

Health Investment over the Life-Cycle

Timothy J. Halliday*, Hui He[†] and Hao Zhang[‡]

University of Hawai'i at Mānoa

May 16, 2011

Abstract

We quantify what drives the rise in medical expenditures over the life-cycle. Two motives are considered. First, health delivers a flow of utility each period (the consumption motive). Second, better health enables people to allocate more time to productive or pleasurable activities (the investment motive). We calibrate a model of endogenous health accumulation to match key economic targets and gauge its performance by comparing consumption, labor supply, and medical expenditure profiles from the model to their counterparts in the

*Assistant Professor, Department of Economics, University of Hawai'i at Mānoa and IZA.

[†]Assistant Professor in the Department of Economics at the University of Hawai'i at Mānoa.
Corresponding Author: E-mail: huihe@hawaii.edu.

[‡]Ph.D. Candidate in the Department of Economics at the University of Hawai'i at Mānoa.

data. Under the benchmark parameters, the precipitous rise in medical expenditures over the life cycle is primarily driven by the value of health as a consumption good, not an investment good. While this conclusion is robust to different specifications of health investment and preferences, it is quite sensitive to parameters that govern how health affects time endowments.

JEL codes: E21, I12

Keywords: Health Investment, Consumption Motive, Investment Motive, Life-Cycle Model

1 Introduction

Why do people invest in their health?¹ On the one hand, health may be desirable in and of itself, and so people may invest in it because it directly adds to their well-being. On the other hand, good health may be a means to something else, such as higher productivity or healthier days that can be spent working or relaxing. Here, good health behaves like something akin to human capital in the sense that just as people do not derive utility directly from additional years of schooling, they also do not derive additional utility from better health. These competing motives for health

¹While 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.

investment were first elegantly modelled by Grossman (1972) in a seminal paper, in which he referred to the former motive as the “consumption motive” and the latter as the “investment motive.”

Although Grossman explains these motives qualitatively, little if anything is understood about how the motives for health investment evolve over the life-course in the *quantitative* sense. In this paper, we answer the question: “Why do people invest in their health?” using techniques that not only allow us to quantify the relative importance of these competing motives but also to better understand how health investments affect other life-cycle behaviors, particularly, consumption and labor supply. This is one of the first papers to shed light on this issue.

While the answer to this question is interesting in its own right, it is also important if we wish to arrive at a better understanding of what drives the increase in medical expenditures over the life-cycle, which is, in turn, important for understanding overall trends in medical expenditures. Several papers document the dramatic increase in medical expenditure over the life-cycle, especially after age 65 (Meara, White and Cutler 2004; Jung and Tran 2010). This paper quantifies which primitive aspects of individual behavior are responsible for this run-up of medical expenditures over the life course. In doing so, we provide an important benchmark for other quantitative macroeconomists and structural labor economists who wish to analyze

the economic consequences of policy interventions in health insurance markets.²

Our work is part of a new and growing macro-health literature that incorporates endogenous health accumulation into dynamic models.³ For example, Hall and Jones (2007), Suen (2006), and Fonseca et al. (2009) use a Grossman-type model to explain the recent increases in aggregate medical expenditures in the US. Feng (2008) examines the macroeconomic and welfare implications of alternative reforms to the health insurance systems in the U.S. Jung and Tran (2009) study the general equilibrium effects of the newly established health savings accounts (HSAs). Yogo (2009) builds a model of health investment to investigate the effect of health shocks on the portfolio choices of retirees. Finally, Huang and Huffman (2010) develop a general equilibrium growth model with endogenous health accumulation and a simple search friction to evaluate the welfare effect of the current tax treatment of employer-provided medical insurance in the U.S.

²This 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.

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

In this paper, we calibrate a partial equilibrium overlapping generations model of endogenous health investment. The 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 and consumption may be complements or substitutes of varying degrees. 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.

We now summarize our results. First, we show that the benchmark model with both the consumption and investment motives can match the life-cycle profiles of key economic variables such as consumption, working hours, health status and medical expenditure quite well. Second, under the benchmark parameters, we find that the consumption motive is more important than the investment motive in replicating the run-up of medical expenditures over the life-cycle. In other words, older people invest in their health mainly because its marginal utility is extremely high and not because better health allows them to enjoy more leisure or to work more. However, additional experiments show that this conclusion is quite sensitive to how health impacts time allocations. Increasing the sick time ratio raises the importance of the investment motive. Our exercise thus calls for a serious empirical investigation of how health

impacts time allocation so that researchers can arrive at a better understanding of health investment.

Based on the benchmark model, we also conduct a counterfactual experiment that investigates the effect of survival probabilities on consumption, savings and health expenditure over the life-cycle, although we do not explicitly endogenize the survival probabilities. In the benchmark, we use survival probabilities from 2002. By feeding the 1960 survival probabilities into the model, we can get a sense of how increased longevity (which is perhaps due to technological innovations in medicine) has affected behavior. We find that shorter longevity⁴ reduces savings and health expenditure significantly and has smaller effects on working hours. Our results show that changing survival probabilities alone can explain about 37% of the rise in the health expenditure-GDP ratio from 1960 to 2002. One interpretation of this is that technological progress has reduced the costs of purchasing extra life years, which has, in turn, raised the demand for medical care.⁵

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 the PSID and the MEPS. Section 4 presents

⁴Life expectancy in 1960 was just 69.8 years compared to 77.2 years in 2002 in the U.S. (World Bank, WDI).

⁵Fonseca et al. (2009) show that technological change in medical service explains 59% of the rise in life expectancy at age 50 over the period 1965-2005.

the parameterization of the model. Section 5 presents the life-cycle profiles generated from our benchmark model. Section 6 shows a series of counterfactual experiments. In Section 7, we conduct the sensitivity analysis. Section 8 concludes.

2 Model

This section describes an overlapping generations model with endogenous health accumulation. In this model, the economy is populated by identical individuals of measure one in which 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 probabilities $\{\varphi_j\}_{j=1}^J$ are treated as exogenously given. There are no annuity markets in the economy. At 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. Finally, factor prices are exogenously given in the model.

2.1 Preferences

An individual derives utility from consumption, leisure and health. She maximizes her discounted lifetime utility

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

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

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

We assume that consumption and leisure are non-separable and we take a Cobb-Douglas specification as the benchmark.⁶ The parameter ρ determines the weight of consumption. Since we know less about the elasticity of substitution among consumption, leisure, and health, we allow a more flexible CES specification between the consumption-leisure combination and health. The elasticity of substitution between consumption-leisure combination and health is $\frac{1}{1-\psi}$. The parameter λ measures the relative importance of the consumption-leisure combination in the utility function.

⁶We consider an alternative specification with the separability between consumption and leisure in Section 7.1.

The parameter σ determines the intertemporal elasticity of substitution.

2.2 Budget Constraints

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

$$n_j + l_j + s_j = 1, \text{ for } 1 \leq j \leq J. \quad (3)$$

We assume sick time s_j is a decreasing function of health status

$$s_j = Qh_j^{-\gamma} \quad (4)$$

where Q is the scale factor and γ measures the sensitivity of sick time to health. Notice that in contrast to recent structural work that incorporates endogenous health accumulation (*e.g.*, Feng 2008, Jung and Tran 2009), health does not directly affect labor productivity. Allowing health to affect the allocation of time but not 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.” Indeed, we will also show in Section 7.2 that the alternative model with health affecting labor productivity yields very similar results to the benchmark.

The individual works until an exogenously given mandatory retirement age j_R . Her labor productivity differs due to differences in age. We use ε_j to denote her efficiency unit at age j . Let w be the wage rate and r be the rate of return on asset holdings. Accordingly, $w\varepsilon_j n_j$ is age- j labor income. At age j she faces the following budget constraint

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

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

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 κ of some base income, which we take as the average lifetime labor income

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

where κ is referred to as the replacement ratio. An age- j retiree faces the following budget constraint

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

We assume that agents are not allowed to borrow, so that⁷

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

2.3 Health Investment

Following Grossman (1972), we assume that the individual has to invest in goods to produce health. The accumulation of health across ages is given by

$$h_{j+1} = (1 - \delta_{h_j})h_j + Bm_j^\xi \quad (7)$$

where δ_{h_j} is the age-dependent depreciation rate of the health stock, B measures the productivity of medical care technology, and ξ represents the return to scale for health investment.

⁷In an unreported experiment, based on the benchmark parameter values in Section 5, 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 very similar to those in the benchmark model.

We assume that the depreciation rate takes the form

$$\delta_{h_j} = \frac{\exp(d_0 + d_1j + d_2j^2)}{1 + \exp(d_0 + d_1j + d_2j^2)}. \quad (8)$$

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.

2.4 Individual's Problem

At age j , this individual solves a dynamic programming problem. The state space at the beginning of age j is described by a vector (a_j, h_j) , where a_j is the asset holding at the beginning of age j , and h_j is health status at age j . 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

$$V_j(a_j, h_j) = \max_{c_j, m_j, a_{j+1}, l_j, n_j} \{U(c_j, l_j, h_j) + \beta \varphi_{j+1} V_{j+1}(a_{j+1}, h_{j+1})\} \quad (9)$$

subject to

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

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

$$h_{j+1} = (1 - \delta_{h_j})h_j + Bm_j^\xi, \forall j$$

$$n_j + l_j + s_j = 1, s_j = Qh_j^{-\gamma}, \forall j$$

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

and the usual non-negativity constraints.

3 The Data

We construct the data counterparts of the model 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 for 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.

Figures 1 through 3 show the life-cycle profile 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. 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 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 50s, 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 75.⁹

⁸We 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.

⁹We 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 unfortunately the HRS does not have any data on the earlier part of the life-cycle which is crucial for our analysis. We chose the PSID over the HRS as it had more comprehensive information over

