Health Investment over the Life-Cycle*

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Abstract

We quantify what drives the rise in medical expenditures over the life-cycle using a dynamic overlapping generations model of health investment. Three

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motives for health investment 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 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 consumption motive since better health improves the quality of life. The survival motive is quantitatively less important when compared to the other two motives. We also conduct a series of counter-factual policy experiments to investigate how modifications to Social Security, medical expenditure subsidies and health care technologies affect the behavior of medical expenditures.

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## 1 Introduction

In this paper, we ask what factors determine the allocation of medical expenditures over the life-cycle from a quantitative macroeconomic perspective. While there is a growing macro-health literature that has investigated the determinants of the ag-
aggregate ratio of medical expenditures to GDP in the economy (e.g. Suen 2006, Hall and Jones 2007, Fonseca et al. 2009, Zhao 2010, He and Huang 2013), little work has been done that quantitatively investigates the driving forces behind 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.

We view health as a type of capital stock following Grossman (1972). In our model, health capital takes medical expenditures as its sole input. 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 healthier days that can be spent working or relaxing. 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 (2000) explains the first two of these motives qualitatively, little if anything is understood about how the three motives evolve over the life-cycle.

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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 since our main focus is on medical expenditures. 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. For an alternative model with both medical expenditure and time inputs for health production, see He and Huang (2013). However, their model does not have life-cycle feature.
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 asset holdings, consumption and labor supply. This is one of the first papers to shed light on this issue.

To accomplish this, we calibrate an overlapping generations model with endogenous health accumulation. 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 probabilities well. We then carry out a decomposition exercise to quantitatively isolate the effect of each motive on medical expenditure. 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 mainly because better health allows them to enjoy more leisure and to work more, while older people invest in their health mainly because health improves their quality of life. The survival motive becomes more important with age but matters less when compared to the other two motives.

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. In particular, our focus on the life-cycle enables us and others to make statements about how policies will affect health investment behavior over the life-cycle and distribute medical resources across generations which is something that previous work on health investment does not do.

We conduct a series of counterfactual experiments to investigate how modifications to Social Security, expansion of government-subsidized health expenditures

\footnote{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 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.}
(which mimics some features of Medicare and Medicaid), and increases in medical technological productivity affect the life-cycle behavior of health investment and the aggregate medical expenditure-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. However, those policies do raise social welfare. On the other hand, the introduction of a subsidy to health expenditures increases medical expenditures over the entire life-cycle and significantly increases the medical expenditure-GDP ratio. This rise in expenditures is particularly acute towards the end-of-life suggesting that government-sponsored health care shifts resources from the young to the old. The subsidy, however, decreases social welfare. Finally, government policies that aim to improve medical technological productivity reduce the life-cycle profile of medical expenditures and decrease the aggregate medical expenditure-GDP ratio. Meanwhile those policies manage to improve health status throughout the life-cycle and improve social welfare. Our results therefore suggest that increasing health care TFP is a better policy than subsidizing medical care usage.

Our work is part of a new and growing macro-health literature that incorporates endogenous health accumulation into dynamic models.\textsuperscript{3} For example, Hall and Jones

\textsuperscript{3}There is also a substantial literature that has incorporated health into computational life-cycle models as an\textit{ exogenous} process. Some model it as an exogenous state variable (Rust and Phelan
(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 (2009) 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 (2013) 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 literature.4

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 quanti-

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4Ozkan (2010) develops a general equilibrium life-cycle model of health capital to study the effect of income inequality on life-cycle profiles of medical expenditures across income groups.
fies 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

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

where $\beta$ 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 $\varphi_{J+1} = 0$. 

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We assume that this survival probability is a function of health status \( h \) and that \( \varphi'(h_j) > 0 \) 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 2009, 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 (1972), 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.”

The agent works until an exogenously given mandatory retirement age $j_R$. Labor productivity differs due to differences in age. We use $\varepsilon_j$ 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

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

where $m_j$ is health investment in goods, $a_{j+1}$ is assets, $\tau_{ss}$ 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 $b$. 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 $\kappa$ of some base income, which we take as the average lifetime labor income

$$b = \kappa \frac{\sum_{i=1}^{j_R-1} w\varepsilon_i n_i}{j_R - 1}$$

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Footnote:

5In a separate appendix which is available at http://huihe.weebly.com/research.html, we show that the alternative model in which health affects labor productivity yields very similar results to the benchmark model.
where $\kappa$ is the replacement ratio. An age-$j$ retiree then faces the budget constraint

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

We assume that agents are not allowed to borrow, so that\(^6\)

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

### 2.3 Health Investment

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

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

where $\delta_{h_j}$ 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 $j+1$.

