

# Health Insurance and Retirement Decisions

John Karl Scholz and Ananth Seshadri





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**John Karl Scholz**

**Ananth Seshadri**

University of Wisconsin-Madison

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Michigan Retirement Research Center  
University of Michigan  
P.O. Box 1248  
Ann Arbor, MI 48104  
[www.mrrc.isr.umich.edu](http://www.mrrc.isr.umich.edu)  
(734) 615-0422

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Mark J. Bernstein, Ann Arbor; Julia Donovan Darlow, Ann Arbor; Laurence B. Deitch, Bloomfield Hills; Shauna Ryder Diggs, Grosse Pointe; Denise Ilitch, Bingham Farms; Andrea Fischer Newman, Ann Arbor; Andrew C. Richner, Grosse Pointe Park ; Katherine E. White, Ann Arbor; Mary Sue Coleman, ex officio

# **Health Insurance and Retirement Decisions**

## **Abstract**

We develop a rich model to study the complex interrelationship between health insurance and retirement decisions. The decision to retire depends on a number of factors including availability of health insurance, health shocks, pensions, Social Security, and how consumption and health interact in the utility function. We incorporate these features in a computational model of optimal wealth and retirement decisions, solving the model household-by-household using data from the HRS. We use the model to study two important SSA priority areas: first, to what extent do people remain in the labor force until age 65 in order to maintain health insurance for themselves (and after age 65 to maintain health insurance for their spouses)? Second, do early retirees have poorer health than others and does the availability of Medicare interact with their decision to claim benefits?

## **Citation**

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# 1 Introduction

In this paper we seek to enhance understanding of the relationship between health insurance and retirement decisions. Economic models of life-cycle consumption and wealth accumulation (that start at the beginning of working life) treat retirement as being exogenous, and therefore retirement is unaffected by unforeseen household circumstances, or abstract from decisions regarding medical expenses, treating these expenses as exogenous. We propose to develop a rich life-cycle model of optimal consumption and retirement decisions where the stock of health affects utility and longevity and is influenced by one's health insurance status. We will use the model to study the complex interplay of saving/consumption decisions, retirement, social security policy and macroeconomic shocks.

Health and consumption decisions are interlinked, yet the ways that consumption and health interact are hard to untangle. Health changes, such as disability or illness, affect labor market decisions and hence income and consumption possibilities. But causality also operates in the other direction, where consumption decisions such as smoking or exercise affect health. There are also unobserved differences between people in their ability to produce and maintain health and human capital, leading to correlations between health and lifetime income and wealth. This paper examines links between health, consumption and wealth.

There are many possible ways to examine these links. Our analysis starts from ideas dating back at least to Grossman (1972), who argued that health is the cumulative result of investment and choices (along with randomness) that begin *in utero*. We model household utility as being a function of consumption and health, where individuals make optimizing decisions over consumption and the production of health. In our model, health affects not just utility but also longevity. Surprisingly, given the centrality of health to economic decision-making and well-being, numerical models of lifecycle

consumption choices generally treat health in a highly stylized fashion. Authors commonly do not model health as being an argument of utility and do not allow health to affect longevity (see, for example, Hubbard, Skinner, and Zeldes, 1995; Engen, Gale, Uccello, 1999; Palumbo, 1999; and Scholz, Seshadri, Khitatrakun, 2006). Instead medical expense shocks that proxy for health shocks affect the lifetime budget constraint. Households in these papers respond to exogenous medical expense shocks by decreasing consumption, saving for precautionary reasons.

In this paper we formulate a lifecycle model that we solve household-by-household, where health investments (including time-use decisions) affect longevity and health affects utility. By modeling investments in health, longevity becomes an endogenous outcome, which allows us to study the effects of changes in safety net policy, for example, on mortality as well as wealth. Our model also captures the effects of poor health on sick time and hence on earnings and retirement.

In the lifecycle consumption papers noted above, households will respond to cuts in safety net programs by increasing precautionary saving. In our model households might maintain consumption at the cost of activities that degrade health and consequently affect longevity. In practice, these health-reducing activities might include working an additional job (and foregoing sleep); foregoing exercise; or eating high-calorie, inexpensive fast food rather than healthier home-cooked meals. Over the long run, the consequences of these decisions can be large. In a world without health-related social insurance, young forward-looking households may recognize the futility of accumulating wealth to offset expected late-in-life health shocks and simply enjoy a higher standard of living for a shorter expected lifetime. Depending on lifetime earnings or the economic environment, other households may sharply increase precautionary saving in a world without health-related social insurance. Our model provides quantitative insight about these responses.

We, of course, are not the first to examine the links between health, consumption,

and wealth. Clear discussions are given in Smith (2005) and Case and Deaton (2005) and many other places. De Nardi, French and Jones (2010) and Palumbo (1999) are more closely related to our work. In their models, the only response that households have to the realization of medical expense shocks is to alter consumption. Death occurs through the application of life tables with random longevity draws.<sup>1</sup> They document that late-in-life health shocks, including nursing home expenses, and social insurance play a substantial role in old age wealth decumulation.

We build on the past lifecycle consumption and health literature in at least three ways. First, our specification of utility is different. Most prior papers that add health or medical expenditures to utility assume it is separable from consumption in preferences. Two important exceptions are Murphy and Topel (2006), who use a utility function that features consumption-health complementarity to value improvements in health, and Yogo (2009) who models health and portfolio choices of the elderly in an economy that features complementarity between consumption and health. Health is the object of interest in our approach and we model health production. We allow consumption and health to be complements or substitutes in preferences. In practice, we find consumption and health are complements and complementarity is quantitatively important to understanding the evolution of health and wealth as individuals age. In particular, consumption will optimally decline in old age, tracking the inevitable deterioration of health, which implies consumption will be shifted to earlier periods in the

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<sup>1</sup>In section 9 of De Nardi, French and Jones (2010) they write down and estimate key structural parameters of a model where consumption and medical expenditures are arguments of utility, and where health status and age affect the size of medical-needs shocks. Their model is estimated on a sample of single individuals age 70 and over. They find that endogenizing medical expense shocks has little effect on their findings that medical expenses are a major saving motive and that social insurance affects the saving of the income-rich and the income-poor.

Two other related papers model intertemporal consumption decisions and include health in the utility function. Fonseca, Michaud, Galama, and Kapteyn (2009) write down a model similar to ours and solve the decision problem for 1,500 representative households. Consumption and health are separable in utility in their model and the focus of their work is on explaining the causes behind the increases in health spending and life expectancy between 1965-2005. Yogo (2009) solves a model similar to ours for retired, single women over 65 to examine portfolio choice and annuitization in retirement.

life cycle relative to models that ignore health-consumption interactions.

Second, most papers do not examine health investments and consumption decisions of households younger than 65. Health capital, however, may be well-formed by prior decisions and expenditures by the time an individual reaches 65. We model health production from the start of working life.<sup>2</sup> Forward-looking households will respond to income shocks, health shocks, or to changes in institutions by altering their health investments and consumption during their working lives.

Third, Palumbo (1999) and De Nardi, French and Jones (2010) and other related studies have shown that anticipated and realized medical expenses are an important determinant of wealth decumulation patterns in old age. The focus of our work differs. We develop a model of consumption and longevity to study how health and income shocks affect consumption plans, and how health and income shocks affect investments in health capital over the lifecycle. If death occurs when health capital falls below a given threshold, households may respond to policy or exogenous shocks by reducing or increasing consumption and hence altering longevity relative to a world where health is not an argument in preferences. Studying the trade-off between consumption and health investments on health, longevity, and wealth offers new insights into household behavior.

The decision to retire is also something we model. An obvious way for some households to respond to perceived or actual shortfalls in retirement wealth is to work longer than they originally anticipated or to invest less in their health. Similarly, households with perceived or actual net worth surpluses may choose to retire earlier than initially expected. Of course, these households may also be concerned with the prospect of facing unusually bad health shocks or other necessary expenses or they may wish to leave assets to children or philanthropic organizations. Retirement decisions are also influenced by

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<sup>2</sup>Health is undoubtedly influenced by shocks and decisions made *in utero* and in childhood. We do not have data on these experiences, however, so lack of data and computational demands lead us to start our analysis at the beginning of working life.



health status, which in turn is also a consequence of decisions made by individuals. This complex interrelationship is relatively understudied and has immense policy significance.

Empirical studies uniformly find a large positive association between retiree health insurance and early retirement. Rogowski and Karoly (2000) estimate probit models of early retirement as a function of retiree health insurance, health, and other characteristics using the first and third waves of the Health and Retirement Study (HRS). Madrian (1994a, 1994b) and Hurd and McGarry (1993) also find similar results. Gruber and Madrian (2002) characterize the literature as suggesting that retiree health insurance increases the retirement hazard by 30 to 80 percent.

