Health Investment over the Life-Cycle*

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February 13, 2009

Abstract

We study the evolution of health investment over the life-cycle within the context of an overlapping generations general equilibrium model. We calibrate the model to match key economic aggregates and quantify the importance of health as both a consumption and investment good. Good health has a high investment value early in the life-course, but this steadily declines with age until retirement when it is zero. In contrast, the consumption value of health exhibits a hump shape due to a continuously increasing marginal utility

*We would like to thank seminar participants in the Economics Brownbag Workshop at the University of Hawai'i at Mānoa for useful feedback.

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of health and an effective discount factor that decreases with age. Health investment, which is driven by both consumption and investment motives, also affects individuals' labor supply and consumption decision over the life-cycle.

1 Introduction

In a seminal paper, Grossman (1972a) develops the canonical model of health investment. In it, two motives guide a person's health investment. The first is that individuals derive utility from being healthy. The second is that good health enables individuals to supply more labor either to the labor market or at home. The former reason is referred to as the "consumption motive" and the latter as the "investment motive." The relative importance of each of these motives will change over an individual's life and, in particular, as people age, health will gradually move from an investment good to a consumption good. Indeed, for the young and healthy, the marginal utility of good health is low and the number of years that they still have to live is high and so, for them, the consumption motive is low and the investment motive is high. In contrast, for the old and frail, the opposite is true and so, their health investment is primarily driven by the consumption motive. While this discussion is a direct qualitative implication of the Grossman Model, little if anything is understood about how the motives for and returns to health investment evolve over the life-course in the quantitative sense. Indeed, to date, no study (at least that we are aware of) has attempted to carry out such an exercise using data on labor supply, health and medical expenditures from the United States. This is our paper's primary task.

To accomplish this, we build on Grossman's original work and extend it to an overlapping generations general equilibrium framework (GE) while embedding the current rules of the US Social Security system. We calibrate the model by matching key economic aggregates and assess its performance by comparing the life-cycle profiles of key outcomes from the model to those calculated from the data. Using these calibrated parameters and the Euler Equation for health investment, we calculate the returns to health investment and then quantify the relative importance of each of the motives discussed above. In addition, because we have a structural model, we are able to shed light on the role that time investment (as opposed to goods investment) in health plays as people age. This is important because time investment in health is inherently difficult to measure (or even conceptualize) and so our paper provides a deductive means of assessing this critical but little understood input to health.

In addition, because we endogenize the health stock and labor supply, our framework is able to shed light on potential consequences of social security reform that have yet to receive much attention in the literature. These insights are made possible because we extended Grossman's model to a GE framework. We run counter-factual policy simulations in which we calculate the impact of some commonly proposed social security reforms such as reduced benefits and a later retirement age on the labor supply, health investment and morbidity of the working-aged population.

Our paper primarily contributes to and bridges the gap between two literatures within economics. The first is the literature on the theory and, subsequently, the econometric estimation of models of health investment. The theoretical literature began with Grossman (1972a) but, since then, has grown substantially with many authors such as Muurinen (1982) and Picone, Uribe and Wilson (1998) generalizing Grossman's original work. For a comprehensive discussion of these developments, we refer the reader to Grossman (1999). Accompanying these theoretical developments has been empirical work that has attempted to structurally estimate the parameters of Grossman's original model. While the later attempts by Wagstaff (1993) have proved more successful than the earlier attempts by Wagstaff (1986) and Grossman (1972b), no attempt has proven entirely satisfactory. We believe that the reason for this is that, as pointed out by Wagstaff (1993), previous attempts have largely relied on approximations of the Euler Equation for health investment which do not adequately account for the dynamics inherent in the health investment decision. By avoiding any linearizations of the Euler Equations, our work avoids these complications.

Secondly, we also contribute to a growing literature that has incorporated health into computational models of life-cycle behavior. Many of these studies either incorporated health as an exogenous state variable (Rust and Phelan 1997; French 2005) or modeled health expenditure as exogenous shocks (De Nardi, French and Jones 2006; Jeske and Kitao 2007). In contrast, our model endogenizes health investment, which allows us to answer the research questions proposed, and provides a more comprehensive analysis of the impact of health investment on relevant economic decisions.

This has spawned the most recent generation of papers that incorporate health into computational life-cycle models of behavior. In this generation, health is modeled as a durable consumption good *a la* Grossman (1972a). For example, Hall and Jones (2007) use a Grossman-type model to explain the recent increases in medical expenditures in the US. Yogo (2008) also uses a model of health investment to investigate the portfolio choice of retirees and argues that the large savings rate observed among the elderly is the consequence of a large bequest motive and not a precautionary motive as others (*e.g.* Palumbo 1999) have argued. Neither paper would have been able to make their conclusions without an endogenous health stock. Our paper fits into this strand of the literature. However, there are notable differences. We investigate the *life-cycle* motives for health investment and its interaction with labor supply. While Hall and Jones (2007) investigate the evolution of medical expenses over time, they do not do so over the life-course nor do they consider labor supply. Yogo (2008) is also similar to our work, but he also does not consider labor supply and retirement. Finally, because we remain true to Grossman's original framework, we are also able to further much of the literature on the estimation of models of health investment that was started by Michael Grossman and Adam Wagstaff.

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 constructed from PSID and MEPS. Section 4 presents the parameterization of the model. Section 5 presents the life-cycle profiles generated from our benchmark model. Section 6 shows the decomposition of the consumption and investment motives. Section 7 discusses the consequences of experiments on social security reform. Section 8 concludes.

2 Model

2.1 Demographics

The economy is populated by overlapping generations of finite-lived individuals with measure one. Each individual lives at most J periods. For each age $j \leq J$, the conditional probability of surviving from age $j-1$ to j is denoted by $\varphi_j \in (0,1)$. Notice that we have $\varphi_0 = 1$ and $\varphi_{J+1} = 0$. The survival probability $\{\varphi_j\}_{j=1}^{J}$ is treated as exogenously given. We assume that annuity market is absent in this economy and accidental bequests are collected by the government and uniformly distributed back to all agents currently alive.

Each period the number of newborns grows at a constant rate n. The share of age-j individuals in the population μ_j is given by

$$\mu_j = \frac{\mu_{j-1}\varphi_j}{1+n}$$

with $\sum_{j=1}^{J} \mu_j = 1$. We will use the age share as weights to calculate aggregate quantities in the economy.

