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## Abstract

This paper studies the lifetime effects of exogenous changes in health insurance coverage (e.g. Medicare, PPACA, termination of employer-provided plans) on the dynamic optimal allocation (consumption, leisure, health expenditures), status (health, wealth and survival rates), and welfare. We solve, structurally estimate, and simulate a parsimonious life cycle model with endogenous exposition to morbidity and mortality risks to analyze the impact of young (resp. old) insurance status conditional on old (resp. young) coverage. Our results highlight strong substitution across instruments (health expenditures, and leisure) as well as across time (postponing and accelerating expenses, leisure) induced by changes in insurance statuses.

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

**JEL classification**— D91, G11, I13

# 1 Introduction

The health insurance status of individuals can change exogenously over the life cycle. For instance, employer-provided insurance often ends at retirement. Moreover, prior to the signing into law of the Patient Protection and Affordable Care Act (PPACA, a.k.a. Obamacare) in 2010, Medicare provided guaranteed and subsidized insurance principally for elders,<sup>1</sup> whereas PPACA extends these provisions to younger individuals. The purpose of this paper is to analyze the impact of such exogenous, and predictable changes in health insurance for the life cycle allocations (i.e. consumption, health expenditures and leisure), status (wealth, health levels and survival), as well as welfare of households.

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

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

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<sup>1</sup>See Table 1 for details on Medicare coverage and financing.

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

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

The previous discussion suggests that (i) the timing of health insurance coverage should affect the allocations *throughout* the life cycle, and (ii) the mechanisms through which these effects take place are non trivial, especially when exposition to morbidity and mortality risks is endogenous. Understanding how changes in coverage affect the life cycle allocations is important for several reasons. First, from a Public Finance perspective, the resources spent on compulsory coverage programs such as Medicare are substantial, making it the fourth item on the Federal budget in 2011 (see Table 2). Moreover, these

resources will expand as PPACA becomes operational and starts imposing health insurance on large, previously uninsured segments of the US population.<sup>2</sup> Since both involve exogenous changes in insurance statuses, charting the dynamic effects on consumption, wealth, leisure, health expenditures and levels is warranted for policy evaluation purposes. Second, from a normative aspect, imposing market-provided insurance affects endogenous exposure that can also be adjusted through self-insurance. Moral hazard substitution can take place both across instruments (e.g. health expenditures vs healthy leisure vs precautionary health balances) and across time (e.g. less leisure or expenditures now vs more later). Since these substitutions affect exposure to longevity and sickness risks, the net effect of insurance on welfare is not trivially obtained. Moreover, because longevity is altered, indirect effects of health insurance can obtain for other programs such as Social Security. Finally, from a General Equilibrium perspective, we can expect non-trivial Macro effects of the resulting changes on savings and leisure through financial and labor markets.

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

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<sup>2</sup>The percentage of health uninsured Americans aged 19–64 was 21% in 2011-12, ranging from 5% in Massachusetts, and 11% in DC or Vermont, to 29% in Nevada or Florida, and 32% in Texas (Henry J. Kaiser Family Foundation, 2014).

Towards that objective, we propose a stochastic life cycle framework where health is modeled as human capital. More precisely, the health stock is depreciable, and can be augmented through both health investment (i.e. expenditures) and time (i.e. leisure). Depreciation is age-increasing in order to capture more pressing health problems facing the elders. The health production technology is subject to decreasing returns and path dependence, in the sense that health issues cannot be resolved through expenditures and leisure only but also depend on past decisions via the current health status. The joint inclusion of leisure and expenditures in the production of health is innovative and is meant to capture the tradeoffs between more work and disposable resources for medical spending versus more rest and healthy leisure as preventive and curative health measures. It also accounts for moral hazard problems in insurance whereby agents insured against health expenditures risk may find it optimal to shirk on unobservable healthy activities.

Death and sickness risks are usually analyzed separately and/or as exogenous processes in the literature. We instead follow recent theoretical developments pioneered in Hugonnier et al. (2013) that endogenize the *joint* exposure to mortality and morbidity risks. More precisely, sickness entails additional depreciation (also increasing in age) of the health stock, but its likelihood of occurrence can be diminished through better health. Similarly, the longevity is stochastic and endogenous in the sense that healthier agents face a lower risk of dying. Both the morbidity and mortality endogeneities are fully internalized in the dynamic allocations made by households, while self-insurance against sickness and death is also subject to diminishing and bounded returns.

Our specification of the budget constraint contributes to existing literature by fully endogenizing the labor supply decisions, taking as given the observed patterns of increasing wages up to age 65, and falling thereafter. Although we abstract from irreversible retirement in order to capture the rising trend in elders' employment,<sup>3</sup> this limitation is not restrictive. Indeed, we fully allow for corner solutions with no labor market participation as an optimal response to falling wages, and rising health issues for the

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<sup>3</sup>The employment of workers aged 65 and over increased by 101% between 1977 and 2007, compared with an overall increase of 59 % for adults (Bureau of Labor Statistics, 2008).

elders. Importantly, health insurance is exogenously set and includes private, Medicare, and no insurance variants; this allows us to carry out counter-factual analysis whereby the coverage status is varied across age in order to assess the life cycle effects.

We also innovate in our specification of preferences. Instantaneous utility is defined over consumption and leisure, as well as bequeathed wealth. Since mortality risk is health-dependent, we show that this modeling choice constitutes an explicit alternative to the traditional approach of resorting to implicit valuable services of health; better health is valued because it reduces the likelihood of death whose utility cost is only partially compensated by bequeathed wealth. We further show that the stochastic horizon with endogenous health-dependent death intensity is isomorphic to a fixed horizon problem with endogenous health-dependent discounting; an healthier agent faces a lower likelihood of dying and behaves as a more patient individual. The endogenous risk of living too short is thus accounted for through the bequest function, whereas that of living too long is internalized through the health-dependent discounting.

Precisely because discounting is endogenous, the model admits no closed-form solution. It is therefore solved numerically through recursive iteration on the value function. The resulting allocations are then simulated over a large number of optimal life cycle trajectories. By minimizing the distance between the simulated allocations and health and wealth statuses and the corresponding observed life cycle moments, we recover a Simulated Moments Estimation (SME) of the deep parameters. This estimation is *fully* structural in the sense that it does not rely on any of the exogenous auxiliary processes (e.g. idiosyncratic income shocks, survival rates) that are commonly appended and estimated outside of the model in a two-step estimation approach. Rather, the only stochastic processes that are involved are the morbidity and mortality innovations, and those processes are entirely generated by the model, and estimated as such in a single-step procedure. This approach significantly complicates the estimation, yet ensures a one-to-one mapping, and therefore full internal consistency between the theoretical and the empirical methods. Empirical validity is confirmed by a very close match of the

predicted and observed life-cycle and unconditional moments for health statuses and longevity, OOP's, leisure, and wealth. This empirical performance is quite remarkable given that the theoretical framework is very parsimonious,<sup>4</sup> and that no external forcing processes are appended.

Key to our analysis, the differences in the dynamic allocations and statuses across the insurance and age dimensions can be isolated in order to identify the marginal allocative effects of the health insurance status when young (conditional upon old-age status), and when old (conditional upon young-age status). First, we find that (i) the young insured are noticeably healthier, (ii) durability implies that health remains higher for some time after they reach old age, and (iii) this persistence is stronger if they are uninsured after retirement. This last result is consistent with young insured building up precautionary health balances in anticipation of post-retirement termination of insurance coverage. Insured elders are also healthier after retirement, but tend to be less healthy if uninsured when young. This suggests optimal stockpiling whereby costly health maintenance is postponed until after coverage begins.

Unsurprisingly, OOP expenses are lower for the insured with little evidence of cross-coverage effects. A more powerful substitution induced by insurance can be found in healthy leisure decisions. Young and old insured find it optimal to reduce leisure, especially around mid life, and increase it after retirement. This effect obtains for two reasons. The lower price of health expenditures relative to healthy leisure induces a static substitution away from the latter and the fact that observed wages are highest around mid life, and fall sharply after retirement provides incentives to substitute more work when young in favor of more leisure when old.

Better health naturally leads to increases in survival rates for both young and old insured. The combination of better longevity, lower exposure to morbidity and OOP risks, and more hours worked implies that wealth is higher for the insured. Consequently,

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<sup>4</sup>Indeed, the model is constructed using only five key equations: a law of movement for health, endogenous sickness and death arrival rates, a budget constraint and insurance contract as well as a specification of preferences.

so is welfare, and we find that health insurance is optimal at all ages, except for the young adults. Up to their mid-30's, high initial health stocks, low wealth, and low wages make it optimal for the young to self insure through leisure, and health balances rather than through markets. As health-related problems, and wages subsequently start to escalate, lower exposure to OOP risks through market-provided insurance becomes a welcomed alternative to uninsurance and more reliance on healthy leisure. We close our discussion of the results by demonstrating robustness to cohort effects.

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

## 2 Relevant literature

First, a vast literature initiated by Kotlikoff (1989) studies consumption decisions in the presence of health-related risks and concludes that prudent agents faced with OOP expenses and labor income uncertainty, as well as the risk of living too long should increase precautionary savings.<sup>5</sup> The empirical evidence is partially supportive of that conjecture. On the one hand, slow asset decumulation 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 behavior 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,

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<sup>5</sup>Studies of health-related risks effects on savings decisions include Hubbard et al. (1994, 1995); Levin (1995); Palumbo (1999); Dynan et al. (2004); French (2005); Scholz et al. (2006); Hall and Jones (2007); Skinner (2007); Edwards (2008); De Nardi et al. (2009); Fonseca et al. (2013); De Nardi et al. (2010); Ozkan (2011); French and Jones (2011); Scholz and Seshadri (2012); Hugonnier et al. (2013). See Table 3 for classification.

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 analyzes the life cycles of asset accumulation in the presence of health-related risks, under various health expenditures insurance regimes (none, private, public), and also emphasizes their influence for precautionary savings for both young and old agents. In contrast, we do allow possible hedging through health-related decisions, rather than impose completely undiversifiable mortality and morbidity risks. Since the agents can reduce their exposure to death and sickness risks, this mitigates the requirement to maintain precautionary savings.

Second an related, two alternative frameworks can be used to study the effects of health-related risks on medical expenses. First, stochastic health expenditures have been modeled as exogenous, and thus tantamount to undiversifiable income shocks.<sup>6</sup> Persistence and predictability of health expenses can be obtained by assuming a Markovian process, and/or correlating these shocks to observable exogenous health and socioeconomic statuses. Second, endogenous health expenditures have been modeled as generating an implicit utilitarian service flow by Blau and Gilleskie (2008); De Nardi et al. (2010). More explicit approaches, in the spirit of Grossman (1972), model health as a durable good providing implicit utility service flows, whose level can be adjusted through health expenditures.<sup>7</sup> Following pioneering work by Cropper (1977), other alternatives append self-insurance services by allowing health to (partially) reduce morbidity and/or mortality risks.<sup>8</sup> 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 labor revenues have been modeled by assuming inelastic labor supply, and focusing on their effects on wages by Case and Deaton

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<sup>6</sup>See for example Hubbard et al. (1995); Rust and Phelan (1997); Palumbo (1999); French (2005); Scholz et al. (2006); Edwards (2008); De Nardi et al. (2009, 2010); French and Jones (2011); Scholz and Seshadri (2013).