Another set of papers use structural models to analyze the effects of retiree health benefits on early retirement. Gustman and Steinmeier (1994) and Lumsdaine, Stock, and Wise (1994), for example, factor health insurance into the budget constraint based on the average cost of insurance and find retirement behavior is similar to behavior that arises when ignoring health insurance, implying a small effect of retiree health insurance on retirement. Rust and Phelan (1997) take into account risk aversion and the full distribution of health costs and find larger effects of retiree health insurance on retirement than papers that do not model risk aversion. Blau and Gilleskie (2001) estimate a structural model of joint retirement by married couples and find little effect of retiree health insurance when health insurance only enters the budget constraint and a larger effect when health insurance is allowed to influence utility directly.

Burkhauser, Couch, and Phillips (1996) relate early retirement to health status, analyzing a sample of 62-year-olds observed in the Health and Retirement Survey. They compare the health and financial assets of those who took early benefits and those who did not and find that the great majority of people who take early benefits are in good health, a result that is consistent with the currently established view that most retirements are essentially voluntary responses to financial incentives. They report that fewer than 10 percent of men who take early benefits are in poor health and have no

other source of pension income beyond Social Security benefits. The comparable figure for women is 20 percent. Smith (1999) confirms the basic finding of Burkhauser and others (1996) using several panels of the SIPP. He concludes that most retirees who take early benefits do not report health problems that limit work.

We build on several previous papers. Some earlier structural papers with endogenous retirement abstract from savings decisions. Most prior work assumes that health status evolves exogenously or that individuals face medical expense shocks. In our model, out-of-pocket medical expenses are endogenous and get translated into total medical expenses depending on the health insurance status of the individual. We model the evolution of health as well as labor supply decisions (separately for both members of a married household) and allow for health to affect utility as well as longevity. Most, if not all of these features are missing from the existing literature. We believe these features are important in understanding the interplay between retirement decisions and health insurance status.

After calibrating our model to match key moments for the typical household, we find the model is able to match the cross-sectional variation in medical expenses, longevity, the stock of health and consumption in the Health and Retirement Study. We also match changes in wealth, health spending, and health status between 1998 and 2008. In addition, we match patterns of medical spending, health stocks as well as longevity earlier in the lifecycle. We finally examine the effect of health insurance on retirement decisions.

## **2 Descriptive Facts**

We use Health and Retirement Study (HRS) data from 1992 through 2008. The Health and Retirement Study (HRS) is sponsored by the National Institute of Aging and conducted by the University of Michigan with supplemental support from the Social Security

Administration. The HRS is a national panel study with a sample (in 1992) of 12,652 persons in 7,702 households. It oversamples blacks, Hispanics, and residents of Florida. The sample is nationally representative of the American population 50 years old and above. The baseline 1992 study consisted of in-home, face-to-face interviews of the 1931–41 birth cohort and their spouses, if they were married. Follow up interviews have continued every two years through 2010. As the HRS has matured, new cohorts have been added. Our sample includes households from the AHEAD cohort, born before 1924; Children of Depression Age (CODA) cohort, born between 1924 and 1930; the original HRS cohort, born between 1931 and 1941; the War Baby cohort, born between 1942 and 1947; and the Early Boomer cohort, born between 1948 and 1953. The sample is a representative, randomly stratified sample of U.S. households born before 1953.<sup>3</sup>

We start with 30,548 (19,058 unique households) individuals in the RAND HRS Version J (RAND, June 2010). We keep 11,494 households in which either the head or the surviving spouse responded in 2008. We drop 287 households with insufficient earnings to estimate the household fixed effect in the earnings model. Next, we drop 35 households in which both the household head and their spouse are the same gender. This leaves with 11,172 households in our sample.

In addition to a wide range of health information, the HRS has excellent measures of household financial well-being. To measure household net worth we use respondents' reports of the value of primary and secondary residences, other real estate, vehicles, businesses, as well as a wide range of personal savings instruments (IRA, Keogh accounts, stocks, mutual funds, investment trusts, checking accounts, saving accounts, money market accounts, CDs, government savings bonds, Treasury bills, bonds, bond funds, and "other savings"). Household financial liabilities are subtracted from the sum of household wealth and include the value of all mortgages, land contracts, and "other debt."

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<sup>3</sup>Comprehensive information on the HRS is available at <http://hrsonline.isr.umich.edu/>.

Observed household medical expenses are reported as both out-of-pocket and total expenses. In this paper we use the out-of-pocket measure, which includes the costs respondents pay for hospitals, nursing homes, doctors, dentists, outpatient surgery, prescription drugs, home health care, and care in special facilities. While we have reasonable confidence in reported out-of-pocket medical expenses in the HRS, total expenses are considerably more difficult for a household to report accurately in an interview survey. Because of this we use moments for total medical expenses by age, cross-classified by insurance status, drawn from the 2008 Household Component of the Medical Expenditure Panel Survey (MEPS) to calibrate parameters that map out-of-pocket expenses into total expenses.<sup>4</sup> The MEPS is administered by the Agency for Healthcare Research and Quality and contains detailed information on health care expenditures.

Our model must be capable of matching several descriptive facts about health and wealth. The first fact is perhaps obvious, but self-reported health declines with age. The HRS asks respondents about their self-reported health status, where respondents can respond on a 5-point scale (excellent, very good, good, fair, or poor). Figure 1 plots the average responses for two groups of responses in 2008 by cohort. The modal response for the four oldest cohorts is good while it is very good for the youngest cohort, the Early Boomers. The percentage of respondents reporting excellent or very good health declines monotonically with age across cohorts. The percentage of respondents reporting poor or fair health rises with age across cohorts. Recognizing this biological fact, health depreciates in our model of health production.

The second fact highlighted is that exercise is positively correlated with lifetime income as shown in Figure 2. This relationship is potentially important in a model of health production as there is abundant evidence that exercise, smoking, and diet influence health and hence longevity.<sup>5</sup> Nevertheless, the computational demands that

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<sup>4</sup>Information is available at [http://www.meps.ahrq.gov/data\\_stats/mepsnet/mepsnethc08.shtml](http://www.meps.ahrq.gov/data_stats/mepsnet/mepsnethc08.shtml)

<sup>5</sup>See, for example, Paffenbarger et al. (1993), Willette (1994), Mokdad et al. (2004), and Warburton et al. (2006).

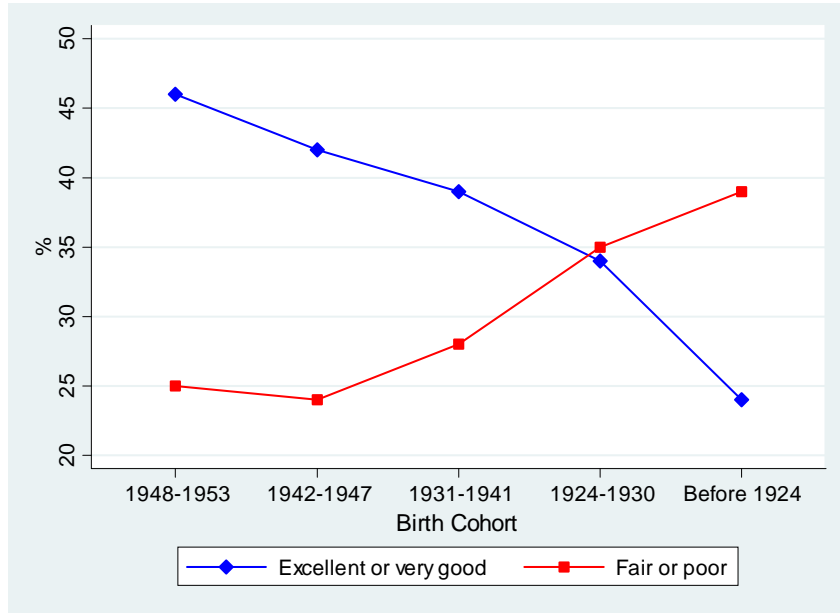


Figure 1: Self-Reported Health and Age (Birth Cohort), HRS 2008

arise in solving our dynamic programming model household-by-household with endogenous consumption and health production requires parsimonious modelling. Given this requirement, we assume health can be improved by investments of money and by investments of time. Specifically, time investments in health production reduce leisure. Both working and retired households face a combined time and financial budget constraint, which we describe in greater detail below. In this way, we capture the essential trade-off between non-health related consumption and health investment.

The third fact is "the gradient:" health is positively related to socioeconomic status, whether measured by lifetime income, net worth, or related measures. As Figure 3 makes clear, the positive relationship between self-reported health and net worth is strongly present in the HRS. The Figure is similar when households are sorted by lifetime income quintile as opposed to net worth quintile. Illuminating economic decisions over the lifecycle that result in the joint distribution of health and wealth, household-by-household, is a central challenge for this paper.

