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Health Investment over the Life-Cycle

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Abstract

We quantify what drives the rise in medical expenditures over the life-cycle. Three motives are considered. First, health delivers a flow of utility

each period (the consumption motive). Second, better health enables people to allocate more time to productive or pleasurable activities (the investment motive). Third, better health improves survival prospects (the survival motive). We calibrate an overlapping generations model with endogenous health accumulation to match key economic targets and then we gauge its performance by comparing key age-profiles from the model to their counterparts in the data. We find that the investment motive is more important than the consumption motive until about age 50. After that, the rise in medical expenditures is primarily driven by the value of health as a consumption good. The survival motive is quantitatively less important when compared to the other two motives. Finally, with our calibrated model, we conduct a series of counter-factual experiments to investigate how modifications to social security, government-run health insurance, and longevity impact the life-cycle behavior of medical expenditures as well as the aggregate medical expenditures-GDP ratio.

JEL codes: E21, I12

Keywords: Health Investment Motive, Medical Expenditure, Life Cycle

1 Introduction

In this paper, we consider the question of what factors determine the allocation of medical expenditures over the life-cycle. While there is a nascent, but growing literature that has investigated the determinants of the aggregate ratio of medical expenditures to GDP in the economy (e.g. Suen 2006, Hall and Jones 2007, Fonseca et al. 2009, Zhao 2010), little work has been done that investigates the *life-cycle* behavior of medical expenditures, particularly, its dramatic rise after age 65 which has been documented in Meara, White and Cutler (2004) and Jung and Tran (2010). This paper fills this void.

Following Grossman (1972), we view health as a type of capital stock which takes medical expenditures as its sole input.[1] In the model, there are three motives for health investment. First, health may be desirable in and of itself, and so people may invest because it directly adds to their well-being. Grossman refers to this as the "consumption motive." Second, good health may be a means to higher productivity or healthier days that can be spent working or relaxing. Here, good health behaves like something akin to human capital in the sense that just as people do not derive

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[1]While we acknowledge that there are a variety of ways in which health investment can take place, such as exercising, sleeping, and eating healthy, this paper considers only expenditures on medical services. Moreover, recent work by Podor and Halliday (2012) shows that the life-cycle profile of exercise is flat suggesting that exercise is of little importance when considering life-cycle economic behavior.

utility directly from additional years of schooling, they also do not derive additional utility from better health. Grossman refers to this motive as the "investment motive." Finally, better health improves the likelihood of survival. We refer to this as the "survival motive."

Although Grossman explains the first two of these motives qualitatively, little if anything is understood about how the three motives evolve over the life-course in the *quantitative* sense. In this paper, we elucidate how each of these three motives contributes to the life-cycle behavior of medical expenditures using techniques that not only allow us to quantify their relative importance but also to better understand how health investments affect other life-cycle behaviors such as assets holdings, consumption and labor supply. This is one of the first papers to shed light on this issue.

In addition, by quantifying which primitive aspects of individual behavior are responsible for the run-up of medical expenditures over the life course, we provide an important benchmark for other quantitative macroeconomists and structural labor economists who wish to analyze the economic consequences of health policy interventions.[2] In particular, our focus on the life-cycle enables us and others to make

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[2]This paper also contributes to a literature on life-cycle economic behavior that has largely been concerned with savings and consumption motives but has paid relatively less attention to the life-cycle motives for health-related behaviors and, particularly, expenditures on medical care. There is a vast literature that has attempted to better understand whether and when consumers behave as buffer stock or certainty equivalent agents (e.g., Carroll 1997 and Gorinchas and Parker 2002) as

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statements about how policies will distribute resources *across* generations which is something that previous work on health investment does not do.

To accomplish this, we calibrate an overlapping generations model with endogenous health investment. This model, which closely follows Grossman (1972), allows health to affect utility directly (the consumption motive) and indirectly via time allocation (the investment motive). In addition, health also affects survival (the survival motive). Parameters are chosen so that the model can replicate key economic ratios. We then gauge the performance of the model by comparing key life-cycle profiles from the model with their counterparts in the data, with a special focus on several health-related variables.

The calibrated model matches the life-cycle profiles of consumption, working hours, health status, medical expenditure, and survival well. With respect to medical expenditures, we find that the investment motive is more important than the consumption and survival motives until the late 40s and early 50s. After that, the consumption motive is the most important of the three. Younger people invest in their health because better health allows them to enjoy more leisure and to work more, while older people invest in their health because its marginal utility is ex-

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well as the extent to which savings decisions are driven by precautionary motives (e.g., Gorinchas and Parker 2002, Palumbo 1999, Hubbard, Skinner and Zeldes 1994). Much of the earlier literature on these topics has been elegantly discussed in Deaton (1992). However, very little is known about the motives for expenditures on medical care within a life-cycle context. In this paper, we attempt to fill this void.

tremely high due to high depreciation of health capital in later years. The survival motive becomes more important with age but matters little when compared to the other two motives.

Next, we conduct a series of counterfactual experiments to investigate how modifications to social security, expansion of government-sponsored health insurance (e.g., Medicare and Medicaid), and changes in survival affect the life-cycle behavior of health investment and the aggregate medical expenditures-GDP ratio. We find that policies designed to shore-up social security such as lowering the replacement ratio or delaying the retirement age do not affect either the life-cycle or aggregate behavior of medical expenditures significantly. On the other hand, the introduction of Medicare and Medicaid significantly increases medical expenditures over the entire life-cycle and, on aggregate, is able to explain about 23% of the increase in the medical expenditures-GDP ratio from 1960 to 2002. This rise in expenditures is particularly acute towards the end-of-life suggesting that government-sponsored universal health care shifts resources from the young to the old. Finally, when we compute our model using survival probabilities from 1960 in lieu of 2002, we find that we can explain about 36% of the rise in the medical expenditure-GDP ratio over this period. In addition, as with the introduction of government-run health insurance, the bulk of the rise in expenditures occurs late in life. We conclude that

both, the introduction of Medicare and Medicaid and the increase in longevity, play an important role in explaining the concentration of medical expenditures towards the end of the life-cycle as well as the rise in the medical expenditures-GDP ratio from 1960 to 2002.

Our work is part of a new and growing macro-health literature that incorporates endogenous health accumulation into dynamic models.[3] For example, Hall and Jones (2007), Suen (2006), Fonseca et al. (2009), and Zhao (2010) use a Grossman-type model to explain the recent increases in aggregate medical expenditures in the US. Feng (2008) examines the macroeconomic and welfare implications of alternative reforms to the health insurance system in the U.S. Jung and Tran (2009) study the general equilibrium effects of the newly established health savings accounts (HSAs). Yogo (2009) builds a model of health investment to investigate the effect of health shocks on the portfolio choices of retirees. Finally, Huang and Huffman (2010) develop a general equilibrium growth model with endogenous health accumulation and a simple search friction to evaluate the welfare effect of the current tax treatment of employer-provided medical insurance in the U.S. However, none of these focuses on the life-cycle motives for health investment which is our main contribution to the

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[3]There is also a substantial literature that has incorporated health into computational life-cycle models as an *exogenous* process. Some model it as an exogenous state variable (Rust and Phelan 1997; French 2005; De Nardi et al. 2010); others model it essentially as an exogenous income shock (Palumbo 1999; De Nardi et al. 2010; Jeske and Kitao 2009; Imrohoroglu and Kitao 2009a; Kopecky and Koreshkova 2009).

literature.

The balance of this paper is organized as follows. Section 2 presents the model. Section 3 describes the life-cycle profiles of income, hours worked, medical expenditures and health status in the data. Section 4 presents the parameterization of the model. Section 5 presents the life-cycle profiles generated from our benchmark model. Section 6 decomposes the three motives for health investment and quantifies their relative importance. In Section 7, we conduct a series of counterfactual experiments. Section 8 concludes.

2   Model

This section describes an overlapping generations model with endogenous health accumulation. Health enters the model in three ways. First, health provides direct utility as a consumption good. Second, better health increases the endowment of time. Third, better health increases the likelihood of survival.

2.1   Preferences

The economy is populated by identical individuals of measure one. Each individual lives at most J periods and derives utility from consumption, leisure and health. The

agent maximizes her discounted lifetime utility which is given by

$$\sum_{j=1}^{J} \beta^{j-1} \left[\prod_{k=1}^{j} \varphi_k(h_k) \right] u(c_j, l_j, h_j) \tag{1}$$

where β denotes the subjective discount factor, c is consumption, l is leisure, and h is health status. The term, $\varphi_j(h_j)$, represents the age-dependant conditional probability of surviving from age $j-1$ to j. We assume that $\varphi_1 = 1$ and $\varphi_{J+1} = 0$. We assume that this survival probability is a function of health status h and that $\varphi_j'(h_j) > 0$ so that better health improves the chances of survival. In each period, there is a chance that some individuals die with unintended bequests. We assume that the government collects all accidental bequests and distributes these equally among individuals who are currently alive. There is no private annuity market.

2.2   Budget Constraints

Each period the individual is endowed with one unit of discretionary time. She splits this time between working (n), enjoying leisure (l), and being sick (s). The time constraint is then given by

$$n_j + l_j + s(h_j) = 1, \text{ for } 1 \leq j \leq J. \tag{2}$$

We assume that "sick time," s, is a decreasing function of health status so that $s'(h_j) < 0$. Notice that in contrast to recent structural work that incorporates endogenous health accumulation (*e.g.*, Feng 2008, Jung and Tran 2009), health does not directly affect labor productivity. Allowing health to affect the allocation of time as opposed to labor productivity is consistent with Grossman, who says, "Health capital differs from other forms of human capital...a person's stock of knowledge affects his market and non-market productivity, while his stock of health determines the total amount of time he can spend producing money earnings and commodities."[4]

The agent works until an exogenously given mandatory retirement age j_R. Labor productivity differs due to differences in age. We use ε_j to denote efficiency at age j. We let w denote the wage rate and r denote the rate of return on asset holdings. Accordingly, $w\varepsilon_j n_j$ is age-j labor income. At age j, the budget constraint is given by

$$c_j + m_j + a_{j+1} \leq (1 - \tau_{ss})w\varepsilon_j n_j + (1 + r)a_j + T, \text{ for } j < j_R \tag{3}$$

where m_j is health investment in goods, a_{j+1} is assets, τ_{ss} is the Social Security tax rate, and T is the lump-sum transfer from accidental bequests.

Once the individual is retired, she receives Social Security benefits, denoted by b.

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[4]In a separate appendix which is available from the corresponding author, we show that the alternative model in which health affects labor productivity yields very similar results to the benchmark model.