<sup>7</sup>Examples include Case and Deaton (2005); Hall and Jones (2007); Yogo (2009); Fonseca et al. (2013); Khwaja (2010); Ozkan (2011); Galama et al. (2013); Scholz and Seshadri (2012, 2013).

<sup>8</sup>Endogenous morbidity and/or mortality risks are studied by Hall and Jones (2007); Ozkan (2011); Scholz and Seshadri (2012, 2013); Hugonnier et al. (2013).

(2005); Fonseca et al. (2013); Khwaja (2010); Scholz and Seshadri (2012), as well as by Hugonnier et al. (2013) who show that the health effects are then isomorphic to those obtained through utilitarian flows. More explicit approaches study leisure adjustments through 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. Many researchers also analyze the role of health uncertainty for work decisions on the extensive margin. In particular, this research shows that postponing retirement until Medicare eligibility is optimal when retirement is associated with the loss of employer-provided health insurance benefits (Rust and Phelan, 1997; Palumbo, 1999; Fonseca et al., 2013; French and Jones, 2011; Scholz and Seshadri, 2013). Conversely, retirement can also be accelerated if in poor health, and eligible for early retirement (Wolfe, 1985; Bound et al., 2010; Galama et al., 2013). Although our modeling of leisure choices does allow for non-employment, we abstract from discrete and irreversible retirement decisions in our analysis.

Fourth, the detrimental consequences of morbidity and mortality risks can also be mitigated through social insurance programs. Positive effects of Medicare for elders have been shown to include better health and longevity (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 labor 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, or between healthy and unhealthy, we contribute to the normative literature by providing a separate assessment of the welfare gains of insurance across the age dimension.

### 3 Model

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

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

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

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

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

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

( $\ell \in \mathbb{I} \equiv [0, 1]$ ):

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

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

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

where  $g^d$  are age-specific growth rates of deterministic ( $\delta_t$ ), and stochastic ( $\phi_t$ ) depreciation, and where  $g^A$  is a year-specific growth rate of the medical technology. The law of motion (2) derives from the health-as-capital specification in the demand-for-health literature (Grossman, 1972), to which are appended morbidity shocks (Hugonnier et al., 2013), as well as age-increasing deterministic  $\delta_t$  and stochastic depreciation  $\phi_t \epsilon_{t+1}^s$ . Age-increasing depreciation in (3) and displayed in Figure 1.a 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).<sup>9</sup>

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

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<sup>9</sup>See Robson and Kaplan (2007) for discussion and alternative models of ageing and death.

process also includes exogenous productivity improvement in health production, whereby TFP growth in (4) is determined at the year level  $y = t + \kappa$  in order to account for cohort effects that are discussed further below (see Section 5.4).

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

We assume that the health expenditures insurance status  $x = (x^y, x^o) \in \{N, P, M\}^2$  for young ( $x^y$ ) and old ( $x^o$ ) agents is set exogenously among three alternatives, (N)o insurance, (P)ivate 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.<sup>10</sup>

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

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<sup>10</sup>In 2010 over 70% of the employed U.S. population aged 15 and over worked for an employer who offered health plans while more than two-thirds of people aged 18-64 had health insurance provided through either own, or someone else's employer (Janicki, 2013). See also Currie and Madrian (1999); Blau and Gilleskie (2008); McGuire (2011) for incidence and motivations for employer-provided health insurance plans.

deductibles processes are given by:

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

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

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

$$D_t = D_0 \exp[g^D(t + \kappa)], \quad (7)$$

where  $g^P$  is the inflation rate of medical prices, and  $g^D$  that of the deductibles. As illustrated in Figure 2, the contract (5) is standard whereby the insured agent in plans P and M covers all medical expenditures  $P^I I$  up to deductible  $D$  and pay a share of expenses  $\psi$  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.<sup>11</sup>

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

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<sup>11</sup>Medicare coverage for young disabled and Medicaid for poor households are abstracted from for tractability reasons.

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

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

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

where  $R^f$  is the gross risk-free rate of interest. The labor revenues (8) capture the effects of pension income (e.g. Social Security) in  $Y^R$  after age 65, the tax effects of Medicare in  $\tau$  which reduces disposable income for every worker, as well as the age variation in  $w_t$  displayed in Figure 1.b. 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,  $U : \mathbb{R}_+ \times \mathbb{I} \rightarrow \mathbb{R}_{++}$  denote a monotone increasing and concave instantaneous utility when alive, and  $U^m : \mathbb{R} \rightarrow \mathbb{R}_-$  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:

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

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 individual health is non-transferable,  $U^m$  is a function of next-period bequeathed wealth only. In particular, since  $U$  is positive, a negative  $U^m$  indicates a utility cost of mortality, whereas the marginal utility of bequests 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); Rosen (1988); Hugonnier et al. (2013), within-period utility  $\mathcal{U}_t$  must remain positive in order to guarantee strict preference for life in endogenous mortality settings. Preferences (10) provide an explicit alternative to implicit models of health valuation  $\mathcal{U} = U(C, \ell, H)$ , where  $\mathcal{U}_H \geq 0$  (see also the discussion of footnote 14 for explicit health-dependent variants). Indeed, since the endogenous subjective discount factor  $\beta^m$  is monotone increasing, and  $U^m$  is negative, it follows that  $\mathcal{U}_{H,t} \geq 0$  which ensures positive service flows of health associated with mortality risk reduction. Put differently, health is valuable in part because it reduces the likelihood of death whose utility costs are only partially offset by bequeathed wealth .

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

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

subject to the health process (2), and the budget constraint (9). Equation (11) shows that an agent with endogenous stochastic horizon  $T^m$ , constant discounting  $\beta$ , and evolving in an incomplete market environment (first line) is isomorphic to an agent with deterministic horizon  $T$ , endogenous discounting  $\beta^m(H)$ , and operating in a complete market setup (second and third lines). Put differently, endogenous mortality risk implies that an unhealthy agent has a shorter expected life horizon and is tantamount to a more impatient individual. As the following discussion makes clear, the forward-looking agent fully internalizes the impact of his leisure and health expenditure decisions on his discounting with respect to future utility flows.

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

$$U_{C,t} = ([\beta - \beta^m(H_t)] U_{W,t+1}^m + \beta^m(H_t) E_t \{U_{C,t+1} | H_t\}) R^f, \quad (12)$$

$$U_{C,t} OOP_{I,t}^x = \beta^m(H_t) E_t \{V_{H,t+1} | H_t\} A_t I_{I,t}^g, \quad (13)$$

$$(1 - \mathbb{1}^M \tau) w_t = \frac{U_{\ell,t}}{U_{C,t}} + \frac{I_{\ell,t}^g}{I_{I,t}^g} OOP_{I,t}^x, \quad (14)$$

where the marginal out-of-pocket cost is  $OOP_{I,t}^x = P_t^I [1 - \mathbb{1}_X \mathbb{1}_D (1 - \psi)]$ , and where the marginal value of health solves the recursion:

$$\begin{aligned} V_{H,t} = & \underbrace{\beta_{H,t}^m E_t \{V_{t+1} - U_{t+1}^m | H_t\}}_{\text{Mortality control value}} + \underbrace{\beta^m(H_t) E_{H,t} \{V_{t+1} | H_t\}}_{\text{Morbidity control value}} \\ & + \underbrace{\beta^m(H_t) E_t \{V_{H,t+1} [1 - \delta_t - \phi_t \epsilon_{t+1}^s + A_t I_{H,t}^g] | H_t\}}_{\text{Durability and productive capacity value}}, \end{aligned} \quad (15)$$

where we have set,

$$\begin{aligned} E_{H,t} \{V_{t+1} | H_t\} &= -\lambda_{H,t}^s \exp[-\lambda^s(H_t)] E_t \{V(W_{t+1}, H_{t+1}^+) - V(W_{t+1}, H_{t+1}^-)\} \\ H_{t+1}^+ &\equiv (1 - \delta_t) H_t + A_t I^g(H_t, I_t, \ell_t) \\ H_{t+1}^- &\equiv H_{t+1}^+ - \phi_t H_t \end{aligned} \quad (16)$$

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

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 favor 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. Being uninsured ( $\mathbb{1}_X = 0$ ) clearly raises the effective price of investment ( $OOP_I = P^I$ ) and therefore the current marginal OOP cost of health expenditures, thereby lowering their attractiveness. Moreover, as Figure 2 makes clear, the marginal OOP cost of health expenditures is kinked at the deductible for insured agents, and encourages them to spend more once the deductible  $D_t$  is reached. Medicare also implies that  $OOP_{I,t}^x$  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 accompanied by exogenous increases in productivity  $A_t$ , providing additional justification (to age-increasing depreciation) for the higher demand for health care observed for elders (e.g. Hall and Jones, 2007; Fonseca et al., 2013).

Equation (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 in terms of OOP reduction is lower for the insured ( $\mathbb{1}_X = 1$ ) thereby making self-insurance through healthy activities less advantageous, once the deductible is covered ( $\mathbb{1}_D = 1$ ). The effects of Medicare on the leisure-investment trade-off are mixed. On the one hand, Medicare taxes reduce the opportunity cost of leisure regardless of age. On the other hand, the reduction in marginal out-of-pocket cost after Medicare coverage begins alters the leisure-investment trade-off, and encourages elders to work more instead.

Finally, the Envelope condition (15) decomposes the marginal value of health into three parts. The first right-hand side term includes the benefits obtained through the reduction in mortality risk  $\beta_{H,t}^m > 0$  times the continuation utility net of bequest utility. Since  $U_{t+1}^m < 0$ , the increased expected benefit of surviving for healthier agents

is augmented by a lower expected utility cost associated with dying, thereby ensuring that the marginal value of lower mortality risk for healthier agents is always positive. The second right-hand side term includes the marginal value of morbidity risk reduction  $E_{H,t}$ . A straightforward argument indicates that this value is positive.<sup>12</sup> In the third component, durability and productive capacity also implies that the marginal value of health captures the expected future marginal value of the undepreciated health stock, plus the marginal product of health in the gross investment technology. As equations (15) and (16) make clear, imposing exogenous mortality ( $\lambda_H^m = \beta_H^m = 0$ ), exogenous morbidity ( $\lambda_H^s = 0$ ), and path independent gross investment ( $I_H^g = 0$ ) restrict the marginal value of health to its (lower) durability value only. The optimality conditions (13) and (14) show that exogeneity and path independence thus reduce the attractiveness of investing in health through expenditures and through healthy leisure. Note finally that undepreciated health will decline with ageing as the depreciation rates  $\delta_t, \phi_t$  become large. Increasing depreciation plus finite lives and non bequeathable health then make it increasingly costly to maintain the health capital for the elders.