2.2 Preferences

Individuals derive utility from consumption, leisure and health. Each individual maximizes the expected, discounted lifetime utility

$$E_0 \sum_{j=1}^{J} \beta^{j-1} \left[\prod_{k=1}^{j} \varphi_k \right] U(c_j, l_j, h_j) \tag{1}$$

where β denotes the subjective discount factor, c consumption, l leisure, and h health status. The period utility function takes the form

$$U(c_j, l_j, h_j) = \frac{[\lambda(c_j^{\rho} l_j^{1-\rho})^{\psi} + (1-\lambda) h_j^{\psi}]^{\frac{1-\sigma}{\psi}}}{1-\sigma} \tag{2}$$

Motivated by Real Business Cycle literature such as Cooley and Prescott (1995), we assume the elasticity of substitution between consumption and leisure is one. The parameter ρ measures the weight of consumption in this consumption-leisure combination. The elasticity of substitution between consumption and health is $\frac{1}{1-\psi}$. The parameter λ measures the relative importance of consumption-leisure combination in the utility function. The parameter σ is the coeffcient of relative risk aversion.

2.3 Budget Constraints

Each period individuals are endowed with one unit of time. They split the time among working (n), enjoying leisure (l), being sick(s), and investing in health accumulation (v). Therefore, we have following time allocation equation

$$n_j + l_j + s_j + v_j = 1, \text{ for } 1 \leq j \leq J \tag{3}$$

Following Grossman (1972a), we assume sick time s_j is a decreasing function of the health status

$$s_j = Q h_j^{-\gamma} \tag{4}$$

where Q is the scale factor and γ measures the sensitivity of sick time to health.

Each individual works until an exogenously given mandatory retirement age j_R. Individuals differ in their labor productivity due to their differences in age. We use ε_j denote the efficiency unit of an age-j agent. Let w be the wage rate and r be the rate of return on asset holdings. $w\varepsilon_j n_j$ is the age-j individual's labor income. The individual faces the following budget constraint

$$c_j + m_j + a_j \leq (1 - \tau_{ss}) w \varepsilon_j n_j + (1 + r) a_{j-1} + T, \text{ for } j < j_R \tag{5}$$

where m_j is health investment in goods, a_j is asset holding, τ_{ss} is the social security tax rate, and T is the accidental bequests distributed back to the individuals.

Once an individual is retired, she receives the social security benefits b. Following Imrohoroglu, Imrohoroglu, and Joines (1995), we model the social security system in a simple way. The social security benefits are calculated to be a fraction κ of some base income which we take as the average lifetime labor income

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

κ is referred to the replacement ratio. The only role that government plays in this economy is to administer the social security system. The vector (κ, τ_{ss}) represents the policy instruments of the government. An age-j retiree faces the following budget constraint

$$c_j + m_j + a_j \leq b + (1+r)a_{j-1} + T, \forall j \geq j_R \tag{6}$$

We assume that agents are not allowed to borrow so that

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

Finally, there is no annuity market.

2.4 Health Investment

Following Grossman (1972a), we assume that individuals have to use both goods and time to produce health. The accumulation of health stock across ages is given by

$$h_{j+1} = (1 - \delta_{h_j})h_j + B(m_j^{\theta} v_j^{1-\theta})^{\xi} \tag{7}$$

where δ_{h_j} is the age-dependant depreciation rate of health stock, θ measures the relative importance of goods expenditure in health investment, ξ represents the return to scale for health investment and B measures the productivity of medical care technology. Note that most of recent wave of general equilibrium models including health (Suen 2006, Feng 2008) only put the goods input in the health accumulation process whereas we exactly follow Grossman (1972)'s original idea to include both goods and time input into the health accumulation equation. Therefore our model is able to capture the "investment motive" for the health investment.

2.5 Technology

This economy has a constant returns to scale production function

$$Y_t = K_t^{\alpha} N_t^{1-\alpha} \tag{8}$$

in which K and N are aggregate capital and labor inputs, respectively. The final good can be either consumed or invested into physical capital or health stock. The aggregate resource constraint is given by

$$C_t + M_t + I_t = Y_t \tag{9}$$

C_t is aggregate consumption, M_t is aggregate goods expenditure in health, and I_t is aggregate investment in physical capital. Law of motion of aggregate capital thus follows

$$K_{t+1} = (1-\delta)K_t + I_t \tag{10}$$

where δ is the depreciation rate on physical capital.

The representative firm maximizes its profits and ends up with following optimization conditions that determine wage rate and net real return to capital

$$w = (1-a)\left(\frac{K}{N}\right)^{\alpha} \tag{11}$$

$$r = a\left(\frac{K}{N}\right)^{\alpha-1} - \delta. \tag{12}$$

2.6 Individual's Problem

In this economy, an age-j individual solves a dynamic programming problem. The state space at the beginning of age j is described by a vector (a_{j-1}, h_j), where a_{j-1} is the asset holding at the beginning of age j, and h_j is health status at age j. Let $V_j(a_{j-1}, h_j)$ denote the value function of an age-j individual given the state vector (a_{j-1}, h_j). The Bellman Equation is then given by

$$V_j(a_{j-1}, h_j) = \max_{c_j, m_j, l_j, a_j, n_j, v_j} \{U(c_j, l_j, h_j\} + \beta\varphi_{j+1} E_j V_{j+1}(a_j, h_{j+1})\} \tag{13}$$

subject to

$$\begin{aligned}
c_j + m_j + a_j &\leq (1 - \tau_{ss}) w\varepsilon_j n_j + (1 + r) a_{j-1} + T, \forall j < j_R \\
c_j + m_j + a_j &\leq b + (1 + r) a_{j-1} + T, \forall j_R \leq j \leq J \\
h_{j+1} &= (1 - \delta_{h_j}) h_j + B(m_j^{\theta} v_j^{1-\theta})^{\xi}, \forall j \\
n_j + l_j + s_j + v_j &= 1, \forall j \\
a_j &\geq 0, \forall j
\end{aligned}$$

2.7 Stationary Competitive Equilibrium

Given the model environment, the definition of a stationary competitive equilibrium for this economy is standard. Let $\mathcal{A} = \{a_1, a_2, ..., a_m\}$ denote the admissible set of asset holdings, $\mathcal{H}$ =$\{h_1, h_2, ..., h_n\}$ denote the admissible set of health status, $\mathcal{M} = \{m_1, m_2, .., m_p\}$ denote the admissible set of medical expenditure, and $\mathcal{N} = \{n_1, n_2, ..., n_k\}$ denote the set of the discrete grids for possible working hours or time investment in health. Therefore, we have state vector $(a, h) \in \mathcal{A} \times \mathcal{H}$.