Following Imrohoroglu, Imrohoroglu, and Joines (1995), we model the Social Security system in a simple way. Social Security benefits are calculated to be a fraction κ of some base income, which we take as the average lifetime labor income

$$b = \kappa \frac{\sum_{i=1}^{j_R-1} w\varepsilon_j n_j}{j_R - 1}$$

where κ is the replacement ratio. An age-j retiree then faces the budget constraint

$$c_j + m_j + a_{j+1} \leq b + (1+r)a_j + T, \forall j \geq j_R. \tag{4}$$

We assume that agents are not allowed to borrow, so that[5]

$$a_{j+1} \geq 0 \text{ for } 1 \leq j \leq J.$$

2.3   Health Investment

The individual invests in medical expenditures to produce health. Health accumulation is given by

$$h_{j+1} = (1 - \delta_{h_j})h_j + g(m_j) \tag{5}$$

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[5]In an unreported experiment, completely removing the borrowing constraint significantly reduces savings at every age and affects the profile of working hours. However, it generates life-cycle profiles of health expenditure and health status that are very similar to those in the benchmark model.

where δ_{h_j} is the age-dependent depreciation rate of the health stock. The term, $g(m_j)$, is the health production function which transforms medical expenditures at age j into health at age $j + 1$.

2.4   The Individual's Problem

At age j, an individual solves a dynamic programming problem. The state space at the beginning of age j is the vector (a_j, h_j). We let $V_j(a_j, h_j)$ denote the value function at age j given the state vector (a_j, h_j). The Bellman equation is then given by

$$V_j(a_j, h_j) = \max_{c_j, m_j, a_{j+1}, n_j} \{u(c_j, l_j, h_j) + \beta \varphi_{j+1}(h_{j+1}) V_{j+1}(a_{j+1}, h_{j+1})\} \qquad (6)$$

subject to

$$c_j + m_j + a_{j+1} \leq (1 - \tau_{ss}) w \varepsilon_j n_j + (1 + r) a_j + T, \forall j < j_R$$

$$c_j + m_j + a_{j+1} \leq b + (1 + r) a_j + T, \forall j_R \leq j \leq J$$

$$h_{j+1} = (1 - \delta_{h_j}) h_j + g(m_j), \forall j$$

$$n_j + l_j + s(h_j) = 1, \forall j$$

$$a_{j+1} \geq 0, \forall j, \ a_1 = 0, \ h_1 \text{ is given}$$

and the usual non-negativity constraints.

2.5 Competitive Equilibrium

Our focus in this paper is to understand the life-cycle behavior of health investment and to evaluate the impact of different policies on the life-cycle profiles of medical expenditures and health status. To serve this purpose, we take government policy as endogenous. To simplify the analysis, we assume that factor prices are exogenous. We define a recursive competitive equilibrium as follows.

Definition 1 *Given constant prices $\{w, r\}$ and the policy arrangement $\{\kappa\}$, a recursive competitive equilibrium for the model economy is a collection of value functions $V_j(a_j, h_j)$, individual policy rules $C_j(a_j, h_j), M_j(a_j, h_j), A_j(a_j, h_j), N_j(a_j, h_j)$, a measure of agent distribution $\lambda_j(a_j, h_j)$ for every age j, and a lump-sum transfer T such that:*

1. Individual and aggregate behavior are consistent

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\begin{aligned}
K &= \sum_j \sum_a \sum_h \mu_j \lambda_j(a, h) A_{j-1}(a, h) \\
N &= \sum_{j=1}^{j_R - 1} \sum_a \sum_h \mu_j \lambda_j(a, h) \varepsilon_j N_j(a, h) \\
C &= \sum_j \sum_a \sum_h \mu_j \lambda_j(a, h) C_j(a, h) \\
M &= \sum_j \sum_a \sum_h \mu_j \lambda_j(a, h) M_j(a, h).
\end{aligned}
$$

where μ_j is the age share of the age-j agents.[6]

2. *Given constant prices $\{w, r\}$, the policy arrangement $\{\kappa, \tau_{ss}\}$ and the lump-sum transfer T, value functions $V_j(a_j, h_j)$ and individual policy rules $C_j(a_j, h_j)$, $M_j(a_j, h_j)$, $A_j(a_j, h_j)$, and $N_j(a_j, h_j)$ solve the individual's dynamic programming problem (6).*

3. *The measure of agent distribution $\lambda_j(a_j, h_j)$ follows the law of motion*

$$\lambda_{j+1}(a', h') = \sum_{a:a'=A_j(a,h)} \sum_{h:h'=H_j(a,h)} \lambda_j(a, h).$$

4. *National income identity holds*

$$C + M + K' - K = rK + wN.$$

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[6] *The share of age-j individuals in the total population μ_j is determined by*

$$\mu_{j+1} = \mu_j \varphi_{j+1}(h_{j+1}), \forall j$$

$$\sum_{j=1}^{J} \mu_j = 1.$$

5. *Social security system is self-financing*

$$\tau_{ss} = \frac{b \sum_{j=j_R}^{J} \mu_j}{wN}.$$

6. *The lump-sum transfer of accidental bequests is determined by*

$$T = \sum_j \sum_a \sum_h \mu_j \lambda_j(a, h)(1 - \varphi_{j+1}(h)) A_j(a, h).$$

2.6 Euler Equation for Health Investment

Before we move to the quantitative analysis of the benchmark model, we would like

to understand qualitatively the three motives for health investment. After some

tedious algebra, we obtain the following Euler equation for the health investment at

age j

$$\frac{\partial u}{\partial c_j} = \beta g'(m_j) \varphi_{j+1}(h_{j+1}) \left\{ \frac{\partial u}{\partial h_{j+1}} - \frac{\partial u}{\partial l_{j+1}} s'(h_{j+1}) + \frac{\varphi'_{j+1}(h_{j+1})}{\varphi_{j+1}(h_{j+1})} u_{j+1} + \frac{\partial u/\partial c_{j+1}}{g'(m_{j+1})}(1 - \delta_{h_{j+1}}) \right\}.$$

$$(7)$$

The left-hand side of the equation is the marginal cost of using one additional unit

of the consumption good for medical expenditures. However, one additional unit of

medical expenditure will produce $g'(m_j)$ units of the health stock tomorrow. The

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right-hand side of equation (7) shows the marginal benefit brought by this additional unit of medical expenditure. First, better health tomorrow will directly increase utility by $\partial u/\partial h_{j+1}$, which is the first term inside the bracket. This term captures the "consumption motive"(C-Motive). Second, better health tomorrow reduces the number of sick days (recall $s'(h) < 0$) and thus increases the available time that can be spent working or relaxing. Notice that for the working age $(j < j_R)$, we have the intra-temporal condition for the work-leisure choice as follows

$$\frac{\partial u}{\partial l_j} = (1 - \tau_{ss})w\varepsilon_j\frac{\partial u}{\partial c_j} + \frac{\kappa w\varepsilon_j}{j_R - 1}\sum_{p=j_R}^{J}\left(\beta^{p-j}\left[\prod_{k=j+1}^{p}\varphi_k(h_k)\right]\frac{\partial u}{\partial c_p}\right). \tag{8}$$

The left-hand side shows the marginal cost of shifting one additional unit of time from enjoying leisure to working. The right-hand side captures the marginal benefit of this additional unit of working time. The first term shows the direct effect in the current period. The second term represents the indirect effect on the future social security benefits. Substituting equation (8) into (7), for the working age $j < j_R$, the second term inside the bracket of equation (7) becomes

$$\left((1 - \tau_{ss})w\varepsilon_{j+1}\frac{\partial u}{\partial c_{j+1}} + \frac{\kappa w\varepsilon_{j+1}}{j_R - 1}\sum_{p=j_R}^{J}(\beta^{p-j-1}\left[\prod_{k=j+2}^{p}\varphi_k(h_k)\right]\frac{\partial u}{\partial c_p})\right)s'(h_{j+1}). \tag{9}$$

In words, better health tomorrow, through reducing sick time, will increase working time, and hence increase both an individual's current labor income and future social security benefits which will yield higher utility for workers. On the other hand, for the retirees, better health tomorrow reduces their sick time and hence increases their leisure time. The second term in equation (7) thus is the "investment motive" (I-Motive) for both working and retired people. Finally, because the survival probability is a function of the health stock, better health tomorrow will also affect survival. This can be found in the third term inside the bracket of equation (7). One additional unit of health at age $j+1$ will increase the survival probability by $\varphi'_{j+1}(h_{j+1})/\varphi_{j+1}(h_{j+1})$ and, hence, an individual will have a higher chance of enjoying utility at age $j+1$. We call this the "survival motive" (S-Motive). The final term in equation (7) is the continuation value for health investment.

3   The Data

We construct the data counterparts of the model profiles from two sources. The first is the Panel Study of Income Dynamics (PSID), which we use to construct life-cycle profiles for income, hours worked, and health status. The second is the Medical Expenditure Survey (MEPS), which we use to construct life-cycle profiles for medical expenditures.

3.1 Panel Study of Income Dynamics

We take all male heads of household from the PSID from th years 1968 to 2005. The PSID contains an over-sample of economically disadvantaged people called the Survey of Economic Opportunities (SEO). We follow Lillard and Willis (1978) and drop the SEO due to endogenous selection. Doing this also makes the data more nationally representative. Our labor income measure includes any income from farms, businesses, wages, roomers, bonuses, overtime, commissions, professional practice and market gardening. This is the same income measure used by Meghir and Pistaferri (2004). Our measure of hours worked is the total number of hours worked in the entire year. Our health status measure is a self-reported categorical variable in which the respondent reports that her health is in one of five states: excellent, very good, good, fair, or poor. While these data can be criticized as being subjective, Smith (2003) and Baker, Stabile and Deri (2004) have shown that they are strongly correlated with both morbidity and mortality. In addition, Bound (1991) has shown that they hold up quite well against other health measures in analyses of retirement behavior. Finally, in a quantitative study of life-cycle behavior such as this, they have the desirable quality that they change over the life-course and that they succinctly summarize morbidity. A battery of indicators of specific medical conditions such as arthritis, diabetes, heart disease, hypertension, etc. would not do this. For

the purposes of this study, we map the health variable into a binary variable in which a person is either healthy (self-rated health is either excellent, very good or good) or a person is unhealthy (self-rated health is either fair or poor). This is the standard way of partitioning this health variable in the literature.