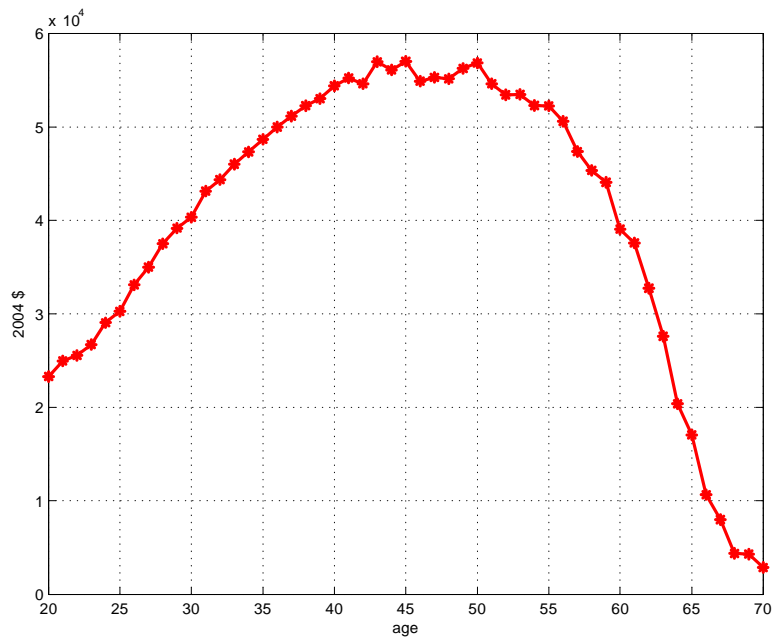


Figure 1: Life-cycle profile of labor income: PSID data

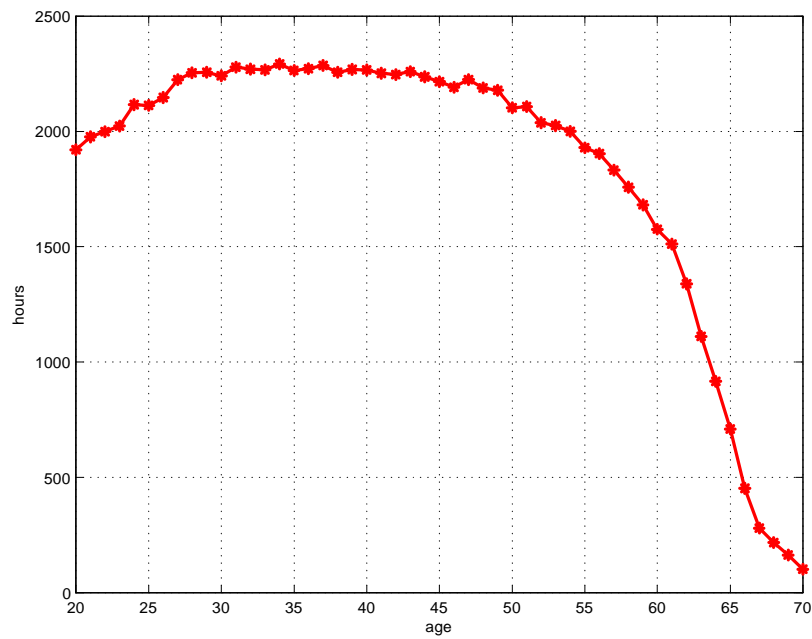


Figure 2: Life-cycle profile of working hours: PSID data

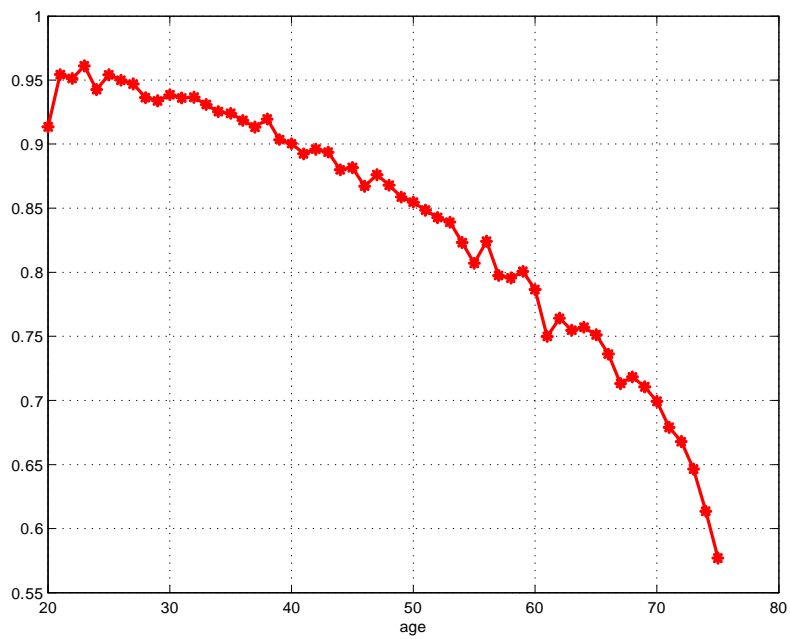


Figure 3: Life-cycle profile of health status: PSID data

3.2 Medical Expenditure Survey

Our MEPS sample spans the years 2003-2007.¹⁰ As discussed in Kashihara and Carper (2008), the MEPS measure of medical expenditures 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 represent agent pays.

Figure 4 shows the life-cycle profile of 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 the medical expenditures increase significantly after age 55. The medical expenditures at age 75 are six times higher than the ones at age 55.

a much larger part of the life-cycle than the HRS.

¹⁰We 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. Including a set of time dummies along with age dummies would not have dealt with this issue.

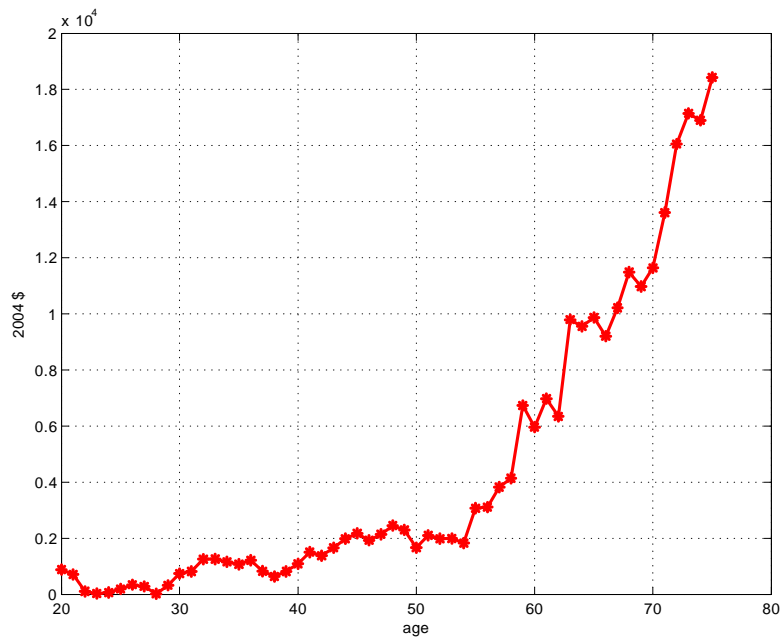


Figure 4: Life-cycle profile of medical expenditures: MEPS data

4 Calibration

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

4.1 Demographics

The model period is five years. An individual is assumed to be born at the real-time age of 20. Therefore, the model period $j = 1$ corresponds to ages 20-24, $j = 2$ corresponds to ages 25-29, and so on. Death is certain after age $J = 16$, which corresponds to ages 95-99. The conditional survival probabilities $\{\varphi_j\}_{j=1}^J$ are taken from the US Life Tables 2002. Retirement is mandatory and occurs at age $j_R = 10$, which corresponds to ages 65-69. We take the age-efficiency profile $\{\varepsilon_j\}_{j=1}^{j_R-1}$ from Conesa, Kitao and Krueger (2009), who constructed it by following Hansen (1993).

4.2 Preferences

We calibrate the annual subjective time discount factor to be 0.9668 to match the capital-output ratio in 2002, which is 2.63.¹¹ Therefore, $\beta = (0.9668)^5$. We choose $\sigma = 2$ to obtain intertemporal elasticity of substitution to be 0.5, which is a value widely used in the literature (e.g., Imrohoroglu et al. 1995; Fernandez-Villaverde and Krueger forthcoming). We calibrate the share of the consumption-leisure combination in the utility function λ to be 0.64 to match the average consumption-labor income ratio for working age, which is 78.5%.¹² We pin down the share of consumption ρ to be 0.339 to match the fraction of average working hours in discretionary time, which is 0.35 from the PSID. Finally, we calibrate the parameter of the elasticity of substitution between consumption-leisure combination and health ψ to be -7.85, which implies an elasticity of $\frac{1}{1-\psi} = 0.11$. This value is picked to match the ratio of average medical expenditure for ages 55-74 to ages 20-54, which is 7.96 from MEPS.¹³ Since the elasticity of substitution between consumption and leisure is one,

¹¹In the current partial equilibrium model, we only focus on the household's problem, therefore we ignore the production side. The capital here thus is the aggregate asset accumulation across all ages. And GDP is equal to the total income which includes both labor and capital income.

¹²Consumption data are taken from Fernandez-Villaverde and Krueger (2007), who use the CEX data set.

¹³The reason why parameter ψ significantly affects the ratio of medical expenditure for ages 55-74 to ages 20-54 so that we can use this ratio to identify ψ is: we know consumption peaks at age 50 and declines after age 50 (see Figure 10). The degree of complementarity between consumption and health thus affects the speed of the decline in health after age 50, which in turn determines the speed of the increase in health investment after age 50. The lower ψ , the more the complementarity between consumption and health, the quicker the decline in health after age 50 and hence the higher

health and consumption-leisure combination are complements. This implies that marginal utility of consumption increases as health stock improves, which is confirmed by several empirical studies (Viscusi and Evans 1990; Finkelstein, Luttmer, and Notowidigdo 2010).

4.3 Social Security

We set the Social Security tax rate to be 10.6%, which is the current rate for US Old-Age and Survivors Insurance (OASI).¹⁴ The Social Security replacement ratio κ is set to be 40%.¹⁵

4.4 Factor Prices

The wage rate w is set to be the average wage rate over the working age in the PSID data, which is \$13.02.¹⁶ The annual interest rate is set to be 4%. Therefore,

the ratio of medical expenditures for ages 55-74 to ages 20-54. Another motivation for choosing age 55 as the dividing line is from Figure 4, we observe that medical expenditure increases sharply after that age.

¹⁴The current Social Security payroll tax rate is 12.4%. It includes 10.6% for OASI and 1.8% for Social Security Disability Insurance (SSDI). Workers who are disabled and under age 65 qualify for SSDI. The Social Security system in our model does not include the aspect of social insurance as SSDI.

¹⁵The replacement ratio of 40% is commonly used in the literature; see for example, Kotlikoff, Smetters, and Walliser (1999) and Cagetti and De Nardi (2009).

¹⁶We first divide annual labor income for ages 20 to 64 from Figure 1 by the annual working hours from Figure 2 to obtain wage rates $w\varepsilon_j$ across ages. We then divide the average wage rate over working ages ($\frac{w \sum_{j=1}^{j_R-1} \varepsilon_j}{j_R-1}$) by the average age-efficiency $\frac{\sum_{j=1}^{j_R-1} \varepsilon_j}{j_R-1}$ to obtain average wage rate w , which is \$13.02.

$$r = (1 + 4\%)^5 - 1 = 21.7\%.$$

4.5 Health Investment

Five model-specific parameters govern the health accumulation process: three parameters that determine the age-dependent depreciation rate of health stock (d_0, d_1, d_2) , the productivity of health accumulation technology B , and the return to scale for health investment ξ . We pick the values of d_0 , d_1 , and d_2 to match three moment conditions regarding health status over the life-cycle: average health status from age 20 to 74, the ratio of average health status for ages 20-29 to ages 30-39, and the ratio of average health status for ages 30-39 to ages 40-49. This ends up with $d_0 = -4$, $d_1 = 0.215$, and $d_2 = 0.00825$. Figure 5 shows the depreciation rate of health stock. We calibrate $B = 0.7$ and $\xi = 0.8$ to match two moment conditions regarding medical expenditure. The first one is the medical expenditure-output ratio, which was 15.1% in 2002.¹⁷ The second is the average medical expenditure-labor income ratio from age 20 to 64, which is 5.8%.

¹⁷Data are from the National Health Account (NHA).