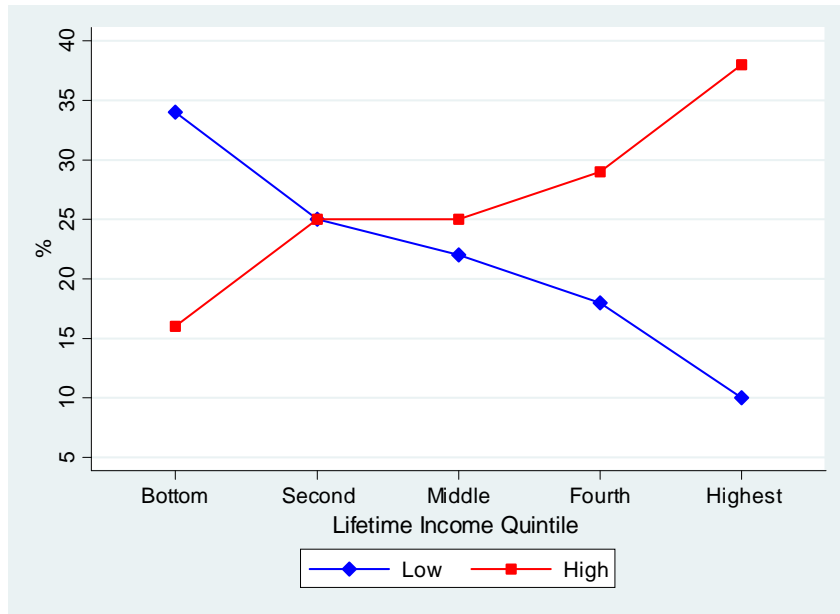


Figure 2: Physical Activity and Lifetime Income, HRS 2008

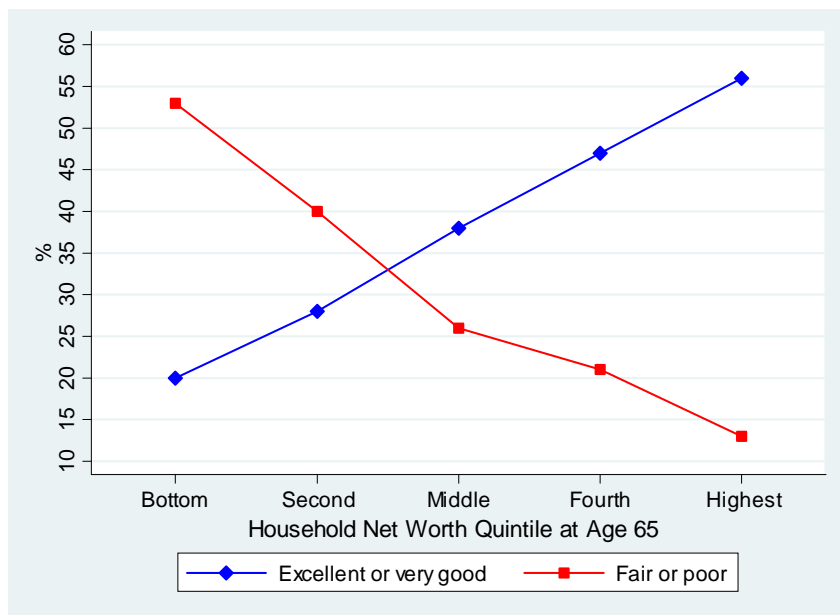


Figure 3: Self-Reported Health and Household Net Worth at Age 65, HRS 2008

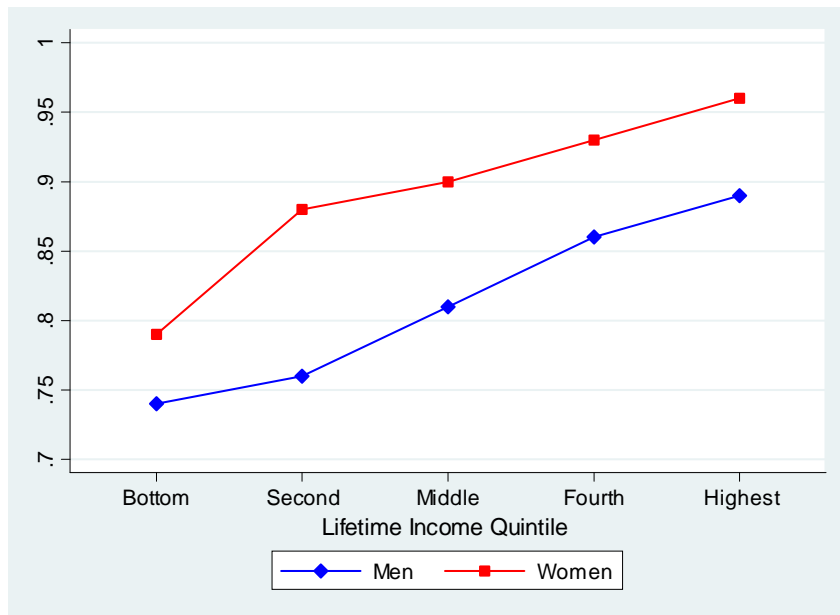


Figure 4: Ten-Year Survival Probabilities to Age 70 for Men and Women by Lifetime Income, HRS Data

The fourth fact that our model must accommodate is that there is a strong relationship between lifetime income and survival in the HRS. To show this, we restrict the sample to birth years that, in principle, would allow someone to reach a specific age by the last year of our HRS sample, 2008. So, for example, when we look at patterns of survival to age 70, we restrict the sample to those born before 1938. We also drop all sample members who were over 60 years old in the year they entered the HRS sample. The ten-year survival probabilities to age 70 shown in Figure 4 increase monotonically with lifetime income, from 74 percent for men in the lowest lifetime income quintile to 89 percent for men in the highest. The gradient for women goes from 79 percent in the lowest lifetime income quintile to 96 percent in the highest.

There are many likely explanations for the positive relationship between lifetime income and survival. We write down and solve a model that captures several of these explanations. Households in our model have different draws on annual earnings and

hence different lifetime incomes. They differ in the timing of exogenous marriage and fertility. Given differences in incomes and demographic characteristics, their consumption and health investments choices will respond to health shocks (that vary by age), earnings shocks (which are also affected by health), and government programs in different ways. Moreover, we allow consumption and health to be gross complements or gross substitutes in utility. The work that follows, therefore, illuminates the channels through which health, consumption, and wealth are related.

### 3 Model Economy

In this section, we present the basic elements of our model and then proceed to describe the dynamic programming problem more formally. Even though our HRS sample begins when individuals are older than 50, we use restricted access earnings data for HRS households that typically starts when household heads are between the ages of 18 and 25. Denote the age at which we begin to observe earnings of a household by  $S$ . We start the decision problem for a household at age  $S$  and assume, at this starting age, all households have zero assets and all household members, husbands and wives, have an identical stock of health.

*Demographics:* With the exception of life expectancy which we model, other demographic variables are treated as exogenous and deterministic by each household. The number of children a household has varies over the life-cycle and this affects consumption needs during the period of time they are attached to the household. This varies across households and is provided in the HRS. Households are either single or married throughout their lives - we do not model marriage and divorce. The marital status is set as of the first HRS wave. We do, however, model transitions from married to single status upon the death of a spouse that occurred after the first HRS wave. For the cohorts we study, divorce rates and remarriage were not as common as they are now.



Retirement is a decision that the household makes. One advantage with our data is that we have detailed information on all these demographic characteristics as of the first HRS wave. For each household, we specify in a deterministic fashion the exact ages in which children arrive and leave and whether they are married or single.

*Stochastic shocks:* There are three sources of uncertainty in our model. First, there are health shocks,  $\varepsilon_{j,g}$ , that are assumed to be i.i.d across individuals and drawn from the distribution  $\Xi_{j,g}(\varepsilon_{j,g})$ , where  $j$  denotes age and  $g$  stands for gender that can either be female (2) or male (1). These shocks vary by gender and by age and adversely affects the stock of health. The variation by gender is essential to match the differential mortality rates of women relative to men. The increasing likelihood of these shocks as households age is critical to obtaining declining health status with aging. Second, we model *household* earnings as an AR(1) process where the i.i.d shocks vary by number of earners ( $n_e$ ), marital status ( $k$ ), education ( $edu$ ) and birth cohort of the household head. Specifically, the distribution of earnings at age  $j + 1$ ,  $e_{j+1}$ , conditional on earnings at age  $j$ ,  $e_j$ , is given by  $\Omega_{j,edu}^{f,n_e,k}(e_{j+1}|e_j)$  where  $f$  denotes household-specific variation that incorporates variation in the intercept term and  $k$  stands for marital status that can either be married (2) or single (1). Birth cohort is implicitly indexed in this distribution through  $f$ . Third, the probability of surviving into the following period depends on the stock of health. Healthier households are more likely to survive into the next period, but there is a chance that any individual can die at a given age. The probability of surviving into the next period is given by the function  $\Psi(h)$  where  $h$  denotes health stock. This function satisfies two properties. First, as  $h$  goes to  $\infty$ ,  $\Psi(h)$  converges to 1. Second,  $\Psi(h) = 0$  for  $h \leq 0$ . This ensures that as soon as  $h$  goes to zero, the individual dies. The health stock affects utility and also affects the probability of surviving into the next period. Our formulation captures the notion that healthier people are less likely to die.