\(^6\)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.
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

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

subject to

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

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

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

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

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

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 on Social Security tax as endogenous. To simplify the analysis, we assume that factor prices are exogenous by defining an equilibrium for a small open economy. We define a recursive competitive equilibrium as follows.

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

1. Individual and aggregate behavior are consistent

\[
K = \sum_{j} \sum_{a} \sum_{h} \mu_j \lambda_j(a, h)A_{j-1}(a, h)
\]
\[
N = \sum_{j=1}^{jR-1} \sum_{a} \sum_{h} \mu_j \lambda_j(a, h)\varepsilon_jN_j(a, h)
\]
\[
C = \sum_{j} \sum_{a} \sum_{h} \mu_j \lambda_j(a, h)C_j(a, h)
\]
\[
M = \sum_{j} \sum_{a} \sum_{h} \mu_j \lambda_j(a, h)M_j(a, h)
\]
where $\mu_j$ is the age share of the age-$j$ agents.\footnote{The share of age-$j$ individuals in the total population $\mu_j$ is determined by $
abla$
\[ \sum_{j=1}^{J} \mu_j = 1. \]}

2. Given constant prices $\{w, r\}$, the policies $\{\kappa, \tau_{ss}\}$ 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. Social Security system is self-financing

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

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

$$T = \sum_{j} \sum_{a} \sum_{h} \mu_j \lambda_j(a, h)(1 - \varphi_{j+1}(h))A_j(a, h).$$
6. National income identity holds

\[ C + M + K' - K = rK + wN. \]

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 \( j \)

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

(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 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 working ages \( j < j_R \), we have the intra-temporal condition for the work-leisure choice as follows

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

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 working ages \( j < j_R \), the second term inside the bracket of equation (7) becomes

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

In words, for a working-age individual, 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 effect is captured by the term
Thus, the second term in equation (7) 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 $\frac{\varphi_{j+1}(h_{j+1})}{\varphi_{j+1}(h_{j+1})}$ and, hence, an individual will have a higher chance of enjoying utility at age $j+1$. We call this term 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 the 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.\(^8\) 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 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.\(^9\)

\(^8\)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.

\(^9\)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
Figure 1: Life-cycle profile of income, working hours, health status, and medical expenditures: PSID and MEPS data
3.2 Medical Expenditure Survey

Our MEPS sample spans the years 2003-2007.\(^\text{10}\) 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.

\(^{10}\)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 (there are 16!), we choose parameter values to solve the equilibrium and simultaneously match all 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.\(^{11}\) Given suitable values for \(\varpi_1\) and \(\varpi_2\), it is decreasing with age at an increasing rate.

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

1. Dependency ratio \(\left( \frac{\text{number of people aged 65 and over}}{\text{number of people aged 20-64}} \right)\), 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 \(\left( \frac{\varphi_{12}-\varphi_{10}}{\varphi_{10}-\varphi_{8}} \right)\) in the model, which is 2.27.

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

\(^{11}\)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

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

(10)

We assume that consumption and leisure are non-separable and we take a Cobb-Douglas specification as the benchmark.\(^{12}\) The parameter \(\lambda\) measures the relative importance of the consumption-leisure combination in the utility function. The parameter \(\rho\) 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 \(\sigma\) determines the intertemporal elasticity of substitution.

For the standard CRRA utility function, \(\sigma\) 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

\(^{12}\)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 the separate appendix that is available at http://huihe.weebly.com/research.html.
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 $c > 0$ in the period utility function to avoid negative utility.$^{13}$

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, $\lambda$, to be 0.69 to match the average consumption-labor income ratio for working age adults, which is 78.5%.$^{14}$ We calibrate the share of consumption $\rho$ 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 $\psi$ 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.$^{15}$ Since the elasticity of substitution between consumption and leisure is