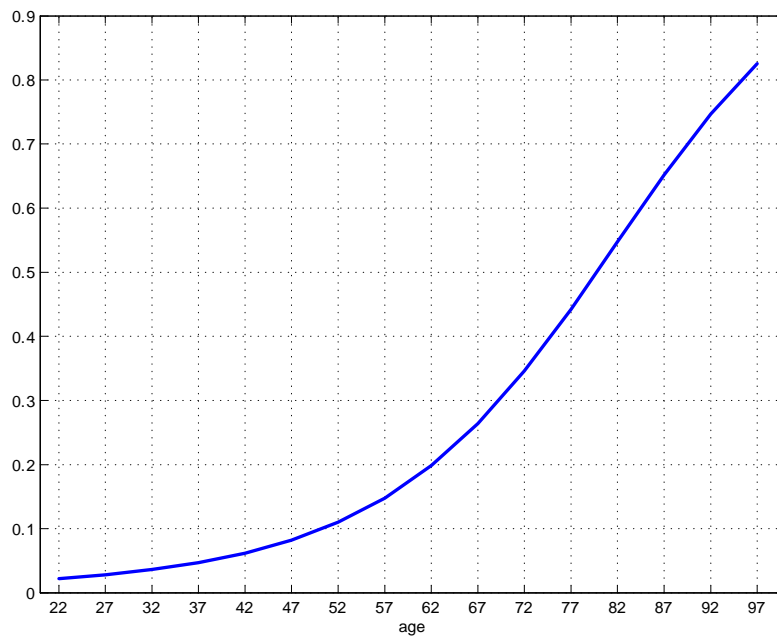


Figure 5: Depreciation rate of health stock

4.6 Sick Time

Finally, we have two parameters that determine sick time in the model. They are the scale factor of sick time Q and the elasticity of sick time to health γ . We calibrate these two parameters to match two moment conditions regarding sick time in the data. Based on data from the National Health Interview Survey, Lovell (2004) reports that employed adults in the US miss, on average, 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.¹⁸ We use this ratio as an approximation to the share of sick time in total discretionary time over working age. We pick $Q = 0.0143$ to match this average sick-time ratio over working age. 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; 1.5 days higher than the rate for younger workers age 18 to 44 years. We choose $\gamma = 2.5$ 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.

¹⁸According to OECD data, American workers, on average, worked 1800 hours per year in 2004; that is equivalent to about 225 working days. Sick leave roughly accounts for 2.1% of these working days. This number is very close to the one reported in Gilleskie (1998).

Parameter	Description	Value	Source
Demographics			
J	maximum life span	16	age 95-99
j_R	mandatory retirement age	10	age 65-69
$\{\varphi_j\}_{j=1}^J$	conditional survival probabilities	Data	US Life Table 2002
Preferences			
β	subjective discount rate	$(0.9668)^5$	calibrated
σ	Intertem. ela. sub. coefficient	2	common value
ψ	elasticity b/w cons. and health	-7.85	calibrated
ρ	share of c in c -leisure combination	0.339	calibrated
λ	share of cons-leisure com. in utility	0.64	calibrated
Health Accumulation			
d_0	dep. rate of health	-4.00	calibrated
d_1	dep. rate of health	0.215	calibrated
d_2	dep. rate of health	0.00825	calibrated
B	productivity of health technology	0.7	calibrated
ξ	return to scale for health investment	0.8	calibrated
Sick Time			
Q	scale factor of sick time	0.0143	calibrated
γ	elasticity of sick time to health	2.5	calibrated
Labor Productivity			
$\{\varepsilon_j\}_{j=1}^{j_R-1}$	age-efficiency profile		Conesa et al. (2009)
Social Security			
τ_{ss}	Social Security tax rate	10.6%	Data
κ	Social Security replacement ratio	40%	Kotlikoff et al. (1999)
Factor Prices			
w	wage rate	\$13.02	PSID
r	interest rate	$(1 + 4\%)^5 - 1$	

Table 1: Parameters of the model

Target (Data source)	Data	Model
Capital-output ratio (2002 NIPA)	2.63	2.63
Non-med. consumption-labor income ratio (CEX and PSID)	78.5%	82.4%
Med. expenditure (ages 55-74)/(ages 20-54) (MEPS)	7.96	7.94
Fraction of average working hours (PSID)	0.35	0.35
Med. expenditure-output ratio (2002 NHA)	15.1%	15.2%
Med. expenditure-labor income ratio (MEPS and PSID)	5.8%	5.7%
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	1.37
Average health status (ages 20-74) (PSID)	0.85	0.84
health (ages 20-29)/health (ages 30-39) (PSID)	1.02	1.04
health (ages 30-39)/health (ages 40-49) (PSID)	1.05	1.05

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.¹⁹ Since we calibrate the model only to target selected aggregate life-cycle ratios, the model-generated life-cycle profiles can be compared with the data to inform us about the performance of the benchmark model.

Figure 6 shows the life-cycle profile of health expenditures. Since one model period represents five years in real life, a data point is an average for each five year bin starting at age 20. Therefore, in the figure, age 22 represents age 1 in the model

¹⁹We define a two-dimensional, equally spaced grid over the state space of assets and health status with 1025 grid points on each dimension. We use backward induction and employ a bracketing method to solve the value function and the associated decision rules for each combination of state variables at each age. The decision rules are then weighted by age shares and the distribution measures to generate the life-cycle profiles. The code is written in Fortran 90 and is run in Linux environment.

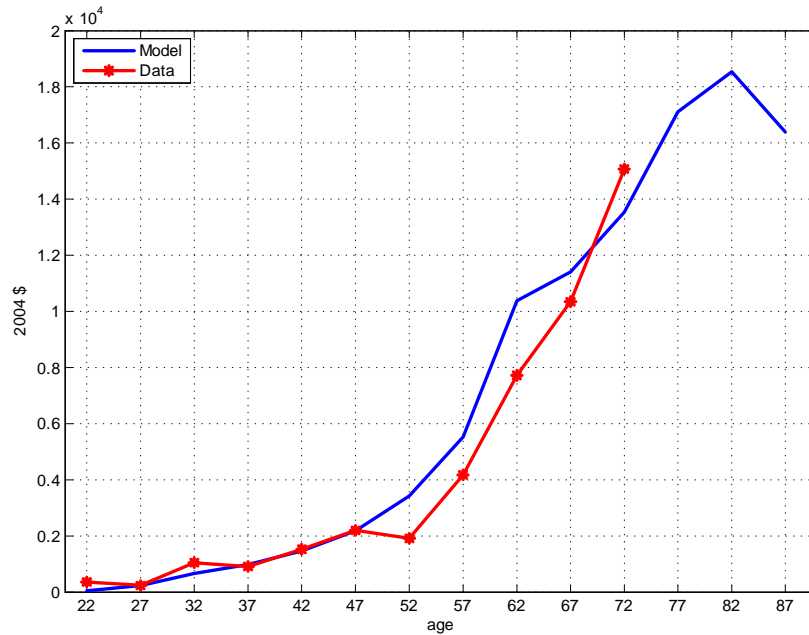


Figure 6: Life-cycle profile of medical expenditure: data vs. model

and ages 20-24 in the real life, age 27 represents age 2 in the model and ages 25-29 in the real life, and so on. As we can see, the model captures the dramatic increase of 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 expenditure increases from \$44 to \$13544.

Health investment (in conjunction with depreciation) determines the evolution of the health stock. Figure 7 displays the life-cycle profile of health status. The model produces decreasing health status over the life-cycle. In the data, average health

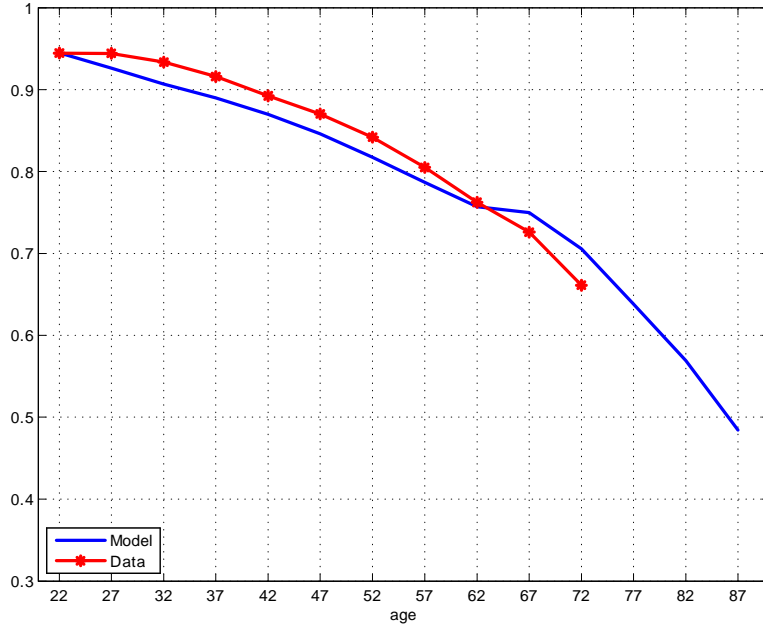


Figure 7: Life-cycle profile of health status: data vs. model

status (fraction of individuals report good health) decreases from 0.9445 for ages 20-24 to 0.6612 for ages 70-74. The model prediction is from 0.9445 to 0.7056.²⁰

The model also does well in replicating other economic decisions over the life-cycle. Figure 8 shows the life-cycle profile of working hours. The model captures 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

²⁰In the computation, we force h to be a continuous variable falls into the range of $[0, 1]$. And the initial health stock h_1 starts from 0.9445 which is the fraction of the population aged 20-24 reported being healthy in the data. In this way, we establish a direct correspondence between the model and the data in terms of health status.

its peak at ages 35-39, and it is quite stable until ages 45-59. It then decreases sharply from about 38% at ages 45-49 to 22% at ages 60-64. In the model, the fraction of working hours reaches the peak (about 37%) at ages 40-45. It then decreases by 11%, to about 33% at ages 60-64. The health stock plays a non-trivial role in the declining portion of the working hours profile; as health status declines, sick time increases over the life-cycle, which, in turn, encroaches upon a person's ability to work. Our model predicts that from ages 40-45 to 60-64, the fraction of sick time in discretionary time increases from 2.03% to 2.87%, which accounts for about 20% of the decline in working hours in the model.

Since we have a good match of working hours, we also replicate the labor income profile in the data quite well as can be seen in Figure 9. However, since the model does not generate enough of a decline in working hours at late ages as shown in Figure 8, the model overpredicts labor income from ages 50-54 to 60-64.