Definition 1 *A* ***stationary competitive equilibrium*** *is a policy combination* $\{\kappa, \tau_{ss}\}$, *a collection of value functions* $V_j(a, h) : \mathcal{A} \times \mathcal{H} \to R$*; individual decision rules for consumption* $C_j : \mathcal{A} \times \mathcal{H} \to R_+$*, medical expenditure* $M_j : \mathcal{A} \times \mathcal{H} \to \mathcal{M}$*, asset holding* $A_j : \mathcal{A} \times \mathcal{H} \to \mathcal{A}$*, labor supply* $N_j : \mathcal{A} \times \mathcal{H} \to \mathcal{N}$*, and time investment in health* $TV_j : \mathcal{A} \times \mathcal{H} \to \mathcal{N}$*; age-dependent distributions of agents over state space* $\Phi_j(a, h)$ *for each age* $j = 1, 2, ..., J$*; a price vector* $\{w, r\}$*; and a lump-sum transfer* T *such that*

(i) Given prices, policy combination and a lump-sum transfer T*, decision rules* C_j, M_j, A_j, N_j, TV_j *and value function* V_j *solve the individuals' problem (13).*

(ii) Price vector $\{w, r\}$ *is determined by the firm's first-order maximization conditions (11) and (12).*

(iii) The law of motion for the distribution of agents over the state space follows

$$\Phi_j(a', h') = \sum_{a:a'=A_j(a,h)} \sum_{h:h'=H_j(a,h)} \Phi_{j-1}(a, h)$$

(iv) Social security system is self-financing (pay-as-you-go):

$$\tau_{ss} = \frac{\sum_{j_R}^{J} \sum_a \sum_h \mu_j \Phi_j(a, h) b}{\sum_{j=1}^{j_R-1} \sum_a \sum_h \mu_j \Phi_j(a, h) w \varepsilon_j n_j}$$

(v) Lump-sum transfer of accidental bequest is determined by

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

(vi) Individual and aggregate behavior are consistent:

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

(vii) Goods market clears:

$$\sum_j \sum_a \sum_h \mu_j \Phi_j(a,h) C_j(a,h) + M + \delta K = Y.$$

(viii) Time constraint is satisfied as in (3).

3 The Data

We employ data 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 Expiture Survey (MEPS) which we use to construct life-cycle profiles for medical expenditures.

3.1 Panel Study of Income Dynamics

Our PSID sample spans the years 1968 to 2005. The PSID contains an over-sample of economically disadvantaged people called the Survey of Eocnomic Opportunities (SEO). We follow Lillard and Willis (1978) and drop the SEO due to endogenous selection. Doing this also make 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 having health 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 (2001) 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 summaraize 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.

Figures 1 through 3 show the life-cycle profile of income, hours and health. 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 25 and 75 (inclusion).

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. Figure 1 shows the income profile (in 2004 dollars). The figure shows a hump shape with a peak at about 60K in the early fifties. A major source of this decline is early retirements. This can be seen in Figure 2 which plots yearly hours worked. Hours worked are pretty steady at just over 40 per week until about the mid-fifties when they start to decline quite rapidly. Figure 3 shows the profile of health status. The figure shows a steady decline in health. Approximately 95% of the population reported being healthy at age 25 and this declined to just under 60% at age 75.

3.2 Medical Expenditure Survey

Our MEPS sample spans the years 2003-2006. As discussed in Kashihara and Carper (2008), the MEPS measure of medical expenditures which 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 expenditure include both out-of-pocket expenditures and expenditures from the insurance company.

Figure 4 shows the life-cycle profile of medical expenditures. The top profile was

Figure 1: Life-cycle profile of labor income: PSID data

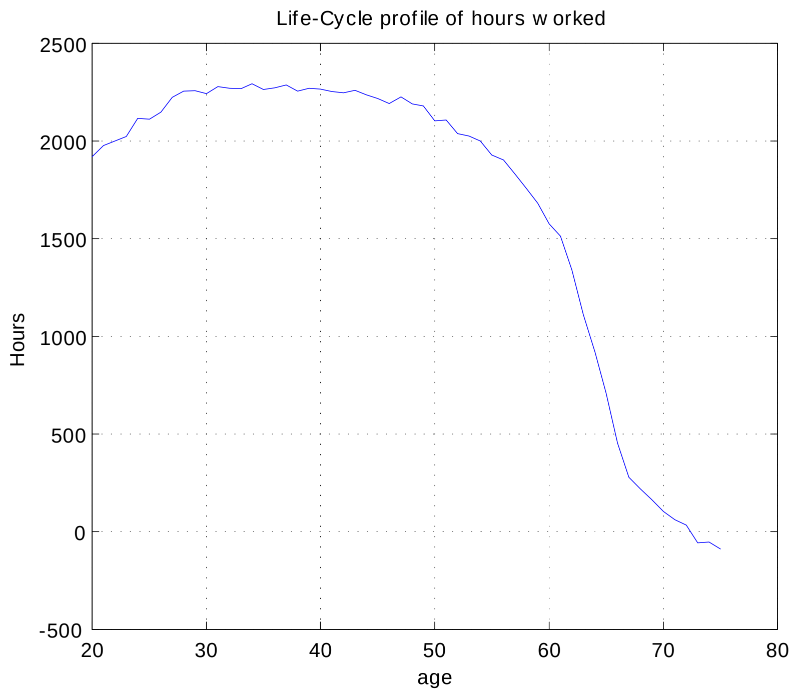

Figure 2: Life-cycle profile of working hours: PSID data

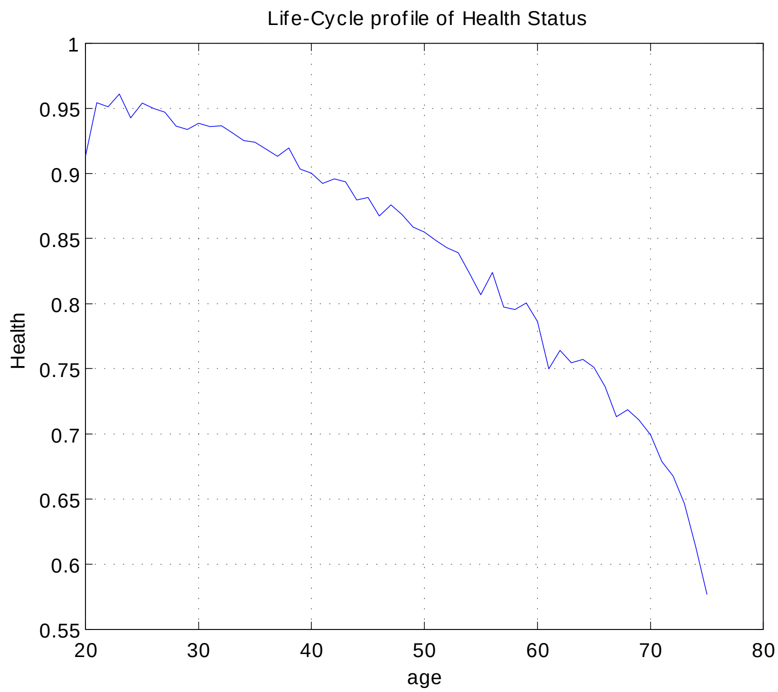

Figure 3: Life-cycle profile of health status: PSID data

calculated the same way as the profiles in the three previous figures. The bottom profile was calculated using a quantile regression. Accordingly, the top figure reports the means and the bottom figure reports the median by age. Both profiles show an increasing and convex relationship with age. Perhaps not surprisingly, we see that the medians are substantially below the means. This is almost certainly the consequence of the notoriously fat tail in medical expenditure data. Because we have a representative agent model, we will be matching the mean profile. However, the divergence between the medians and the means underscores the need to incorporate hetergeneity into the existing framework in future research.