Panels a to c in Figure 1 show the life-cycle profile of the mean of income, hours and health.[7] These calculations were made by estimating linear fixed effects regressions of the outcomes on a set of age dummies on the sub-sample of men between ages 20 and 75. Because we estimated the individual fixed effects, our estimates are not tainted by heterogeneity across individuals (and, by implication, cohorts). Each figure plots the estimated coefficients on the dummy variables, which can be viewed as a life-cycle profile of a representative agent. Panel a in Figure 1 shows the income profile (in 2004 dollars). The figure shows a hump shape with a peak at about 60K in the early 50s. A major source of the decline is early retirements. This can be seen in panel b in the same figure, which plots yearly hours worked. Hours worked are fairly constant at just over 40 per week until about the mid 50s, when they start to decline quite rapidly. Panel c in Figure 1 shows the profile of health status. The

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[7]We took our data on labor income, hours and health status for all years that they were available between the years 1968 to 2005. We were careful to construct our profiles from data that were based on the same variable definition across survey years to ensure comparability across waves. The questions that were used to construct the variables do differ somewhat across waves, and so we did not use all waves from 1968-2005 to construct our profiles. For labor income, we used 1968-1993, 1997-1999, and 2003-2005. For hours, we used 1968-1993 and 2003-2005. For health status, we used 1984-2005; the health status question was not asked until 1984.
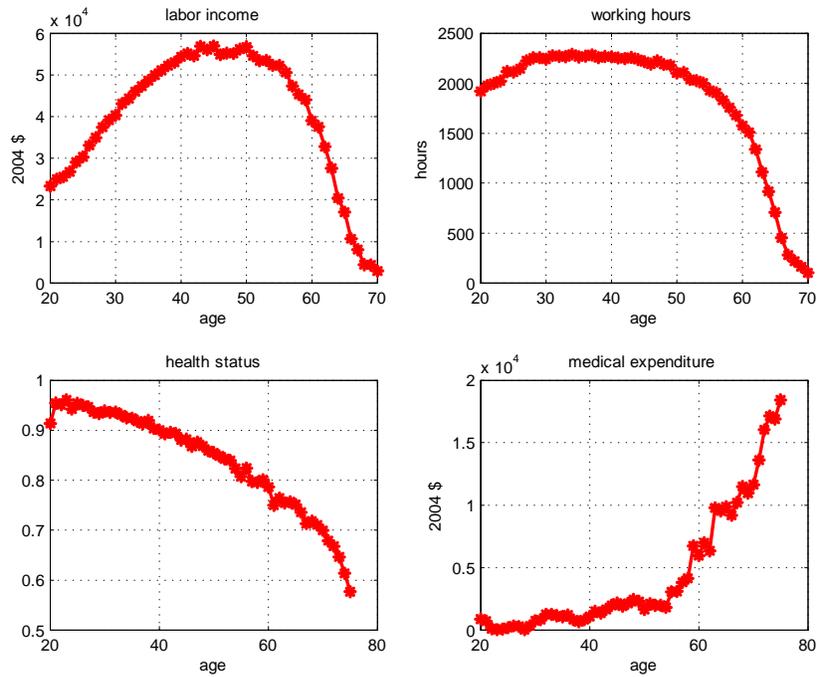
Figure 1: Life-cycle profile of income, working hours, health status, and medical expenditures: PSID and MEPS data

figure shows a steady decline in health. Approximately 95% of the population report being healthy at age 25, and this declines to just under 60% at age 75.[8]

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[8]We did not calculate these profiles beyond ages 75 because the PSID does not have reliable data for later ages due to high rates of attrition among the very old. There are other data sources such as the Health and Retirement Survey (HRS) that do have better data on the elderly, but unfortuantely the HRS does not have any data on the earlier part of the life-cycle which is crucial for our analysis. We chose the PSID over the HRS as it had more comprehensive information over a much larger part of the life-cycle than the HRS.

3.2 Medical Expenditure Survey

Our MEPS sample spans the years 2003-2007.[9] As discussed in Kashihara and Carper (2008), the MEPS measure of medical expenditures that we employ includes "direct payments from all sources to hospitals, physicians, other health care providers (including dental care) and pharmacies for services reported by respondents in the MEPS-HC." Note that these expenditures include both out-of-pocket expenditures and expenditures from the insurance company. Since our model does not distinguish these two, medical expenditures in the model are the total medical expenditures a representative agent pays (i.e. out-of-pocket plus what the insurer pays).

Panel d in Figure 1 shows the life-cycle profile of mean medical expenditures (in 2004 dollars). The profile was calculated in the same way as the profiles in the three previous figures; i.e., we estimated linear fixed effects regressions with a full set of age dummies on the sub-sample of males ages 20 to 75. The profile shows an increasing and convex relationship with age. Consistent with the findings in the literature, we find that medical expenditures increase significantly after age 55. The medical expenditures at age 75 are six times higher than at age 55.

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[9]We were careful not to use MEPS data prior to 2003 since it has been well documented that there has been a tremendous amount of medical inflation over the past 15 to 20 years. As such, we were concerned that this may have altered the age profile of medical expenditures.

4 Calibration

We now outline the calibration of the model's parameters. For the parameters that are commonly used, we borrow from the literature. For those that are model-specific, we choose parameter values to match relevant moment conditions as closely as possible.

4.1 Demographics

The model period is five years. An individual is assumed to be born at the real-time age of 20. Therefore, the model period $j = 1$ corresponds to ages 20-24, $j = 2$ corresponds to ages 25-29, and so on. Death is certain after age $J = 16$, which corresponds to ages 95-99. Retirement is mandatory and occurs at age 65 ($j_R = 10$ in the model). We take the age-efficiency profile $\{\varepsilon_j\}_{j=1}^{j_R-1}$ from Conesa, Kitao and Krueger (2009), who constructed it following Hansen (1993).

Similar to Fonseca, et al. (2009), we assume that the survival probability is a logistic function that depends on health status

$$\varphi_j(h_j) = \frac{1}{1 + \exp(\varpi_0 + \varpi_1 j + \varpi_2 j^2 + \varpi_3 h_j)}$$

where we impose a condition that requires $\varpi_3 < 0$ so that the survival probability

is a positive function of an individual's health. Note that the survival probability is also age-dependant.[10] Given suitable values for ϖ_1 and ϖ_2, it is decreasing with age at an increasing rate.

We calibrate the four parameters in the survival probability function to match four moment conditions in the data which we take from the US Life Table 2002. The four moment conditions are:

1. Dependency ratio ($\frac{\text{number of people aged 65 and over}}{\text{number of people aged 20-64}}$), which is 39.7%.

2. Age-share weighted average death rate from age 20 to 100, which is 8.24%.

3. The ratio of survival probabilities for ages 65-69 to ages 20-24, which is 0.915.

4. The ratio of the change in survival probabilities from ages 65-69 to 75-79 to the change in survival probability from ages 55-59 to 65-69 ($\frac{\varphi_{12}-\varphi_{10}}{\varphi_{10}-\varphi_8}$ in the model), which is 2.27.

Our calibration obtains $\varpi_0 = -5.76; \varpi_1 = 0.285; \varpi_2 = 0.0082; \varpi_3 = -0.30.$

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[10] Age typically affects mortality once we partial out self-reported health status (SRHS). This is true, for example, in the National Health Interview Survey.

4.2 Preferences

The period utility function takes the form

$$u(c_j, l_j, h_j) = \frac{\left[\lambda (c_j^\rho l_j^{1-\rho})^\psi + (1-\lambda)h_j^\psi\right]^{\frac{1-\sigma}{\psi}}}{1-\sigma} + \underline{c}. \tag{10}$$

We assume that consumption and leisure are non-separable and we take a Cobb-Douglas specification as the benchmark.[11] The parameter λ measures the relative importance of the consumption-leisure combination in the utility function. The parameter ρ determines the weight of consumption in the consumption-leisure combination. Since we know less about the elasticity of substitution among consumption, leisure, and health, we allow for a more flexible CES specification between the consumption-leisure combination and health. The elasticity of substitution between the consumption-leisure combination and health is $\frac{1}{1-\psi}$. The parameter σ determines the intertemporal elasticity of substitution.

For the standard CRRA utility function, σ is usually chosen to be bigger than one. The period utility function thus is negative. This is not a problem in many environments since it is the rank and not the level of utility that matters. However, for a model with endogenous survival, negative utility makes an individual prefer

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[11]We consider an alternative specification with the separability between consumption and leisure in the sensitivity analysis, which yields similar results to the benchmark model. We present this in a separate appendix that is available from the corresponding author.

shorter lives over longer lives. To avoid this, we have to ensure that the level of utility is positive. Following Hall and Jones (2007), we add a constant term $\underline{c} > 0$ in the period utility function to avoid negative utility.[12]

We calibrate the annual subjective time discount factor to be 0.9659 to match the capital-output ratio in 2002, which is 2.6 so that $\beta = (0.9659)^5$. We choose $\sigma = 2$ to obtain an intertemporal elasticity of substitution of 0.5, which is a value widely used in the literature (e.g., Imrohoroglu et al. 1995; Fernandez-Villaverde and Krueger 2011). We calibrate the share of the consumption-leisure combination in the utility function, λ, to be 0.69 to match the average consumption-labor income ratio for working age adults, which is 78.5%.[13] We calibrate the share of consumption ρ to be 0.342 which matches the fraction of working hours in discretionary time for workers, which is 0.349 from the PSID. We calibrate the parameter of the elasticity of substitution between the consumption-leisure combination and health ψ to be -7.70, which implies an elasticity of $\frac{1}{1-\psi} = 0.11$. This value is chosen to match the ratio of average medical expenditures for ages 55-74 to ages 20-54, which is 7.96 from the MEPS.[14] Since the elasticity of substitution between consumption and leisure is

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[12]See also Zhao (2010).

[13]Consumption data are taken from Fernandez-Villaverde and Krueger (2007), who use the CEX data set.

[14]The reason why parameter ψ significantly affects the ratio of medical expenditures of ages 55-74 to ages 20-54 is that we know that consumption peaks at age 50 and declines after (see panel f in Figure 2). The degree of complementarity between consumption and health thus affects the speed of the decline in health after age 50, which in turn determines the speed of the increase in health

one, health and the consumption-leisure combination are complements. This implies that the marginal utility of consumption increases as the health stock improves, which is confirmed by several empirical studies (Viscusi and Evans 1990; Finkelstein, Luttmer, and Notowidigdo 2010). Finally, as shown in equation (7), the level of utility u enters into the "S-Motive." This means that the constant term $\underline{c}$ in the period utility function affects health investment through the survival probability. We, thus, calibrate $\underline{c}$ to match the ratio of the change in survival to the change in medical expenditures from ages 20-24 to 30-34, which is -0.0018 in the data. Given the calibrated value of $\underline{c}$, which is 3.40, period utility is positive at every age in the benchmark model.

4.3   Social Security

The Social Security replacement ratio κ is set to 40%. This replacement ratio is commonly used in the literature (see for example, Kotlikoff, Smetters, and Walliser (1999) and Cagetti and De Nardi (2009)).