Figure 10 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 differ-

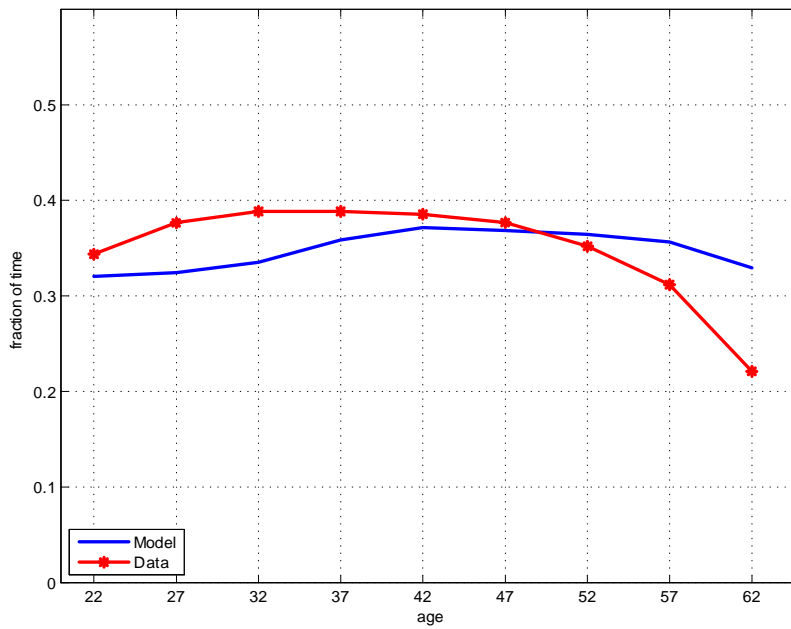


Figure 8: Life-cycle profile of working hours: data vs. model

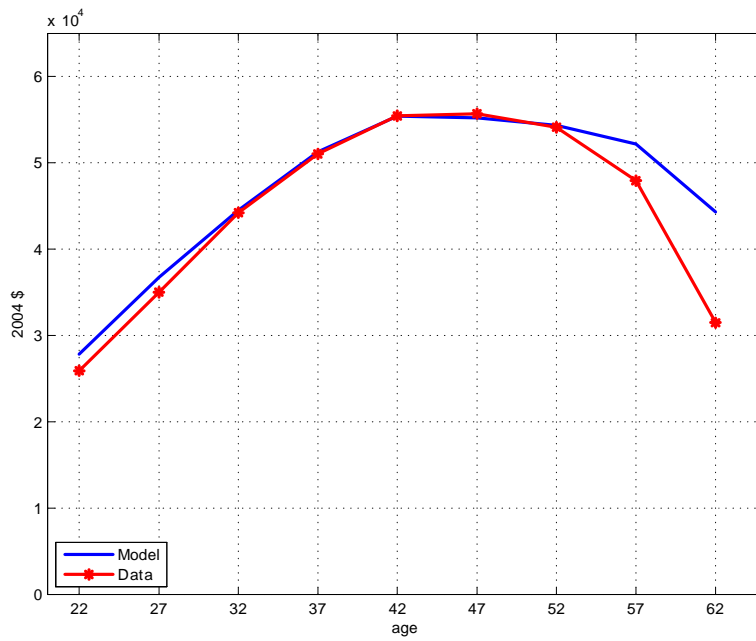


Figure 9: Life-cycle profile of labor income: data vs. model

ence 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.²¹²²

Finally, Figure 11 shows the time allocation between leisure and sick time. At ages 20-24, leisure accounts for about 66.3% of discretionary time. Due to the hump shape of working hours (see Figure 8), it gradually decreases to around 61% at ages 40-44, after which it steadily increases to 64% at ages 60-64. Due to retirement at age 65, leisure increases dramatically to 97% of discretionary time at ages 65-69. After age 70, it begins to decrease again as sick time accelerates. At the end of the life-course, sick time accounts for 43% of discretionary time.

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 captures the

²¹A 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 an evidence, when we use an alternative preference with a separable utility function between consumption and leisure in the sensitivity analysis in Section 7, we obtain a much smoother consumption profile around retirement age.

²²Non-separability of health from consumption and leisure and the complementarity between health and consumption-leisure combination also play a role in generating changes health status (and hence medical expenditures) around retirement age. As shown in Figure 7, the decline of health status slows down at retirement age 62. The reason is when individuals retire, leisure suddenly increases. Since health is also complementary to leisure, an increase in leisure tends to increase health as well.

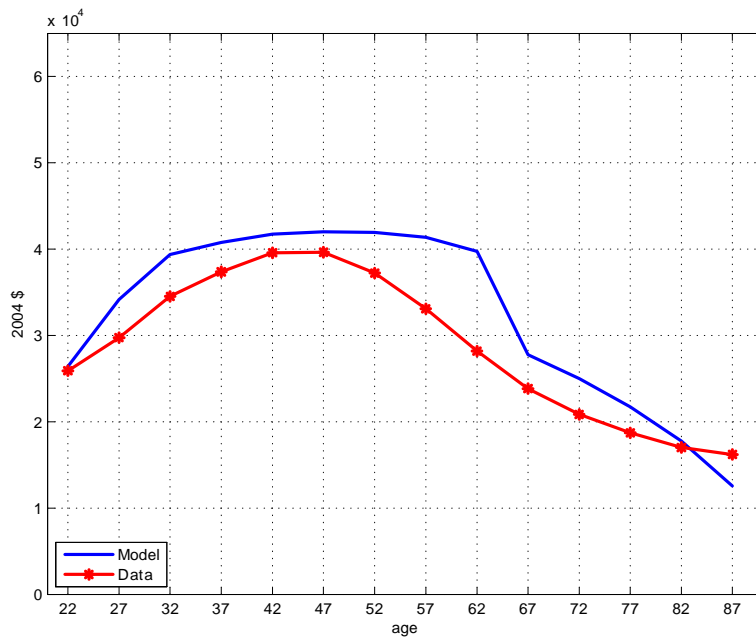


Figure 10: Life-cycle profile of consumption: data vs. model

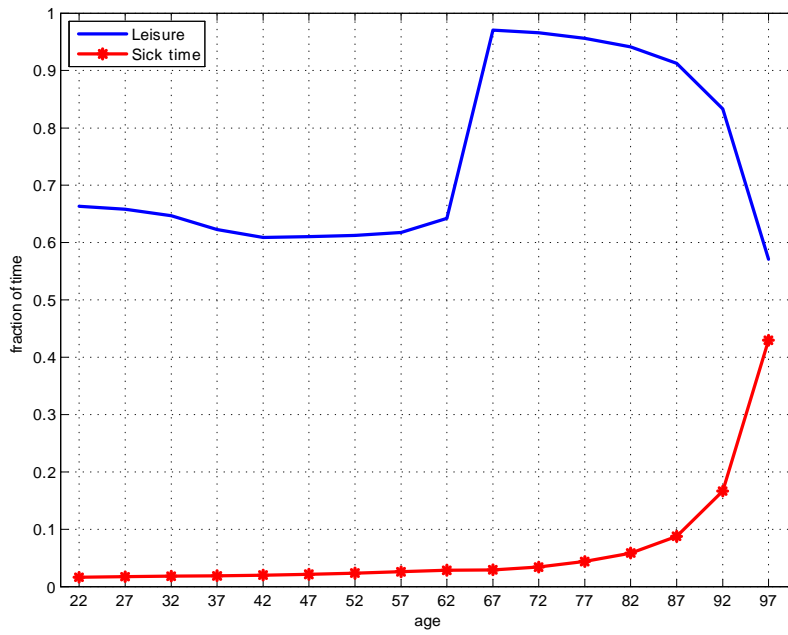


Figure 11: Life-cycle profile of sick time and leisure: model

hump shape of consumption. Second, it captures the hump shape of working hours and labor income. Third and most important, it captures rising medical expenditures and decreasing health status over the life-cycle.

6 Counterfactual Experiments

Based on the success of the benchmark model, we use the model to run three counterfactual experiments. First, we quantify the relative importance of the consumption and investment motives for investing in health on life-cycle economic decisions. Second, we study how the relative importance of both motives changes as the importance of sick time increases. Third, we investigate the effect of survival probabilities (and hence longevity) on economic behavior over the life-cycle .

6.1 Decomposition of Health Investment Motives

The first experiment is to decompose the investment and consumption motives for health investment and study their respective effects on life-cycle economic decisions.

The benchmark model includes both motives. “C-Motive only” is a model with only the consumption motive, which we obtain by setting $Q = 0$ and keeping all other parameters at their benchmark values. In contrast, “I-Motive only” is a model with the investment motive only, which we obtain by setting $\lambda = 1$ and keeping all other

parameters at their benchmark values. This way, we shut down each motive one at a time to compare its results to those in the benchmark case. The exercise thus helps us to identify the impact of each motive separately.

Figure 12 reports the comparison among these three models of the life-cycle profile of medical expenditures. “C-Motive only” tracks the benchmark model quite well, while “I-Motive only” predicts significantly less medical expenditures. Medical expenditures in “I-Motive only,” however, still increase dramatically after retirement. This is because sick time directly competes with leisure after retirement. Higher health status implies less sick time and more leisure, which in turn gives higher utility. As individuals age, sick time encroaches upon leisure (shown in Figure 11). It gives a stronger incentive to invest in health and hence reduces sick time. In other words, although “I-Motive only” shuts down health in the utility function explicitly, sick time still affects utility indirectly through leisure.²³ On the other hand, since sick time also affects working time before retirement, medical expenditures in “I-Motive only” prior to retirement are driven by both leisure (less sick time implies more leisure) and consumption (less sick time implies more working hours, which implies higher labor income, which implies more consumption).

In contrast to the “I-Motive only” case, the “C-Motive only” model completely

²³We thank Nobu Kiyotaki for pointing out this interpretation.

shuts down the time allocation channel, and therefore, leisure is always equal to one after retirement. However, since health directly enters the utility function as a consumption commodity and health is decreasing over time due to natural depreciation, the scarcity of the health stock pushes up the marginal utility of health and encourages rising health investment. Put differently, “C-Motive only” captures the *direct* utility gain from health, whereas “I-Motive only” captures the *indirect* utility gain from health through consumption and leisure. And Figure 12 shows clearly that under benchmark parameters, the C-motive strictly dominates I-motive at any age. “C-motive only” almost replicates the benchmark case, while “I-motive only” significantly underestimates the benchmark case. Since the benchmark case mimics the data quite well, this suggests that the dramatic rise in medical expenditures over the life-cycle is driven more by the consumption rather than the investment motive. In other words, older people invest in their health mainly because their marginal utility is extremely high and not because better health allows them to enjoy more leisure or to work more.

Differences in medical expenditures determine differences in health status. Figure 13 shows that “C-Motive only” produces a health stock quite similar to that in the benchmark model, especially after retirement. In contrast, “I-Motive only” generates a significantly lower health stock than that in the benchmark (and the data).

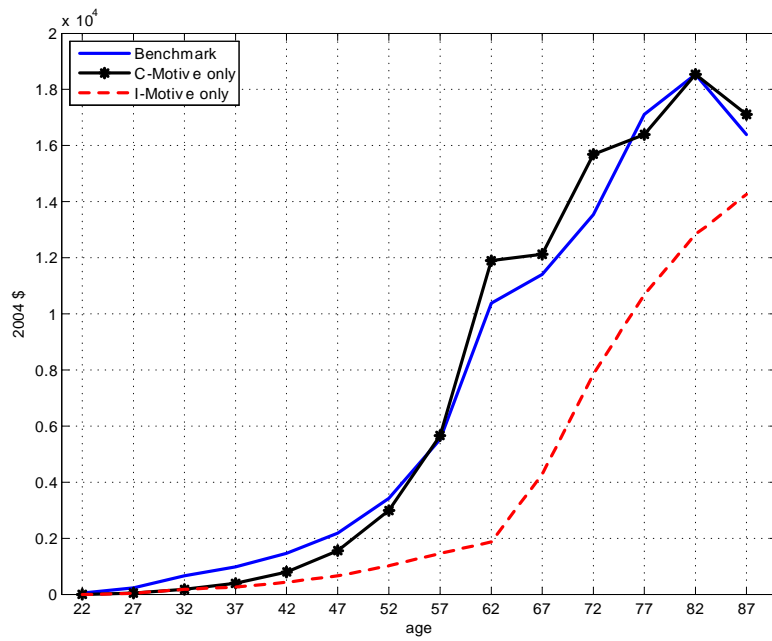


Figure 12: Life-cycle profiles of medical expenditure: decomposition

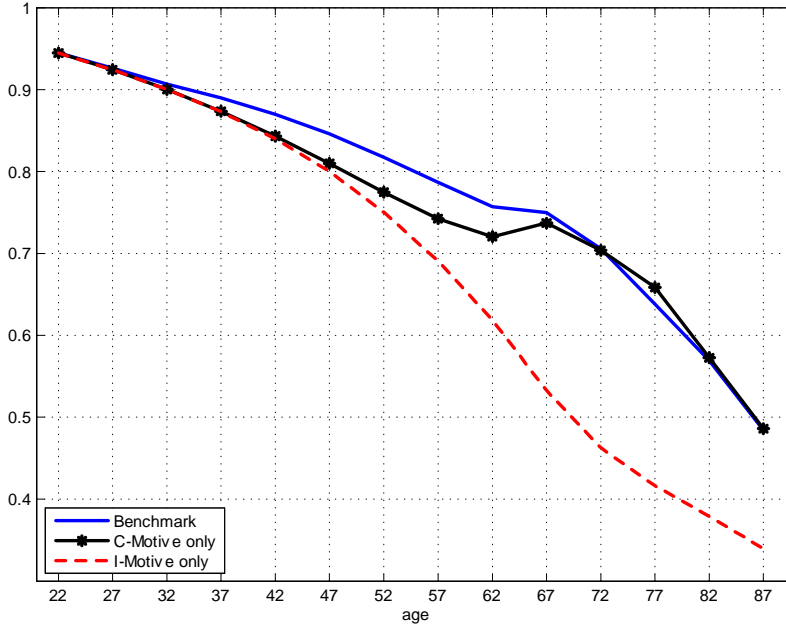


Figure 13: Life-cycle profiles of health status: decomposition

Both “C-motive” and “I-motive” are equally important before ages 40-44, but after, “C-Motive” progressively becomes more important and, eventually, dominates after retirement.