## 4 Empirical strategy

This section outlines the empirical methods that we rely upon to solve and estimate the model. After discussing the choice of functional forms and insurance plans, we introduce the iterative, and simulation procedures from which the Simulated Moments Estimation is obtained.<sup>13</sup> We close the section by an overview of the data used in the estimation.

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<sup>12</sup>Conjecture that  $V_{H,t} > 0, \forall t$  in (15), in which case  $\beta^m(H_t)E_{H,t}\{V_{t+1} | H_t\} > 0$  in (16) since health is valuable and the low future health outcome is less likely for healthier agents ( $\lambda_{H,t}^s \leq 0$ ). Observing that  $\beta_{H,t}^m > 0$ , and  $U^m(W_{t+1}) < 0$ , while  $\delta_t + \phi_t < 1$  and  $I_{H,t}^g \geq 0$  and solving forward (15) then confirms the positive marginal value of health conjecture.

<sup>13</sup>A more detailed technical appendix outlining the empirical procedure is available upon request.

## 4.1 Functional forms and insurance plans

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

$$\lambda^m(H) = \lambda_0^m + \lambda_1^m H^{-\xi^m}, \quad (17)$$

$$\lambda^s(H) = \lambda_2^s - \frac{\lambda_2^s - \lambda_0^s}{1 + \lambda_1^s H^{-\xi^s}}, \quad (18)$$

$$I^g(H, I, \ell) = I^{\eta_I} \ell^{\eta_\ell} H^{1-\eta_I-\eta_\ell}, \quad \eta_I, \eta_\ell \in (0, 1), \quad (19)$$

$$U(C, \ell) = [\mu_C C^{1-\gamma} + (1 - \mu_C) \ell^{1-\gamma}]^{\frac{1}{1-\gamma}}, \quad \mu_C \in (0, 1), \quad (20)$$

$$U^m(W) = \mu_m \frac{W^{1-\gamma}}{1-\gamma}. \quad (21)$$

Equations (17) and (18) both encompass limits to self-insurance as the intensities are bounded below by  $\lambda_0^k = \lim_{H \rightarrow \infty} \lambda^k(H)$ , whereas exogeneity of the morbidity and mortality risks is obtained by imposing the restrictions  $\lambda_1^k = 0$  or  $\xi^k = 0$ ,  $k = m, s$ . Morbidity risk is also bounded above by  $\lambda_2^s = \lim_{H \rightarrow 0} \lambda^s(H)$  to avoid spiraling optimal paths where health falls, inducing more sickness, and further depreciation and certain subsequent sickness and death (see Hugonnier et al., 2013, for discussion). The Cobb-Douglas technology (19) ensures diminishing returns to expenditures, leisure and health inputs for gross investment, whereas the Constant Elasticity of Substitution (CES) specification (20) allows for unconditionally positive utility and therefore helps guarantee preference for life over death,  $\mathcal{U}_t > 0$  in (10).<sup>14</sup> Conversely, the bequest function (21) is negative when the curvature parameter  $\gamma$  is greater than one, ensuring that death is costly, whereby the marginal value of bequeathed wealth remains positive.

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<sup>14</sup>For completeness, we also experimented with a variant of preferences (20) allowing for explicit utility for health:

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

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

Next, we consider four exogenous insurance plans corresponding to No and Private insurance when young ( $1 \leq t < 65$ ), and No, and Medicare when old ( $t \geq 65$ ), and denoted  $x = (x_y, x_o) \in \mathbb{X} = \{\text{PM}, \text{PN}, \text{NM}, \text{NN}\}$ .<sup>15</sup> The descriptions as well as corresponding expressions for OOP's, premia and income are outlined in Table 4. Plan PM (our benchmark case) encompasses full insurance. Plan PN captures the effects of employment-provided insurance which is terminated at retirement, whereas plans NN and NM illustrate the effects of market failures leading to exclusion from health insurance. This classification allows for a convenient identification of the marginal effects of (i) young agents insurance status conditional on the elders insurance status (by contrasting PM vs NM, and PN vs NN), as well as those of the (ii) elders' insurance status conditional on young insurance status (by contrasting PM vs PN and NM vs NN).

## 4.2 Iteration

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

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

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

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<sup>15</sup>Plan NP is arguably of limited empirical relevance, and is abstracted from. Plan PP was also considered with results qualitatively similar to those under plan PM.

plan-specific allocations, and welfare are obtained as:

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

and are used in the simulation phase.<sup>16</sup>

### 4.3 Simulation

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  $\epsilon$  generated from the endogenous intensities in (1) and the laws of motion for  $Z$  in (2) and (9). Specifically, for each simulated agent  $i = 1, 2, \dots, K_I$  and Monte-Carlo replication  $n = 1, 2, \dots, K_N$  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  $t = 16, 17, \dots, T$ ,
  - (a) Optimal rules  $Q_t^{i,n}$  and value function  $V_t^{i,n}$  are computed using a bilinear interpolation of the policy functions (23) that were obtained in the iterative phase, and are evaluated at the state  $Z_t^{i,n}$ .
  - (b) Mortality and morbidity shocks are endogenously drawn from the generalized Bernoulli,

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

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<sup>16</sup>To facilitate exposition, we henceforth drop the explicit dependence of variables on plan  $x$  from the notation.

(c) State variables are updated,

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

The output sequence  $\{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\}$ , is the one along the optimal path over ages  $t = 16, \dots, T$ , and can be used to compute both the life cycle and the unconditional statistics across surviving agents. In particular, let  $\mathbb{1}_t^{i,n} \in \{1, \text{NaN}\}$  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:

$$\begin{aligned} \hat{M}_t &= \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n} \{Q_t^{i,n}, V_t^{i,n}, Z_t^{i,n}\}}{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}, \\ \hat{S}_t &= \frac{\sum_{i=1}^{K_I} \sum_{n=1}^{K_N} \mathbb{1}_t^{i,n}}{K_I K_N}. \end{aligned} \quad (24)$$

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

$$\hat{M} = \frac{\sum_{t=16}^T \hat{M}_t}{T - 16}, \quad (25)$$

$$\hat{S} = \sum_{t=16}^T \hat{S}_t. \quad (26)$$

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

#### 4.4 Calibration and estimation strategy

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

is the estimated parameters subset:

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

The values for the calibrated parameter  $\Theta^c$  are identified via the literature whenever possible, and through an extensive trial and error process. The estimated parameters  $\Theta^e$  are those for which we have scant prior information, namely the parameters of the intensity processes  $\lambda^k(H)$ , as well as the deterministic and stochastic depreciation processes  $(\delta_t, \phi_t)$ . The coefficient of relative risk aversion  $\gamma$  is also included in the estimation set as further check of the model. The parameters in  $\Theta^e$  are identified through an SME estimator. In particular, let  $\hat{\mathbf{M}}(\Theta) \in \mathbb{R}^{K_M}$  be the collection of theoretical life cycle moments  $\{\hat{M}_t\}$  given in (24),  $\mathbf{M} \in \mathbb{R}^{K_M}$  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  $\Theta^e$  is given as:

$$\hat{\Theta}^e = \underset{\Theta^e}{\operatorname{argmin}} [\hat{\mathbf{M}}(\Theta) - \mathbf{M}]' \Omega [\hat{\mathbf{M}}(\Theta) - \mathbf{M}]. \quad (27)$$

In practice, the theoretical life cycles moments  $\hat{\mathbf{M}}(\Theta)$  in (27) are computed over 5-year intervals between the age of 20 and 80, and involve out-of-pocket expenditures, leisure, wealth, and health for our benchmark insurance case PM (Private when young, Medicare when old).<sup>17</sup> The corresponding empirical moments  $\mathbf{M}$  are taken from various widely-used health and socio-economic surveys corresponding to the American population for years 2010 and 2011, and are discussed in further details below. The SME of  $\hat{\Theta}^e$  in (27) is consequently over-identified with a total of 52 moments (i.e. 4 life cycles  $\times$  13 five-year bins) that are used to identify 9 structural parameters.

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<sup>17</sup>More precisely, we initialize the simulation by taking 100 draws (without replacement) from the observed distribution over health and wealth at age 16, such that this sample is representative of the general population at the beginning of adult age. We then simulate 500 trajectories from the initial grid along the optimal path. This procedure is therefore equivalent to simulating 50'000 individual life cycles from which the 5-year moments are computed.

Our estimation strategy differs substantially from mainstream practices in structural estimation of life-cycle models. In particular, standard approaches subsequently append exogenous stochastic processes to the numerical solutions of 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 first 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 only upon the realization of the morbidity and mortality shocks which are drawn from the *endogenous* intensities given by (1). Put differently, exogenous processes are neither appended ex-post 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 number of moments we consider is much larger, and corresponds to an extensive set of conditional means generated by the model (i.e. allocations, and state variables along the optimal paths). This additional information plays a crucial role in allowing us to identify and estimate a larger subset of deep parameters for which we have limited prior information.

## 4.5 Data

Our empirical strategy requires life cycle data on leisure, out-of-pocket health expenditures, wealth, and health status.<sup>18</sup> Ideally, a single panel data-base regrouping all these variables would be used. Unfortunately, to the best of our knowledge, such a data-base does not exist. We therefore rely on various well-known panels that are representative of the American population at a given point in time. These sources are presented in Table 5.

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<sup>18</sup>We also solve for health investment, but do not include it in the SME procedure. Comparable health investment data refers to the quantity consumption and utilization rates of health services, and is more difficult to measure than OOP's, and is therefore abstracted from the empirical evaluation. In the spirit of out-of-sample validation, we nonetheless use a quantity proxy defined as mean expenses divided by the medical price index in assessing the model's life cycle performance (see Figure 6).

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). Out-of-pocket medical expenses are taken from the Medical Expenditures Survey (MEPS), and are the mean OOP expenses per person, conditional upon expenditures.

Finally, consistent with the income equation (8), healthy leisure is the amount of time spent not working, and is obtained from the American Time Use Survey (ATUS). One could reasonably argue that only a limited share, say  $\chi \in (0, 1)$ , of total leisure time, say  $L_t = 1 - N_t$ , is actually spent on healthy leisure activities, i.e.  $\ell_t = \chi L_t$  while the rest is engaged in non-healthy leisure (e.g. couch potatoes). This is inconsequential for our approach since substituting in the Cobb-Douglas technology (19) and using the TFP process (4) reveals that effective gross investment is now  $A_t I_t^g = \tilde{A}_t I_t^{\eta_I} L_t^{\eta_L} H_t^{1-\eta_I-\eta_L}$ , where  $\tilde{A}_t \equiv A_t \chi^{\eta_L} = \tilde{A}_0 \exp[g^A(t + \kappa)]$  is the effective TFP. Since the initial technology  $\tilde{A}_0$  is a calibrated free parameter, it implicitly encompasses the effective healthy leisure share.