$^{13}$See also Zhao (2010).
$^{14}$Consumption data are taken from Fernandez-Villaverde and Krueger (2007), who use the CEX data set.
$^{15}$The reason why parameter $\psi$ significantly affects the ratio of medical expenditures of ages 55-74 to ages 20-54 is following. We know that consumption peaks at early 50s and declines after (see panel f in Figure 2). The relationship between consumption and health in the utility function therefore could affect the speed of the decline of consumption after age 55. The more complementary between
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 $u$ affects the “S-Motive.” This means that the constant term $c$ in the period utility function affects health investment through the survival probability. And this effect should be more relevant to older ages. We therefore calibrate $c$ to match the ratio of the change in survival to the change in medical expenditures from ages 65-69 to 55-59, which is -0.68 in the data. The resulting $c$ is 3.40. As Hall and Jones (2007) point out, $c$ also determines the value of a statistical life (VSL). We thus also check the average VSL across age groups given the calibrated value of $c$. Our benchmark model generates an average VSL of 7.63 million dollars, which is in the range of the estimates of empirical literature.\footnote{Hall and Jones (2007) show that the estimates of VSL in the literature range from about two million to nine million dollars. We calculate VSL following Hall and Jones (2007), i.e., VSL is equal to the marginal cost of saving a life, which is defined as $1/(\partial \bar{\psi}_j/\partial m_j)$ for age $j$. Our number is also in line with the estimates from Zhao (2010).}

\footnote{Hall and Jones (2007) show that the estimates of VSL in the literature range from about two million to nine million dollars. We calculate VSL following Hall and Jones (2007), i.e., VSL is equal to the marginal cost of saving a life, which is defined as $1/(\partial \bar{\psi}_j/\partial m_j)$ for age $j$. Our number is also in line with the estimates from Zhao (2010).}
4.3 Social Security

The Social Security replacement ratio $\kappa$ 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).

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 $13.02$. The annual interest rate is set to be 4%. 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

$$\delta_{h_j} = \frac{\exp(d_0 + d_1j + d_2j^2)}{1 + \exp(d_0 + d_1j + d_2j^2)}.$$  

\textsuperscript{17}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 ($\frac{\sum_{j=1}^{j=R-1} \varepsilon_j}{w}$) by the average age-efficiency $\frac{\sum_{j=1}^{j=R-1} \varepsilon_j}{w_j}$ to obtain average wage rate $w$, which is $13.02$.

\textsuperscript{18}4% is a quite common target for the return to capital in life-cycle models. See for example Fernandez-Villaverde and Krueger (2011).
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

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

where $B$ measures the productivity of medical care, and $\xi$ represents the return to scale for health investment. Accordingly, we have five model-specific parameters governing the health accumulation process: $d_0, d_1, d_2, B, \xi$. 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.\(^{19}\) 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.\(^{20}\) The second is the average medical expenditure-labor income ratio from age 20 to 64, which is 5.8%.\(^{21}\)

\(^{19}\)We choose to match the ratios of health status in earlier ages here is to leave the match of health status in later life-cycle as out-of-sample prediction. The calibration here thus avoids data-fitting problem.

\(^{20}\)Data are from the National Health Accounts (NHA).

\(^{21}\)This ratio is calculated based on the data from panel a and d in Figure 1.
4.6 Sick Time

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

\[ s(h_j) = Q h_j^{-\gamma} \]  \hspace{1cm} (12)

where \( Q \) is the scale factor and \( \gamma \) measures the sensitivity of sick time to health. We calibrate these two parameters to match two moment conditions in the data. 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.\(^{22}\) 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.

\(^{22}\)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
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( J )</td>
<td>maximum life span</td>
<td>16</td>
<td>age 95-99</td>
</tr>
<tr>
<td>( j_R )</td>
<td>mandatory retirement age</td>
<td>10</td>
<td>age 65-69</td>
</tr>
<tr>
<td>( \varpi_0 )</td>
<td>survival prob.</td>
<td>(-5.76)</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \varpi_1 )</td>
<td>survival prob.</td>
<td>0.285</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \varpi_2 )</td>
<td>survival prob.</td>
<td>0.0082</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \varpi_3 )</td>
<td>survival prob.</td>
<td>(-0.30)</td>
<td>calibrated</td>
</tr>
</tbody>
</table>