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investment after age 50. For lower values of ψ, we see more complementarity between consumption and health and, so health declines more quickly after age 50. Hence, we then see a higher ratio of medical expenditures for ages 55-74 to ages 20-54.

4.4 Factor Prices

The wage rate w is set to the average wage rate over the working age in the PSID data, which is $13.02.[15] The annual interest rate is set to be 4%.[16] Therefore, $r = (1 + 4\%)^5 - 1 = 21.7\%$.

4.5 Health Investment

We assume that the depreciation rate of health in equation (5) takes the form

$$\delta_{h_j} = \frac{\exp(d_0 + d_1 j + d_2 j^2)}{1 + \exp(d_0 + d_1 j + d_2 j^2)}. \tag{11}$$

This functional form guarantees that the depreciation rate is bounded between zero and one and (given suitable values for d_1 and d_2) increases with age.

The production function for health at age j in equation (5) is specified as

$$g(m_j) = Bm_j^\xi$$

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[15]We first divide annual labor income for ages 20 to 64 from panel a in Figure 1 by the annual working hours from panel b in Figure 1 to obtain wage rates $w\varepsilon_j$ across ages. We then divide the average wage rate over working ages $\left(\frac{w \sum_{j=1}^{j_R-1} \varepsilon_j}{j_R-1}\right)$ by the average age-efficiency $\frac{\sum_{j=1}^{j_R-1} \varepsilon_j}{j_R-1}$ to obtain average wage rate w, which is $13.02.

[16]4% is a quite common target for the return to capital in life-cycle models. See for example Fernandez-Villaverde and Krueger (2011).

where B measures the productivity of medical care, and ξ represents the return to scale for health investment. Accordingly, we have five model-specific parameters governing the health accumulation process: d_0, d_1, d_2, B, ξ. We choose values of d_0, d_1, and d_2 to match three moment conditions regarding health status: average health status from age 20 to 74, the ratio of health status for ages 20-29 to ages 30-39, and the ratio of health status for ages 30-39 to ages 40-49. This results in $d_0 = -4.25$, $d_1 = 0.238$, and $d_2 = 0.00823$. We calibrate $B = 0.68$ and $\xi = 0.8$ to match two moment conditions regarding medical expenditure. The first is the medical expenditure-GDP ratio, which was 15.1% in 2002.[17] The second is the average medical expenditure-labor income ratio from age 20 to 64, which is 5.8%.[18]

4.6 Sick Time

Following Grossman (1972), we assume that sick time takes the form

$$s(h_j) = Qh_j^{-\gamma} \tag{12}$$

where Q is the scale factor and γ measures the sensitivity of sick time to health. We calibrate these two parameters to match two moment conditions in the data.

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[17]Data are from the National Health Accounts (NHA).
[18]This ratio is calculated based on the data from panel a and d in Figure 1.

Based on data from the National Health Interview Survey, Lovell (2004) reports that employed adults in the US on average miss 4.6 days of work per year due to illness or other health-related factors. This translates into 2.1% of total available working days.[19] We use this ratio as an approximation to the share of sick time in total discretionary time over working ages. We choose $Q = 0.0145$ to match this ratio. Lovell (2004) also shows that the absence rate increases with age. For workers age 45 to 64 years, it is 5.7 days per year which is 1.5 days higher than the rate for younger workers age 18 to 44 years. We choose $\gamma = 2.7$ to match the ratio of sick time for ages 45-64 to ages 20-44, which is 1.36.

Table 1 summarizes the parameter values used for the benchmark model. Table 2 shows the targeted moment conditions in the data and the model.

5   Benchmark Results

Using the parameter values from Table 1, we compute the model using standard numerical methods.[20] Since we calibrate the model only to target selected aggregate life-cycle ratios, the model-generated life-cycle profiles, which are shown in Figure 2,

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[19]According to OECD data, American workers, on average, worked 1800 hours per year in 2004; that is equivalent to about 225 working days. Sick leave roughly accounts for 2.1% of these working days. This number is very close to the one reported in Gilleskie (1998).

[20]The computational method is similar to the one used in Imrohoroglu et al. (1995). The details are provided in a separate appendix which is available from the corresponding author.

Parameter	Description	Value	Source
	Demographics		
J	maximum life span	16	age 95-99
j_R	mandatory retirement age	10	age 65-69
ϖ_0	survival prob.	-5.76	calibrated
ϖ_1	survival prob.	0.285	calibrated
ϖ_2	survival prob.	0.0082	calibrated
ϖ_3	survival prob.	-0.30	calibrated
	Preferences		
β	subjective discount rate	$(0.9659)^5$	calibrated
σ	Intertem. ela. sub. coefficient	2	common value
ψ	elasticity b/w cons. and health	-7.70	calibrated
ρ	share of c in c-leisure combination	0.342	calibrated
λ	share of cons-leisure com. in utility	0.69	calibrated
$\underline{c}$	constant term in utility	3.4	calibrated
	Health Accumulation		
d_0	dep. rate of health	-4.25	calibrated
d_1	dep. rate of health	0.238	calibrated
d_2	dep. rate of health	0.00823	calibrated
B	productivity of health technology	0.68	calibrated
ξ	return to scale for health investment	0.8	calibrated
	Sick Time		
Q	scale factor of sick time	0.0145	calibrated
γ	elasticity of sick time to health	2.7	calibrated
	Labor Productivity		
$\{\varepsilon_j\}_{j=1}^{j_R-1}$	age-efficiency profile		Conesa et al. (2009)
	Social Security		
κ	Social Security replacement ratio	40%	Kotlikoff et al. (1999)
	Factor Prices		
w	wage rate	\$13.02	PSID
r	interest rate	0.2167	Fernandez-Villaverde et al. (2011)

Table 1: Parameters of the model

Target (Data source)	Data	Model
Capital-output ratio (2002 NIPA)	2.6	2.6
Non-med. consumption-labor income ratio (CEX and PSID)	78.5%	78.1%
Med. expenditure (ages 55-74)/(ages 20-54) (MEPS)	7.96	8.04
Fraction of average working hours (PSID)	0.349	0.349
Med. expenditure-output ratio (2002 NHA)	15.1%	15.1%
Med. expenditure-labor income ratio (MEPS and PSID)	5.8%	4.7%
Fraction of average sick time (ages 20-64) (Lovell 2004)	2.1%	2.1%
Sick time (ages 45-64)/Sick time (ages 20-44) (Lovell 2004)	1.36	1.36
Average health status (ages 20-74) (PSID)	0.845	0.842
health (ages 20-29)/health (ages 30-39) (PSID)	1.02	1.03
health (ages 30-39)/health (ages 40-49) (PSID)	1.05	1.04
dependency ratio (US Life Table 2002)	39.7%	39.5%
average death rate (ages 20-100) (US Life Table 2002)	8.24%	8.25%
sur. prob. (ages 65-69)/sur. prob. (ages 20-24) (Life Table 2002)	0.915	0.913
$\triangle$sur (65-69 to 75-79)/$\triangle$sur (55-59 to 65-69) (Life Table 2002)	2.27	2.28
$\triangle$sur (20-24 to 30-34)/$\triangle$med. exp. (20-24 to 30-34) (MEPS and Life Table)	-0.0018	-0.0014

Table 2: Target moments: data vs. model

can be compared with the data to inform us about the performance of the benchmark

model.

Panel a in Figure 2 shows the life-cycle profile of health expenditures. Since one

model period represents five years in real life, a data point is an average for each five

year bin starting at age 20. Therefore, in the figure, age 22 represents age $j = 1$ in

the model and the average for ages 20-24 in the data, age 27 represents age $j = 2$

in the model and the average for ages 25-29 in the data, and so on. As we can

see, the model replicates the dramatic increase in medical expenditures in the data.

From ages 25-29 to ages 70-74, medical expenditure increases from \$361 to \$15068
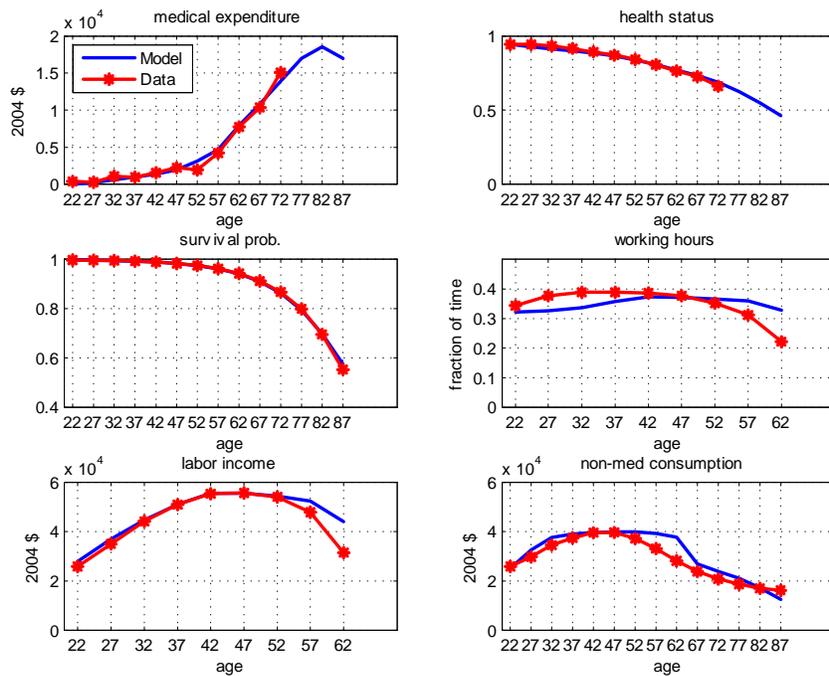
Figure 2: Life-cycle profiles: benchmark model vs. data

in the data, while the model predicts that medical expenditures increase from $193 to $13900.

Health investment (in conjunction with depreciation) determines the evolution of the health stock. Panel b in Figure 2 displays the life-cycle profile of health status. The model produces decreasing health status over the life-cycle. In the data, average health status (the fraction of individuals report being healthy) decreases from 0.9445 for ages 20-24 to 0.6612 for ages 70-74. The model predicts a change from 0.9445 to 0.6862.[21]

Since the survival probability is endogenous in the model, panel c in Figure 2 compares the model-generated survival probability with the data taken from US Life Tables in 2002. The model almost perfectly matches declining survival probabilities over the life-cycle in the data.

The model also does well in replicating other economic decisions over the life-cycle. Panel d in Figure 2 shows the life-cycle profile of working hours. As can be seen, the model replicates the hump shape of working hours. In the data, individuals devote about 34% of their non-sleeping time to working at ages 20-24. The fraction of working time increases to its peak at ages 35-39, and it is quite stable until ages

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[21]In the computation, h is a continuous variable that falls into the range of $[0, 1]$. The initial health stock h_1 is set to be 0.9445 which is the fraction of the population aged 20-24 who report being healthy in the data.