4 Calibration

We now outline the calibration of the model's parameters. Following Cooley and Prescott (1995), we choose particular values for the parameters of the model partly in order to be consistent with microeconomic evidence and relevent literature, and partly to match selected long-run averages of US data.

4.1 Demographics

The model period is one year. Individuals are assumed to be born at the real-time age 21 and they can live up to a maximum age of $J = 65$ years. Death is certain

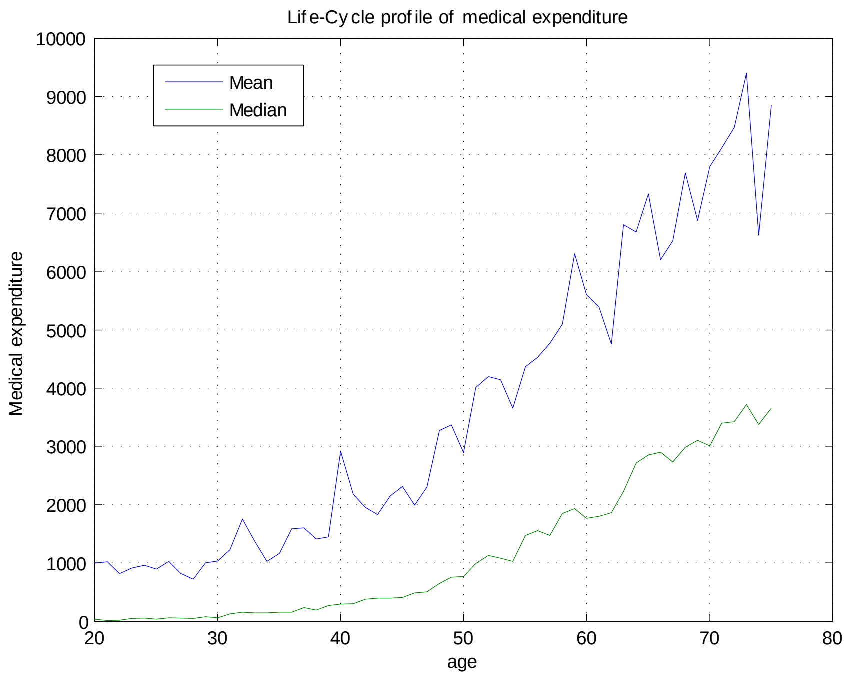

Figure 4: Life-cycle profile of medical expenditures: MEPS data

after age J which corresponds to the real-time age of 85. The conditional survival probabilities $\{\varphi_j\}_{j=1}^{J}$ are taken from Faber (1982). Retirement is mandatory and occurs at age $j_R = 45$, which corresponds to the real-time age of 65. Based on Hansen (1993), we construct age-efficiency profile $\{\varepsilon_j\}_{j=1}^{j_R-1}$ from the PSID. The details of the construction are shown in the Appendix.

4.2 Preferences

We set the subjective time discount factor $\beta = 0.97$. We choose a coefficient of relative risk aversion $\sigma = 2$, which is a value widely used in the literature (e.g., Imrohoroglu, Imrohoroglu, and Joines (1995); Fernandez-Villaverde and Krueger (2001)). Following Yogo (2008), we set elasticity of substitution between consumption and health $\frac{1}{1-\psi} = 0.11$, this implies $\psi = -8$. Health and consumption thus are complements. Following Cooley and Prescott (1995), we choose the weight of consumption in this consumption-leisure combination $\rho = 0.36$.

4.3 Health Investment

We assume age-dependent depreciation rate of health stock δ_{h_j} takes the form

$$\delta_{h_j} = \frac{\exp(a_0 + a_1 j + a_2 j^2)}{1 + \exp(a_0 + a_1 j + a_2 j^2)}. \tag{14}$$

This functional form guarantees $\delta_{h_j} \in (0,1)$. And it also increases as individuals age. We think that it captures a natural deterioration trend of the health stock. Other important parameters in health accumulation process: productivity of health accumulation technology B, share of goods expenditure in health investment θ, and the return to scale for health investment ξ will be calibrated to match selected long-run averages of US data.

4.4 Technology

Following Prescott (1986), we set the capital share in production function $\alpha = 0.36$. The depreciation rate of physical capital $\delta = 0.069$ is taken from Imrohoroglu, Imrohoroglu, and Joines (1999). We allow labor-augumenting technological change in the model economy and set it equal US long-run growth rate of per capita output 1.6%.

4.5 Social Security

The social security replacement ratio κ is set to be 40%. Since the social security system is self-financed, this replacement ratio thus determines the social security payroll tax in the model economy.

Selected Statistics	**Value**
Capital-Output Ratio	2.6
Consumption-Output Ratio	0.78
Health Expenditure-GDP Ratio	0.17
Working Hours Ratio	0.22
Sick Time Ratio	
h_{64}/h_{65}	1.0152
h_{65}/h_{66}	1.0159
h_{24}/h_{25}	1.0029

Table 1: Target statistics for calibration

4.6 The Remaining Parameters

There are nine parameters remain to be determined. They are share of consumption-leisure composition in utility function λ, productivity of health accumulation technology B, share of goods expenditure in health investment θ, the return to scale for health investment ξ, scale factor of sick time A, elasticity of sick time to health γ, and three parameters that determine age-dependent depreciation rate of health stock a_0, a_1, a_2. Our strategy is to choose these parameter values so that the model economy replicates certain long-run empirical characteristics of the U.S. economy. These long-run statistics are summarized in Table 1.

We summarize our baseline parameterization in Table 2.

Parameter	**Description**	**Value**
n	population growth rate	2%
J	maximum life span	65
j_R	mandatory retirement age	45
$\{\varphi_j\}_{j=1}^{J}$	conditional survival probabilities	Faber (1982)
$\{\varepsilon_j\}_{j=1}^{j_R-1}$	age-efficiency profile	see text
β	subjective time discount factor	0.97
σ	coefficient of relative risk aversion	2
ψ	elasticity of substitution b/w consumption and health	-8
ρ	share of comsumption in consumption-leisure combination	0.36
λ	share of consumption-leisure composition in utility	0.85
a_0		-5.8
a_1		0.05
a_2		0
B	productivity of health accumulation technology	0.1
θ	share of goods expenditure in health investment	0.4
ξ	return to scale for health investment	0.8
Q	scale factor of sick time	0.04
γ	elasticity of sick time to health	0.6
α	capital share in production	0.36
δ	depreciation rate of physical capital	0.069
g	growth rate of tech. change	1.6%
κ	social security replacement ratio	40%

Table 2: Parameters of the model

5 Results

Using the calibrated parameters values summarized in Table 2, we compute the model using the standard numerical method. We report model-generated life cycle profiles in Figure 5 to Figure 10.