## 5 Results

Following a brief discussion of the estimated and calibrated parameters, we present the output obtained from the iterative phase, followed by the results obtained from the simulation phase.

### 5.1 Parameters

The estimated and calibrated values (Panel a) and calibration sources (Panel b) for some of the main parameters of interest are displayed in Table 6, whereas the remaining

calibrated parameters are presented in Table 7. The standard errors are reported in parentheses (omitted) for the parameters that are estimated (calibrated). The estimation results confirm that all our structural estimates  $\Theta^e$  are significant at the 5% level.

First, regarding the mortality (17), and the morbidity (18) intensities, our estimated parameters warrant the conjecture that both mortality and morbidity are endogenous ( $\lambda_1^s, \lambda_1^m \neq 0$ ), and that both risks are not fully diversifiable ( $\lambda_0^s, \lambda_0^m \neq 0$ ). Unsurprisingly, they also confirm that the endowed incidence of sickness is much more likely than that of death ( $\lambda_0^s > \lambda_0^m$ ), whereas the large calibrated value for  $\lambda_2^s$  is consistent with the absence of limitations in morbidity risk reduction. Finally, both the calibrated curvature ( $\xi^s > \xi^m$ ), and the estimated endogenous ( $\lambda_1^s > \lambda_1^m$ ) parameters are consistent with more potent effects of better health in reducing sickness, than death risk.

Second, the depreciation parameters confirm that both deterministic and stochastic depreciations (3) are positive ( $\delta_0, \phi_0 > 0$ ), and are increasing in age ( $g^\delta, g^\phi > 0$ ). Figure 1.a shows that stochastic morbidity  $\phi_t$  is a strong determinant of total health depreciation rates, and that sickness is much more consequential for elders. We also witness a positive exogenous trend in healthcare productivity (4) that is however less than that observed in Table 7 with respect to health care prices and insurance deductibles ( $0 < g^A < g^P, g^D$ ). Furthermore, the calibrated values  $\eta_I, \eta_\ell$  for the health investment technology (19) are indicative of an important role of healthy leisure, and of current health status in the gross investment function.

Third, the preferences parameters in (20) and (21) are consistent with a consumption (leisure) share of  $\mu_C = 1/3$  ( $\mu_\ell = 2/3$ ) (e.g. Kydland, 1995, p. 148), and a low weight  $\mu_m = 2\%$  attributed to joy-of-giving in the bequest function (e.g. French and Jones, 2011; De Nardi et al., 2009). The estimated curvature parameter indicates that consumption and leisure are mainly complements, with a low elasticity of substitution between the two ( $1/\gamma < 1$ ), and that the risk aversion with respect to bequeathed wealth is realistic.

## 5.2 Iterative results

Figure 3 displays the optimal allocations, as well as the welfare functions of the pre-determined health and wealth state. For that purpose, we compute the mean values between ages 60–65, under benchmark plan PM.<sup>19</sup>

Our results confirm that, unless both health and wealth are very low, consumption, leisure, and out-of-pocket expenses are all decreasing in health. As discussed earlier, a lower risk of dying when health improves is tantamount to lower discounting and encourages the healthier agent to reduce consumption and increase savings in the face of a longer expected life horizon. Moreover, the health dynamics (2) entail that better current health increases expected future health which, when combined with the lower risk of becoming sick for healthier agents, justifies a reduction in both health expenditures, and healthy leisure activities. However, for the very poor and very unhealthy, the risk of dying becomes high enough that investment is abandoned in favor of other expenses when health deteriorates further. As expected, both consumption and leisure are increasing in wealth. Investment however is not monotone in wealth; it first increases for the unhealthy, and then falls in wealth in favor of more leisure when sufficiently healthy. Finally welfare is clearly monotone increasing in both wealth and health, as can be expected from the discussion of Envelope condition (15). Observe that concavity is more pronounced with respect to health, as could be anticipated from the diminishing returns in the self-insurance technology (17) and (18), and in the gross investment function (19).

## 5.3 Simulation results

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

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<sup>19</sup>Other results are available upon request.

### 5.3.1 Unconditional moments

We first compute the unconditional statistics (25) for the surviving agents over ages 20–80, as well as the expected lifetime (26). This exercise is repeated for the four health insurance plans (PM, PN, NN and NM).<sup>20</sup> Comparing the simulated with the observed moments in Table 8 confirms that the model does quite well in capturing the age-independent features of the data. Indeed, out-of-pocket expenditures, leisure, wealth, health and expected longevity are all accurately reproduced.

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

### 5.3.2 Life-cycle properties

The simulated life cycles are presented in Figures 4–9, and are given as the mean allocations, and states at each age across the simulation output, using (24). To facilitate the discussion, the observed (red line, when available) and the simulated (blue line) levels are reported in Panels A, where the simulation corresponds to our benchmark PM case. The confidence intervals are computed from the estimated variance-covariance of the parameters, using the delta method, and are plotted as the dashed blue lines for the variables with observable counterparts. We also report the marginal effects of being insured when young (i.e. PM-NM, and PN-NN) in Panels B, and the marginal effects of being insured when old (i.e. PM-PN, and NM-NN in Panels C).

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<sup>20</sup>More precisely, using the calibrated and estimated parameters for our benchmark case PM, we recalculate the iterative and simulation output for each of the three other insurance plans, from which the life cycles, and the unconditional moments are computed. Ideally, separate estimations would have been performed for each of the four alternative cases. However, data limitations (noticeably the fact that plans PN or NN are not observed) imposes a unique estimation relying on the most prevalent case – plan PM – and a counter-factual exercise relying on the same set of estimated parameters.

The simulated health statuses in Figure 4.A predict levels, as well as an optimal decline that are consistent with those observed for the data.<sup>21</sup> Our results in Panel B indicate that young insured agents are healthier, starting at mid-life. The effects are long-lasting because of the persistence in the health dynamic process (2).<sup>22</sup> Persistence in better health is also more important when the elder's status is uninsured (PN-NN), consistent with insured young agents building up precautionary health stock before coverage terminates. The results in Panel C are consistent with stockpiling whereby young uninsured agents who will be insured when old (NM-NN) optimally choose to let health run down and substitute better health when old and insured.<sup>23</sup>

Second, the levels and life-cycle increases in out-of-pocket expenditures displayed in Figure 5.A are consistent with those observed in the data, with the exception of the 60's, where the model somewhat underestimates the actual levels. This underestimation of OOP's can be traced to our assumption that everyone is insured at all ages under our benchmark PM case, whereas a sizable share of the US pre-retirement population remain uninsured (see footnotes 2 and 29). Both Panels B and C indicate a sharp reduction in OOP's for the insured, with little evidence of pre- or post-coverage effects. The health investment life cycle in Figure 6.A shows a lifetime increase which is consistent with patterns observed in the data, except also for an underestimation of actual investment between the ages 60-80. In Panel B, being insured when young induces an increase in health-care consumption after age 30, that accelerates at retirement, but with little spillovers afterwards. Similarly, Panel C shows an increase in investment after entitlement begins for the insured elders, but little pre-retirement effects.<sup>24</sup>

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<sup>21</sup>See Case and Deaton (2005); Scholz and Seshadri (2012); Van Kippersluis et al. (2009) for further evidence and discussion of observed health evolution.

<sup>22</sup>See also McWilliams et al. (2007) for medical evidence that previously insured young agents have better morbidity conditions after age 65.

<sup>23</sup>Stockpiling prior to Medicare coverage has been identified by Ozkan (2011); Scholz and Seshadri (2012). Health improving effects, and moderate increases in longevity for elders under Medicare have been also identified by Lichtenberg (2002); Khwaja (2010); Finkelstein and McKnight (2008); Card et al. (2009); Scholz and Seshadri (2012).

<sup>24</sup>Significant reduction in OOP exposure under Medicare has been identified by Khwaja (2010); Finkelstein and McKnight (2008); Scholz and Seshadri (2012); De Nardi et al. (2010). Lichtenberg (2002); Finkelstein (2007); Card et al. (2009) also present evidence of increased consumption of health care for old insured.

Third, the observed leisure life cycle in Figure 7.A is also reproduced quite well by the model, although we tend to underestimate somewhat the sharp reduction in working time after retirement.<sup>25</sup> Panel B shows that young insured prefer to reduce their healthy leisure, especially at mid-life when wages are at their highest levels, before wages fall sharply after retirement (see Figure 1.b). Similarly, insured elders in Panel C substitute less leisure at mid life in favor of more later on, after wages have fallen.<sup>26</sup>

Fourth, wealth life cycles are also reproduced very accurately by the model in Figure 8.A, with optimal accumulation when young and dissaving after retirement.<sup>27</sup> We saw that being insured when young reduces exposure to OOP expenditures and induces a reduction in healthy leisure time, i.e. an increase in labor supply. Furthermore, the increase in health levels discussed earlier leads to longer expected life horizon (Table 8). All elements concur to increase the optimal wealth levels in Panel B. The effect of better longevity also justifies building up more wealth balances when young for insured elders in Panel C.

Finally, since welfare is monotone increasing in both health and wealth (Figure 3.D), it displays a similar inverted U shape as the latter in Figure 9.A, peaking at age 65 before falling under the combined influence of diminishing health and wealth afterwards.<sup>28</sup> In Panels B and C, longer expected lifetime, better health and wealth, as well as reduced exposure to morbidity and OOP risks justify why being insured is unambiguously welfare increasing after mid life, especially when uninsured in the other periods. The absence of clear welfare gains prior to age 40 is consistent with the larger incidence of uninsurance among younger cohorts,<sup>29</sup> and is explained by the low wages (Figure 1.b), the relatively

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<sup>25</sup>See Rust and Phelan (1997) for further discussion of leisure-work decisions around age 65.

<sup>26</sup>analyses of Medicare on elders' leisure choices also are indicative of more leisure after retirement (Currie and Madrian, 1999; French, 2005).

<sup>27</sup>See also De Nardi et al. (2010, 2009); Dynan et al. (2004) for discussion and evidence of asset decumulation in old age.

<sup>28</sup>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.

<sup>29</sup>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.

high endowed health level (Figure 4.A), and therefore low morbidity rates, and the low accumulated wealth (Figure 8.A) which all contribute to raise the marginal cost of insurance premia.