### Preferences

<table>
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<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>subjective discount rate</td>
<td>((0.9659)^{0.9659})</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Intertem. ela. sub. coefficient</td>
<td>2</td>
<td>common value</td>
</tr>
<tr>
<td>( \psi )</td>
<td>elasticity b/w cons. and health</td>
<td>(-7.70)</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \rho )</td>
<td>share of ( c ) in ( c )-leisure combination</td>
<td>0.342</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>share of cons-leisure com. in utility</td>
<td>0.69</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \zeta )</td>
<td>constant term in utility</td>
<td>3.4</td>
<td>calibrated</td>
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### Health Accumulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_0 )</td>
<td>dep. rate of health</td>
<td>(-4.25)</td>
<td>calibrated</td>
</tr>
<tr>
<td>( d_1 )</td>
<td>dep. rate of health</td>
<td>0.238</td>
<td>calibrated</td>
</tr>
<tr>
<td>( d_2 )</td>
<td>dep. rate of health</td>
<td>0.00823</td>
<td>calibrated</td>
</tr>
<tr>
<td>( B )</td>
<td>productivity of health technology</td>
<td>0.68</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \xi )</td>
<td>return to scale for health investment</td>
<td>0.8</td>
<td>calibrated</td>
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### Sick Time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Q )</td>
<td>scale factor of sick time</td>
<td>0.0145</td>
<td>calibrated</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>elasticity of sick time to health</td>
<td>2.7</td>
<td>calibrated</td>
</tr>
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</table>

### Labor Productivity

<table>
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<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( { \varepsilon_j }_{j=1}^{R-1} )</td>
<td>age-efficiency profile</td>
<td>Conesa et al. (2009)</td>
<td></td>
</tr>
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</table>

### Social Security

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \kappa )</td>
<td>Social Security replacement ratio</td>
<td>40%</td>
<td>Kotlikoff et al. (1999)</td>
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### Factor Prices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>( w )</td>
<td>wage rate</td>
<td>$13.02</td>
<td>PSID</td>
</tr>
<tr>
<td>( r )</td>
<td>interest rate</td>
<td>0.2167</td>
<td>Fernandez-Villaverde et al. (2011)</td>
</tr>
</tbody>
</table>

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
 Δsur (65-69 to 75-79)/Δsur (55-59 to 65-69) (Life Table 2002) | 2.27 | 2.28
 Δsur (55-59 to 65-69)/Δmed. exp. (55-59 to 65-69) (MEPS and Life Table) | -0.063 | -0.068

Table 2: Target moments: data vs. model

5 Benchmark Results

Using the parameter values from Table 1, we compute the model using standard numerical methods. 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, 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 days. This number is very close to the one reported in Gilleskie (1998).

23 The computational method is similar to the one used in Imrohoroglu et al. (1995). The details are provided in the separate appendix.
Figure 2: Life-cycle profiles: benchmark model vs. data
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 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.\(^{24}\)

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.

\(^{24}\)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.
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 45-49. 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 to 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-separability 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.\footnote{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 the separate appendix), we obtain a much smoother consumption profile around retirement age.}

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 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 $\omega_3 = 0$ while keeping all other parameters at their benchmark values. Because health does not affect survival, the third term in equation (7) vanishes.

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 mo-
Figure 3: Life-cycle profile of medical expenditures: decomposition
tive 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 much 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 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
Figure 4: Life-cycle profiles of consumption, investment, and survival motive for health investment
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.

To some extent, the low importance of the S-Motive is surprising since one would think an important feature of the value of health is to extend life span (as modeled in Suen 2005 and Zhao 2010). However, notice that our model also includes the explicit feature of consumption value for health (i.e., health directly enters into utility function). In other words, health in our model not only extends life span, but also improves the quality of life. In that sense, the combination of C-Motive and S-Motive in our model is isomorphic to the role that health plays in the literature such as Suen (2005) and Zhao (2010). Our decomposition exercise thus provides a deeper understanding on the reason why people value health over the life-cycle. By differentiating the C-Motive from the S-Motive, we show that an individual invests in health mainly because health improves the quality of life, not because health simply extends the length of life.

Differences in medical expenditures determine differences in health status, which
Figure 5: Life-cycle profiles of health status and survival probability: decomposition
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 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

Our benchmark model offers a quantitative analysis of health investment over the life-cycle within a framework featuring various roles of health. Our focus on the life-
cycle enables us to make statements about how policies will affect health investment behavior over the life-cycle and distribute medical resources across generations which is something that previous work on health investment does not do. With various roles of health in the model, we are also able to provide a comprehensive analysis of the possible impact of different policies on health expenditure and health status.