Figure 5 shows the life cycle profile of health expenditure. It shows an interesting pattern. It is close to zero until age 50, and it starts to increase. From age 60 to age 73, it increases dramatically from 0.0078 to 0.1563, 20 times higher. But after age 73, model predicts a sharp decline in medical spending. We explain the reason for this in the next section.

Since it is hard to compare the model-generated medical expenditures with the data, we turn to an important ratio to examine the model's performance. Figure 6 shows the life-cycle pattern of health expenditure-labor income ratio. In the data, this ratio is very low and stable until age 50, then it increases dramatically after age 62. The model captures this pattern. From age 62 to age 70, this ratio increases from 0.145 to 2.702 in the data, while the model predicts that the health expenditure-labor income ratio increases from 0.167 to 2.176.

Figure 7 shows the life-cycle profile of health investment in time. It exhibits an interesting pattern. Individuals seldom invest their time in health accumulation until age 50. Then time investment in health increases from below 1% of the total

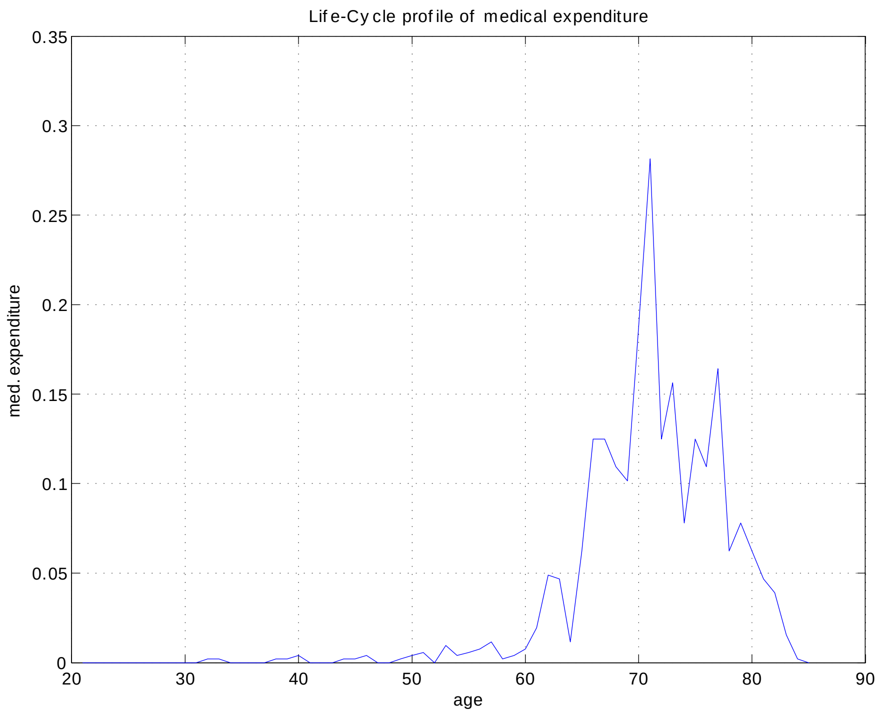

Figure 5: Life-cycle profile of medical expenditures: model

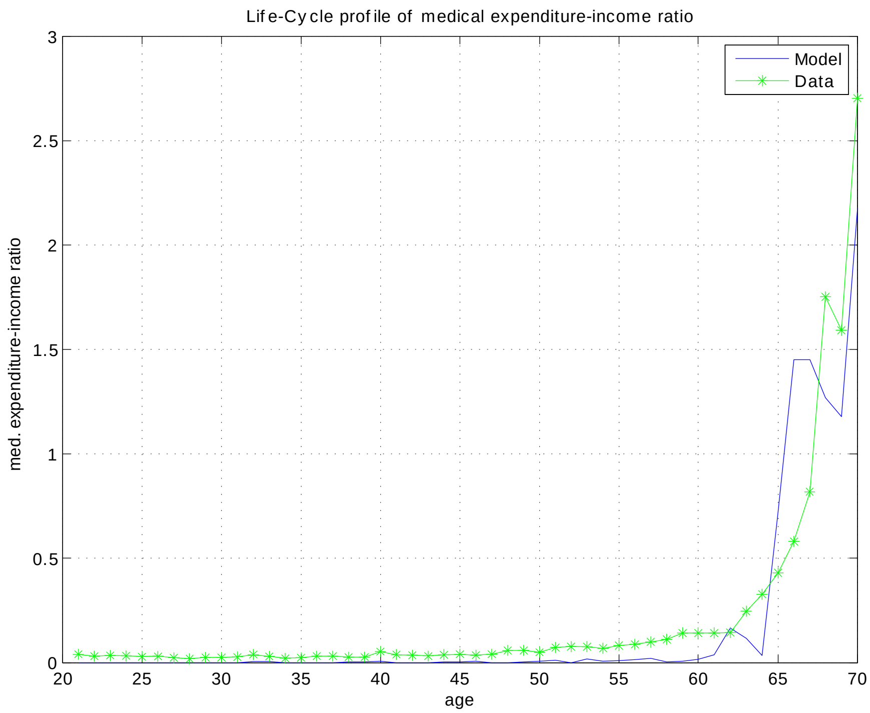

Figure 6: Life-cycle profile of medical expenditure-income ratio: model vs. data

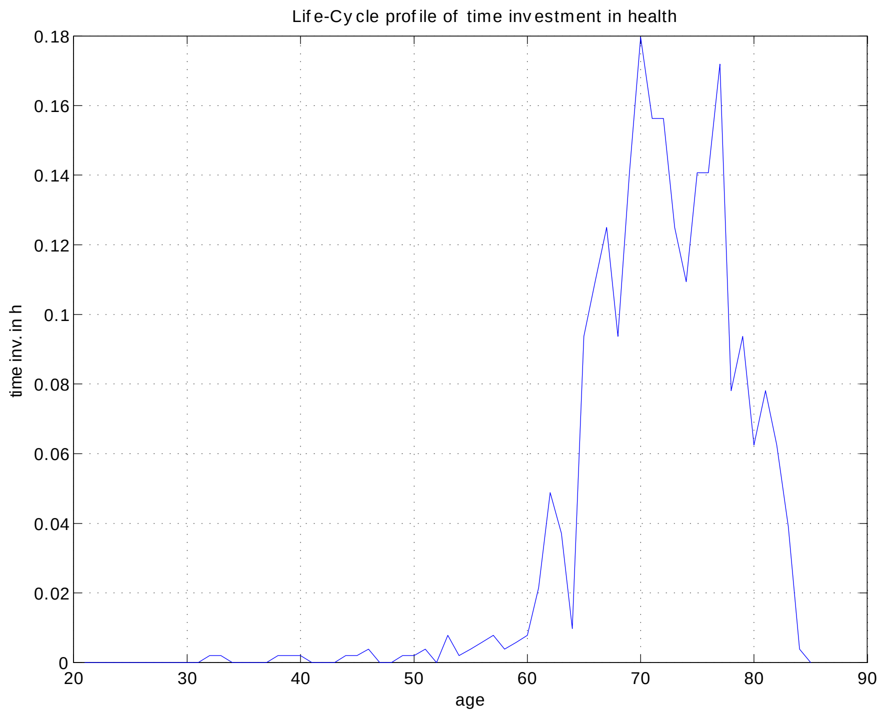

Figure 7: Life-cycle profile of time investment in health: model

available time to 18% at age 70. However, it decreases after age 70, probably driven by the declining motives for health investment towards the end of life.