## 5.4 Robustness to the cohort effects

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

In order to better understand how these cohort effects may influence our results, we recompute the full iterative and simulation output for the PM benchmark case, taking as given the estimated parameters, but changing the cohort indicators  $\kappa$ . Inspecting the medical TFP (4), the medical prices (6), and the deductibles (7) processes reveals how the life cycle allocations should be altered. In Figure 10, we plot our benchmark life cycles for  $\kappa = -37$  (dashed blue line), along with those corresponding to a younger cohort  $\kappa = -30$  (solid blue line), and to an older cohort  $\kappa = -44$  (solid red line). Our results show (i) remarkable qualitative robustness to changing the cohort, and (ii) marginal cohort effects that are consistent with intuition. Since younger (older) cohorts have access to better (worse) health technology, they achieve better (worse) health levels in Panel A. Longer expected horizon explains why the younger cohort need to maintain

higher post-retirement wealth balances in Panel B. Better health technology further allows the younger cohort to take on less leisure (Panel C). Finally, the combination of higher prices and deductibles explain why they must also spend more on OOP expenditures (Panel D).

## 6 Conclusion

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

This paper proposes a (relatively) simple model that is capable of keeping track of these complex mechanisms. This framework relies on three fundamental hypotheses. First, we follow a long tradition in Health Economics in modeling health as a depreciable, and adjustable human capital in order to account for persistence. Second, exposition to morbidity and mortality risks can be (partially) adjusted through health investment and leisure decisions. This allows us to account for self-insurance, as well as for substitution, both in the inter-temporal domain, and among the various health-maintenance instruments. Third, agents are not myopic, but are forward looking in their dynamic decisions, thereby fully accounting for backward induction elements. We solve, simulate and estimate this model under a benchmark case for insurance status. This

exercise reveals remarkable consistency with respect to observed unconditional and life cycle moments.

By varying the health insurance status when young (conditional on old status), and when old (conditional on young status), we are able to identify the marginal effects on the life cycle allocations. We show that better health obtains for young insured, and that this effect persists long after retirement. Insured elders are also healthier after retirement, but stockpile health maintenance when young until after coverage begins. Health insurance also implies substitution in the form of less leisure, and therefore more labor supply, especially at mid life when wages are at their highest level. Better health entails less exposure to sickness risk (which reduces the need for precautionary wealth balances), but longer expected lifetime (which increase the need for post-retirement wealth balances). Combined with more work, the latter is the dominant force behind higher wealth for the insured.

Finally, our results show that the conjunction of lower health expenses risk exposition, more longevity, better health and larger wealth balances imply that health insurance is unambiguously welfare increasing starting at mid-life. Before that age, high endowed health, low wages and low accumulated financial resources means that self-insurance remains a valid alternative to market-provided insurance. Note that welfare improvements of health insurance does not imply dynamic Pareto optimality from society's point of view. Indeed, our bequest motive is low, such that our agents have limited concern for the future generations who end up paying part of the current costs of public insurance schemes such as Medicare or PPACA. Moreover, the general-equilibrium efficiency costs of tax-financed insurance schemes have not been addressed in our model and could turn out to be quite important.

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## A Tables

**Table 1:** Medicare 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

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

**Table 4:** Insurance plans, net effects and restrictions

(a) Statuses and net effects				
		Status: old		
Status: young	Insured	Uninsured	Net effects	
Insured	PM	PN		Insured old
Uninsured	NM	NN		
Net effects	Insured young			

(b) OOP's, premia, and income				
plan $x$	$OOP_t^x(I_t)$	$\Pi_t^x$	$Y_t^x(\ell_t)$	
PM	$P_t^I I_t - \mathbb{1}_D(1 - \psi)(P_t^I I_t - D_t)$	$\Pi[1 - \mathbb{1}_R(1 - \pi)]$	$\mathbb{1}_R Y^R + (1 - \tau)w_t(1 - \ell_t)$	
PN	$P_t^I I_t - (1 - \mathbb{1}_R)\mathbb{1}_D(1 - \psi)(P_t^I I_t - D_t)$	$(1 - \mathbb{1}_R)\Pi$	$\mathbb{1}_R Y^R + w_t(1 - \ell_t)$	
NM	$P_t^I I_t - \mathbb{1}_R \mathbb{1}_D(1 - \psi)(P_t^I I_t - D_t)$	$\mathbb{1}_R \Pi \pi$	$\mathbb{1}_R Y^R + (1 - \tau)w_t(1 - \ell_t)$	
NN	$P_t^I I_t$	0	$\mathbb{1}_R Y^R + w_t(1 - \ell_t)$	

*Notes:* Insurance plans: (N)o insurance, (P)ivate 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
<i>W</i>	Survey of Consumer Finances (SCF), Federal Reserve Bank. Financial assets held.
<i>H</i>	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.
<i>S</i>	National Vital Statistics System (NVSS), Center for Disease Control. Survival rates
<i>I</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, divided by price of medical goods and services $P_I$ .
<i>OOP</i>	Consumer Expenditures Survey (CEX), Bureau of Labor Statistics. Table 3, average annual expenditures and characteristics, by age of reference person. Healthcare minus Health insurance plus 50% Personal care products and services.
$\ell$	American Time Use Survey (ATUS), Bureau of Labor Statistics. Share of usual hours not worked per week, $1 - \text{uhrsworkt}/40$

**Table 6:** Key parameters

(a) Estimated and calibrated parameter values

Mortality (17)			
$\lambda_0^m$	$\lambda_1^m$	$\xi^m$	
0.0061 (0.0021)	0.0073 (0.0026)	2.5	
Morbidity (18)			
$\lambda_0^s$	$\lambda_1^s$	$\lambda_2^s$	$\xi^s$
0.3376 (0.1621)	3.6041 (1.1022)	50.0	4.9
Depreciation (3)			
$\delta_0$	$g^\delta$	$\phi_0$	$g^\phi$
0.0198 (0.0066)	0.0146 (0.0054)	0.0592 (0.0266)	0.0106 (0.0051)
TFP (4) and gross investment (19)			
$A_0$	$g^A$	$\eta_I$	$\eta_\ell$
1.5	0.004	0.20	0.40
Preferences (10), (20) , (21)			
$\mu_C$	$\mu_M$	$\beta$	$\gamma$
0.33	0.02	0.9656	3.8769 (1.8005)

(b) Calibrated parameters sources

$\xi^m, \lambda_2^s, \xi^s$	Hugonnier et al. (2013, Tab. 2)
$\eta_I, \eta_\ell$	Free parameters
$A_0, g^A$	Free parameter, The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
$\mu_C, \mu_m, \beta,$	Various literature, and French and Jones (2011), De Nardi et al. (2009)

*Notes:* Standard errors reported in parentheses (omitted) for estimated (calibrated) parameters. Estimated parameters based on SME estimator (27).

**Table 7:** Other calibrated parameter values and sources

(a) Calibrated values

parameter	value	parameter	value	parameter	value	parameter	value
$T$	100	$\kappa$	-37				
$\psi$	0.200	$\Pi$	0.0413	$\Pi^M$	0.0167		
$P_0^I$	1.6504	$g^P$	0.0064	$D_0$	0.0100	$g^D$	0.0064
$Y^R$	0.1476	$\tau$	0.0145	$R^f$	1.04		
$W_{\min}$	0.05	$W_{\max}$	5	$H_{\min}$	0.1	$H_{\max}$	3
$C_{\min}$	0.05	$C_{\max}$	1	$I_{\min}$	0.01	$I_{\max}$	0.10
$\ell_{\min}$	0.10	$\ell_{\max}$	1				
$K_Z$	$(20 \times 20)$	$K_Q$	$(30 \times 30 \times 30)$				

(b) Sources

$T, \kappa$	Life tables, Arias (2010). Median age, U.S. Census Bureau (2011a, Tab. 2, p. 4).
$P_0^I, g^P$	National Center for Health Statistics (2012), Tab 126, CPI and annual percent change for all items, selected items and medical care components, 2010.
$\psi, \Pi, \Pi_M, \tau, D, g^D$	Henry J. Kaiser Family Foundation (2011a,b); Medicare.gov (n.d.). The Boards Of Trustees, Federal HI and SMI Trust Funds (2012, p. 190)
$R^f$	Federal Reserve Bank of St-Louis (n.d.).
$Y^R$	Average monthly Social Security benefit for a retired worker Social Security Administration (n.d.).
$w_t$	Median usual weekly earnings of full-time wage and salary workers by selected characteristics, 2010 annual averages Bureau of Labor Statistics (2011, Tab 1)

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

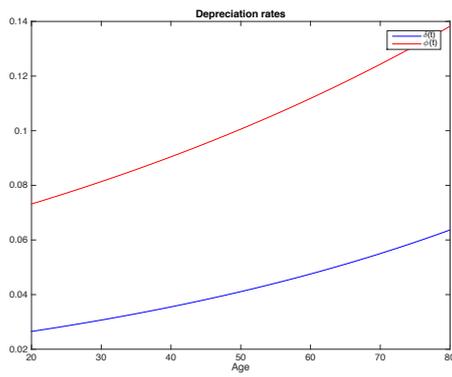
**Table 8:** Data and simulated unconditional moments (age 20–80)

Series	Data	Simulated			
		PM	PN	NN	NM
Out-of-pocket, $OOP^*$	0.0162	0.0138	0.0156	0.0218	0.0199
Leisure, $\ell$	0.3774	0.3784	0.3808	0.3877	0.3852
Wealth, $W^*$	2.2112	2.2933	2.2465	1.9364	1.9754
Health, $H$	2.0863	2.0184	2.0184	2.0126	2.0142
Survival, $S^\dagger$	77.9	78.17	78.15	77.42	77.76
Welfare, $V$	NaN	6.5767	6.5267	6.2101	6.3785

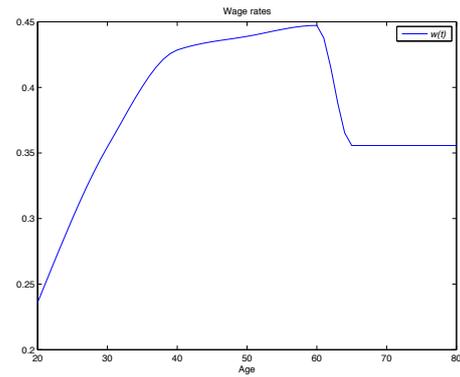
*Notes:* Unconditional statistics computed using (24)–(26). \*: in 100,000\$ †: in years.