The model setting allows us to consider three sets of policy changes. First, 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 motive is very important in driving up medical expenditures prior to retirement. Second, the government can have a direct impact on health investment by subsidizing medical expenditures. Third, the government also can indirectly affect health investment by encouraging medical sector technological change via increases in \( B \). In this section, we run a series of counterfactual experiments that quantitatively investigate the effect of these policies on health investment behavior. In addition, due to the equilibrium structure of the model, we are also able to show the impact of the policies on the aggregate medical expenditure-national income ratio.\(^{26}\)

\(^{26}\)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.
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, $\kappa$, 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 values of \( \kappa \). 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 Imrohoroglu et al. (1995). The effect is also shown in Table 3; as the replacement ratio \( \kappa \) 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 \( \kappa \). 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

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

Note that both the Social Security tax rate \( \tau_{ss} \) and the replacement ratio \( \kappa \) enter the expression. The government in the model has to balance the budget since the Social
Figure 7: Life-cycle profiles of medical expenditures and health status: different replacement ratio
Security system is self-financing. Therefore a lower replacement ratio also leads to a lower Social Security tax rate \( \tau_{ss} \) as shown in the second column of Table 3. A lower \( \tau_{ss} \) tends to increase the magnitude of the investment motive by increasing current after-tax labor income. In contrast, a lower \( \kappa \) in the same term 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 \( \kappa \) 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 substantially higher asset holdings for a lower values of \( \kappa \), 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 \( \kappa \) generates higher medical expenditures over the life-cycle, it is not surprising to see in panel b of Figure 7 that a lower \( \kappa \) 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 \( \kappa \) 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 expenditure-national income ratio does not change much as $\kappa$ changes. For example, when $\kappa$ 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 $\kappa$ increases medical expenditures. However, this puzzle is resolved once we consider that lower $\kappa$ increases both capital accumulation and labor supply and, so the denominator of the ratio increases by a greater amount than the numerator (shown in the eighth column for comparison of GDP to the benchmark level). Overall, changing the replacement ratio does not affect medical expenditures significantly.

Finally, we calculate the welfare effects of different replacement ratios compared to the benchmark model. First, we define the lifetime utility of a newborn

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

with the period utility function defined as in equation (10). For benchmark model, we have the allocation $(c^b, l^b, h^b)$ and the associated utility $U(c^b, l^b, h^b)$. For each policy change, we have the new allocation $(c^*, l^*, h^*)$ and the associated utility $U(c^*, l^*, h^*)$. Then following the literature (e.g., Conesa et al. 2009 and Fehr et al. 2013), the wel-
Table 3: Selected aggregate variables: different replacement ratio

<table>
<thead>
<tr>
<th>$\kappa$</th>
<th>$\tau_{as}$</th>
<th>b (2004$)$</th>
<th>$M/Y$</th>
<th>$K/Y$</th>
<th>n</th>
<th>h</th>
<th>$Y_{\kappa}/Y_{ben}$</th>
<th>CEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
<td>0</td>
<td>14.9%</td>
<td>5.5</td>
<td>0.352</td>
<td>0.811</td>
<td>1.16</td>
<td>6.33%</td>
</tr>
<tr>
<td>20%</td>
<td>7.95%</td>
<td>9482</td>
<td>15.0%</td>
<td>4.1</td>
<td>0.351</td>
<td>0.794</td>
<td>1.08</td>
<td>3.24%</td>
</tr>
<tr>
<td>40%</td>
<td>15.85%</td>
<td>18796</td>
<td>15.1%</td>
<td>2.6</td>
<td>0.349</td>
<td>0.779</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>60%</td>
<td>23.7%</td>
<td>27814</td>
<td>15.2%</td>
<td>1.0</td>
<td>0.345</td>
<td>0.764</td>
<td>0.92</td>
<td>−3.26%</td>
</tr>
</tbody>
</table>

Table 3: Selected aggregate variables: different replacement ratio

fare consequence of switching from the steady-state benchmark allocation $(c^b, l^b, h^b)$ to alternative allocation $(c^*, l^*, h^*)$, or consumption equivalent variation (CEV) of the policy change is

$$CEV = \left[ \frac{U(c^*, l^*, h^*)}{U(c^b, l^b, h^b)} \right]^{1/(1-\sigma)} - 1$$

We report the CEV for each policy change in the ninth column of Table 3. The results show that in the current model, a reduction in replacement ratio is a welfare improvement, while zero replacement ratio, i.e., privatization of Social Security gives the highest social welfare. The results are consistent with the finding in Kotlikoff, Smetters, and Walliser (1999), although they do not model health.

