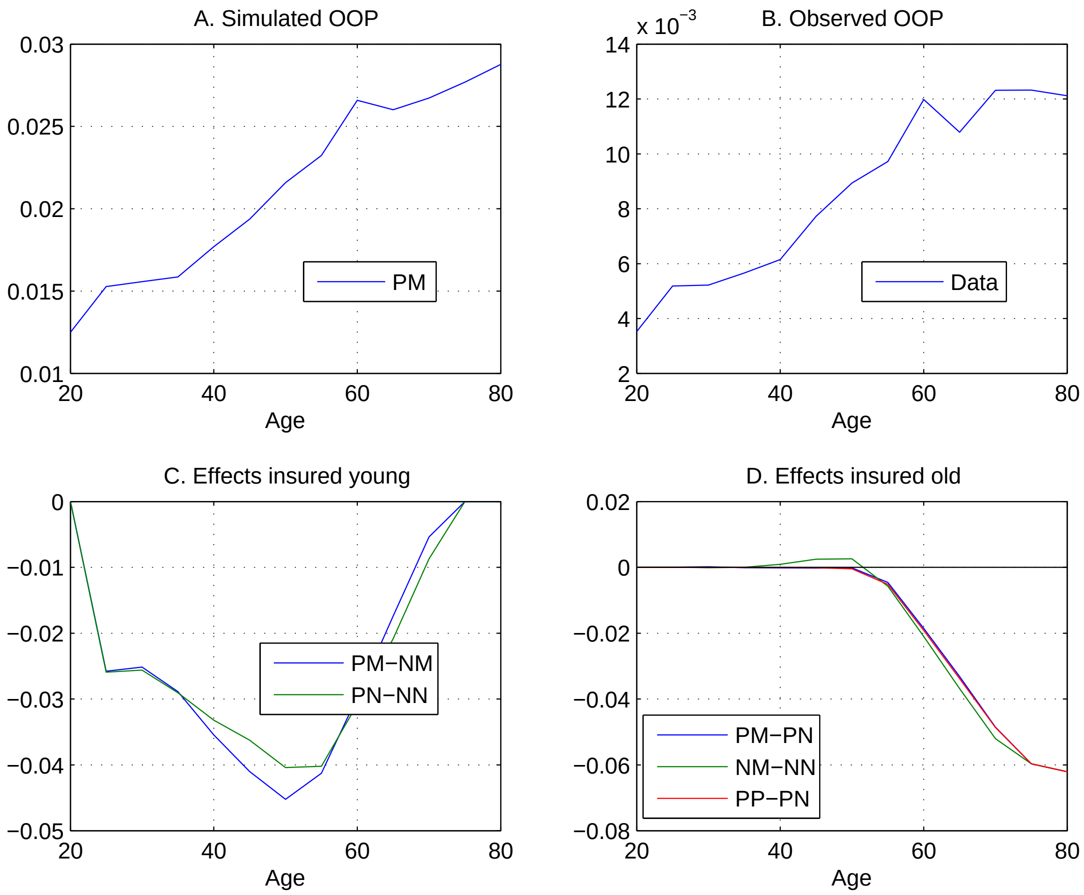


Figure 8: Simulated life cycle healthy leisure

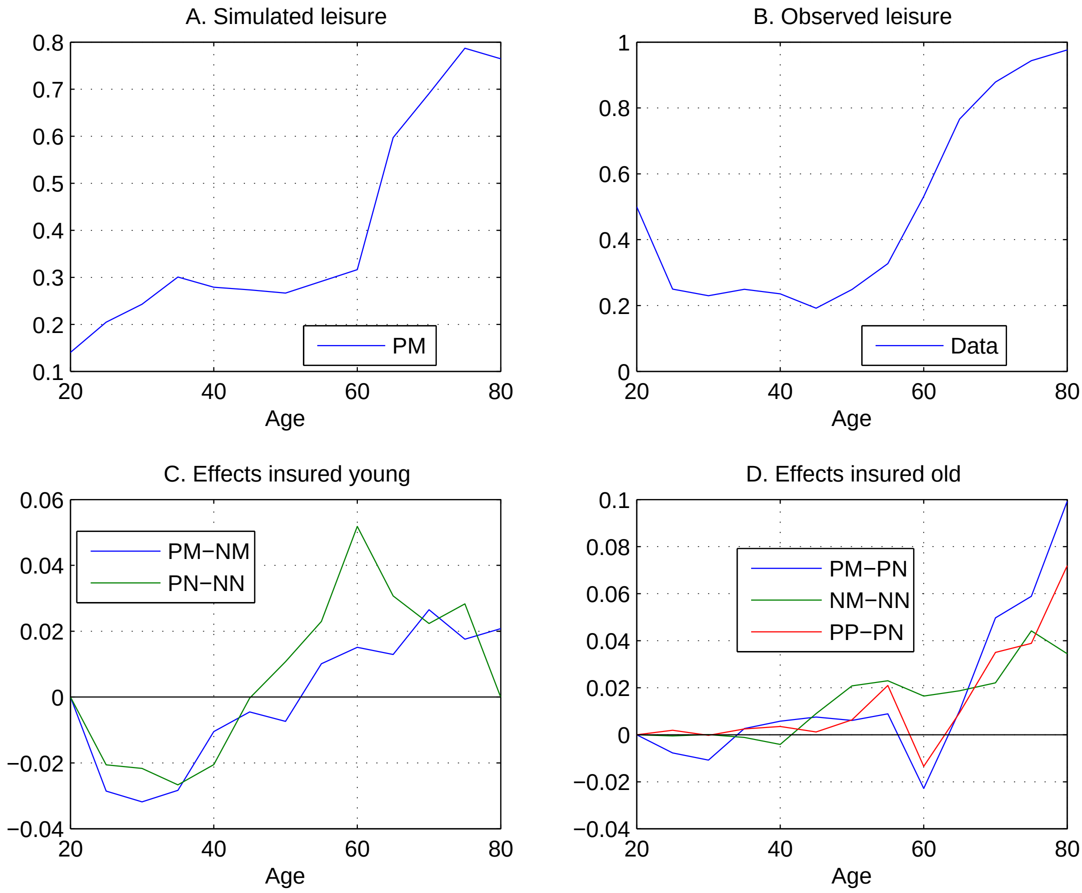


Figure 9: Simulated life cycle wealth

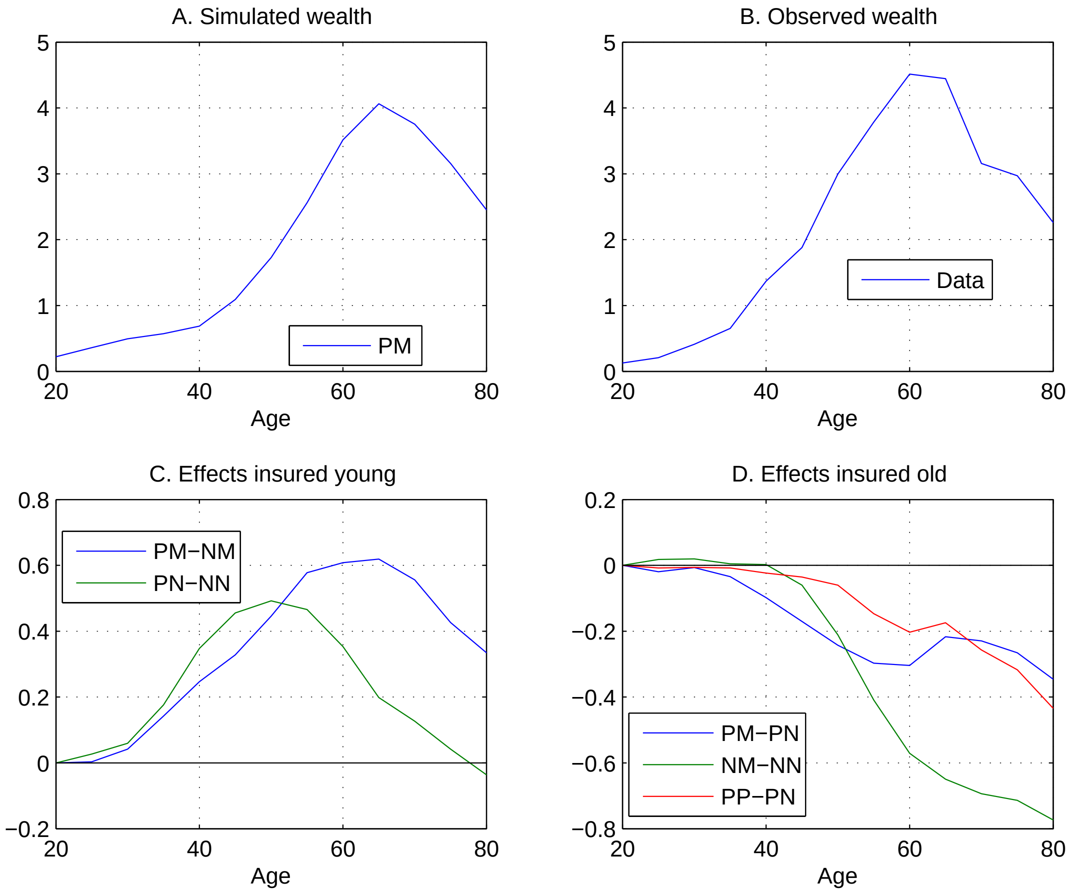
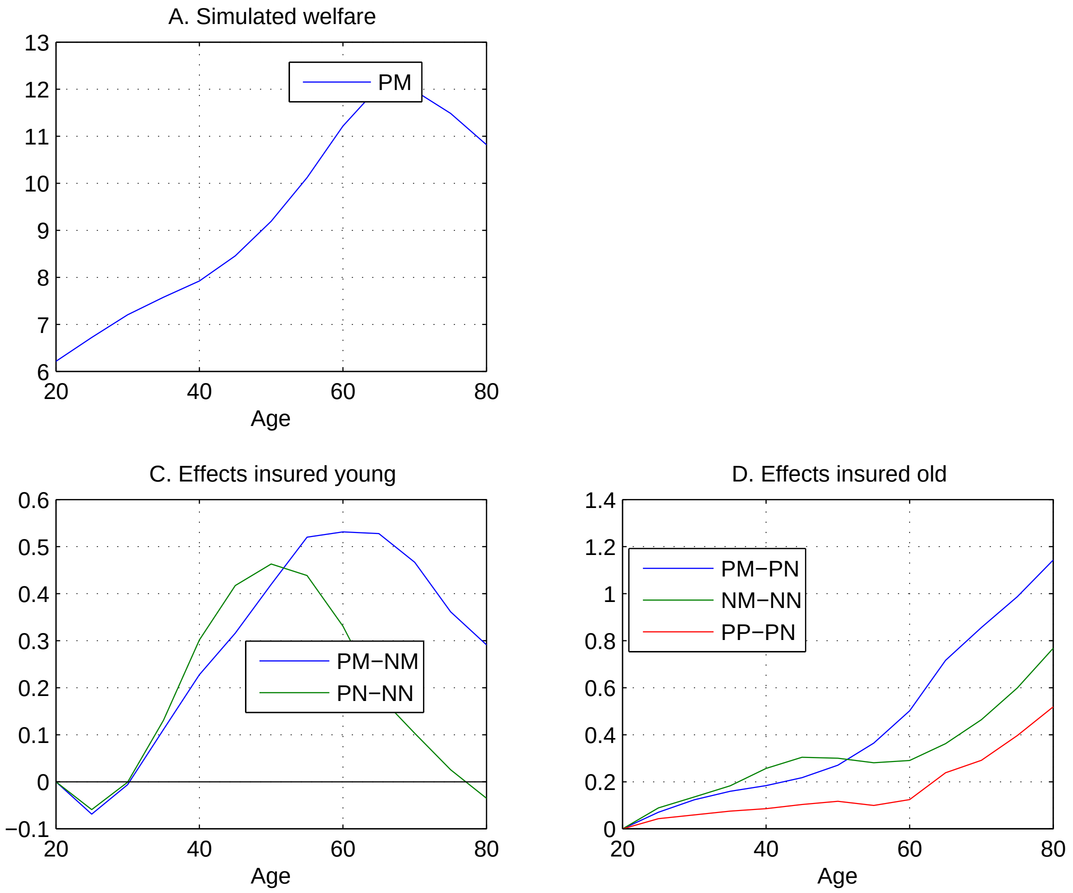


Figure 10: Simulated life cycle welfare



C Numerical methods

C.1 Iterative methods

Denote the full parameter set as Θ. For a given Θ, the iterative step consists in solving the model numerically by backward induction via a Value Function Iteration approach. This involves discretizing the state space which involves the health and wealth statuses.

Let $Z = (H, W) \in \mathbb{Z}$, 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 κ, the Value Function Iteration consists of iterating recursively over ages $t = T, T-1, \ldots, 1$ in order to solve:

$$\begin{aligned} V_t^x(Z) &= \max_{\{Q_t \in \mathbb{Q}\}} \mathcal{U}(Q_t, Z) + \exp[-\rho^m(Z)] \mathrm{E}_t \left\{ V_{t+1}^x(Z_{t+1}) \mid Z \right\}, \\ \text{s.t. } Z_{t+1} &= Z_{t+1}(Q_t, Z, \epsilon_{t+1}) \end{aligned} \tag{22}$$

at each state $Z \in \mathbb{Z}$, and for each plan $x \in \mathbb{X}$. In order to account for the *long reach of childhood* effects (e.g. Smith, 1999), the model is solved for all periods rather than only until a sufficient degree of convergence has been obtained. The output we recover consists of the age- and plan-specific allocations, and welfare:

$$\{Q_t^x(Z), V_t^x(Z)\}_{t=1}^T, \quad \forall Z \in \mathbb{Z}, x \in \mathbb{X}, \tag{23}$$

that will be used in the simulation phase.[12]