## B Figures

**Figure 1:** Depreciation rates and wages



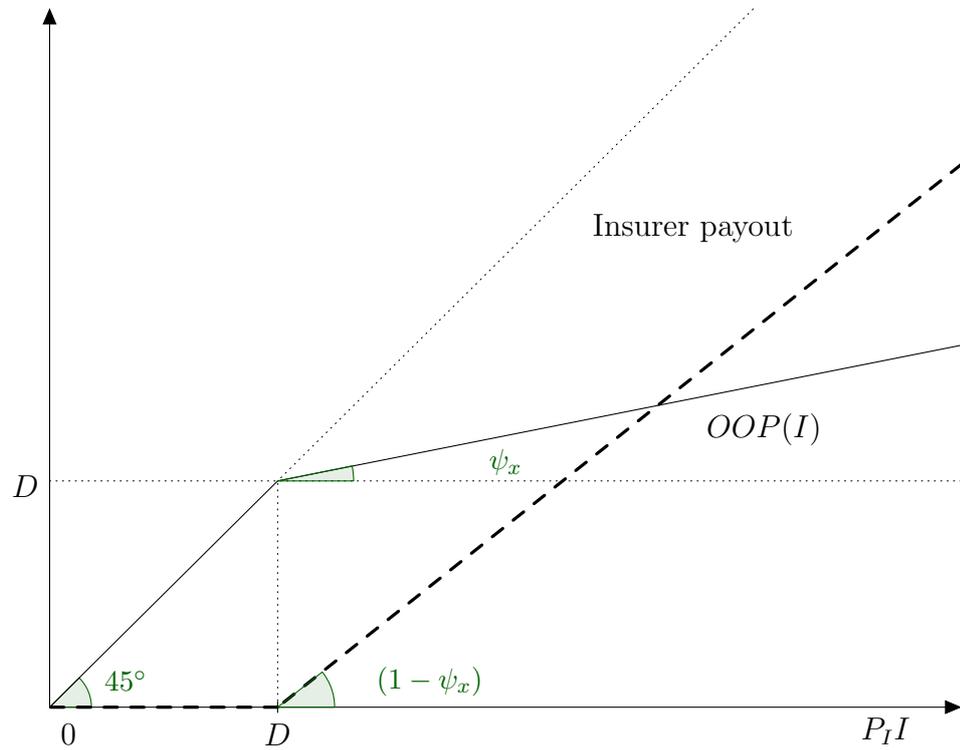
(a) Depreciation



(b) Wages

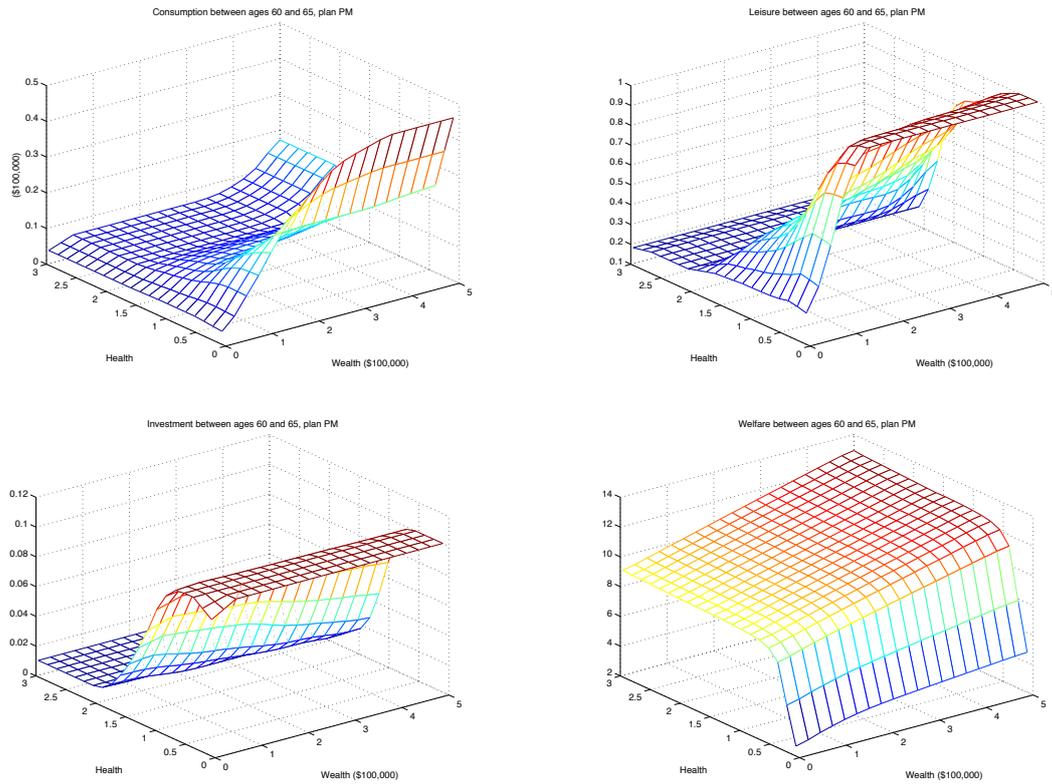
*Notes:* (a) From estimated parameters in Table 6.a; (b) Bureau of Labor Statistics (2011, Tab. 1).

**Figure 2:** Out-of-pocket health expenditures and insurer payouts



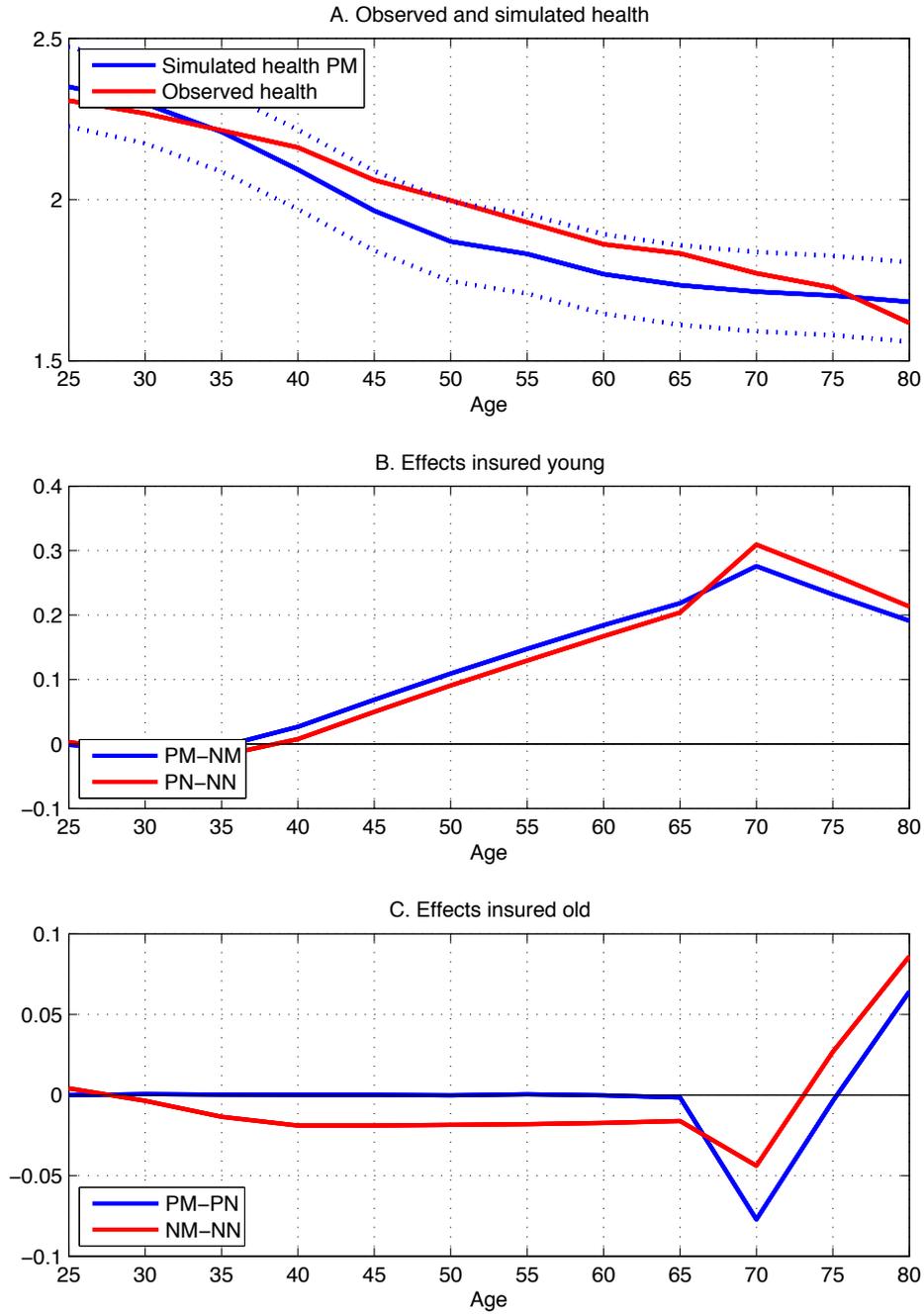
*Notes:* Solid line: Out-of-pocket expenditures (5) for deductible  $D$  and co-payment rate  $\psi$  as function of health expenditures  $P_I I$ . Dashed line: Insurance payout by insurer.

Figure 3: Iteration results



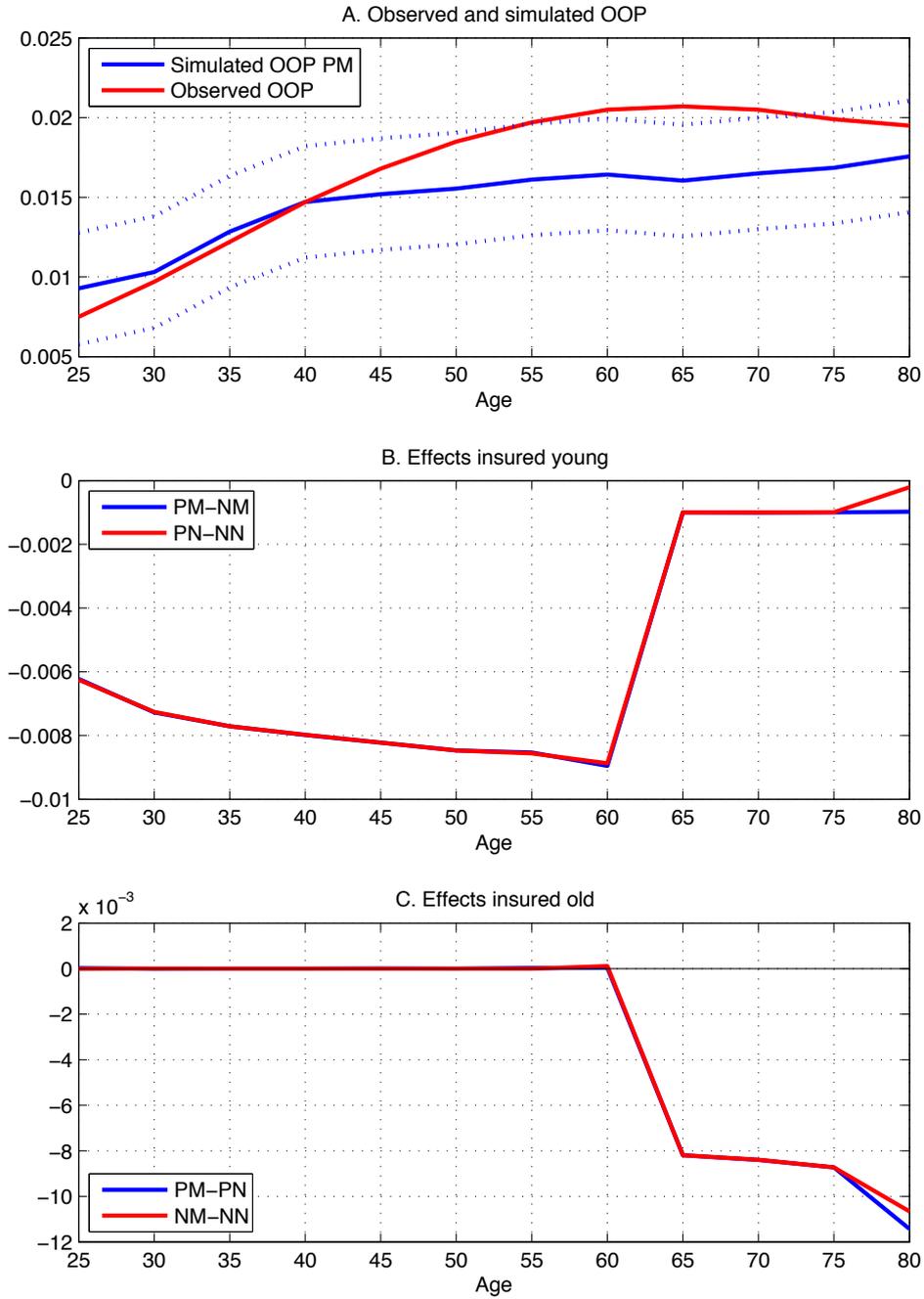
Notes: Optimal allocations and welfare (23) calculated between ages 60-65, under benchmark plan PM.