Goods and time investment in health both determine the evolution of the health stock. Figure 8 demonstrates life cycle profile of health status. The model captures decreasing health status over th elife cycle very well.

Health investment in goods and time also affects other economic decisions over the life cycle. Figure 9 shows the life cycle profile of working hours. Model replicates

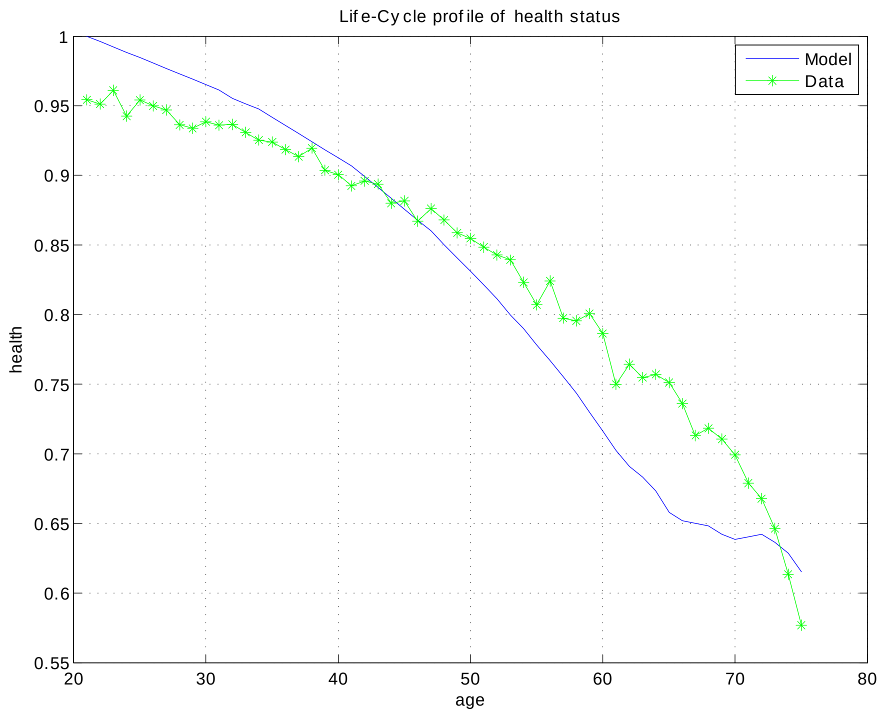

Figure 8: Life-cycle profile of health status: model vs. data

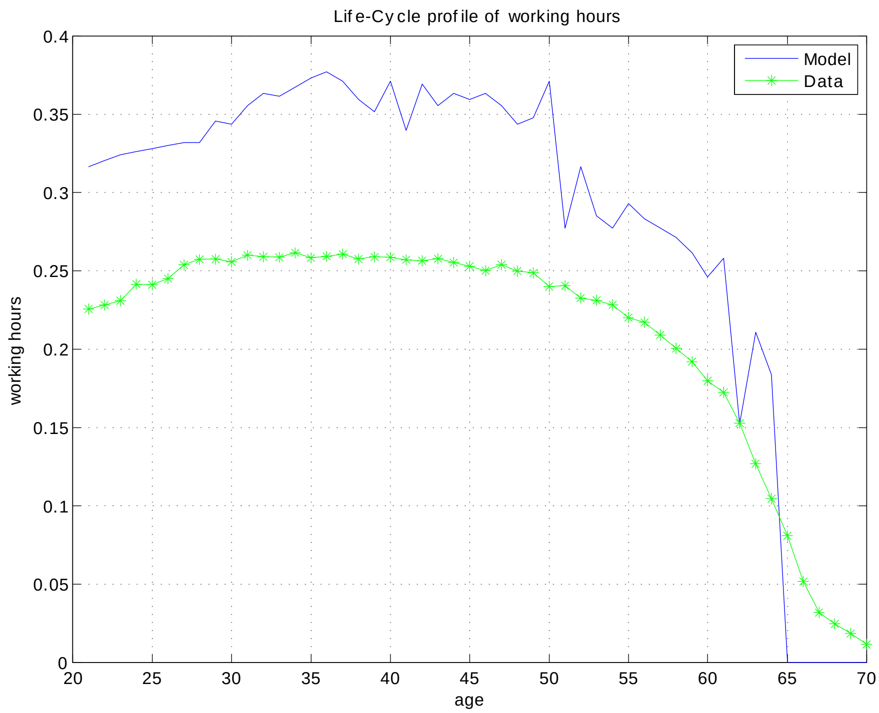

Figure 9: Life-cycle profile of working hours: model vs. data

the hump shape of working hours until age 60 and also captures the drmatical drop of working hours after age 60. Combining Figure 7 and Figure 9, we see clearly that the rapid increase in time investment in health significantly contributes to the drop in working hours after 55. Time investment in health "crowds out" time in the labor market.

Health investment also crowds out consumption. In Figure 10, we see the life cycle profile of consumption (excluding medical expenditure) also exhibits a hump