Figure 14 shows the effects of the different motives on working hours. There is not much variation prior to ages 35-39. After that, “C-Motive only” has the highest working hours and “I-Motive only” has the lowest. The benchmark model lies in the middle. The reason why “C-Motive only” has working hours that are significantly higher than those in “I-Motive only” is twofold. First, since we shut down sick time in

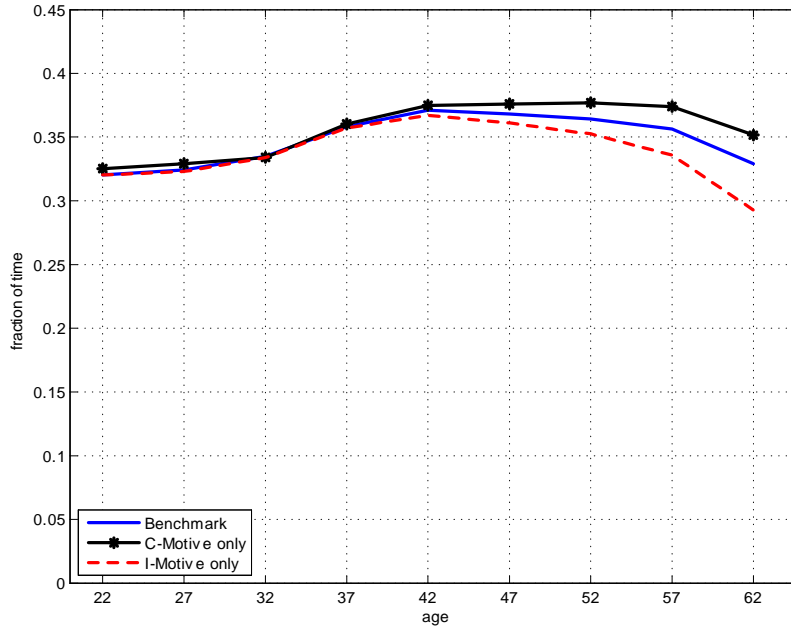


Figure 14: Life-cycle profiles of working hours: decomposition

“C-Motive only,” a large portion of sick time is shifted to working hours. This effect is roughly captured by the difference between working hours under “C-Motive only” and the benchmark model. Second, with lower health status in “I-Motive only,” sick time is higher than in the benchmark. This effect is roughly the difference between working hours in the benchmark and in “I-Motive only.”

Figure 15 shows time allocation under different health investment motives. Panel B presents the life-cycle profiles of sick time under three scenarios. By construction, “C-Motive only” has zero sick time. Since sick time is a negative function of health

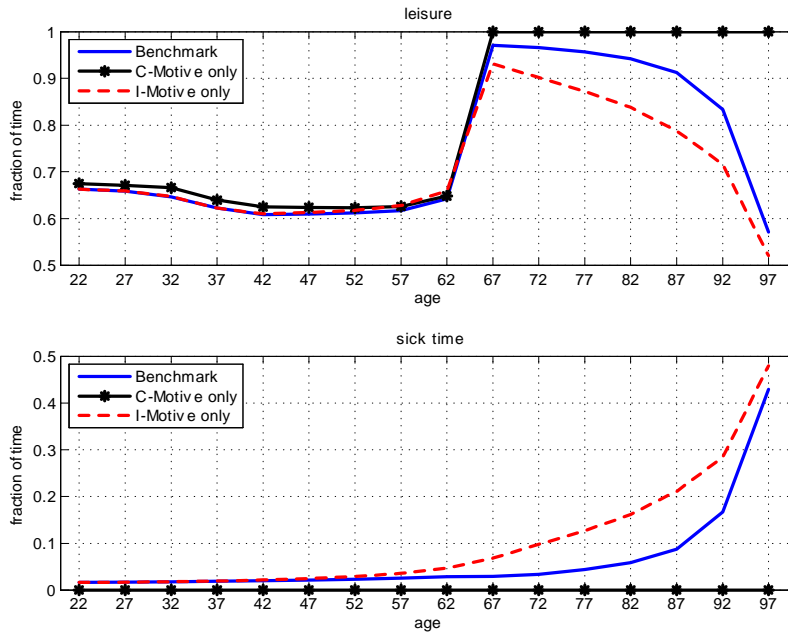


Figure 15: Life-cycle profiles of leisure and sick time: decomposition

status and health status is much higher in the benchmark model than in the “I-Motive only” case (see Figure 13), sick time is less in the benchmark model than in the “I-Motive only” case. Panel A demonstrates the life-cycle profiles of leisure. Before retirement, sick time accounts for a small fraction of time. Leisure mainly interacts with working time, and hence, it exhibits a U shape. The “C-Motive only” case has the highest amount of leisure. After retirement, leisure interacts only with sick time. In contrast to panel B, the “I-Motive only” case has the lowest amount of leisure because sick time is the highest in this scenario.

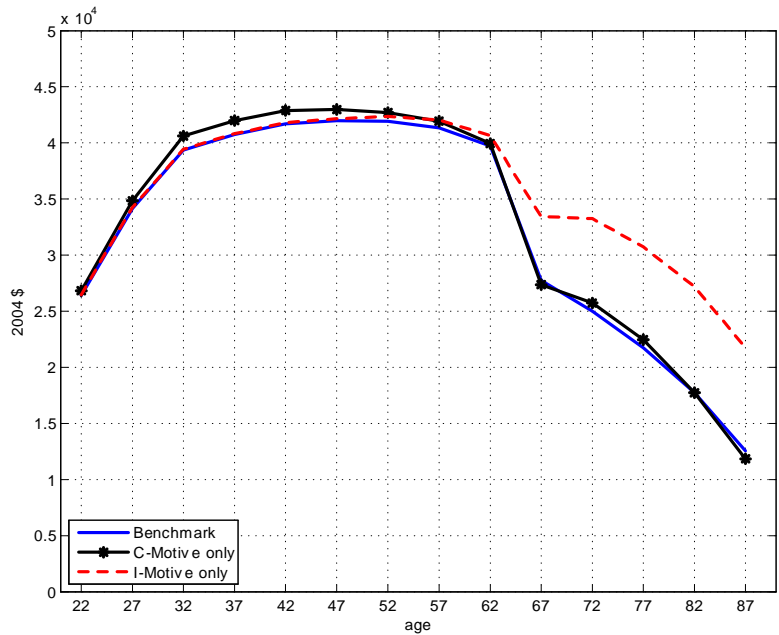


Figure 16: Life-cycle profiles of consumption: decomposition

Finally, Figure 16 shows the life-cycle profiles of non-medical consumption in the three scenarios. Once again, “C-Motive only” closely tracks the benchmark. “I-Motive only,” however, generates much higher consumption after retirement. The reason is that “C-Motive only” includes health in the utility function and, hence, enables the complementarity between consumption and health. Because health depreciates faster after retirement, consumption declines further because of this complementarity compared to “I-Motive only” which excludes the complementarity.

To summarize, Figures 12-16 show that the consumption motive is more impor-

tant than the investment motive in explaining the rising medical expenditures and declining health over the life-cycle. “C-Motive only” also matches the consumption profile better. The message is clear: incorporating health in the utility function is crucial in replicating life-cycle profiles of key economic decisions. Our decomposition exercise thus shows that under benchmark parameters, health is more like a consumption good than an investment good. In this sense, health capital is different from human capital because its value as a consumption good dominates, while for human capital we would expect exactly the opposite.

6.2 Increasing Sick Time

The sick time ratio which we use as a target for calibration is the average number of days off per year that employed adults take due to illness. This ratio, however, might be too low because non-participation due to illness should also account for a large part of the sick time of a representative agent. For example, a person who drops out the labor market due to disability is not included in the sick time ratio of 2.1% above. But in the model, the sick time of people who are out of the labor force should also be included in the measure of sick time. We address this issue here by doing an additional experiment in which we increase sick time.

In 2000, severe disabilities were reported by 8.7% (14.9 million) of the working-age

population (ages 18-64) in the U.S.²⁴ We assume that severe disability is a absorbing state (individuals are never recovered from the disabilities) and it will exclusively remove a person from the labor market (i.e., a person with disability supplies zero working time) but does not affect his leisure time. Given this assumption, it is easy to show that the average sick time ratio for a representative agent is the weighted sum of sick time ratio for employed adults, which is 2.1%, and sick time ratio for persons with severe disabilities. While we do not know exactly what the latter ratio is, we assume that sick time for the disabled is equal to the amount of time that they would have worked had they not been disabled - about 35%. Since the weight is 91.3% for the former and 8.7% for the latter, we obtain a sick time ratio of 5%. In other words, if we take into account non-participation due to illnesses, the sick time on average accounts for about 5% of the discretionary time for working age population.

Given this new target, we recalibrate the model and simulate the key life-cycle profiles in Figure 17.²⁵ The model matches the life-cycle profiles of medical expenditures, health status, working hours, and non-medical consumption quite well.

Based on the performance in Figure 17, we redo the exercise in Section 6.1 to de-

²⁴See <http://www.efmoody.com/insurance/disabilitystatistics.html>

²⁵The new parameter values are $\beta = (0.959)^5$, $\psi = -12$, $\rho = 0.342$, $\lambda = 0.64$, $d_0 = -3.82$, $d_1 = 0.255$, $d_2 = 0.008$, $B = 0.6$, $\xi = 0.6$, $Q = 0.038$, $\gamma = 2.6$.