*Preferences and Choices:* A household maximizes expected lifetime utility by choosing consumption, health investments, and leisure. Incorporation of health capital into

an otherwise standard consumption-savings problem involves two additional choice and one additional state variable. It is nevertheless a significant complication. In addition to affecting longevity, we assume that households derive direct satisfaction from health. Lifetime utility for a single household at any age  $j$  in retirement,  $V_{j,g}^1$ , is given by

$$V_{j,g}^1 = \underset{c_j, i_j, l_j, m_j^{oop}}{Max} \{n_j U(c_j/n_j, l_j, h_j) + \beta E_j[\Psi(h_{j+1})V_{j+1,g}^1]\}.$$

This household maximizes expected lifetime utility by choices of consumption,  $c_j$ , time investments in health,  $i_j$ , leisure,  $l_j$ , and out-of-pocket medical expenses,  $m_j^{oop}$  that affects the stock of health in the next period through a production function for health. The first argument inside the parenthesis denotes momentary utility during that age while the second term stands for the (expected) continuation value. The expectation operator  $E_j$  denotes the expectation over future health shocks.  $g$  is the gender of the head of the household,  $\beta$  is the annual discount factor,  $h_j$  is the individuals' stock of health,  $n_j$  is a household equivalence scale and is a function of the number of adults,  $A_j$ , and children,  $K_j$ , in the household, so  $n_j = g(A_j, K_j)$ .

We assume that health affects the time endowment of the husband and the wife through Grossman's formulation of sick time: households experience some loss in their time endowment,  $s(h_j)$ , which is inversely related to their health status  $h_j$ . Upon retirement, an individual splits his or her time endowment of  $1 - s(h_j)$  in each period between leisure  $l_j$  and activities that augment health investments  $i_j$ . Before retirement, we assume that an individual spends an indivisible amount of time  $\omega(h_j, g, k, j, a_j, e_j)$  working each period (this function is given exogenously) and spends the rest of his time endowment  $1 - s(h_j) - \omega(h_j, g, k, j, a_j, e_j)$  on either leisure  $l_j$  or on health investments  $i_j$ .<sup>6</sup> In this formulation, whether people with lower stocks of health have less time to

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<sup>6</sup>In our model, we assume that poor health adversely affects the time that an individual spends in the labor market. While poor health may well affect investments in human capital and consequently the wage rate that an individual faces, we observe data on earnings and we do not observe either hours

spend on investments in health and leisure depends on the strength of two effects. On the one hand, lower health stocks are associated with more sick time. On the other hand, labor supply is increasing in the stock of health. Which effect dominates depends on the relative strength of the two effects. The decision problem during the working phase is very similar to the decision problem specified above with one notable difference. There is an additional source of uncertainty - uncertain future earnings for ages prior to retirement. A complete description of the dynamic programming problem for the working and the retirement phase is given below.

The married household's decision problem at age  $j$  in retirement involves taking into account the choices of two decision makers. The value function is given by

$$V_j^2 = \underset{c_j, i_{h,j}, l_{h,j}, m_{h,j}^{oop}, i_{w,j}, l_{w,j}, m_{w,j}^{oop}}{Max} \left\{ \begin{array}{l} \left( n_j [\mu U(c_j/n_j, l_{h,j}, h_{h,j}) + (1 - \mu) U(c_j/n_j, l_{w,j}, h_{w,j})] \right) \\ + \beta E_j \left[ \begin{array}{l} \Psi(h_{h,j+1}) \Psi(h_{w,j+1}) V_{j+1}^2 \\ + [1 - \Psi(h_{h,j+1})] \Psi(h_{w,j+1}) V_{j+1,2}^1 \\ + \Psi(h_{h,j+1}) [1 - \Psi(h_{w,j+1})] V_{j+1,1}^1 \end{array} \right] \end{array} \right\}$$

The first two terms inside the parenthesis above stand for momentary utility for the couple where  $\mu \in [0, 1]$  is the weight on the husband's utility in household utility,  $h_{h,j}$  is the husband's stock of health,  $l_{h,j}$  is leisure of the husband,  $h_{w,j}$  and  $l_{w,j}$  are corresponding health stock and leisure of the wife, and  $m_{h,j}^{oop}$  and  $m_{w,j}^{oop}$  are out of pocket medical expenses for the husband and wife, which affect their stocks of health in the

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worked or the wage rate. Consequently, data limitations prevent us from disentangling the impact of bad health on the wage from the effect of bad health on hours worked. Furthermore, the analysis in French (2005) suggests that health status has a much larger impact on labor supply and labor force participation than on the wage rate. To be sure, if we did have data on hours worked, we would be in a position to introduce a labor supply dimension to our model. The lack of information on hours worked leads us to approximate a labor supply function for individuals in different states using data from the PSID. Besides health ( $h$ ), gender ( $g$ ), marital status ( $k$ ), age ( $j$ ), wealth ( $a$ ) and earnings ( $e$ ), labor supply also depends on whether an individual is a union member, which is assumed to be exogenous and taken from data. Details are in the Appendix.

next period through health production specified below. The expectation operator  $E_j$  now denotes the expectation over future health shocks facing both the husband and the wife. The three products of functions  $\Psi$  and  $V$  inside the expectation operator give the continuation values of the household when both the husband and the wife live to next period, only the wife lives to next period and only the husband lives to next period respectively. Setting  $\mu$  to be 0 (1) will give us the corresponding lifetime utility for a household headed by a single female (male). This representation of preferences captures the notion that while consumption is a public good within the family, leisure and health are largely the result of individual choices. Understanding the complex decisions made by members of a given family requires us to recognize that they are independent actors - something that our collective model does.

*The Production of Health:* A challenge when modelling health is that there is at best mixed evidence that marginal expenditures on medical care in the U.S. buy greater health, and hence longevity.<sup>7</sup> This phenomenon is sometimes referred to as “flat of the curve” medicine. It is noteworthy just how hard scholars need to look to find evidence that expenditures on medical care have a discernible, positive effect on health and particularly mortality outcomes. Card, Dobkin, and Maestas (2008), for example, is one of a small number of studies that find expenditures are positively correlated with survival. Their work is based on a very large sample of people admitted to emergency rooms in California: they find positive effects of spending apply to a small subset of conditions that lead people to show up in emergency rooms. Doyle (2009) shows that men who have heart attacks when vacationing in Florida have higher survival probabilities if they end up being served by high- rather than low-expenditure hospitals.

In addition to evidence that health investments enhance health, Oster et al (2012)

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<sup>7</sup>See, for example, the Dartmouth Health Atlas (<http://dartmouthatlas.org/>), which documents little relationship between regional variation in health spending and health outcomes. Finkelstein and McKnight (2008) find little effect of Medicare on mortality when the program was initiated. Chay, Kim and Swaminathan (2010) challenge this assessment.

show that those diagnosed with a terminal disease are less likely to quit risky behaviors. Specifically, they study the effect of Huntington disease on health investments. Individuals who learn they carry the Huntington disease mutation through genetic testing or symptom onset are much less likely to quit smoking than comparable individuals without this information. Those with earlier symptom onset are less likely to have ever undergone cancer screening (conditional on age). Of course, other studies suggest that *marginal* medical expenditures have little discernible effect on health.

In addition to the evidence above, it is clear that some expenditures improve health. Antibiotics can effectively cure strep throat. Treatment can help people survive cancer. A good orthopedist can help people recover fully from broken bones. Given this, we assume that household members possess a health stock and investments improve health. The accumulation process of the stock of health for a household member is given by

$$h_{j+1} = F_t(m_j, i_j) + (1 - \delta)h_j - \varepsilon_{j,g}, \quad j \in \{S, \dots\}, g \in \{1, 2\}$$

The stock of health at the next age,  $h_{j+1}$ , is determined by the production of health, given by  $F_t(m_j, i_j)$  which depends on calendar time  $t$  because we allow productivity of health technology to change over time. Health capital is produced using time,  $i_j$ , which could be exercise or other health-producing activities, and medical expenditures. Total medical expenditures,  $m_j$ , are a function  $M^{ins}(\cdot)$  of out of pocket medical expenses,  $m_j^{oop}$ , where the function  $M^{ins}(\cdot)$  is determined by health insurance status (*ins*) and will be specified later when we discuss calibration. In the above equation,  $\delta$  stands for the depreciation rate of health. Introducing age-dependent shocks to health,  $\varepsilon_{j,g}$  is both realistic and necessary if we are interested in matching biological processes and the data. They vary by gender. In typical lifecycle models, medical expenditures have only financial consequences. Here medical expenditures have financial consequences and affect health capital which, in turn, affects utility and longevity. The modeling

approach mimics the modeling of human capital – additions to human capital can be either consumption or investment as in Becker (1964), Mincer (1974) and the subsequent, vast human capital literature.