**Figure 4: Life cycle health**



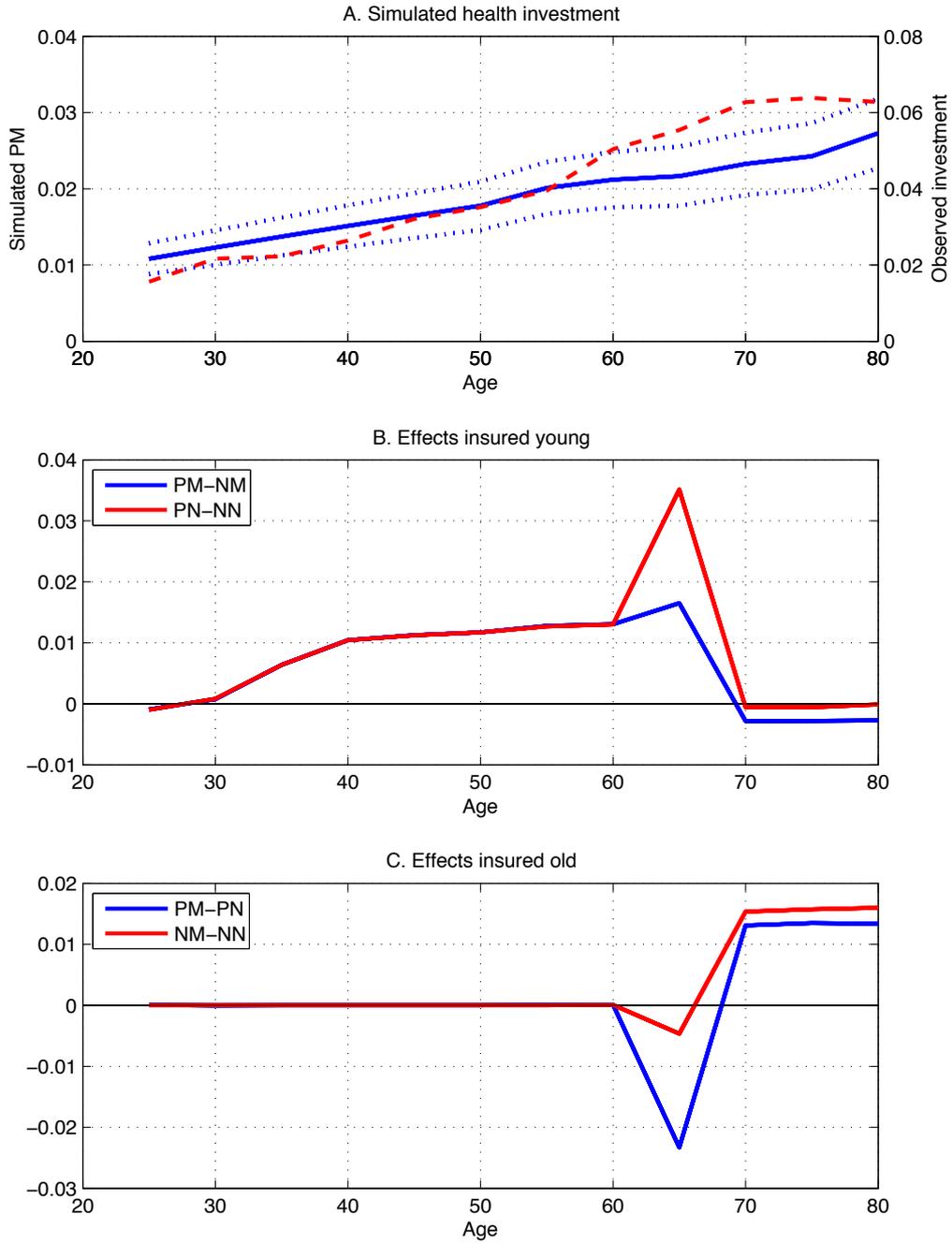
*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

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



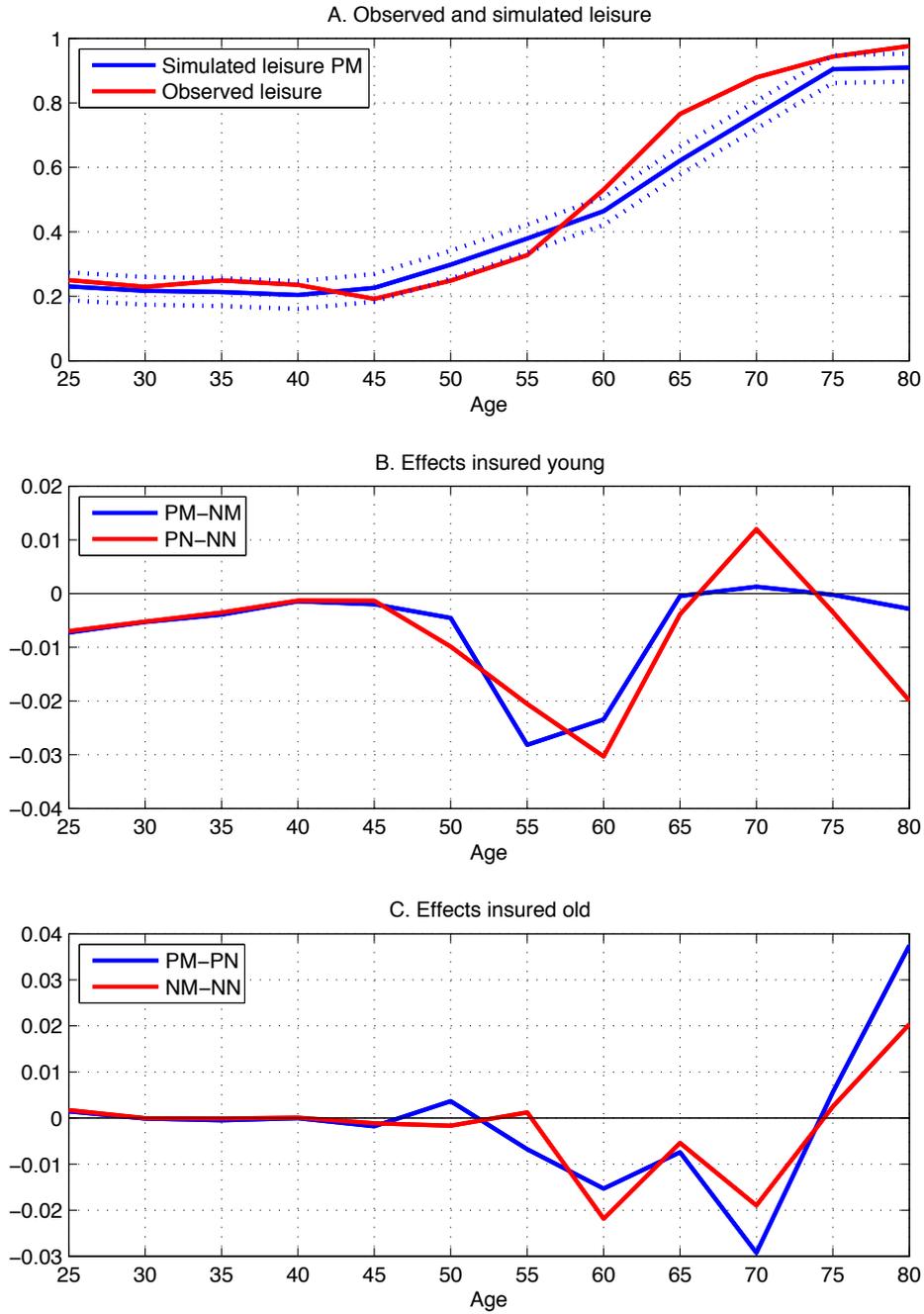
*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