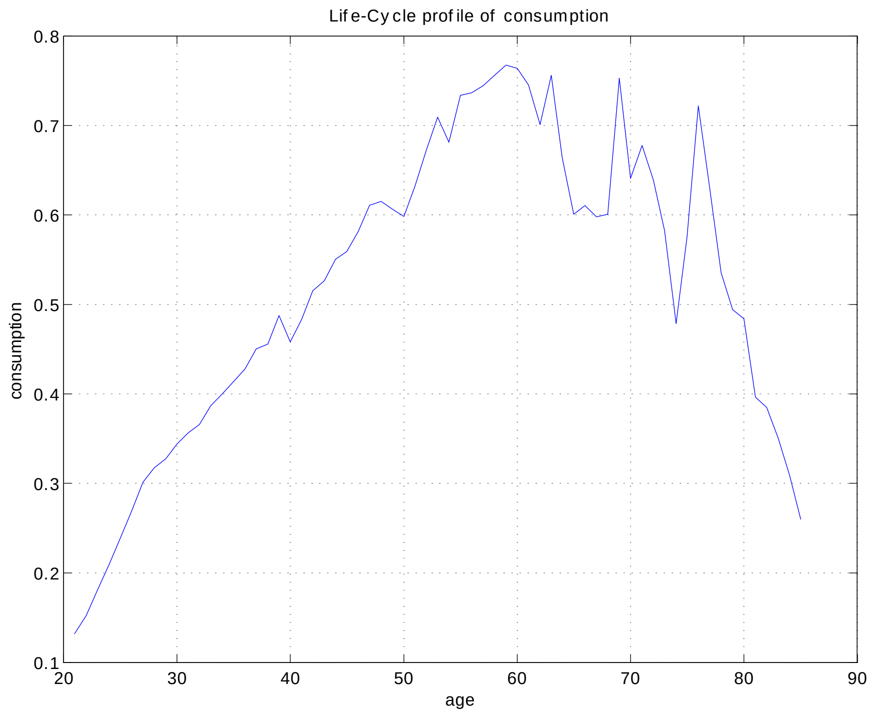

Figure 10: Life-cycle profile of consumption: model

shape. Indeed, consumption declines after age 60 which is when medical expenditure starts to increase dramatically. Accordingly, goods investment in health "crowds out" consumption.

6 Motives for Health Investment

The Euler Equation for health investment is given by[1]

$$\frac{\partial U}{\partial c_j} = \beta\varphi_{j+1} MPM_j[\frac{\partial U}{\partial h_{j+1}} - \frac{\partial U}{\partial c_{j+1}} w\varepsilon_{j+1}\frac{\partial s_{j+1}}{\partial h_{j+1}} + (1-\delta_{h_{j+1}})\frac{\partial U/\partial c_{j+1}}{MPM_{j+1}}] \tag{15}$$

where $MPM_j = \theta\xi B m_j^{\theta\xi-1} v_j^{(1-\theta)\xi}$ is the marginal product of health investment in goods at age j. This equation provides the optimal rule for health investment. The marginal utility of consumption at age j, on the left-hand side of the equation, represents the marginal cost of investing one additional unit of goods in health accumulation, while the marginal benefits of this one additional unit of goods investment in health accumulation consist of three terms. The first term, $MPM_j\frac{\partial U}{\partial h_{j+1}}$, shows that improvement in health due to this investment will directly increase the individual's utility. This term captures the "consumption" motive for the health investment. Better health tomorrow will also raise the individual's labor income *via* a reduction in sick time. This is refered to as the "investment" motive for the health investment and is captured by the second term on the right-hand side of Equation (15), $-MPM_j\frac{\partial U}{\partial c_{j+1}} w\varepsilon_{j+1}\frac{\partial s_{j+1}}{\partial h_{j+1}}$. Note that since $\varepsilon_j = 0$ for age $j \geq j_R$, therefore "investment" motive disappears after the retirement. Better health tomorrow also provides

[1]Please refer to Appendix 2 for the derivation of this equation.

a better starting point for future health accumulation. It is shown in the third term $(1-\delta_{h_{j+1}})\frac{MPM_j}{MPM_{j+1}}\frac{\partial U}{\partial c_{j+1}}$. We call it the "continuation value" for health investment.

Figure 11 shows the decomposition of these three terms over the life cycle. For young people, who are very healthy, the marginal utility of health is extremely small. On the other hand, they are very active in the labor market, therefore, benefits from working longer hours vis reducing sick time are important. Accordingly, the investment motive dominates the consumption motive. When people get older, their health deteriorates and marginal utility of health, thus, increases. Meanwhile, they face a shorter working life when they near retirement. Their health investment thus is primarily driven by the consumption motive. The third panel shows the continuation value of health investment. Not surprisingly, it decreases over the life cycle due to the high depreciation rate of the health stock later in life.

Through repeated substitution, we obtain

$$\frac{\partial U}{\partial c_j} = MPM_j \sum_{t=1}^{J-j} \underbrace{\beta^t \left(\prod_{k=j+1}^{j+t} \varphi_k\right) \left(\prod_{k=j+1}^{j+t-1} (1-\delta_{h_k})\right)}_{\text{effective discount factor}} \left[\underbrace{\frac{\partial U}{\partial h_{j+t}}}_{\text{consumption motive}} - \underbrace{\frac{\partial U}{\partial c_{j+t}} w\varepsilon_{j+t} \frac{\partial s_{j+t}}{\partial h_{j+t}}}_{\text{investment motive}} \right].$$

This equation states that the marginal benefit of one additional unit of goods investment in health at age j is the sum of discounted accumulative "consumption" and "investment" values from age $j+1$ towards the end of life J. The effective discount

Figure 11: Decomposition of Euler Equation for health

factor for period t ahead of age j consists of three components: subjective time discount factor β^t, unconditional survival probability up to age $j+t$, and accumulation depreciation rate from age j to age $j+t$.

We show the cumulative “consumption” and “investment” motives in Figure 12. In this Figure, we see that the cummulative “investment” motives decrease over the life cycle and become zero after retirement. What is more interesting, however, is that the cumulative “consumption” motives exhibit a hump shape. They increase until age 60, and then decrease. There are two reasons for this. First, the marginal utility of health steadily increases with age due to health depreciation. Second, the effective discount factor, which depends on the subjective discount rate, survival probability and the rate of health depreciation, steadily decreases over the life-course. Early in life the increase in the marginal utility of health dominate the decrease in the subjective discount factor. However, this reverses at around age 60 when the decreasing discount factor is dominant.

7 Policy Experiment: Social Security

To be added.