*Budget Constraints:* Consumption, health investments and leisure are chosen to maximize expected utility subject to the constraints.

$$y_j = e_j + ra_j + T_t(e_j, a_j, j, n_j), j \in \{S, \dots, R\}$$

$$y_j = SS \sum_{j=S}^R e_j + DB(e_R) + ra_j + T_{R,t}(e_R, \sum_{j=S}^R e_j, a_j, j, n_j), j \in \{R+1, \dots\}$$

$$c_j + a_{j+1} + m_{h,j}^{oop} + m_{w,j}^{oop} = y_j + a_j - \tau_t(e_j + ra_j), j \in \{S, \dots, R\}$$

$$c_j + a_{j+1} + m_{h,j}^{oop} + m_{w,j}^{oop} = y_j + a_j - \tau_t \quad SS \sum_{j=S}^R e_j + DB(e_R) + ra_j, j \in \{R+1, \dots\}$$

In these expressions  $y$  is household income, and  $e$  is household earnings,  $a$  is household assets,  $r$  is the interest rate,  $T$  is a transfer function that depends on earnings, assets, age and the number of adult equivalents in the household. The husband and wife in a household are assumed to enter the labor market simultaneously at age  $S$  of the head and retire simultaneously at age  $R$  of the head. Social security ( $SS$ ) is a function of lifetime earnings, defined benefit pensions ( $DB$ ) are a function of earnings in the last year of life,  $\tau$  is a payroll and income tax function, and the transfer function for retirees ( $T_R$ ) is a function of the last earnings observation before retirement (which approximates DB pensions), aggregate earnings over the lifetime (which approximates social security income), assets, age, and family structure. Transfer functions ( $T$  and  $T_R$ ) and tax function ( $\tau$ ) are year-specific and thus indexed by calendar time  $t$ .

*Timing:* The number of children is exogenous in the model as is health insurance status. Household members are assumed to have perfect foresight on the entire paths

of both fertility and health insurance, social security rules ( $SS$ ), the defined benefit pensions function ( $DB$ ), the time varying transfer functions ( $T$  and  $T_R$ ) and time varying tax function  $\tau$ . If the household is not retired, the household realizes its earnings shock at the beginning of each period and then makes decisions on consumption, health investments and leisure. The health shock is realized at the end of each period after the decisions have been made.

### 3.1 Working Household's Dynamic Programming Problem

A working single household between ages  $S$  and  $R$  obtains income from labor earnings and assets. The dynamic programming problem at age  $j < R$  for a working single household is given by

$$W_{t,edu,g}^{f,n_j,n_e,1}(e_j, E_{j-1}, a_j, j, h_j) = \max_{c_j, i_j, m_j^{oop}} \left\{ \begin{array}{l} n_j U(c_j/n_j, 1 - s(h_j) - \omega(h_j, g, 1, j, a_j, e_j) - i_j, h_j) + \\ \beta \int_{\varepsilon_{j,g}} \int_{e_{j+1}} C_{t+1,g}^{f,work}(j+1) d\Omega_{j,edu}^{f,n_e,1}(e_{j+1}|e_j) d\Xi_{j,g}(\varepsilon_{j,g}) \end{array} \right\} \left( \right.$$

subject to

$$y_j = e_j + ra_j + T_t(e_j, a_j, j, n_j)$$

$$c_j + a_{j+1} + m_j^{oop} = y_j + a_j - \tau_t(e_j + ra_j)$$

$$h_{j+1} = F_t(M^{ins}(m_j^{oop}), i_j) + (1 - \delta)h_j - \varepsilon_{j,g}$$

$$E_j = E_{j-1} + e_j$$

where  $C_{t+1,g}^{f,work}(j+1) = \Psi(h_{j+1})W_{t+1,edu,g}^{f,n_{j+1},n_e,1}(e_{j+1}, E_j, a_{j+1}, j+1, h_{j+1})$ . In the above equation,  $W_{t,edu,g}^{f,n_j,n_e,1}(e_j, E_{j-1}, a_j, j, h_j)$  denotes the expected present discounted value of life-

time utility for household  $f$  at age  $j$  in year  $t$ .  $E_{j-1}$  stands for cumulative earnings up to the current age while  $C_{t+1,g}^{f,work}(j+1)$  gives the continuation value of the household. We integrate over health and non-health-related earnings shocks. The other variables are defined above.

The dynamic programming problem for a single household at age  $R$ , the last working period, is almost the same as the above dynamic programming problem at age  $j < R$ . The only difference is that, at age  $R$ , the continuation value,  $W_{t+1,edu,g}^{f,n_{j+1},n_e,1}(e_{j+1}, E_j, a_{j+1}, j+1, h_{j+1})$ , should be replaced by  $V_{t+1,g}^{n_{R+1},1}(e_R, E_R, a_{R+1}, R+1, h_{R+1})$ , the value function for single retirees introduced below, because the household will be retired in the next period.

Similarly, the dynamic programming problem at age  $j < R$  for a working, married household is given by

$$W_{t,edu}^{f,n_j,n_e,2}(e_j, E_{j-1}, a_j, j, h_{h,j}, h_{w,j}) = \max_{c_j, i_{h,j}, i_{w,j}, m_{h,j}^{oop}, m_{w,j}^{oop}} \left\{ \left( n_j \left[ \begin{array}{l} \mu U(c_j/n_j, 1 - s(h_{h,j}) - \omega_{h,j} - i_{h,j}, h_{h,j}) + \\ (1 - \mu) U(c_j/n_j, 1 - s(h_{w,j}) - \omega_{w,j} - i_{w,j}, h_{w,j}) \end{array} \right] + \right. \right. \\ \left. \left. \beta \int_{\varepsilon_{j,1}} \int_{\varepsilon_{j,2}} \int_{e_{j+1}} C_{t+1}^{f,work}(j+1) d\Omega_{j,edu}^{f,n_e,2}(e_{j+1}|e_j) d\Xi_{j,2}(\varepsilon_{j,2}) d\Xi_{j,1}(\varepsilon_{j,1}) \right) \right\}$$

subject to

$$y_j = e_j + ra_j + T_t(e_j, a_j, j, n_j)$$

$$c_j + a_{j+1} + m_{h,j}^{oop} + m_{w,j}^{oop} = y_j + a_j - \tau_t(e_j + ra_j)$$

$$h_{h,j+1} = F_t(M^{ins}(m_{h,j}^{oop}), i_{h,j}) + (1 - \delta)h_{h,j} - \varepsilon_{j,1}$$

$$h_{w,j+1} = F_t(M^{ins}(m_{w,j}^{oop}), i_{w,j}) + (1 - \delta)h_{w,j} - \varepsilon_{j,2}$$

$$E_j = E_{j-1} + e_j$$



where

$$C_{t+1}^{f,work}(j+1) =$$

$$\begin{aligned} & \Psi(h_{h,j+1})\Psi(h_{w,j+1})W_{t+1,edu}^{f,n_{j+1},n_e,2}(e_{j+1}, E_j, a_{j+1}, j+1, h_{h,j+1}, h_{w,j+1}) \\ & + [1 - \Psi(h_{h,j+1})]\Psi(h_{w,j+1})W_{t+1,edu,2}^{f,n_{j+1},n_e,1}(e_{j+1}, E_j, a_{j+1}, j+1, h_{w,j+1}) \\ & + \Psi(h_{h,j+1})[1 - \Psi(h_{w,j+1})]W_{t+1,edu,1}^{f,n_{j+1},n_e,1}(e_{j+1}, E_j, a_{j+1}, j+1, h_{h,j+1}) \end{aligned}$$

$W_{t,edu}^{f,n_j,n_e,2}(e_j, E_{j-1}, a_j, j, h_{h,j}, h_{w,j})$  denotes the expected present discounted value of lifetime utility for a married household  $f$  at age  $j$  in year  $t$ .  $\omega_{h,j} = \omega(h_{h,j}, g = 1, k = 2, j, a_j, e_j)$  and  $\omega_{w,j} = \omega(h_{w,j}, g = 2, k = 2, j, a_j, e_j)$  are labor supply of the husband and wife respectively. The three product terms in  $C_{t+1}^{f,work}(j+1)$  give the continuation values of the household when both the husband and the wife live to next period, only the wife lives to next period and only the husband lives to next period respectively. We integrate over health shocks facing both the husband and the wife and non-health-related earnings shocks facing the household. The other variables are defined above.

### 3.2 Retired Household's Dynamic Programming Problem

A retired single household between ages  $R+1$  and death obtains income from social security, defined-benefit pensions, and assets. The dynamic programming problem at age  $j$  for a retired single household is given by

$$\begin{aligned} & V_{t,g}^{n_j,1}(e_R, E_R, a_j, j, h_j) = \\ & \max_{c_j, i_j, m_j^{oop}} \left\{ \begin{aligned} & n_j U(c_j/n_j, 1 - s(h_j) - i_j, h_j) + \\ & \beta \int_{\varepsilon_{j,g}} \Psi(h_{j+1}) V_{t+1,g}^{n_{j+1},1}(e_R, E_R, a_{j+1}, j+1, h_{j+1}) d\Xi_{j,g}(\varepsilon_{.,g}) \end{aligned} \right\} \end{aligned}$$

subject to

$$y_j = SS(E_R) + DB(e_R) + ra_j + T_{R,t}(e_R, E_R, a_j, j, n_j)$$

$$c_j + a_{j+1} + m_j^{oop} = y_j + a_j - \tau_t(SS(E_R) + DB(e_R) + ra_j)$$

$$h_{j+1} = F_t(M^{ins}(m_j^{oop}), i_j) + (1 - \delta)h_j - \varepsilon_{j,g}$$

In the above equation the value function,  $V_{t,g}^{f,n_j,1}(e_R, E_R, a_j, j, h_j)$ , denotes the expected present discounted value of maximized utility from age  $j$  until the date of death for this single household. Total earnings up to the current period are denoted by  $E_R$  while the last earnings draw at the age of retirement is  $e_R$ . Note that these values do not change once the household is retired. Relative to the working phase, household indicator  $f$ , number of earners  $n_e$  and education of the head  $edu$  do not appear in the value function during retirement because these variables only affect earnings.