45-59. It then decreases sharply from about 38% at ages 45-49 to 22% at ages 60-64. In the model, the fraction of working hours reaches the peak (about 37.3%) at ages 40-45. It then decreases by 12%, to about 33% at ages 60-64. The health stock plays a non-trivial role in the declining portion of the working hours profile; as health status declines, sick time increases over the life-cycle, which, in turn, encroaches upon a person's ability to work. Our model predicts that from ages 40-45 to 60-64, the fraction of sick time in discretionary time increases from 2.01% to 2.96%, which accounts for about 21% of the decline in working hours in the model.

Since we have a good fit for working hours, we also replicate the labor income profile in the data quite well as can be seen in panel e in Figure 2. However, since the model does not generate enough of a decline in working hours at late ages as shown in panel d, the model over-predicts labor income from ages 50-54 to 60-64.

Panel f in Figure 2 shows the life-cycle profile of consumption (excluding medical expenditure) in the model. Similar to the data displayed in Figure 1 in Fernandez-Villaverde and Krueger (2007), it exhibits a hump shape. The profiles in both the data and the model peak in the late 40s. Fernandez-Villaverde and Krueger (2007) measure the size of the hump as the ratio of peak consumption to consumption at age 22 and they obtain a ratio of 1.60. Our model replicates this ratio. A noticeable difference between the model and the data is the sharp drop in consumption right

after retirement. The reason is the non-seperability between consumption and leisure in the utility function. Consumption and leisure are substitutes in our benchmark preferences. Retirement creates a sudden increase in leisure and, hence, substitutes for consumption after retirement.[22]

To summarize, our life-cycle model with endogenous health accumulation is able to replicate life-cycle profiles from the CEX, MEPS and PSID. First, it replicates the hump shape of consumption. Second, it replicates the hump shape of working hours and labor income. Third and most important, it replicates rising medical expenditures and decreasing health status and survival probabilities over the life-cycle.

6 Decomposition of Health Investment Motives

Based on the success of the benchmark model, we run a series of experiments to quantify the relative importance of the three motives for health investment as shown in equation (7). "No C-Motive" is a model in which we shut down the consumption motive by setting $\lambda = 1$ while keeping all other parameters at their benchmark

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[22]A sudden drop in consumption after retirement is common in the literature that uses non-separable utility functions, e.g., Conesa et al. (2009). Bullard and Feigenbaum (2007) show that consumption-leisure substitutability in household preferences may help explain the hump shape of consumption over the life-cycle. As evidence, when we use an alternative preference with a separable utility function between consumption and leisure in a sensitivity analysis (shown in a separate appendix), we obtain a much smoother consumption profile around retirement age.
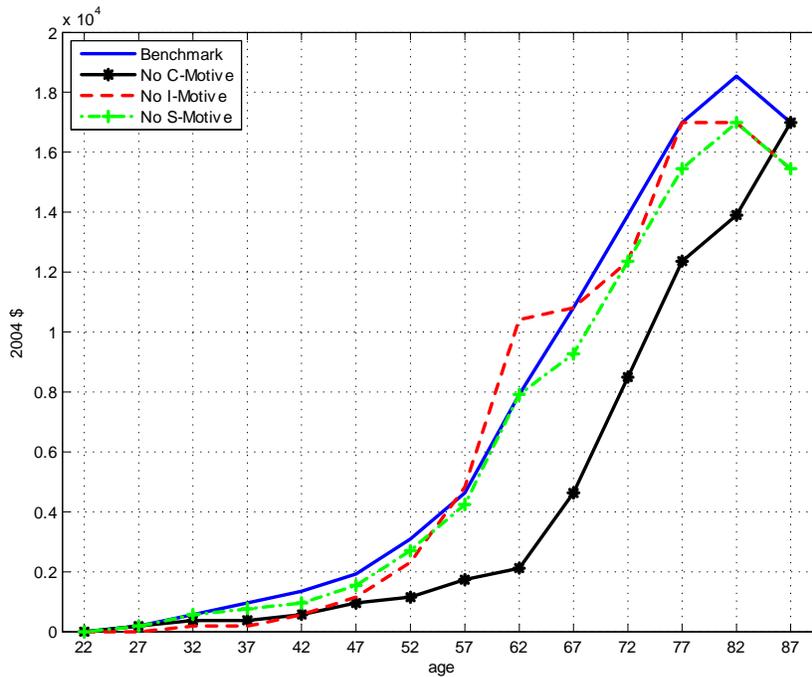
Figure 3: Life-cycle profile of medical expenditures: decomposition

values. Since health status does not enter into the utility function, the first term inside the bracket of equation (7) disappears. "No I-Motive" is a model without the investment motive which obtains by setting $Q = 0$ while keeping all other parameters at their benchmark values. Since there is no sick time in the model, the second term in equation (7) vanishes. "No S-Motive" is a model without the survival motive that obtains by setting $\varpi_3 = 0$ while keeping all other parameters at their benchmark values. Because health does not affect survival, the third term in equation (7) vanishes.

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The results of this exercise are reported in Figure 3. When compared to the benchmark model, medical expenditures in the No C-Motive model are significantly lower than that the benchmark model throughout the life-course. Hence, the consumption motive accounts for a significant part of medical expenditures. On the other hand, the No I-Motive model predicts even lower medical expenditure than that in the No C-Motive case before the late 40s implying that the investment motive via sick time is quantitatively more important than the consumption motive in driving up medical expenditures before age 50. However, after age 50, the difference between the No I-Motive case and the benchmark model is much smaller than the difference between the No C-Motive case and the benchmark model. It indicates that the investment motive is dominated by the consumption motive in driving up medical expenditures at later ages. Finally, the No S-Motive model shows that medical expenditures are lower than that in the benchmark model with the difference getting bigger as people age. However, the survival motive is quantitatively less important than the other two motives.

The relative importance of these three motives can also be shown clearly when we directly plot the three terms in equation (7) in Figure 4. Consistent with Figure 3, this figure shows that the I-Motive dominates the other two prior to the late 50s but is over-taken by the C-Motive after. However, after retirement, the I-Motive
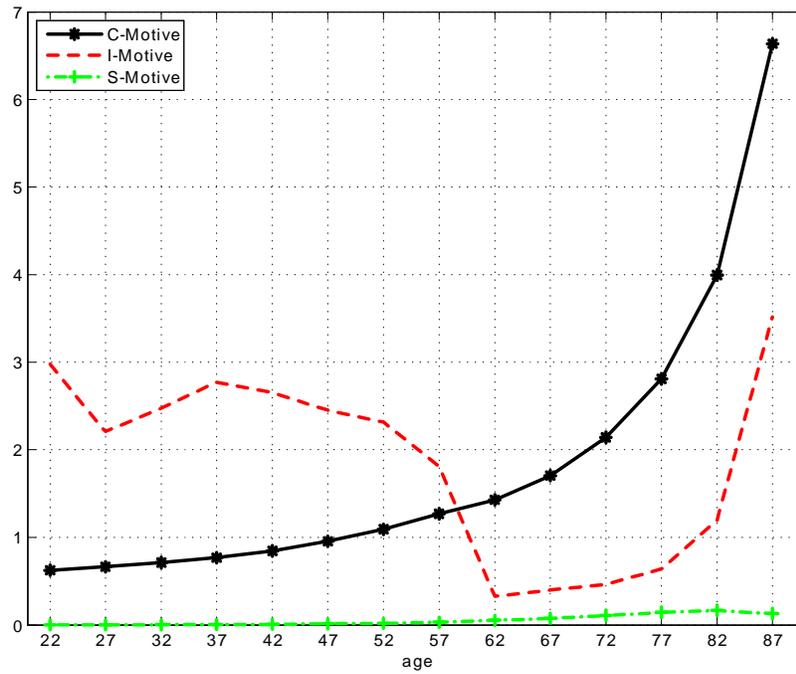
Figure 4: Life-cycle profiles of consumption, investment, and survival motive for health investment

becomes more important but is still less important than the C-Motive. The reason for this is that, as individuals age and their health deteriorates, sick time encroaches upon leisure making the investment side of the model more important.

Compared to the non-monotonic pattern of the I-Motive, the importance of the C-Motive increases monotonically with age. This is because health directly enters into the utility function as a consumption commodity and because health is decreasing over time due to natural depreciation. The scarcity of the health stock late in life pushes up the marginal utility of health and encourages rising health investment. After the early 60s, rising medical expenditure is driven more by the consumption than the investment motive. Finally, as shown in the figure, although its importance is increasing as people age, the S-Motive is quantitatively less important than the other two motives.

Differences in medical expenditures determine differences in health status, which in turn, affects survival. Panel a in Figure 5 shows that the No C-Motive model generates a significantly lower health stock than in the benchmark model (and the data), particularly after retirement. Consistent with both Figures 3 and 4, the No I-Motive model predicts a lower health stock than that in the No C-Motive case prior to the late 40s. However, after retirement, the impact of the I-Motive on health status significantly decreases. Afterwards, the C-Motive becomes more important
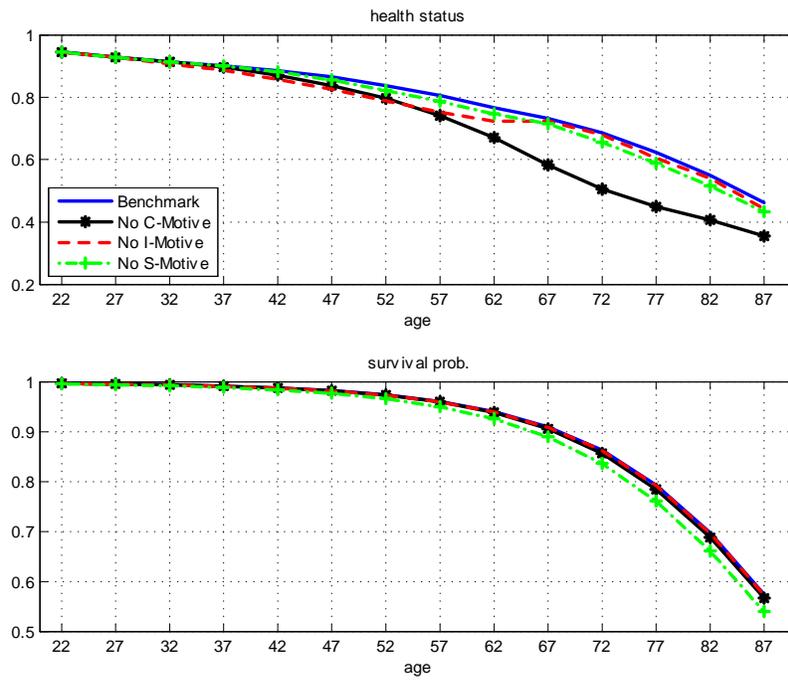
Figure 5: Life-cycle profiles of health status and survival probability: decomposition

which is consistent with Figures 3 and 4. Also consistent with Figures 3 and 4, the No S-Motive model generates a very small deviation in health status from the benchmark model.