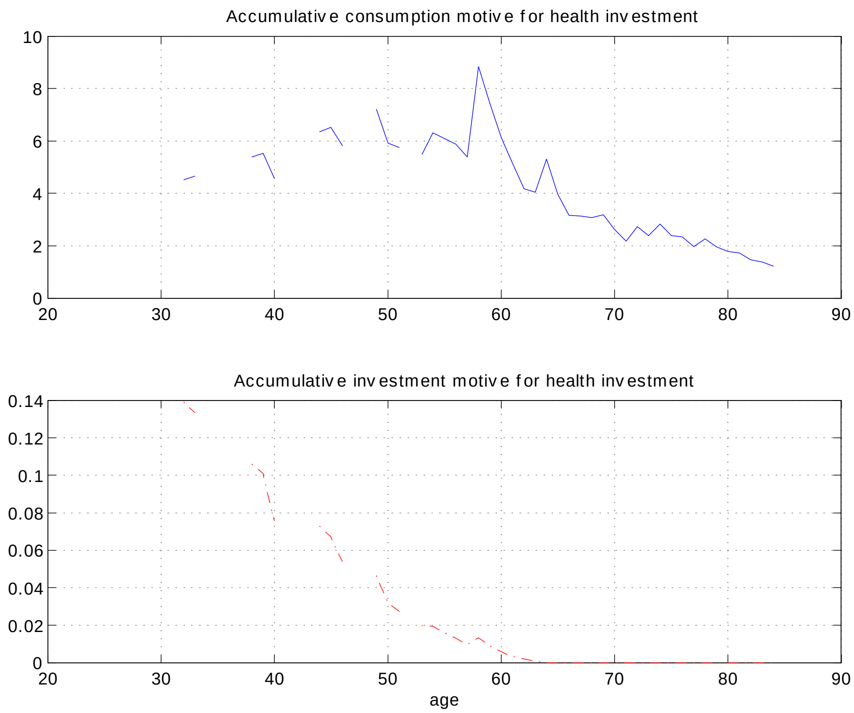

Figure 12: Decomposition of consumption and investment motive

8 Conclusions

We studied the motives underlying the life-cycle behavior of health investment. To accomplish this, we generalized Grossman's model of health investment to a general equilibrium setting with overlapping generations and calibrated the model to match key economic aggregates. We found that the calibrated model fits key life-cycle profiles well. We then used the Euler Equation for health investment to decompose the motives for health invesment into their consumption value and investment value. We found that the consumption motive exhibits a hump-shape where it increases with age due to an increasing marginal utility of health but then decreases due to high effective discounting which occurs later in the life-course. This consumption motive reaches its peak during the late fifties. In contrast, we found that the investment motive steadily declines with age until retirement when it is exactly zero. The reason for this monotonic decline is that, when people age, they have fewer years left to work. Consequently, it becomes less important to have a stock of healthy time to offer on the labor market. After retirement, wages are zero and so there is no investment motive.

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9 Appendix 1: Construction of the Efficiency Unit Profile

The construction of the efficiency unit profile is based on Hansen (1993). First, we construct individual i's wage at age a by dividing their yearly income by the total hours worked during that year:

$$w_{i,a} = \frac{y_{i,a}}{h_{i,a}}. \tag{A1}$$

Next, we regress wages on a set of age dummies:

$$w_{i,a} = \alpha_i + \sum_{j=20}^{64} d_{i,a}^{j} \delta^{j} + \upsilon_{i,a}. \tag{A2}$$

We include individual fixed effects to address heterogeneity across people and cohorts. We then calculate the predicted wages and take averages for all ages 20 to 64. This is slightly different than Hansen (1993) in two respects. First, we address cohort and individual heterogeneity whereas Hansen does not. Second, Hansen essentially calculates average income and average hours by age and then divides the two to calculate average wages. This is slightly different than what we have done since

$$E\left[w_{i,a}\right] \neq \frac{E\left[y_{i,a}\right]}{E\left[h_{i,a}\right]} \tag{A3}$$

due to Jensen's Inequality. Figure 1A shows the wage profile using four methods: fixed effects and OLS estimates of a regression of wages on a set of age dummies and fixed effects and OLS estimation of regressions of income and hours on a set of age dummies. We refer to the last two methods as Hansen's methods. As it turns out, the four methods show similar results except for the later ages where our method yields higher wages. Most of this appears to be a consequence of omitted cohort effects although aggregation bias also seems to matter somewhat. Finally, to calculate the efficiency unit profile, we take the average predicted wages by age and divide by the average wage. Figure 2A shows this profile.

Figure 13: Life-cycle wage profile

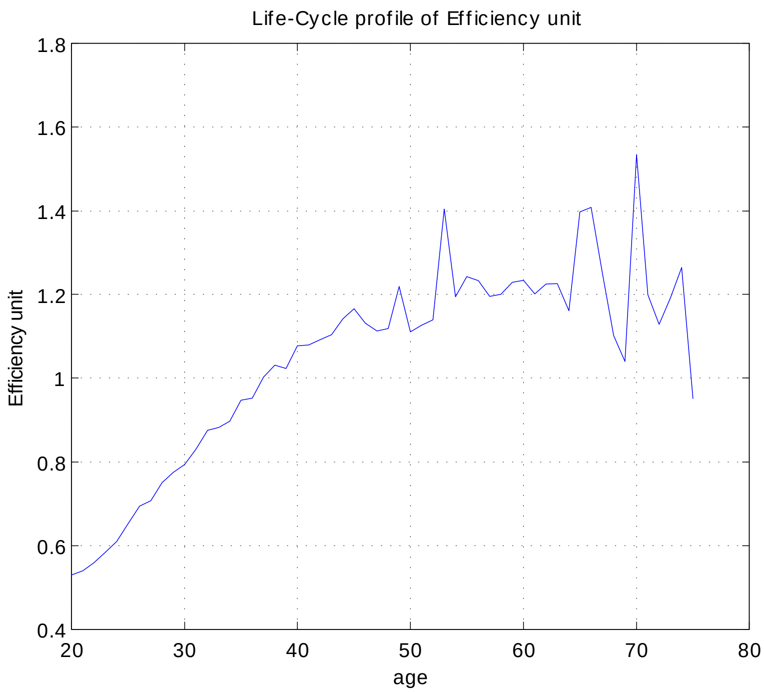

Figure 14: Life-cycle profile of age-efficiency unit

10 Appendix 2: Derivation of Equation (15)

We derive the FOCs for the individual's problem (13) as follows:

$$
\begin{aligned}
c_j &: \beta^{j-1}\left[\prod_{k=1}^{j}\varphi_k\right]\frac{\partial U}{\partial c_j} = \phi_j & (16)\\
m_j &: \phi_j = \mu_j MPM_j & (17)\\
h_{j+1} &: \beta^{j}\left[\prod_{k=1}^{j+1}\varphi_k\right]\frac{\partial U}{\partial h_{j+1}} - \mu_j + (1-\delta_{h_j})\mu_{j+1} - \phi_{j+1} w\varepsilon_{j+1}\frac{\partial s_{j+1}}{\partial h_{j+1}} = 0 & (18)
\end{aligned}
$$

where ϕ_j and μ_j are the associated Langrangian multipliers for the budget constraint equation (5) and the skill accumulation equation (7) respectively. We also have

$$
\begin{aligned}
\frac{\partial U}{\partial c_j} &= \frac{\rho F}{c_j}\\
\frac{\partial U}{\partial h_j} &= (1-\lambda)[\lambda(c_j^{\rho} l_j^{1-\rho})^{\psi} + (1-\lambda)h_j^{\psi}]^{\frac{1-\sigma}{\psi}-1} h_j^{\psi-1}\\
MPM_j &= \theta\xi B m_j^{\theta\xi-1} v_j^{(1-\theta)\xi}\\
\text{with } F &= \lambda[\lambda(c_j^{\rho} l_j^{1-\rho})^{\psi} + (1-\lambda)h_j^{\psi}]^{\frac{1-\sigma}{\psi}-1}(c_j^{\rho} l_j^{1-\rho})^{\psi}.
\end{aligned}
$$

Substituting (16) and (17) into (18), we obtain equation (15).