Similarly, the dynamic programming problem at age  $j$  for a retired married household is given by

$$V_t^{n_j,2}(e_R, E_R, a_j, j, h_{h,j}, h_{w,j}) = \max_{c_j, i_{h,j}, i_{w,j}, m_{h,j}^{oop}, m_{w,j}^{oop}} \left\{ \begin{array}{l} \left( n_j \left[ \begin{array}{l} \mu U(c_j/n_j, 1 - s(h_{h,j}) - i_{h,j}, h_{h,j}) + \\ (1 - \mu) U(c_j/n_j, 1 - s(h_{w,j}) - i_{w,j}, h_{w,j}) \end{array} \right] \right. \\ \left. + \beta \int_{\varepsilon_{j,1}} \int_{\varepsilon_{j,2}} C_{t+1}^{retired}(j+1) d\Xi_{j,2}(\varepsilon_{j,2}) d\Xi_{j,1}(\varepsilon_{j,1}) \right) \end{array} \right\}$$

subject to

$$y_j = SS(E_R) + DB(e_R) + ra_j + T_{R,t}(e_R, E_R, a_j, j, n_j)$$

$$c_j + a_{j+1} + m_{h,j}^{oop} + m_{w,j}^{oop} = y_j + a_j - \tau_t(SS(E_R) + DB(e_R) + ra_j)$$

$$h_{h,j+1} = F_t(M^{ins}(m_{h,j}^{oop}), i_{h,j}) + (1 - \delta)h_{h,j} - \varepsilon_{j,1}$$

$$h_{w,j+1} = F_t(M^{ins}(m_{w,j}^{oop}), i_{w,j}) + (1 - \delta)h_{w,j} - \varepsilon_{j,2}$$

where

$$C_{t+1}^{retired}(j + 1) =$$

$$\begin{aligned} & \Psi(h_{h,j+1})\Psi(h_{w,j+1})V_{t+1}^{n_{j+1},2}(e_R, E_R, a_{j+1}, j + 1, h_{h,j+1}, h_{w,j+1}) \\ & + [1 - \Psi(h_{h,j+1})]\Psi(h_{w,j+1})V_{t+1,2}^{n_{j+1},1}(e_R, E_R, a_{j+1}, j + 1, h_{w,j+1}) \\ & + \Psi(h_{h,j+1})[1 - \Psi(h_{w,j+1})]V_{t+1,1}^{n_{j+1},1}(e_R, E_R, a_{j+1}, j + 1, h_{h,j+1}) \end{aligned}$$

In the above equation the value function,  $V_t^{n_j,2}(e_R, E_R, a_j, j, h_{h,j}, h_{w,j})$  denotes the expected present discounted value of maximized utility from age  $j$  until the date of death for this married household. The three product terms in  $C_{t+1}^{retired}(j + 1)$  give the continuation values of the household when both the husband and the wife live to next period, only the wife lives to next period and only the husband lives to next period respectively. We integrate over the distribution of health shocks facing the husband and the wife in the married couple.

## 4 Model Parameterization and Calibration

In this section we specify functional forms and parameter values that we use to solve the model. We start by specifying functional forms for utility and health production. We then set some parameter values based on information from the literature or from reduced form estimates from the HRS. We identify the other parameters by fitting the predictions of the model for the typical household to data on wealth accumulation, medical expenses and survival probabilities. Once we have these parameter values, we then solve the model household-by-household and examine predictions for each household in our sample.

*Preferences:* We assume that momentary utility for a household member has a

constant relative risk-averse form. We further assume the sub-utility function over consumption-leisure composite and health has a constant elasticity of substitution. Hence the period utility takes the form

$$U(c/n, h, l) = \frac{\{\lambda[(c/n)^\eta l^{1-\eta}]^\rho + (1-\lambda)h^\rho\}^{\frac{1-\sigma}{\rho}}}{1-\sigma} + B.$$

Following Hall and Jones (2007),  $B$  is a large enough constant to guarantee that utility is positive. The elasticity of substitution between the consumption-leisure composite and health is  $1/(1-\rho)$ . The discount factor ( $\beta$ ) is set at 0.97, the value used in Hubbard, Skinner, and Zeldes (1995); and Engen, Gale, and Uccello (1999). We also set  $\eta = 0.36$  from Cooley and Prescott (1995). Finally, we set  $\sigma$ , the coefficient of relative risk aversion equal to 3, a value commonly used in many studies including Hubbard, Skinner, and Zeldes (1995). We analyze the sensitivity of our results to  $\beta, \sigma$  and  $\eta$ . We calibrate  $B, \rho$  and  $\lambda$ .

*Equivalence Scale:* This is obtained from Citro and Michael (1995) and takes the form

$$n = g(A, K) = (A + 0.7K)^{0.7}$$

where  $A$  indicates the number of adults and  $K$  indicates the number of children in the household.

*Rate of Return:* We assume an annualized real rate of return,  $r$ , of 4 percent. This assumption is consistent with McGrattan and Prescott (2003), who find that the real rate of return for both equity and debt in the United States over the last 100 years, after accounting for taxes on dividends and diversification costs, is about 4 percent.

*Taxes:* The tax function we use are taken from Gouveia and Strauss (1994). The specification for effective taxes for household  $f$  in year  $t$  with income  $y$  (in thousands) is:

$$\tau_{f,t} = b_t [y_{f,t} - (y_{f,t}^{-\rho_{\tau,t}} + s_t)^{-\frac{1}{\rho_{\tau,t}}}]$$

where  $b$ ,  $\rho_{\tau}$ ,  $s$  are year-specific parameters to be estimated. To obtain these parameters for our sample window, we assembled data from 1951 to 2007 using the Statistics of Income volumes available electronically through the Boston Public Library. For each year, the SOI data gives the mean tax liability for a range of income classes (AGI). These data were used to fit a tax function in each year: 1951 to 2007. The criteria for the fit was to minimize the sum of squared errors in the average effective tax rate:

$$\sum_f \left( \frac{\text{estimated tax}_f - \text{observed tax}_f}{\text{taxable income}_f} \right)^2.$$

*Earnings and Earnings Expectations:* Earnings data come from three sources: Social Security Administration Summary Earnings files, SSA earnings detail files (W2 information), and HRS self-reports. In the process of assembling the earnings data priority is given to each of these sources in the order listed. Earnings data in the Summary Earnings files is subject to top-coding. Before imputing the top coded earnings observations we first check to see if W2 earnings records exist; these data are available for most respondents starting in 1978. If W2 data is not available, HRS self-reports of earnings are used (if available).

The remaining top-coded earnings observations are split into two windows, 1951-1977 and 1978-2007. In the first period no top-coded earnings are recovered from W2 or HRS data. A censored regression model is estimated to predict the top-coded earnings in each year using the following covariates: gender, education, birth year, race, census region, marital status, average percentile in the earnings distribution over the past 5 years (if available), average percentile in the earnings distribution over the next 5 years (if available), number of children in the household, total years reported working, and

average real household net worth over the HRS study years (1992, 1994, ... 2008). The covariates used are taken from the first wave the respondent appears in the HRS.

In the second window, 1978 – 2007 many top-coded earnings observations are recovered using W2 data. An earnings model with the same covariates is estimated on the high-income observations that were recovered using W2 and HRS data. The parameters of these estimates are used to predict earnings for the high-income observations that remain top-coded. Starting in 1992 a new covariate, labor force status, is added and the covariates used for prediction are taken from the nearest HRS interview. Missing earnings are filled in when possible using HRS responses. Missing earnings in years following the respondents' last year of work or retirement year are set to zero. Missing earnings are set to zero for respondents who report never having worked. Missing earnings for respondents younger than age 17 are also set to zero. The remaining missing earnings are imputed via an earnings model using most of the variables listed above. The difference is that instead of using the spot in the earnings distribution, the respondent's average real earnings in the past/next five years are used when available.