Finally, panel b in Figure 5 reports the effect of the three motives on survival. Since the No S-Motive case directly shuts down the role that health plays in survival, we see that the No S-Motive model predicts lower survival throughout the entire life-cycle than that in benchmark case. The other two motives affect survival indirectly via their effect on health status. The results however show that their impact on survival is not quantitatively significant.

7   Counterfactual Experiments

From equations (7) and (8), one can see that social security policy as embedded in the parameters, $\{\tau_{ss}, \kappa, j_R\}$, will affect the investment motive for working age people. We have learned from the previous section that this is very important prior to retirement. The Euler equation in (7) also shows that the survival probability is an important part of the marginal benefit of health investment, and hence could affect the life-cycle profiles of medical expenditures as well. In this section, we run a series of counterfactual experiments that quantitatively investigate the effect of different policies and survival probabilities on the health investment behavior. In

addition, due to the equilibrium structure of the model, we are also able to show the impact on the aggregate medical expenditures-national income ratio.[23]

7.1   Changing the Replacement Ratio

Changing the replacement ratio is often cited as a means of shoring-up social security in the U.S. and elsewhere. Clearly, such a policy would affect social security taxes and benefits, but whether it would affect medical expenditures remains an open question. In this section, we run a counterfactual experiment where we change the replacement ratio, κ, from its benchmark level of 40% to 0%, 20% and 60%, respectively, while keeping the other parameters at their benchmark values.

Figure 6 shows the life-cycle profiles of asset holdings and total income (labor plus capital income) generated by different κ. In our model, the main motive for savings is to support consumption (both non-medical and medical consumption) in old age. Therefore, it is not surprising to see that a lower replacement ratio, which implies lower social security benefits after retirement (see the third column in Table 3), will induce agents to save more over the entire life-cycle. This is consistent with the finding in Imrohoroglu et al. (1995). This is also shown in Table 3; as the

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[23]Since we assume exogenous factor prices, the model does not contain any feedback from them, although it does capture equilibrium effects from endogenous government policy. We provide the reader with this caveat when interpreting our results on aggregate ratios.
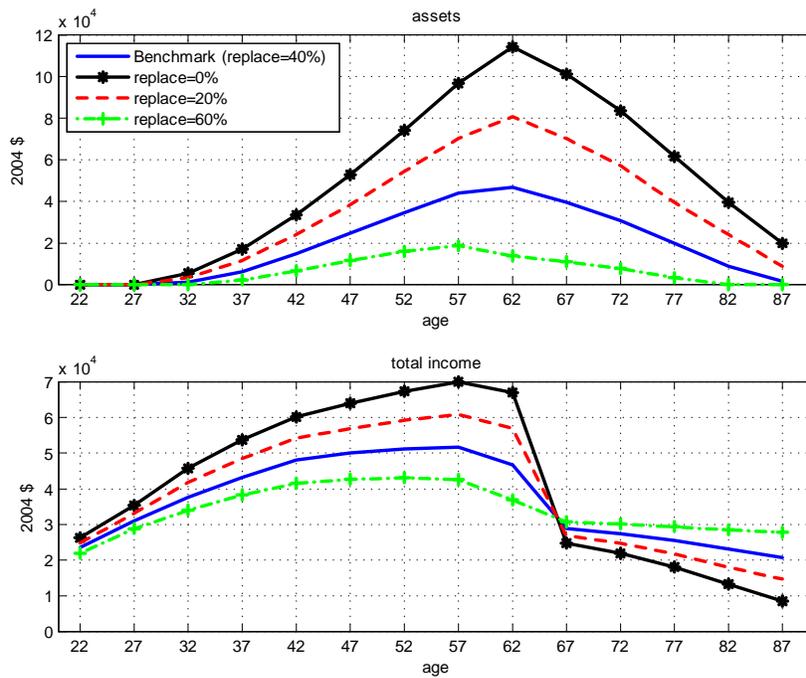
Figure 6: Life-cycle profiles of assets and total income: changing replacement ratio
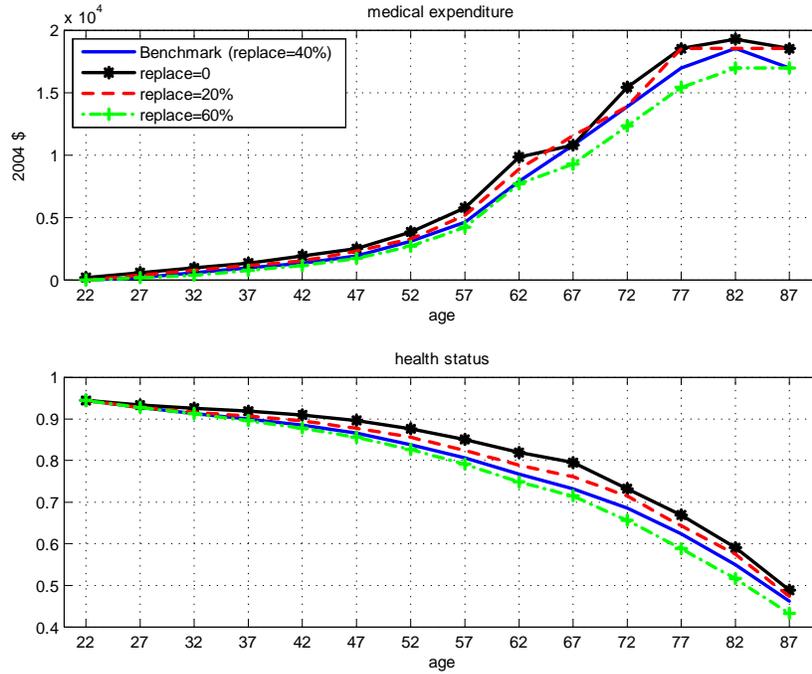
Figure 7: Life-cycle profiles of medical expenditures and health status: different replacement ratio

replacement ratio κ increases, the capital-wealth ratio K/Y decreases. With higher asset holdings, panel b in Figure 6 shows that total income is also higher when the replacement ratio is smaller.

Figure 7 shows the life-cycle profiles of medical expenditures and health status for different κ. Panel a shows that a lower replacement ratio leads to higher medical expenditures over the life-cycle. To understand the intuition of this quite surprising result, we have to go back to Euler equation (7). For working age agents, we know

that the investment motive is

$$\left((1 - \tau_{ss}) w \varepsilon_{j+1} \frac{\partial u}{\partial c_{j+1}} + \frac{\kappa w \varepsilon_{j+1}}{j_R - 1} \sum_{p=j_R}^{J} (\beta^{p-j-1} \left[\prod_{k=j+2}^{p} \varphi_k(h_k) \right] \frac{\partial u}{\partial c_p}) \right) s'(h_{j+1}).$$

Note that both the social security tax rate τ_{ss} and the replacement ratio κ enter the expression. The government in the model has to balance the budget since the social security system is self-financing. Therefore a lower replacement ratio also leads to a lower social security tax rate τ_{ss} as shown in the second column of Table 3. A lower τ_{ss} tends to increase the magnitude of the investment motive by increasing current after-tax labor income. A lower κ, of course in the same term also tends to reduce the magnitude of I-Motive. Its impact, however, is lower since it affects utility via its impact on future labor income that is the base for social security benefits, which is discounted by both the time preference and the conditional survival probability. Therefore, other things equal, a lower κ leads to a higher investment motive for working age agents, and hence results in higher medical expenditures. Another channel that affects health investment is total income. With much higher assets holdings for a lower κ, total income is higher, which is also shown in the eighth column of Table 3. For example, for $\kappa = 0$, total income is about 16% higher than the benchmark case with $\kappa = 40\%$. Since medical care is a normal good, higher income leads to higher medical expenditures. Since a lower κ generates higher medical

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κ	τ_{ss}	b (2004\$)	M/Y	K/Y	n	h	$Y_\kappa/Y_{benchmark}$
0%	0%	0	14.9%	5.5	0.352	0.811	1.16
20%	7.95%	9482	15.0%	4.1	0.351	0.794	1.08
40%	15.85%	18796	15.1%	2.6	0.349	0.779	1.00
60%	23.7%	27814	15.2%	1.0	0.345	0.764	0.92

Table 3: Selected aggregate variables: different replacement ratio

expenditures over the life-cycle, it is not surprising to see in panel b of Figure 7 that a lower κ also leads to higher health status. Hence, as shown in the seventh column of Table 3, which computes the average health status from age 20 to 90, when κ decreases from 40% to zero, average health status for ages 20-90 increases from 0.779 to 0.811.

Although different replacement ratios do generate sizable changes in medical expenditures over the life-cycle, as shown in the fourth column of Table 3, on the aggregate level, the medical expenditures-national income ratio does not change much as κ changes. For example, when κ decreases from 40% to zero, the social security system is completely shut down. The M/Y ratio, however, only decreases from 15.1% to 14.9%. This is somewhat counter-intuitive since smaller κ increases medical expenditures. However, this puzzle is resolved once we consider that lower κ increases both capital accumulation and labor supply and, so the denominator of the ratio increases by a greater amount than the numerator. Overall, changing the replacement ratio does not affect medical expenditures significantly.
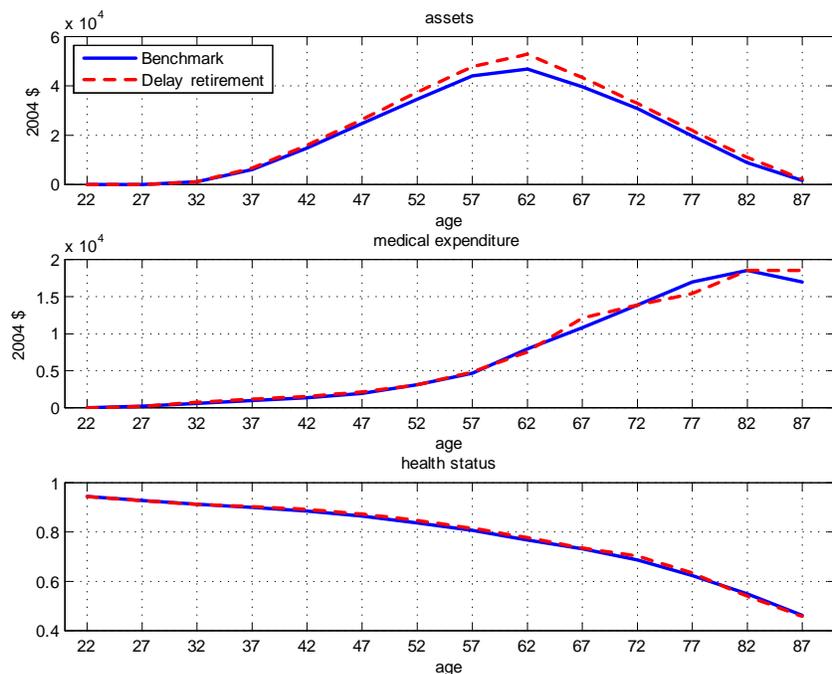
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Figure 8: Life-cycle profiles of assets, medical expenditures and health status: delay retirement age

7.2   Delaying Retirement

Many proposals to reform social security suggest that the retirement age will have to be postponed by a few years. In this section, we run an experiment in which we delay the retirement age j_R by one more period from $j_R = 10$ to $j_R = 11$ while keeping the other parameters at their benchmark values. This corresponds to an increase in the retirement age from 65 to 70 in actuality.