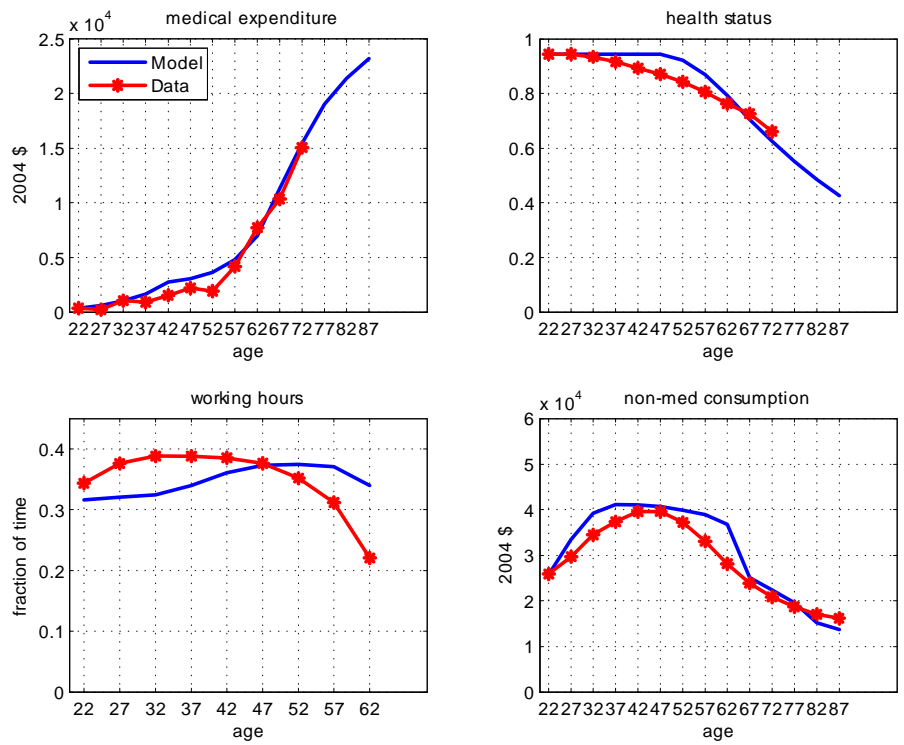


Figure 17: Life-cycle profiles of the model with alternative sick time ratio

compose C-motive and I-motive, respectively. Figure 18 shows quite different results compared to the benchmark case when sick time ratio is equal to 2.1%. As shown in panel a, “I-motive only” now becomes the major driving force behind medical expenditures for most working ages until ages 55-59. “C-motive only” surpasses it after. However, as individuals age, the investment motive dominates again after ages 75-79. This is because at later ages, sick time crowds out a big part of leisure time. In the current case, sick time accounts for around 25% of discretionary time at ages 80-84. It increases to 35% at ages 85-89 and 45% at ages 90-94. In the last period of the life-cycle, sick time claims about two-thirds of discretionary time. With a 5% sick time ratio, the increase in sick time over life-cycle is much more dramatic than the benchmark case as in Figure 11. Therefore, it is not surprising that investment motive plays a more important role in health investment now. The importance of investment motive is also confirmed in panel b which shows “I-motive only” dominates in shaping health status for most ages.

A caveat for the sick time ratio of 5% is that it is based on two extreme assumptions which might put it as the upper bound of the sick time ratio.²⁶ An accurate sick time ratio probably lies in between the one we used for the benchmark case and

²⁶According to the 1985 Society of Actuaries, 44.1% of individuals at age 24 recovers for five years after a disabilities onset. Although this percentage decreases as age, at age 55, the recovery ratio is still about 12%. (see <http://www.efmoody.com/insurance/disabilitystatistics.html>)

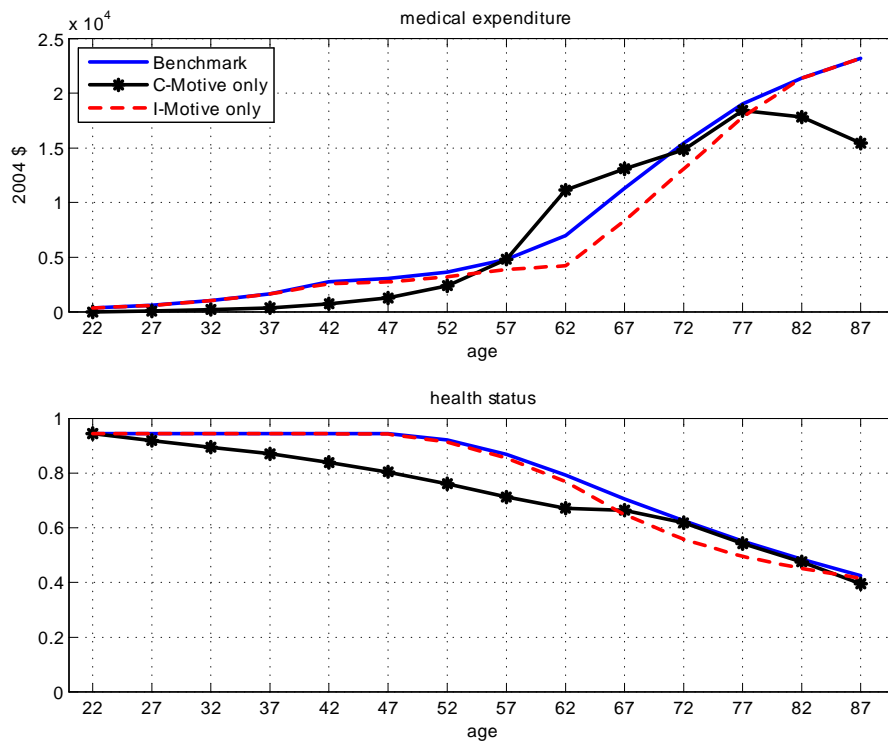


Figure 18: Life-cycle profiles of the model with alternative sick time ratio: decomposition

the 5% we used here. This number, however, is very important in determining the relative importance of the investment motive in health expenditures as we showed in this section. In this sense, our exercise here calls for a serious empirical investigation of health-related time loss.

6.3 Changing Survival Probabilities

In our benchmark model, health affects utility and time allocation. However, it does not affect survival probabilities. Several studies (e.g., Hall and Jones 2007; Suen 2006; Feng 2008) model health as a determinant of survival probabilities. Survival probabilities, however, might also affect health investment. In the second experiment, we investigate how changes in longevity affect health investment and other life-cycle economic decisions. We replace the 2002 survival probabilities in the benchmark with the survival probabilities from 1960.²⁷ The difference in survival probabilities between these two years, which is shown in Figure 19, implies 7.4 fewer years of life. Life expectancy in 1960 was 69.8 years compared to 77.2 years in 2002.

Shorter longevity lowers the effective discount rate of an individual and, thus, affects all life-cycle economic decisions. Figure 20 shows that with 1960 survival

²⁷Except for the data input of survival probability, we keep all parameter values unchanged from the benchmark model.

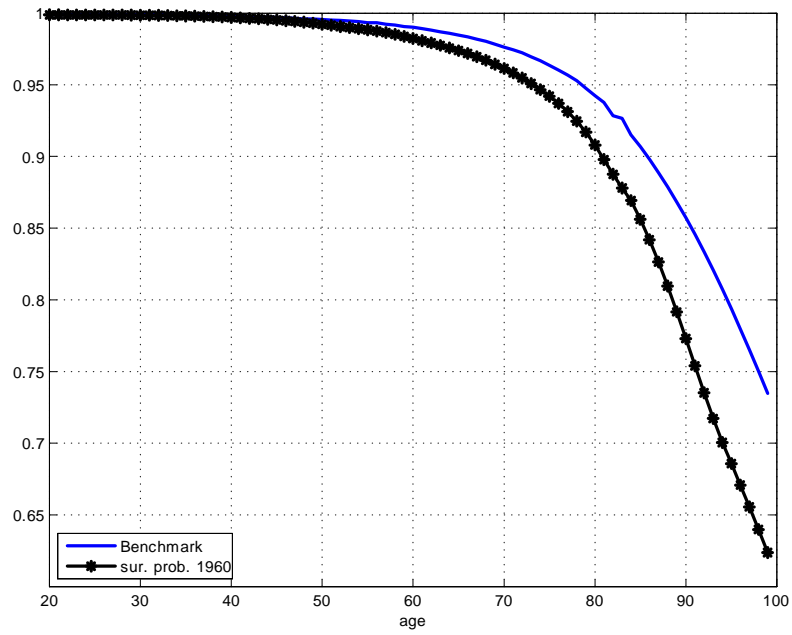


Figure 19: Life-cycle profile of survival probabilities: data

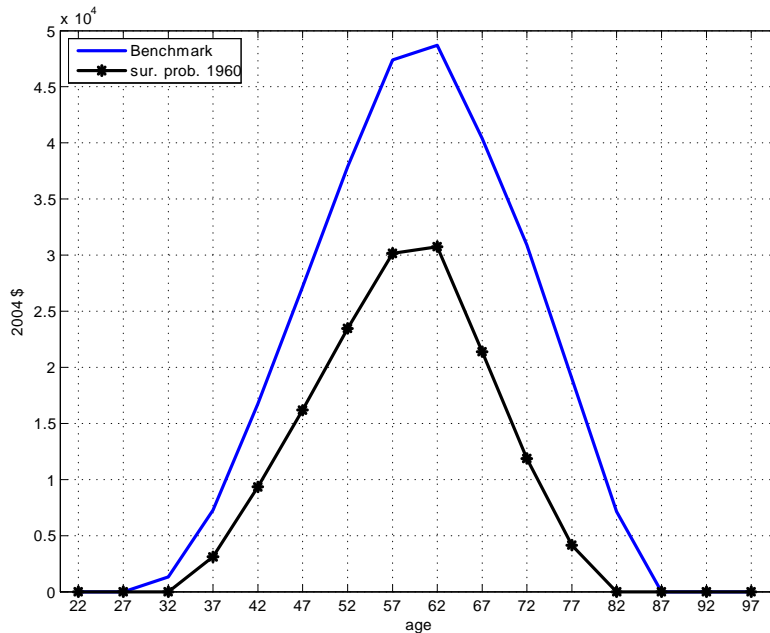


Figure 20: Life-cycle profile of asset holding: change in survival probability

probabilities, individuals significantly reduce their savings at all ages.²⁸ The capital-wealth ratio decreases from 2.60 in the benchmark model to 1.50.²⁹

Shorter longevity also reduces health investment as shown in Panel a in Figure 21. The effect is more pronounced after ages 55-59, when the survival probabilities

²⁸The effects of adult longevity on life-cycle and aggregate savings have been studied empirically in Bloom et al. (2003) and Kinugasa and Mason (2007). They all find that the effects are significantly positive. De Nardi, French and Jones (2009) use an estimated structural model based on De Nardi, French and Jones (2010) to assess the effect of heterogeneity in life expectancy on the savings by the elderly. They find that the differences in life expectancy related to observable factors such as income, gender, and health have large effects on savings.

²⁹The caveat here is that this is just a partial equilibrium result, since the factor prices are fixed. When the capital-output ratio goes down due to shorter longevity, the interest rate may rise to encourage capital accumulation. Therefore, the decrease in savings might be dampened by the general equilibrium effect.

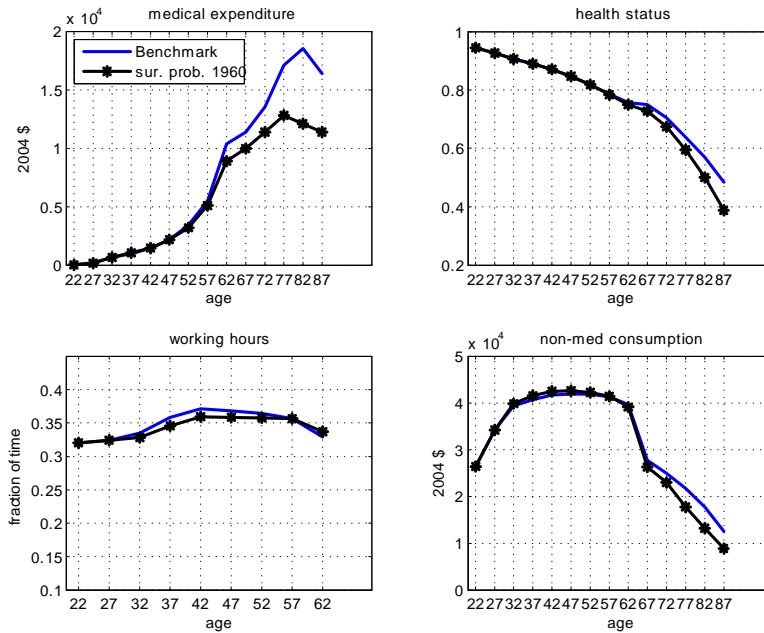


Figure 21: Life-cycle profiles: change in survival probability

in 1960 start to diverge from the benchmark. The medical expenditure-output ratio decreases from 15.2% in the benchmark to 11.5%. This ratio was 5.2% in 1960 in the data (NHA). Therefore, rising life expectancy alone can explain about 37% of the rise in the health expenditure-GDP ratio from 1960 to 2002. With less health investment, panel b shows that health status is lower than the benchmark case, especially after ages 55-59. Lower health stock also brings additional sick time and, hence, reduced working hours. Finally, with a higher effective discount rate, individuals shift consumption forward.