Earnings expectations are a central influence on life-cycle consumption and health accumulation decisions, both directly and through their effects on expected pension and social security benefits.<sup>8</sup> We aggregate individual earnings histories into household earnings histories, putting earnings in constant dollars using the CPI-U. The household model of log earnings (and earnings expectations) is

$$\log e_j = \alpha^f + \beta_1 j + \beta_2 j^2 + u_j$$

$$u_j = \rho_e u_{j-1} + \epsilon_j$$

where, as mentioned above,  $e_j$  is the observed earnings of the household  $f$  at age  $j$

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<sup>8</sup>Due to data and computational limitations, we assume that earnings expectations are independent of health status. Credibly relaxing this assumption would require data on wage rates, hours, and health prior to when households enter the HRS.

in 2008 dollars,  $\alpha^f$  is a household specific constant,  $u_j$  is an AR(1) error term of the earnings equation, and  $\epsilon_j$  is a zero-mean i.i.d., normally distributed error term. The estimated parameters are  $\alpha^f$ ,  $\beta_1$ ,  $\beta_2$ ,  $\rho_e$  and  $\sigma_\epsilon$ .

We divide households into six groups according to education, marital status and the number of earners in the household, resulting in six sets of household-group-specific parameters, which we then estimate separately for each of the five HRS cohorts (resulting in 30 sets of parameters).<sup>9</sup> Estimates of the persistence parameter,  $\rho_e$ , across groups range from 0.69 to 0.82.

*Transfer Programs:* We model public income transfer programs using the specification in Hubbard, Skinner and Zeldes (1995). Specifically, the transfer that a household receives while working is given by

$$T = \max\{0, \underline{c} - [e + (1 + r)a]\}$$

whereas the transfer that the household receives upon retiring is

$$T_R = \max\{0, \underline{c} - [SS(E_R) + DB(e_R) + (1 + r)a]\}$$

This transfer function guarantees a pre-tax income of  $\underline{c}$  and implies that earnings, retirement income, and assets reduce public benefits dollar for dollar. To set  $\underline{c}$  for each year we use information from Moffitt (2002) for 1960, 1964, 1968 to 1998 and extend the series using data from The Urban Institute, Mathematica Policy Research Inc., Center for Medicare and Medicaid Services, and the UKCPR National Welfare Data.<sup>10</sup> These

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<sup>9</sup>The groups are (1) married, head without a college degree, one earner; (2) married, head without a college degree, two earners; (3) married, head with a college degree, one earner; (4) married, head with a college degree, two earners; (5) single without a college degree; and (6) single with a college degree. We estimate the parameters separately for the AHEAD, CODA, HRS, War Babies, and Early Boomer cohorts. A respondent is an earner if his or her lifetime earnings are positive and contribute at least 20 percent of the lifetime earnings of the household.

<sup>10</sup>See <http://www.ukcpr.org/AvailableData.aspx>

data are at the state level so we take a weighted average according to state population in each year. Benefits have trended down since 1974 when the consumption floor for a single parent, two-child family peaked at \$14,767 (in year 2008 dollars). In 2007 the same family would have received transfers worth \$11,308.

*Defined benefit pensions:* Pension expectations and benefits come from an empirical defined-benefit pension function estimated with HRS data. The function includes indicator variables for having a defined benefit plan and belonging to a union, and variables for years in the pension by the retirement date, household earnings in the last year of work and the fraction of household earnings earned by the male and the fraction earned by the female.

*Health Shocks:* We assume health shocks follow a log normal distribution with mean  $\mu_{j,g}^\varepsilon$  and variance  $\sigma_\varepsilon^2$ . Notice that we allow the mean to vary by gender and age. In practice, we discretize the support of log health shock, which is the real line, into five grid points and call the one that gives the worst health outcome the bad shock. These five grid points are fixed and do not vary over age or across gender. The probability of getting a bad health shock, however, varies both over age and across gender because of  $\mu_{j,g}^\varepsilon$ .

*Health production:* We assume that the production of health is given by  $F_t(m, i) = A_t (m^\chi i^{1-\chi})^\xi$ , where total medical expenses are a function of out-of-pocket expenses,  $m = M^{ins}(m^{oop})$  and health is also produced with time,  $i$ . We assume  $A_t$  grows at 2 percent per year reflecting aggregate improvements in productivity of health technology. Total medical expenditures are related to out-of-pocket expenditures by a linear function that depends on insurance status. For the uninsured ( $ins = 0$ ) this function takes the form,  $m = \begin{cases} m^{oop} + \underline{m}, & \text{bad shock} \\ m^{oop}, & \text{no bad shock} \end{cases}$ . In the absence of a bad health shock, health care expenditures come directly out of the uninsured household's pocket. In the event that the uninsured household suffers a bad health shock, a baseline level of care,  $\underline{m}$ , is



provided via charity care.

For an insured household, total medical expenses are paid partially out of pocket and partially through insurance,  $m = \underbrace{D + \zeta(m - D)}_{\text{OOP}} + \underbrace{(1 - \zeta)(m - D)}_{\text{insurance}}$ . There are two parts of out-of-pocket expenses, the deductible  $D$  and a fraction  $\zeta \in [0, 1]$  of the balance,  $(m - D)$ , that remains after the deductible has been paid.

We use the Medical Expenditure Panel Survey (MEPS) to calibrate the parameters of the medical expense model for six different insurance categories. Households in which the head is younger than 65 may be: uninsured, insured with public insurance only, or insured with any sort of private insurance. Three more categories capture older households: Medicare only, Medicare with supplemental public insurance (but no private), or Medicare and any private insurance.

To calibrate the value of charity care for the uninsured, we draw from Doyle (2005) who suggests the previous estimates "center around forty percent less care for the uninsured."<sup>11</sup> The average total medical spending for the insured (under age 65) in the event of a health shock in the 2008 MEPS data was  $\bar{m}_i = \$3,768$ . Average out-of-pocket spending for the uninsured was  $\bar{m}_u^{oop} = \$861$ . Using the relationship that  $0.6\bar{m}_i = \bar{m}_u = \bar{m}_u^{oop} + \underline{m}$  we recover the average value of charity care in the event of an adverse health shock,  $\underline{m} = \$1,400$ .

To calibrate the "generosity parameter,"  $\zeta$ , for each of the insurance types, we use estimates of the average deductible, average total medical spending and average out-of-pocket spending. The spending model implies that  $m^{oop} = D + \zeta(m - D)$ , which can be rewritten to solve for  $\zeta = \frac{m^{oop} - D}{m - D}$  for each insurance type. The resulting values are  $\zeta = 0.039$  for households under 65 with any private insurance;  $\zeta = 0.063$  for households under 65 with only public insurance;  $\zeta = 0.159$  for households over 65 with Medicare

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<sup>11</sup>See, for example, Currie and Gruber (1997), Currie and Thomas (1995), Haas and Goldman (1994), Long, Marquis, and Rodgers (1997), and Tilford *et al.* (1999) who provide information on medical care use for the insured and uninsured.

only;  $\zeta = 0.145$  for households over 65 with Medicare and some private insurance; and  $\zeta = 0.042$  for households over 65 with Medicare and supplemental public insurance.

*Survival Probability:* The survival function is given by the cumulative distribution function  $\Psi(h) = 1 - \exp(-\psi_1 h^{\psi_2})$ .

*Working Time:* As mentioned previously, working time  $\omega(h, g, k, j, a, e)$  depends on health, gender, marital status, age, assets, earnings and union status and this is calibrated from PSID.

*Sick Time:* We assume that the amount of sick time is given by  $s(h) = h^{-\alpha}$ .

*Initial conditions:* The age  $S$  at which a household enters the labor market is taken to be the age of the household head when we first observe the household in our data, and thus could vary across households. Initial assets are set to be zero for all households. The initial stock of health is assumed to be the same for all husbands and wives. Other individual level heterogeneities include education, gender, marital status and household level heterogeneities include health insurance status and number of children. As mentioned earlier, these are taken to be what they were when a household first enters the HRS.

## 4.1 Calibration

While several parameters are set based on estimates from the literature or by estimating reduced form empirical models from the HRS, additional critical parameters still need to be specified. We use information on asset holdings, life tables and medical expenses for the typical household in the HRS to pin down these parameters. The 19 parameters we calibrate are  $\lambda$ , the utility weight on consumption relative to health;  $\rho$ , which determines the elasticity of substitution between consumption and health;  $\mu$ , the weight on the husband in the household utility function;  $B$ , the constant in utility to guarantee that it is positive;  $\psi_1$ , the coefficient on health in the survival function;  $\psi_2$ , the curvature of the survival function with respect to health;  $\xi$ , the curvature of the health production

function;  $\chi$ , the share parameter of monetary input in health production;  $\delta$ , the annual depreciation rate of health;  $\alpha$ , the elasticity of sick time with respect to health status;  $\sigma_\varepsilon$ , the standard deviation of the i.i.d health shock,  $\mu_{65,1}^\varepsilon, \mu_{75,1}^\varepsilon, \mu_{85,1}^\varepsilon, \mu_{85+,1}^\varepsilon$ , the mean of the health shock for men less than 65 years of age, between 65 and 75, between 75 and 85 and above 85 respectively; and  $\mu_{65,2}^\varepsilon, \mu_{75,2}^\varepsilon, \mu_{85,2}^\varepsilon, \mu_{85+,2}^\varepsilon$ , the corresponding values for women.