Figure 8 shows the life-cycle profiles of assets, medical expenditures and health

$\mathbf{j}_R$	$\boldsymbol{\tau}_{ss}$	$\mathbf{b}$ (2004$)	M/Y	K/Y	$\mathbf{n}$	$\mathbf{h}$	$Y_{j_R}/Y_{benchmark}$
10	15.85%	18796	15.1%	2.6	0.349	0.779	1.00
11	10.90%	18135	14.4%	2.7	0.350	0.784	1.07

Table 4: Selected aggregate variables: delay retirement age

status when the retirement age is delayed for one period in the model. Panel a shows that due to the delay, an individual increases assets holding over the life-cycle. The main reason is that now she works for a longer period and, hence, her labor income increases enabling her to save more. Panel b and c show that this policy change would not significantly affect medical expenditures and health status.

On the aggregate level, as shown in Table 4, we can see that by delaying retirement, the number of workers increases and the pool of retirees shrinks. Accordingly, the social security tax rate τ_{ss} significantly decreases. The social security benefit, however, does not decrease much. The reformed social security system decreases the medical expenditures-national income ratio from 15.1% to 14.4%. This decrease is not due to changes in medical expenditures, but rather increases in total income as shown in the eighth column of the table, which in turn is due to increases in both capital accumulation and labor supply as shown in fifth and sixth column of the table.

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7.3 Subsidizing Medical Expenditures

During the past 50 years, the U.S. has implemented two government-run health insurance programs: Medicare and Medicaid. In this section, we run an experiment that mimics some features of these programs to quantitatively investigate their impact on medical expenditures. In addition to the social security tax τ_{ss}, the government now also imposes a tax on working age agents to finance its health insurance program. We call this tax τ_{med}. The government collects this tax revenue and uses it exclusively to subsidize medical expenditures at every age up to a proportion. We call this proportion, or subsidy rate, ϕ. An individual's budget thus becomes

$$c_j + (1 - \phi)m_j + a_{j+1} \leq (1 - \tau_{ss} - \tau_{med})w\varepsilon_j n_j + (1 + r)a_j + T, \forall j < j_R$$

$$c_j + (1 - \phi)m_j + a_{j+1} \leq b + (1 + r)a_j + T, \forall j_R \leq j \leq J.$$

The government also has to balance its medical expenditure budget so that its medical expenditure subsidy is self-financing:

$$\tau_{med} = \frac{\phi \sum_{j=1}^{J} \mu_j m_j}{wN}.$$

Since this experiment is meant to mimic Medicare and Medicaid, we choose a subsidy rate, ϕ, to match the share of medical expenditures paid by Medicare and Medicaid
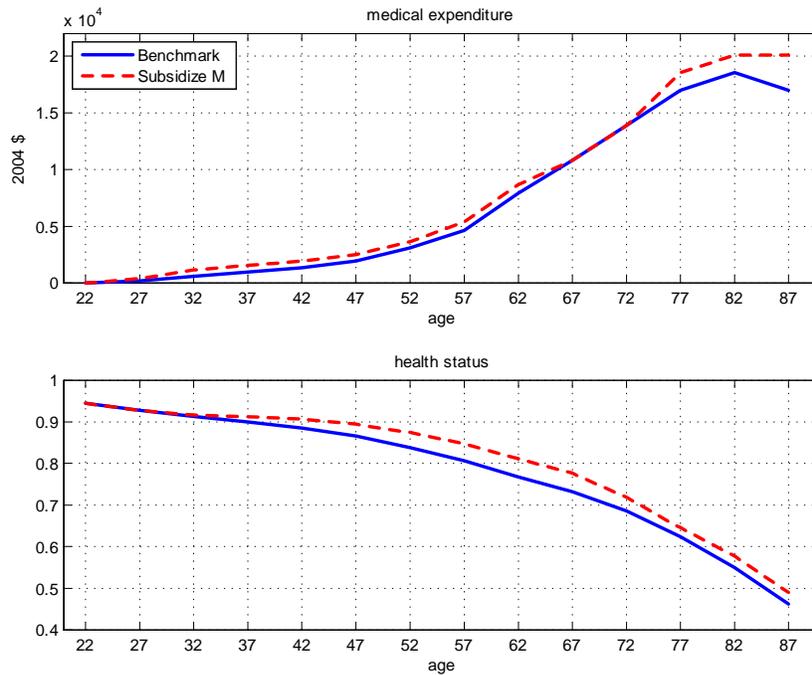
Figure 9: Life-cycle profiles of medical expenditures and health status: subsidize medical expenditures

as a share of total national health expenditures, which was about 32% in 2002.[24] As before, we keep all other parameters at their benchmark values.

Panel a in Figure 9 shows that by introducing a subsidy, medical expenditures increase over the entire life-cycle. This increase is especially high late in life. The subsidy to medical expenditures makes medical care cheaper relative to non-medical consumption goods and hence encourages more usage. Higher medical expenditures

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[24]Data are taken from National Health Expenditures Account (NHE). https://www.cms.gov/NationalHealthExpendData/02_NationalHealthAccountsHistorical.asp#TopOfPage.

ϕ	τ_{med}	M/Y	K/Y	n	h	$Y_\phi/Y_{benchmark}$
0	0	15.1%	2.6	0.349	0.779	1.00
32%	6.03%	17.4%	1.9	0.348	0.803	0.97

Table 5: Selected aggregate variables: subsidize medical expenditures

over the life-cycle also lead to better health status, as shown in panel b.

On the aggregate level, as shown in Table 5, when we introduce health insurance, an additional 6.03% of income tax is needed to finance medical care. This not only encourages higher medical consumption over the life-cycle, but also raises the medical expenditure-national income ratio by 2.3% from 15.1% to 17.4%. Subsidies to medical expenditures also makes investment in health capital relatively more attractive compared to investment in physical capital, which discourages asset holdings and hence decreases the capital-wealth ratio. With lower capital, total income decreases by 3%. Given that the change in the M/Y ratio is much larger, this suggests that the increase in the M/Y ratio mostly comes from higher medical expenditures rather than decreases in income.

Medicare and Medicaid were introduced in 1965 by the Social Security Act. Before they were introduced, the medical expenditures-GDP ratio in the U.S. was 5.2% in 1960 (NHA data). In 2002, this ratio had increased to 15.1%. Our exercise here shows that the introduction of health-related social insurance has contributed about 2.3% of the increase in the M/Y ratio. In other words, the introduction of Medicare

and Medicaid explains about 23% of the increase in M/Y ratio between 1960 and 2002.[25] This finding confirms Finkelstein (2007) who estimates the aggregate effect of the introduction of Medicare in 1965 on health spending. She claims it is very significant and over six times larger than what the evidence from individual-level changes in health insurance would have predicted.[26]

7.4   Changing Survival Probabilities

The past 50 years have witnessed a dramatic increase in life expectancy in the U.S. and elsewhere. As shown in Figure 10 in which we compare data on survival probabilities (taken from US Life Table) between 1960 and 2002, only 79% of individuals at age 89 could live up to age 90 in 1960, while this number increased dramatically to 87% in 2002. The difference in survival probabilities implies 7.4 additional years of life. Life expectancy in 1960 was 69.8 years, but was 77.2 in 2002.

In the benchmark model, health affects survival. Survival probabilities, however, might also affect health investment. In the Euler equation (7), an increase in the

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[25]To check the robustness of this result, we also recalibrate the current model with the subsidy to medical expenditures to match moment conditions in Table 2. We then run an experiment that shuts down the subsidy by setting $\phi = 0$. Our results show that the M/Y ratio decreases by about 2% from 15.3% in the benchmark model with $\phi = 0.32$ to 13.3% in the model without subsidy, which is quite close to 2.3% we got here.

[26]Zhao (2010) also finds that an increase in the subsidy rate from 0 to 45% can explain about 36% of the increase in the M/Y ratio between 1950 and 2000. In that model, the only role of health is that it increases longevity. Fonseca et al. (2009) find that the increase in generosity of health insurance can explain 29% of the increase in the M/Y ratio between 1965 and 2005 in a partial equilibrium calibrated life-cycle model. Our finding is consistent with both of the other findings.
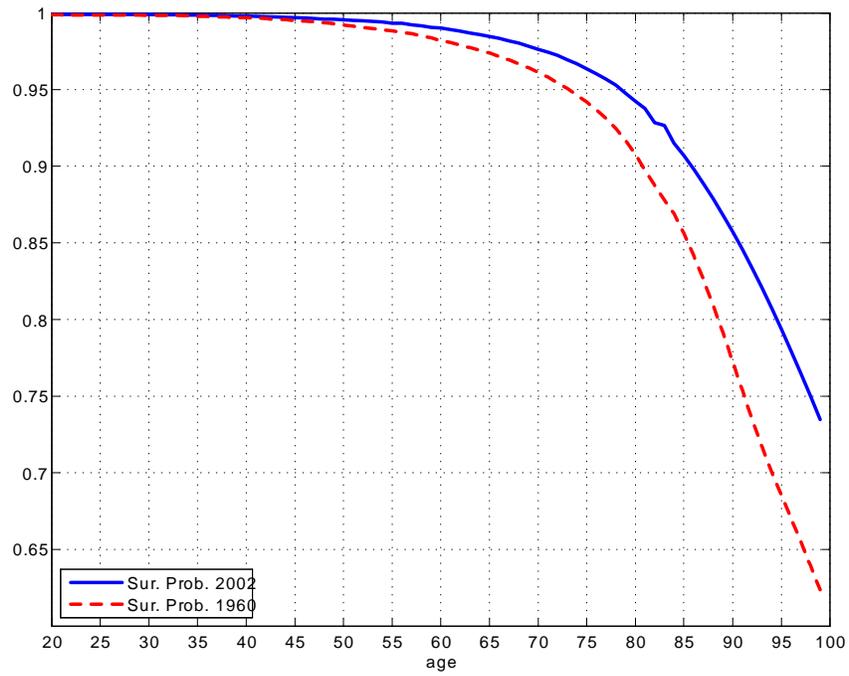
Figure 10: Life-cycle profile of survival probabilities: 1960 vs. 2002

survival probability will raise the marginal benefit of health investment and hence impact the choice between non-medical and medical consumption. In the fourth experiment, we investigate how changes in longevity affect health investment and other life-cycle economic decisions. In order to isolate the effect of the survival probability on health investment, we shut down endogenous survival by assuming that the survival probability is exogenously given by the probabilities shown in Figure 10. With the survival probabilities from 2002, we recalibrate the benchmark model in Section 2 to match the moment conditions in Table 2.[27] Since now the survival probability is exogenous, we do not need to add a constant term $\underline{c}$ to the utility function. We thus set $\underline{c} = -1$ to be consistent with CRRA function. We then replace the 2002 survival probabilities with the survival data from 1960 while keeping all other parameters unchanged from their new benchmark values.