### 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
Figure 8: Life-cycle profiles of assets, medical expenditures and health status: delaying retirement age

increase in the retirement age from 65 to 70 in actuality.

Figure 8 shows the life-cycle profiles of assets, medical expenditures and health status when the retirement age is delayed for one period in the model. Panel a shows that due to the delay, an individual increases asset 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 $\tau_{ss}$ significantly decreases. The Social Security benefit, however, does not decrease much. The reformed Social Security system decreases the medical expenditure-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 the fifth and sixth column of the table. Finally, since higher income leads to higher consumption, almost unchanged leisure and better health, delaying the retirement age increases social welfare, which is equivalent to a 1.63 percentage increase in the allocation of consumption-leisure-health compared to the benchmark one.

<table>
<thead>
<tr>
<th>$j_R$</th>
<th>$\tau_{ss}$</th>
<th>$b$ (2004$$$)</th>
<th>$M/Y$</th>
<th>$K/Y$</th>
<th>$n$</th>
<th>$h$</th>
<th>$Y_{jr}/Y_{ben}$</th>
<th>CEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>15.85%</td>
<td>18796</td>
<td>15.1%</td>
<td>2.6</td>
<td>0.349</td>
<td>0.779</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>10.90%</td>
<td>18135</td>
<td>14.4%</td>
<td>2.7</td>
<td>0.350</td>
<td>0.784</td>
<td>1.07</td>
<td>1.63%</td>
</tr>
</tbody>
</table>

Table 4: Selected aggregate variables: delaying retirement age
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. In addition to the Social Security tax $\tau_{ss}$, we assume that the government now also imposes a tax on working age agents to finance its health insurance program. We call this tax $\tau_{med}$. 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, $\phi$. An individual’s budget thus becomes

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

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

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 some features of public health insurance such as Medicare and Medicaid, we choose a subsidy rate, $\phi$, to match the share of medical...
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 expenditures paid by Medicare and Medicaid in total national health expenditures, which was about 32% in 2002. As before, we keep all other parameters at their benchmark values.

Figure 9: Life-cycle profiles of medical expenditures and health status: subsidize medical expenditures

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\[27\] Data are taken from National Health Expenditures Account (NHE).
subsidy to medical expenditures makes medical care cheaper relative to non-medical consumption goods and hence encourages more usage. Higher 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 the government-sponsored subsidy, an additional 6.03% of income tax is needed to finance medical care. This policy 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 make investment in health capital relatively more attractive compared to investment in physical capital, which discourages asset holdings and hence decreases the capital-wealth ratio.

Finally, the CEV calculation shows that subsidizing medical expenditures is a net welfare loss which is equivalent to a 2.19% decrease in the allocation of the benchmark case. On the one hand, subsidizing medical expenditure makes health investment more attractive and hence distorts the physical capital accumulation, which leads to lower output. On the other hand, subsidizing medical expenditure reduces the relative price of medical expenditures compared to non-medical consumption goods.

Table 5: Selected aggregate variables: subsidize medical expenditures

<table>
<thead>
<tr>
<th>$\phi$</th>
<th>$\tau_{med}$</th>
<th>$M/Y$</th>
<th>$K/Y$</th>
<th>n</th>
<th>h</th>
<th>$Y_{\phi}/Y_{ben}$</th>
<th>CEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>15.1%</td>
<td>2.6</td>
<td>0.349</td>
<td>0.779</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>32%</td>
<td>6.03%</td>
<td>17.4%</td>
<td>1.9</td>
<td>0.348</td>
<td>0.803</td>
<td>0.97</td>
<td>$-2.19%$</td>
</tr>
</tbody>
</table>

54
and hence leads to lower consumption (in equilibrium non-medical consumption-GDP ratio drops about 2.5%). Both channels have a negative impact on the social welfare.

7.4 Encouraging Health Care Technological Change

Technological improvement in health care services have been cited as an important source of rising medical expenditure-GDP ratio in the US (see Suen 2005). The government can impose a policy that aims to accelerate this technological change (e.g., more funding for the National Institute of Health, tax favorable treatment on R&D in drugs, etc.). We now investigate what would happen in the current model if the medical service sector TFP increases.

In our benchmark model, the TFP of medical care technology is calibrated to be 0.68. We analyze two hypothetical scenarios. First, $B$ increases by 10% (to 0.748) and then to 20% (to 0.816). We keep all other parameters at their benchmark values.