7 Sensitivity Analysis

In this section we conduct a sensitivity analysis to investigate how our quantitative findings from the benchmark model are affected if an alternative utility function is used and when we allow health to affect labor productivity rather than time allocation.

7.1 Separability Between Consumption and Leisure

In the benchmark model, we used a non-separable utility function on consumption and leisure. In this section, we choose an alternative specification that allows for separability over consumption and leisure. For consumption and health, we maintain a flexible CES function form. The utility function is

$$U(c_j, l_j, h_j) = \frac{[\lambda c_j^\psi + (1 - \lambda) h_j^\psi]^{\frac{1-\sigma}{\psi}}}{1 - \sigma} + \chi \frac{l_j^{1-\theta}}{1 - \theta} \quad (10)$$

A useful property of this specification is that it implies that the Frisch elasticity of labor supply is $\frac{l_j}{1-l_j-s_j} \frac{1}{\theta}$ at age j . This object varies over the life-cycle as a function of leisure relative to working hours. While early empirical work finds that this elasticity is well below one, more recent estimates find that it centers around unity (Imrohoroglu and Kitao 2009b). We choose $\theta = 1.86$ to match an average value of

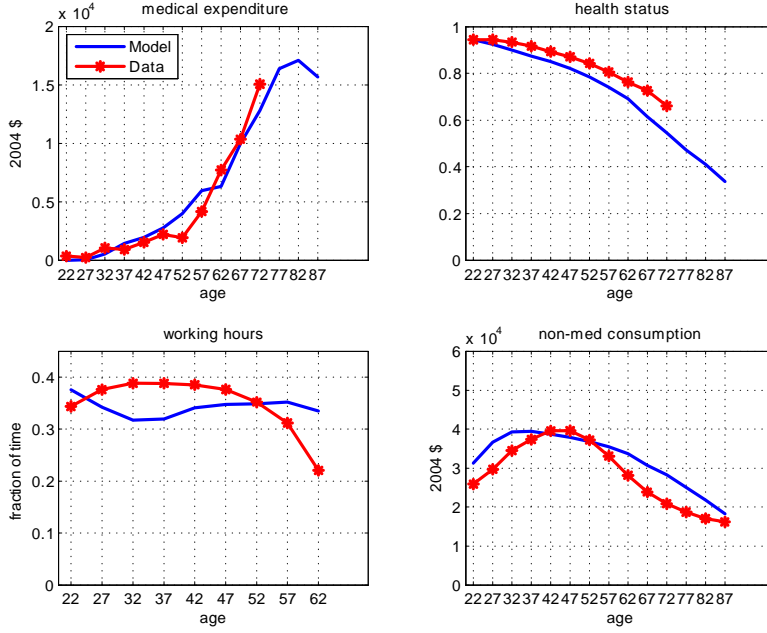


Figure 22: Life-cycle profiles of the model with the alternative preference

one for the labor supply elasticity. We calibrate the weight of leisure $\chi = 1.60$ to match the average fraction of working hours over working age. We also recalibrate the other remaining parameters to match targets as in Table 2.³⁰

Given all these recalibrated parameter values, Figure 22 shows the performance of the model. Although the performance is noticeably worse than in the benchmark in Section 5, we still can capture the basic trends of each variable, with the exception of working hours.

³⁰The new parameter values are $\beta = (0.96)^5$, $\psi = -9$, $\rho = 0.33$, $d_0 = -3.94$, $d_1 = 0.215$, $d_2 = 0.009$, $B = 0.62$, $\xi = 0.88$, $Q = 0.014$, $\gamma = 2.3$.

We now conduct the decomposition experiment from Section 6.1. The benchmark model now refers to the model with the alternative preferences in equation (10). “C-Motive only” is the model obtained by setting $Q = 0$ while keeping all other parameters at their values from the benchmark. “I-Motive only” refers to the model obtained by setting $\lambda = 1$ while keeping all other parameters at their benchmark values. “C-Motive only” generates profiles very similar to those from the benchmark model, whereas “I-Motive only” yields much lower medical expenditures and health status, but much higher working hours and consumption than the benchmark. Our earlier finding that deriving utility from health is crucial is robust to this alternative specification of preferences.

7.2 Time Endowment vs. Productivity

Grossman (1972) argues that the main difference between health capital and human capital is that human capital affects an individual’s productivity, whereas health capital determines the total amount of time that can be spent in market and non-market activities. Our benchmark case follows Grossman. Most of the literature, however, takes a different route and models health as a determinant of individual labor productivity (Jung and Tran 2009, Feng 2008). Will these two different modelling strategies generate significantly different life-cycle profiles? This section answers the

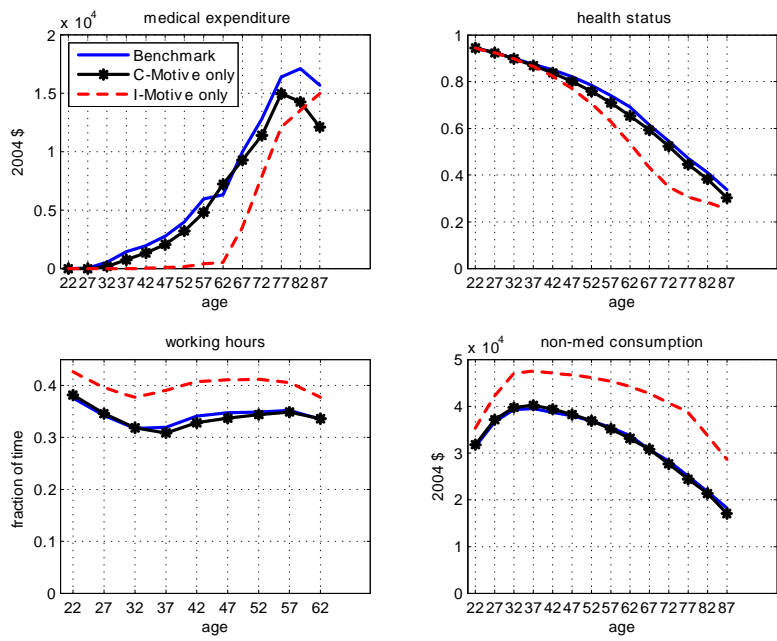


Figure 23: Life-cycle profiles of the model with the alternative preference: decomposition

question by running an experiment in which we replace the investment motive in the benchmark model with a specification of health-related labor productivity. Following Bloom and Canning (2005), we assume that an individual's labor income at age j takes the form $w\varepsilon_j e^{\eta h_j} n_j$, where the labor-efficiency unit ε_j captures the effects of other forms of human capital (such as education) on an individual's labor productivity. The term $e^{\eta h_j}$ describes the effect of health on labor productivity at age j .

As far as we know, there is no estimate of the parameter η from the life-cycle data. Bloom and Canning (2005) estimate $\eta = 0.028$ from an aggregate production function using a cross-country data set. We take their estimate and the age-efficiency profile $\{\varepsilon_j\}$ from the benchmark model and recalibrate all the other parameters to match 9 moment conditions as in Table 2 (except the two targets related to sick time).³¹ We call this the productivity model. We report its comparison to the benchmark model in Figure 24.

If health affects labor productivity, better health transforms into higher wages and hence higher consumption. This gives an incentive to invest in health. Figure 24 shows that the productivity model provides profiles very similar to those in the benchmark model. Therefore, both modelling strategies do a fine job of replicating

³¹The new parameter values are $\beta = (0.9668)^5$, $\psi = -5.75$, $\rho = 0.33$, $\lambda = 0.64$, $d_0 = -3.97$, $d_1 = 0.21$, $d_2 = 0.00825$, $B = 0.7$, $\xi = 0.8$.

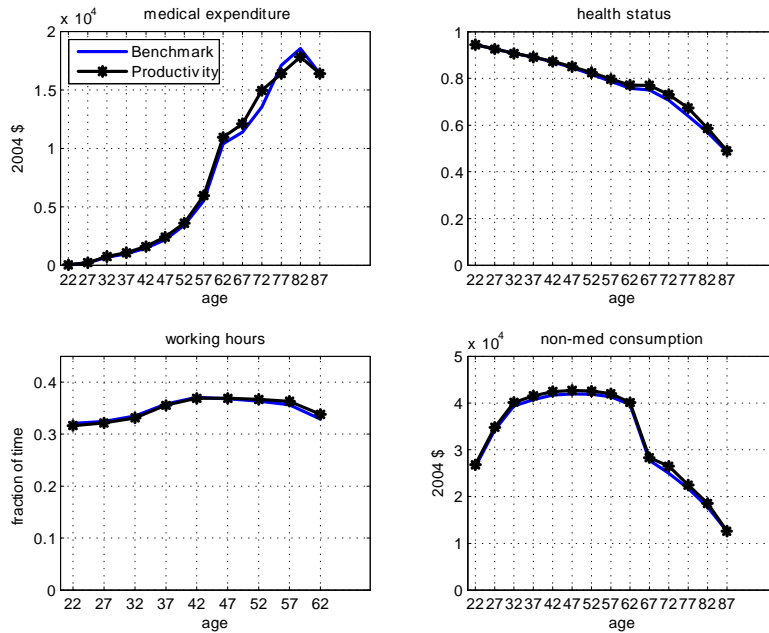


Figure 24: Life-cycle profiles: productivity vs. sick time

life-cycle profiles.

Following the spirit of Section 6.1, we ask how much of medical expenditures is driven by the productivity channel? In other words, we want to compare the investment motives in the benchmark and the productivity model. Strikingly, as shown in Figure 25, the “I-Motive only” model (set $\lambda = 1$, and keep all other parameter values the same as in the productivity model) generates negligible medical expenditure.³² On the other hand, the “C-Motive only” model (set $\eta = 0$ and keep all other parameter values the same as in the productivity model) obtains life cycle

³²This might be due to the small value of η .

profile of medical expenditures very similar to those in the productivity model. This shows that health investment in the productivity model is purely driven by the consumption motive, i.e., the presence of health in the utility function. Indeed, the “C-Motive only” model is almost identical to the productivity model in terms of not only health expenditure but also health status, working hours and consumption. This confirms the dominating role of consumption motive plays in replicating life-cycle profiles as in Section 6.1.

The reason the investment motive through the sick time channel (Figure 12) is quantitatively far more significant than the one through the labor productivity channel here in Figure 25 is that the sick time channel affects both consumption and leisure over the working age. And it significantly affects leisure after retirement, since sick time crowds out leisure directly after retirement. The productivity channel, however, works only until retirement. And it does not affect leisure over the working age. This experiment thus shows that the indirect utility gain through leisure is the main driving force for medical expenditure under the “I-Motive only” model as shown in Figure 12.