Figure 11 shows life-cycle profiles of assets, medical expenditures, and health status using the different survival probabilities. Shorter longevity lowers an individual's effective discount rate and thus affects all life-cycle economic decisions. Panel a in Figure 11 shows that with the 1960 survival probabilities, individuals significantly reduce their savings at all ages.[28] The capital-output ratio decreases from 2.60 in

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[27]The new parameter values are $\beta = (0.9671)^5, \sigma = 2, \psi = -7.75, \rho = 0.339, \lambda = 0.64, d_0 = -3.92, d_1 = 0.218, d_2 = 0.009, B = 0.879, \xi = 0.80, Q = 0.0143, \gamma = 2.55, \kappa = 0.40.$

[28]The effects of adult longevity on life-cycle and aggregate savings have been studied emprically in Bloom et al. (2003) and Kinugasa and Mason (2007). They all find that the effects are significantly positive. De Nardi, French and Jones (2009) use an estimated structural model based on De Nardi,
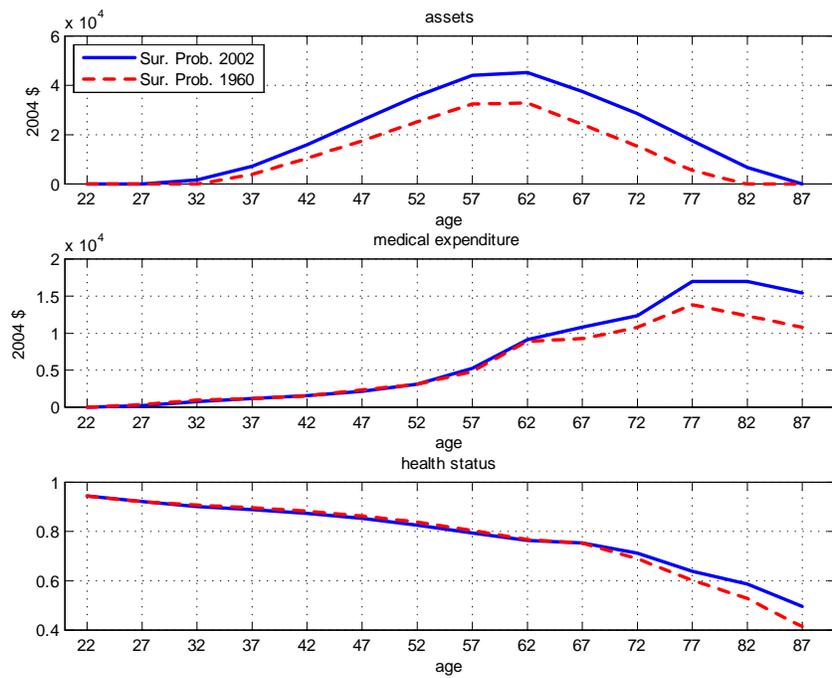
Figure 11: Life-cycle profiles of assets, medical expenditures and health status: change survival probabilities

the benchmark model to 1.70.

Shorter longevity also reduces health investment as shown in panel b in Figure 11. The effect is more pronounced after ages 55-59 which is when the survival probabilities in 1960 start to diverge from those in 2002. With exogenous survival probabilities, the Euler equation for health investment changes to

$$\frac{\partial u}{\partial c_j} = \beta g'(m_j)\varphi_{j+1}\left\{\frac{\partial u}{\partial h_{j+1}} - \frac{\partial u}{\partial l_{j+1}}s'(h_{j+1}) + \frac{\partial u/\partial c_{j+1}}{g'(m_{j+1})}(1 - \delta_{h_{j+1}})\right\}. \qquad (13)$$

With lower $\{\varphi_j\}_{j=1}^J$ in 1960, the effective discount rate $\beta\varphi_{j+1}$ is lower for every age j. The right-hand side of equation (13), i.e., the marginal benefit of health investment, is lower at every j. Health investment therefore is discouraged. Since the difference in survival probabilities is most pronounced at later ages as shown in Figure 10, it is not surprising that the decrease in health expenditures is much more significant at later ages.

Meara, White, and Cutler (2004) find that health expenditure growth has been much faster among the elderly than among the young. As a result, the life-cycle profile of health expenditures per person has become much steeper over time in the U.S. Our counterfactual experiments in Section 7.3 and the current one (panel a in Figure

French and Jones (2010) to assess the effect of heterogeneity in life expectancy on the savings by the elderly. They find that the differences in life expectancy related to observable factors such as income, gender, and health have large effects on savings.

9 and panel b in Figure 11) shed light on potential reasons. Our experiments show that both the introduction of Medicare and Medicaid and the increase in longevity make a significant contribution to the concentration of medical expenditures towards the end of life.

Table 6 shows selected aggregate variables from the model economy. With a lower survival probability, the dependency ratio decreases. That decreases the financial burden of the social security system so that τ_{ss} decreases from 15.9% in the benchmark to 11.8% while the social security benefit remains almost the same. The medical expenditure-national income ratio decreases from 15.1% in the benchmark to 11.5%. This ratio was 5.2% in 1960 in the data. Therefore, rising life expectancy alone can explain about 36% of the rise in the health expenditures-GDP ratio from 1960 to 2002. Notice that this is a significant contribution without any interaction from "policy change" because we do not allow the social security system $\{\kappa, j_R\}$ to change during this period and the government-sponsored health insurance is not present. That said, the 36% that can be explained by changing survival probabilities is orthogonal to the 23% which is can be explained by the introduction of Medicare and Medicaid as in Section 7.3.

φ_j	τ_{ss}	b (2004\$)	M/Y	K/Y	n	h	$Y_\varphi/Y_{benchmark}$
2002	15.92%	18705	15.1%	2.6	0.347	0.783	1.00
1960	11.83%	18553	11.5%	1.7	0.345	0.773	1.03

Table 6: Selected aggregate variables: change survival probabilities

8   Conclusions

We studied the life-cycle behavior of health investment and its effects on other aspects of life-cycle behavior. Three motives for health investment were considered. First, health delivers a flow of utility each period (the consumption motive). Second, better health enables people to allocate more time to productive or pleasurable activities (the investment motive). Third, better health increases longevity (the survival motive). To accomplish this, we calibrated an overlapping generations model with endogenous health investment by matching various ratios from the data. We found that the calibrated model fits key life-cycle profiles of consumption, working hours, health status, medical expenditures, and survival very well.

Based on the success of the benchmark model, we ran a decomposition exercise to quantify the relative importance of each motive. Under benchmark parameters, we found that the investment motive is more important than the consumption motive until the late 40s and the early 50s. After that, the consumption motive takes over and become dominant. In other words, younger people invest in their health because better health allows them to enjoy more leisure or to work more, while older people

invest in their health because its marginal utility is extremely high. Finally, the survival motive is quantitatively less important than the other two motives.

We then conducted a series of counterfactual experiments to investigate how changes to social security policy, the introduction of government-run health insurance (e.g., Medicare and Medicaid) and changes in life-expectancy affect the life-cycle behavior of health investment and the aggregate medical expenditures-GDP ratio. We find that policies aiming to ease the solvency problem that the current social security system is facing, such as lowering the replacement ratio and delaying the retirement age, would not affect either the life-cycle profile of medical expenditures or the medical expenditures-GDP ratio significantly. The introduction of Medicare and Medicaid, however, significantly increases medical expenditures over the entire life-cycle and, on aggregate, is able to explain about 23% of the increase in the medical expenditures-GDP ratio from 1960 to 2002. Finally, changing survival probabilities from those in 1960 to those in 2002 significantly increases medical expenditures over the life course, especially towards the end of life. This can also explain about 36% of the increase in medical expenditures-GDP ratio from 1960 to 2002. We conclude that the introduction of Medicare and Medicaid and the increase in longevity play an important role in explaining the concentration of medical expenditures towards the end of the life-cycle and the rising medical expenditures-GDP ratio over time as

observed in the data.

Our model can be extended along several dimensions. First, we assumed exogenous factor prices for simplicity. Therefore, the model does not capture feedback effects from factor prices. Future work could extend the model by allowing endogenous factor prices to investigate general equilibrium effects from factor prices to health investment behavior. Second, we assumed mandatory retirement at age 65 in the model. In the future, researchers may want to endogenize retirement to shed light on the effects of health on retirement behavior in a setting with endogenous health. Finally, there is no health uncertainty in the model. Adding uncertainty would allow us to analyze the effects of health insurance against idiosyncratic medical expenditure shocks on an individual's health investment. It will also generate heterogeneity in medical expenditures across individuals.

With these extensions, this model provides a platform to carry out some very important policy experiments. For example, we can analyze the welfare cost of the Medicare system. While Medicare facilitates risk-sharing, it also has costs. First, the Medicare tax distorts labor supply. Second, if individuals know that they will be insured against medical expenditure risk when they are older, they may reduce their health investment when young, thereby resulting in higher medical costs to society later on. Another interesting policy experiment would be to analyze the welfare gain

(or loss) of a change from the current system in the United States, which contains both employer-provided health insurance along with public health insurance (such as Medicare and Medicaid) to an alternative regime such as universal health care. Finally, one can also use this framework to quantify the effects of tax-favorable health savings accounts (HSAs) on savings, consumption and health investment. In this sense, we view this paper as a first step in a more ambitious research agenda.

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