Panel a in Figure 10 shows that increasing $B$ reduces medical expenditures over the life-cycle, especially after the mid 50s. However, panel b in the same figure reports that health status improves despite health investment decreasing, which indicates that the efficiency of health investment increases.

Since health works as both a consumption and investment good in the model,
Figure 10: Life-cycle profiles of medical expenditures and health status: increase TFP of health care
increasing $B$ makes investment in health capital more attractive compared to the investment in physical capital (as an evidence, the third column in Table 6 which shows that the capital-output ratio decreases as $B$ increases); on the other hand, increasing $B$ leads to a reduction of relative price of medical expenditures compared to non-medical consumption goods, which in turn induces a switch from non-medical consumption to medical care. Both channels tend to increase health investment over the life-cycle and increases the aggregate medical expenditure-GDP ratio. However, health is complementary to non-medical consumption in our model. Therefore improving health leads to an increase in non-medical consumption, which offsets the relative price effect mentioned above.\footnote{In an experiment, we shut down the complementarity between non-medical consumption and health in the utility function by setting $\psi = 0.0001$ and then increase $B$ by 10\% and 20\% respectively. The results show that $M/Y$ ratio increases from 15.1\% in the benchmark case to 18.6\% and 17.9\%. For the theoretical analysis on the importance of the elasticity of substitution between consumption and health on the sign of the effect of $B$ on medical expenditure, see Batinti (2013).} Under our calibrated parameter values, the latter dominates the first two channels.

Finally, by raising non-medical consumption ($C/Y$ ratio increases by 0.9\% and 1.4\% respectively for two cases) and health status (as shown in the fifth column

### Table 6: Selected aggregate variables: increase TFP of health care

<table>
<thead>
<tr>
<th>$B$</th>
<th>$M/Y$</th>
<th>$K/Y$</th>
<th>$n$</th>
<th>$h$</th>
<th>$Y_b/Y_{ben}$</th>
<th>CEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.680</td>
<td>15.1%</td>
<td>2.6</td>
<td>0.349</td>
<td>0.779</td>
<td>1.000</td>
<td>0</td>
</tr>
<tr>
<td>0.748</td>
<td>14.1%</td>
<td>2.4</td>
<td>0.349</td>
<td>0.789</td>
<td>0.996</td>
<td>0.07%</td>
</tr>
<tr>
<td>0.816</td>
<td>13.3%</td>
<td>2.3</td>
<td>0.349</td>
<td>0.799</td>
<td>0.988</td>
<td>0.18%</td>
</tr>
</tbody>
</table>
of Table 6), increasing $B$ improves social welfare by 0.07% and 0.18% respectively, although GDP decreases by 0.4% and 1.2% respectively.

To summarize, based on the current model, we find that policies that are 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. However, those policies do raise social welfare. On the other hand, the introduction of a government subsidy to health expenditures increases medical expenditures over the entire life-cycle and significantly increases the medical expenditure-GDP ratio. This rise in expenditures is particularly acute towards the end-of-life suggesting that government-sponsored health care shifts resources from the young to the old. The subsidy, however, decreases social welfare. Finally, government policies that aim to improve medical technological productivity reduce the life-cycle profile of medical expenditures and decrease the aggregate medical expenditure-GDP ratio. Meanwhile those policies improve health status throughout the life-cycle and improve social welfare. So it appears that encouraging health care technological change is a better policy than subsidizing medical care.
8 Conclusions

We studied the life-cycle behavior of health investment and its effects on other aspects of life-cycle behavior. Specifically, we ask what drives the run-up of medical expenditures over the life-cycle. 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 becomes 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 health improves their quality of life. 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, government-subsidies of medical expenditure and health care technologies affect the life-cycle behavior of health investment and the aggregate medical expenditure-GDP ratio. We find that policies that aim to ease the insolvency of the current Social Security system, 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 expenditure-GDP ratio significantly, although they bring sizable welfare gains. Subsidizing medical expenditures, however, significantly increases medical expenditures over the entire life-cycle and substantially raises the medical expenditure-GDP ratio. The introduction of the subsidy, in addition, brings a welfare loss. Finally, increasing health care TFP reduces the life-cycle profile of medical expenditures and decreases the aggregate medical expenditure-GDP ratio. However, due to the increase in the efficiency of health investment, the policy improves health and improves social welfare. Our results suggests that increasing health care TFP is a better policy than subsidizing medical care usage.

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 of the same age.

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.

References