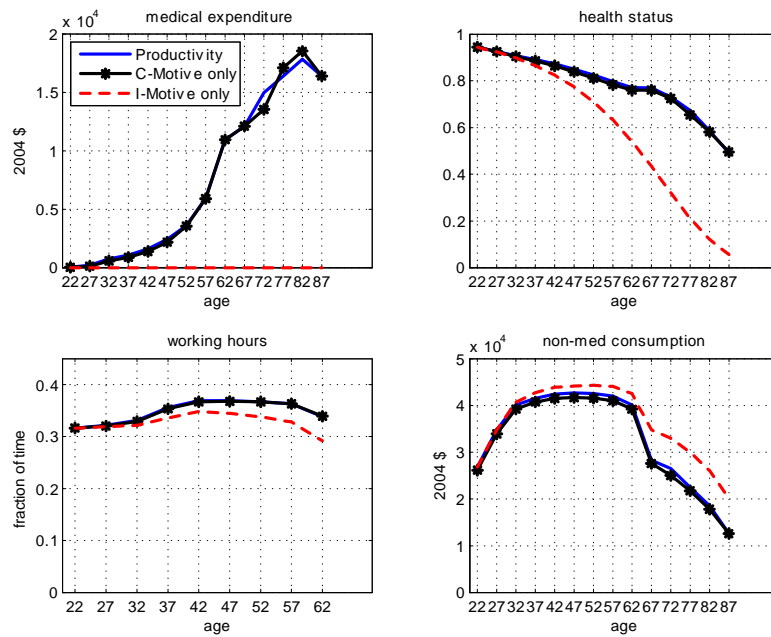


Figure 25: Life-cycle profiles of productivity model: decomposition

8 Conclusions

We studied the life-cycle behavior of health investment and its effects on other aspects of consumer behavior. Two motives 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). To accomplish this, we calibrated an overlapping generations model of endogenous health investment by matching the average ratios of relevant economic variables over the life-cycle. We found that the calibrated model fits key life-cycle profiles of consumption, working hours, health status and medical expenditures very well. Based on this benchmark, we ran a series of counterfactual experiments. We found that, under our benchmark parameters, the consumption motive is more important than the investment motive in driving up medical expenditures over the life-cycle. This conclusion is robust to different specifications of the investment motive and preferences. However, we also find that when we increase the target sick time ratio over working age for calibration from its benchmark value 2.1% to 5%, the investment motive becomes the dominant driving force of medical expenditures. In light of this, we view our exercise as a serious call for further empirical investigation of health-related time loss so that we can better understand the motives behind health investment. As discussed by Podor and Halliday (2011) who investigate the nexus of

health and time allocations, quantifying sick time as it was conceived in the Grossman model is apt to be a difficult task and conventional time use data may not be sufficient since what is cleanly delineated as sick time in a model will be classified as sleeping or some form of leisure in a time diary.

Based on these findings, we also showed the effects of survival probabilities on consumption, savings and medical expenditure. We found that changing survival probabilities from their benchmark values in 2002 to those from 1960 significantly decreased health expenditures and savings and shifted the consumption profile forward. Based on our model, rising life expectancy alone can explain about 37% of the rise in the health expenditure-GDP ratio from 1960 to 2002.

Our model can be extended along several dimensions. First, we assumed an exogenous survival probability for the sake of computational simplicity. However, future work should allow health to affect survival probabilities. By allowing for an endogenous survival probability, we would incorporate another benefit of health investment obtained by increasing the effective discount factor. Second, we assume 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

on an individual's health investment. It will also generate heterogeneity in medical expenditures across individuals so that help us to better understand the distribution of health expenditures as observed in the data.

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

- [1] Baker, M., M. Stabile and C. Deri (2004): “What Do Self-Reported, Objective Measures of Health Measure?” *Journal of Human Resources*, 39, 1067-1093.
- [2] Bloom, D. E., Canning, and B. Graham (2003): “Longevity and Life-cycle Savings,” *Scandinavian Journal of Economics*, 105, 319–338.
- [3] Bloom, D. E. and D. Canning (2005): “Health and Economic Growth: Reconciling the Micro and Macro Evidence,” CDDRI Stanford IIS working paper No. 42.
- [4] Bound, J. (1991): “Self-Reported Versus Objective Measures of Health in Retirement Models,” *Journal of Human Resources*, 26, 106-138.
- [5] Bullard, J., and J. Feigenbaum (2007): “A Leisurely Reading of the Life Cycle Consumption Data,” *Journal of Monetary Economics*, 54, 2305-2320.
- [6] Cagetti, M., and M. De Nardi (2009): “Estate Taxation, Entrepreneurship, and Wealth,” *American Economic Review*, 99, 85-111.
- [7] Carroll, C.D. (1997): “Buffer Stock Saving and the Life-Cycle/Permanent Income Hypothesis,” *Quarterly Journal of Economics*, 107, 1-56.

- [8] Conesa, J., S. Kitao and D. Krueger (2009): “Taxing Capital Income? Not a Bad Idea After All!” *American Economic Review*, 99, 25-48.
- [9] De Nardi, M., E. French, and J. B. Jones (2009): “Life Expectancy and Old Age Savings,” *American Economic Review, Papers and Proceedings*, 110-115.
- [10] De Nardi, M., E. French, and J. B. Jones (2010): “Why Do the Elderly Save? The Role of Medical Expenses,” *Journal of Political Economy*, 118, 39-75.
- [11] Deaton, A. (1992): *Understanding Consumption*. Oxford: Clarendon Press.
- [12] Feng, Z. (2008): “Macroeconomic Consequences of Alternative Reforms to the Health Insurance System in the U.S.,” University of Miami, unpublished mimeo.
- [13] Fernandez-Villaverde, J. and D. Krueger (forthcoming): “Consumption and Saving over the Life Cycle: How Important are Consumer Durables?” *Macroeconomic Dynamics*.
- [14] Fernandez-Villaverde, J. and D. Krueger (2007): “Consumption over the Life Cycle: Facts from Consumer Expenditure Survey Data?” *Review of Economics and Statistics*, 89, 552-565.

- [15] Finkelstein, A., E. Luttmer, and M. Notowidigdo (2010): “What Good is Wealth without Health? The Effect of Health on the Marginal Utility of Consumption,” unpublished mimeo.
- [16] Fonseca, R., P. Michaud, T. Gamama, and A. Kapteyn (2009): “On the Rise of Health Spending and Longevity,” IZA Discussion paper #4622.
- [17] French, E. (2005): “The Effects of Health, Wealth and Wages on Labor Supply and Retirement Behavior,” *Review of Economic Studies*, 72, 395-428.
- [18] Gilleskie, D. (1998): “A Dynamic Stochastic Model of Medical Care Use and Work Absence,” *Econometrica*, 66, 1-45.
- [19] Gorinchas, P.O. and J.A. Parker (2002): “Consumption over the Life-Cycle,” *Econometrica*, 70, 47-89.
- [20] Grossman, M. (1972): “On the Concept of Health Capital and the Demand for Health,” *Journal of Political Economy*, 80, 223-255.
- [21] Hall, R.E. and C.I. Jones (2007): “The Value of Life and the Rise in Health Spending,” *Quarterly Journal of Economics*, 122, 39-72.

- [22] Hansen, G. D. (1993): “The Cyclical and Secular Behavior of the Labour Input: Comparing Efficiency Units and Hours Worked,” *Journal of Applied Econometrics*, 8, 71-80.
- [23] Huang, K. and G. Huffman (2010): “A Defense of the Current US Tax Treatment of Employer-Provided Medical Insurance,” unpublished mimeo.
- [24] Hubbard, G., J. Skinner and S. Zeldes (1994): “The Importance of Precautionary Motives for Explaining Individual and Aggregate Savings,” in Carnegie-Rochester Conference Series on Public Policy, Vol 40, ed. by A.H. Meltzer and C.I. Plosser. Amsterdam: North-Holland, pp. 59-125.
- [25] Imrohoroglu, A. and S. Kitao (2009a): “Social Security, Benefit Claiming and Labor Force Participation: A Quantitative General Equilibrium Approach,” unpublished mimeo.
- [26] Imrohoroglu, A. and S. Kitao (2009b): “Labor Supply Elasticity and Social Security Reform,” *Journal of Public Economics*, 93, 867–878.
- [27] Imrohoroglu, A., S. Imrohoroglu and D. Joines (1995): “A Life-Cycle Analysis of Social Security,” *Economic Theory*, 6, 83-114.

- [28] Jeske, K. and S. Kitao (2009): “U.S. Tax Policy and Health Insurance Demand: Can a Regressive Policy Improve Welfare?” *Journal of Monetary Economics*, 56, 210-221.
- [29] Jung, J. and C. Tran (2009): “The Macroeconomics of Health Savings Accounts,” unpublished mimeo.
- [30] Jung, J. and C. Tran (2010): “Medical Consumption over the Life Cycle: Facts from a U.S. Medical Expenditure Panel Survey,” unpublished mimeo.
- [31] Kashihara, D. and K. Carper (2008): “National Health Care Expenses in the US Civilian Non-institutionalized Population, 2009” Medical Expenditure Panel Survey Statistical Brief #229.
- [32] Kinugasa, T. and A. Mason (2007): “Why Countries Become Wealthy: The Effects of Adult Longevity on Saving,” *World Development*, 35, 1-23.
- [33] Kopecky, K. and T. Koreshkova (2009): “The Impact of Medical and Nursing Home Expenses and Social Insurance Policies on Saving and Inequality,” unpublished mimeo.
- [34] Kotlikoff, L., K. Smetters, and J. Walliser (1999): “Privatizing Social Security in the United States: Comparing the Options,” *Review of Economic Dynamics*, 2, 532–574.

- [35] Lillard, E.L. and R.W. Willis (1978): “Dynamic Aspects of Earnings Mobility,” *Econometrica*, 46, 985-1012.
- [36] Lovell, V. (2004): “No Time to Be Sick: Why Everyone Suffers When Workers Don’t Have Paid Sick Leave,” IWPR Publication #B242p, Institute for Women’s Policy Research, Washington DC.
- [37] Meara, E., C. White, and D. M. Cutler (2004): “Trends In Medical Spending By Age, 1963–2000,” *Health Affairs*, 23, 176-183.
- [38] Meghir, C. and L. Pistaferri (2004): “Income Variance Dynamics and Heterogeneity,” *Econometrica*, 72, 1-32.
- [39] Palumbo, M.G. (1999): “Uncertain Medical Expenses and Precautionary Saving Near the End of the Life-Cycle,” *Review of Economic Studies*, 66, 395-421.
- [40] Podor, M. and T.J. Halliday (2011): “Health Status and the Allocation of Time” forthcoming *Health Economics*.
- [41] Rust, J. and C. Phelan (1997): “How Social Security and Medicare Affect Retirement Behavior in a World of Incomplete Markets,” *Econometrica*, 65, 781-831.
- [42] Smith, J. (2003): “Health and SES over the Life-Course,” unpublished mimeo.

- [43] Suen, R. (2006): “Technological Advance and the Growth in Health Care Spending,” unpublished mimeo.
- [44] Viscusi, W. and W. Evans (1990): “Utility Functions That Depend on Health Status: Estimates and Economic Implications,” *American Economic Review*, 80, 353-374.
- [45] Yogo, M. (2009): “Portfolio Choice in Retirement: Health Risk and the Demand for Annuities, Housing and Risky Assets,” unpublished mimeo.