**Figure 6: Life cycle health investment**



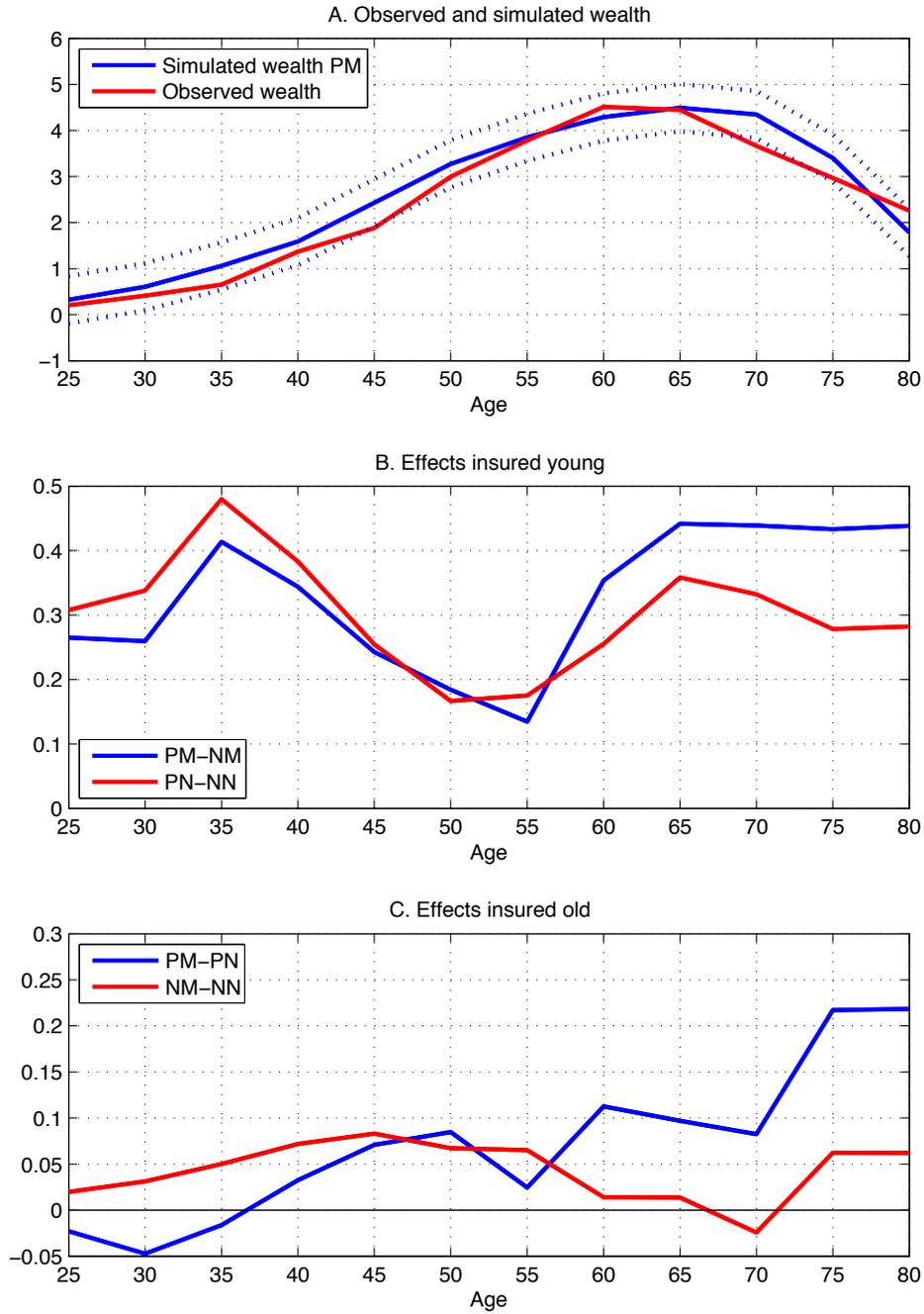
*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

**Figure 7:** Life cycle healthy leisure



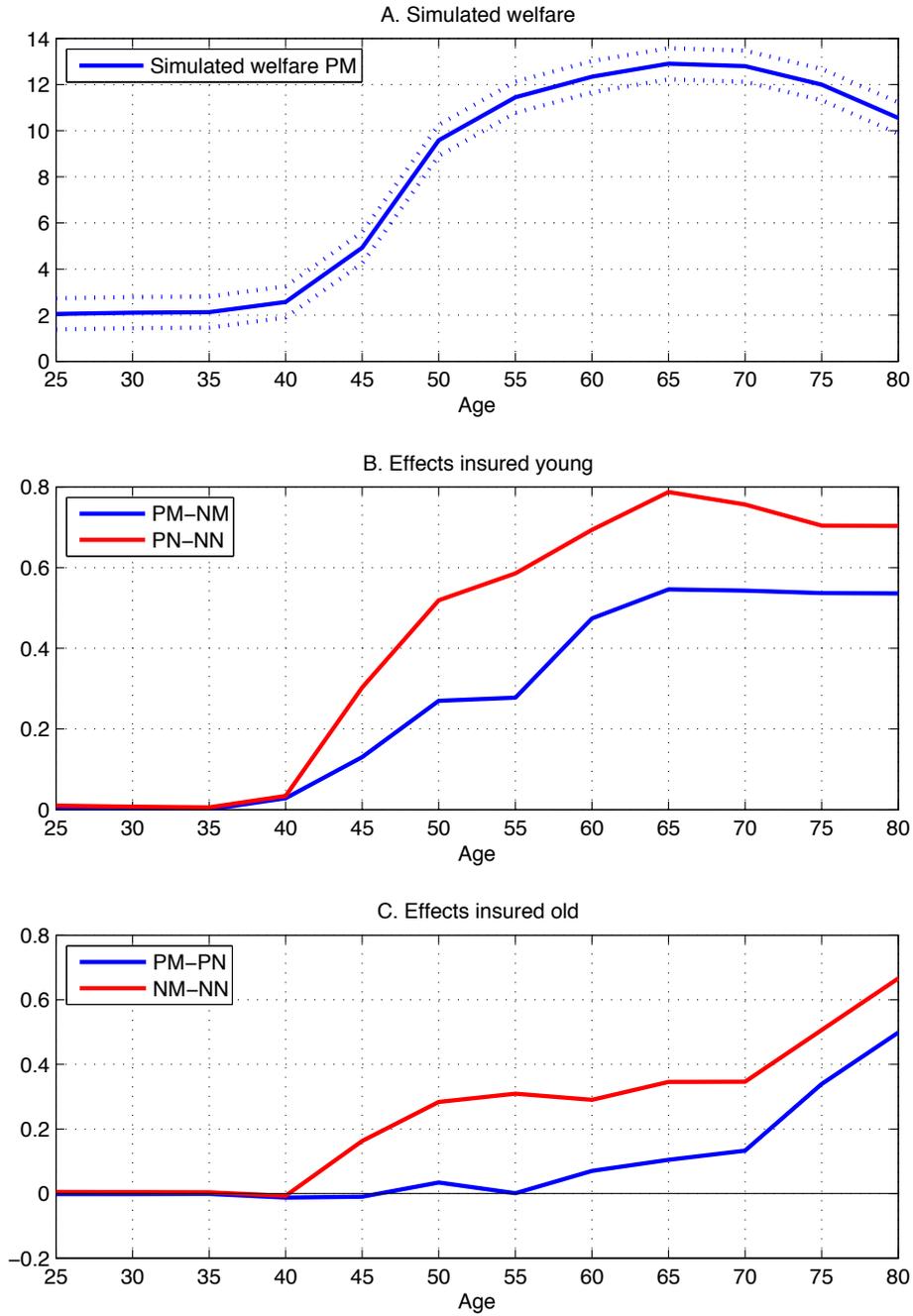
*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

**Figure 8: Life cycle wealth**



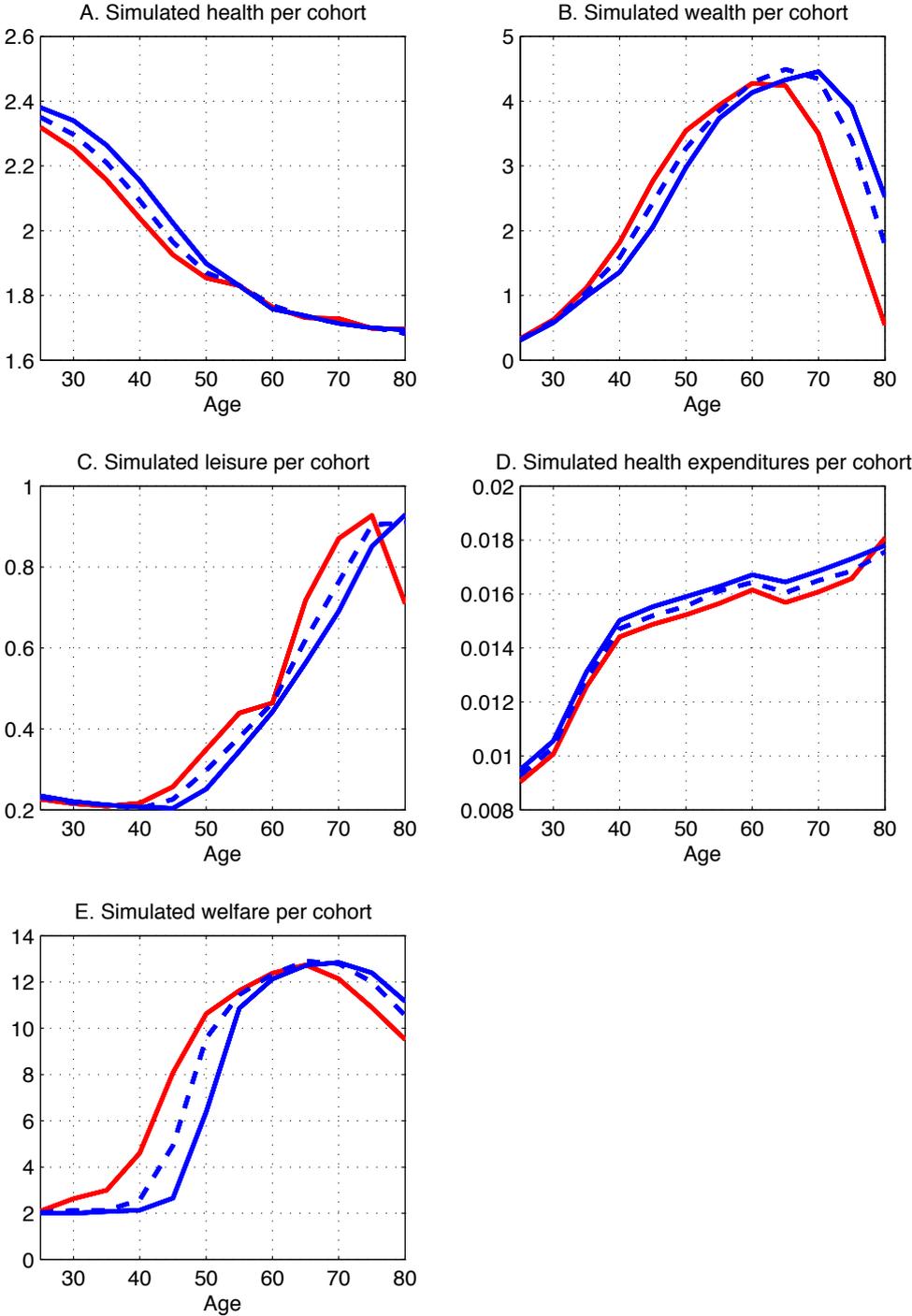
*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

**Figure 9: Life cycle welfare**



*Notes:* A. Mean simulated allocations, statuses and welfare (24) (solid blue line), as well as observed counterpart (solid red line, when available) and standard errors (dotted blue lines). B. and C. are differences in the means of the simulated variables across insurance plans.

Figure 10: Cohort effects



Notes: Dashed blue line:  $\kappa = -37$  (benchmark). Solid blue line:  $\kappa = -30$  (young cohort). Solid red line:  $\kappa = -44$  (old cohort).