C.2 Simulation methods

The iteration phase in (22) 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 (23) in conjunction with the shocks ϵ generated

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

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) the optimal rules and value function are computed using an interpolation of the results obtained in the iterative phase (23),

$$Q_t^{i,n} = \text{interpn}\left(Q_t(Z), Z_t^{i,n}\right), \quad V_t^{i,n} = \text{interpn}\left(V_t(Z), Z_t^{i,n}\right);$$

   (b) the mortality and morbidity shocks are endogenously drawn,

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

   (c) the state variables are updated,

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

Several issues are worth mentioning. First, the output we recover, $\left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}$, is the one along the optimal path over ages $t = 1, \ldots, T$, i.e. with *all* endogeneities accounted for. Second, this output can be used to compute both the life cycle and the population statistics across surviving agents. In particular, let $\mathbb{1}_t^{i,n} \in \{1, \text{NaN}\}$ 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:

$$\hat{M}_t = \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n} \left\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\right\}}{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}, \tag{24}$$

$$\hat{S}_t = \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}{K_I K_N}. \tag{25}$$

Similarly, the corresponding population 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:

$$\hat{M} = \frac{\sum_{t=16}^{T} \hat{M}_t}{T - 16}, \tag{26}$$

$$\hat{S} = \sum_{t=16}^{T} \hat{S}_t. \tag{27}$$

These theoretical moments can be contrasted with the empirical moments in order to assess the model's performance, as discussed below.

C.3 Calibration and estimation strategy

The previous iteration and simulation phases are performed conditional upon a given parameter set $\Theta = (\Theta^c, \Theta^e)$ detailed in equation (21). As mentioned earlier, we let Θ^c denote the subset calibrated using some prior information from the literature and the data, and Θ^e be the estimated parameter subset. The parameter statuses and sources are detailed in Table 6, with values reported in Table 7.

First, the maximum age is set at $T = 100$ years, whereas the cohort is set at minus the median age $\kappa = -37$. The intensities parameters $(\lambda_2^s, \xi^m, \xi^s)$ are taken from Hugonnier et al. (2013). Estimates calculated by the National Center of Health Statistics, the Board of Trustees of the Federal HI, and SMI Trust Funds as well as by the Henry J. Kaiser Family Foundation are used for the medical prices, and insurance levels, and growth characteristics $(P_0^I, g^P, A_0, g^A, \psi, \Pi, \Pi^M, D_0, g^D, \tau)$. The average pension benefit y is obtained from the Social Security Administration, whereas the risk-free rate R^f is set from historical data on short-term Treasury Bills. Finally, the parameters of the investment function (η_I, η_ℓ), the preferences $(\beta, \mu_C, \mu_\ell, \mu_m)$ are identified via the literature whenever possible, and through an extensive trial and error process, both prior to (i.e. in the search for starting values) and following (i.e. in the robustness tests) the estimation phase.

Second, the estimated parameters 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's realism. In particular, let $\hat{\mathbf{M}}(\Theta) \in \mathbb{R}^{K_M}$ be the collection of theoretical life cycle moments and survival rates $\{\hat{M}_t, \hat{S}_t\}$ given in (24), and (25) and conditional upon parameter $\Theta = (\Theta_1^c, \Theta_2^c, \Theta^e)$. Letting $\mathbf{M} \in \mathbb{R}^{K_M}$ 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:

$$\hat{\Theta}^e = \underset{\Theta^e}{\operatorname{argmin}}[\hat{\mathbf{M}}(\Theta) - \mathbf{M}]'\Omega[\hat{\mathbf{M}}(\Theta) - \mathbf{M}]. \tag{28}$$

In practice, the theoretical life cycles moments are computed over 5-year intervals between the age of 20 and 80, and involve consumption, health investment and out-of-pocket expenditures, leisure, wealth, health, and survival rates, for our benchmark insurance case taken to be PM (Private when young, Medicare when old). The corresponding empirical moments 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 in Table 5. The SME of $\hat{\Theta}^e$ is consequently over-identified with a total of 7 life cycles $\times 13$ five-year bins $= 91$ moments used to identify 9 structural parameters.