To calculate these remaining parameters, we solve the dynamic programming problem for the ‘typical’ married, single male, and single female households, where ‘typical’ is defined as the household with average earnings and medical expenses over their lifetimes. We then use the decision rules in conjunction with observed histories of earnings and medical expenses to obtain model predictions. Notice that while we have earnings observations on an annual basis, we only have medical expenses starting in 1992. Hence we integrate out the lifetime sequence of health shocks before arriving at the model predictions for a given age. We then seek to obtain the best fit between model and data relative to the moments we seek to match for these three types of households in 1998. We emphasize that the implicit assumption employed in our strategy is that households are identical in terms of preferences and technology but face different constraints due to the evolution of shocks in the face of incomplete markets. Males differ from females in terms of the probabilities of bad health shock as they age to account for the greater longevity of women relative to men.

The moments we use to identify and pin down the parameters are:<sup>12</sup>

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<sup>12</sup>Moments for net worth data and the retirement age come directly from HRS data. Moments for total medical expenses come from the National Health Expenditure Accounts (using the personal health spending totals by age for 2004), drawn from <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Age-and-Gender-Items/CMS1242122.html>. We disaggregate the National Health Expenditure Account total for married men, married women, single men, and single women using data from the Medical Expenditure Panel Study. The mortality probabilities come from the World Health Organization, [http://www.who.int/healthinfo/statistics/mortality\\_life\\_tables/en/](http://www.who.int/healthinfo/statistics/mortality_life_tables/en/). The data on sick hours come from the PSID.

TABLE 1A  
DATA MOMENTS

Moments	Value
Median net worth in 1998 for married couples (husband age 63.2, wife age 60.9)	\$246,312
Median net worth in 2008 for married couples	\$281,200
Median net worth in 1998 for single males (age 64.1)	\$91,740
Median net worth in 1998 for single females (age 66.7)	\$81,708
The probability of dying between ages 50-54 for males	3.08%
The probability of dying between ages 70-74 for males	13.76%
The probability of dying between ages 80-84 for males	31.69%
The probability of dying between ages 90-94 for males	60.70%
The probability of dying between ages 50-54 for females	1.834%
The probability of dying between ages 70-74 for females	9.57%
The probability of dying between ages 80-84 for females	23.94%
The probability of dying between ages 90-94 for females	52.05%
Average annual total medical expenses for married women age 60-64	\$7,747
Average annual total medical expenses for married women age 70-74	\$12,417
Average annual total medical expenses for married women age 80+	\$17,896
Average annual total medical expenses for single women age 70-74	\$12,479
Average annual total medical expenses for married men age 70-74	\$13,255
Average annual total medical expenses for single men age 70-74	\$13,474
Sick hours relative to total work hours at age 40	0.015

The model with each calibrated parameter generates 19 non-linear equations with 19 unknowns. We obtained an exact match between the model predictions and the moments listed above. The resulting parameter values are given below.

TABLE 1B  
CALIBRATED PARAMETER VALUES

Parameter	$\lambda$	$\rho$	$\mu$	$\alpha$	$B$	$\mu_{65,1}^{\varepsilon}$	$\mu_{75,1}^{\varepsilon}$	$\mu_{85,1}^{\varepsilon}$	$\mu_{85+,1}^{\varepsilon}$	$\delta$
Value	0.70	-3.6	0.43	0.17	32.1	0.30	0.42	0.65	0.86	0.034
Parameter	$\psi_1$	$\psi_2$	$\xi$	$\sigma_{\varepsilon}$	$\chi$	$\mu_{65,2}^{\varepsilon}$	$\mu_{75,2}^{\varepsilon}$	$\mu_{85,2}^{\varepsilon}$	$\mu_{85+,2}^{\varepsilon}$	
Value	0.0012	1.53	0.69	1.22	0.61	0.22	0.36	0.54	0.72	

The elasticity of substitution between consumption/leisure composite and health is  $\frac{1}{1-\rho} = 0.22$ . Later on in the paper, we analyze the effects of changes in  $\rho$  to better understand its effect. The change in wealth between 1998 and 2008 helps identify this parameter. Consumption and health are complements and our calibrated value is very close to the estimates in Finkelstein, Luttmer, and Notowidigdo (2013). In one of the first few papers that simulates a model with endogenous health, Yogo (2009) employs recursive preferences in a study of portfolio choices in retirement and finds that consumption and health are complements in utility. Since Yogo (2009) uses Epstein-Zin preferences, his estimates are not directly comparable to ours (we use time additive separable utility) but it is comforting to note that a substantially different approach also finds evidence in favor of complementarity. In a married household, the weight on the man's utility is 0.43, lower than the weight on the woman's utility. The rate of depreciation of health is 3.4 percent per year. The share of goods in the production of health  $\chi$  is 0.61, suggesting that time and goods are both important in the production of health. Finally, note that the probability of the bad health shock increases with age since the mean (in logs) rises from 0.3 for men less than 65 to 0.86 for men above 85. For women, the same object rises from 0.22 to 0.72. The smaller probability of a bad health realization at any given age for women relative to men is instrumental in matching the higher age specific mortality rates for men.

As mentioned above, we match 19 data moments with the model to identify these 19 parameters. Clearly, altering one of the target data moments changes more than one

parameter. Nevertheless, it is instructive to think about which data moments play a critical role for at least some of the more important parameters.

A lower value of  $\rho$  will lead to a higher level of assets in 1998. In addition, a lower value of  $\rho$  will have implications for asset accumulation/decumulation late in life. Predictable declines in health ought to be associated with predictable declines in consumption. Hence having asset levels in 1998 as well as 2008 helps pin down  $\rho$ .

The parameters governing the production technology for health (for males) as well as the hazard function are pinned down by the mortality probabilities as well as medical expenses. Recall that health affects utility as well as mortality. The importance of health in utility ( $\lambda$ ) as well as the significance of health in improving longevity are both simultaneously pinned down by these moments. The probabilities of dying as people age interact with the technology for producing health to determine medical expenses. For instance if diminishing returns set in quickly, substantial medical expenses need to be expended simply to maintain the stock of health. In contrast, if the medical technology were close to linear, then additional medical expenses will have a large effect on the stock of health. Hence, all these objects (medical technology parameters, importance of health relative to consumption in utility), as well as the parameters of the hazard function, are simultaneously pinned down by the probabilities of the bad shock and medical expenses as men age.

Medical expenses for single women and probabilities of dying for men relative to women help pin down the probabilities of bad health shocks for women. In addition, mean net worth for singles relative to married couples shed light on the utility aggregator in preferences. A change in the parameter governing the importance of men relative to women in a married households ( $\mu$ ) will affect both the wealth of the married households as well as medical expenses for married women relative to single women.

## 4.2 Model Solution

With the calibrated parameters, we solve the dynamic programming problem by linear interpolation on the value function. For each household in our sample we compute optimal decision rules for assets and the stock of health from the oldest possible age (assumed to be 120) to the beginning of working life ( $S$ ) for any feasible realizations of the random variables: earnings and health shocks. Recall that initial assets at age  $S$  are zero and initial health capital is normalized to the same value for all individuals at this age. These decision rules differ for each household, since each faces stochastic draws from different earnings distributions (recall they are household specific). Household-specific earnings expectations also directly influence expectations about social security and pension benefits. Other characteristics also differ across households - the number of children and the ages at which these children enter and leave the household.

We then use the decision rules in conjunction with the observed earnings and medical expenses to obtain the model's predictions for wealth, health, medical expenses and mortality at a given age. Since we do not have data on medical expenses before 1992, we integrate out the health shocks over this time period. Consider a working single household. Recall that the state variables are  $e_j, E_{j-1}, a_j, j$  and  $h_j$ . We start at age  $S$  with  $a_j = 0$  and  $h_S = \bar{h}$ . The decision rule for assets is given by  $a_{j+1} = A_j(e_j, E_{j-1}, a_j, j, h_j)$ . We have annual observations on earnings,  $e_j$ . Knowledge of  $e$  also means we have knowledge of  $E$ . Since we do not observe health shock  $\varepsilon_{j-1,g}$ , which affects  $h_j$ , we integrate out the health shock and assume that  $a_{j+1} = \int A_j(e_j, E_{j-1}, a_j, j, h_j) d\Xi_{j-1,g}(\varepsilon_{j-1,g})$ . Beginning in 1992 (when households are around 56 years of age), we observe the medical expenses chosen by the household. From this point, we use observed medical expenses to back out the health shock. Suppose that  $\hat{m}_{j+1}$  is the observed medical expense at age  $j+1$ . Then  $m_{j+1}^{oop}(e_{j+1}, E_j, a_{j+1}, j+1, h_{j+1}) = \hat{m}_{j+1}$ , where  $h_{j+1} = F_t(M^{ins}(m_j^{oop}), i_j) + (1-\delta)h_j - \varepsilon_{j,g}$ .

## 5 Results

As emphasized in the previous discussion, we calibrate key model parameters to the typical (married, single male and single female-headed) HRS household in 1998. The first question we address, therefore, is how the model matches household wealth, out of pocket medical expenses, and the stock of health.

### 5.1 Net Worth and Medical Expenses

We summarize results for household wealth and out-of-pocket medical expenses by showing median values, breaking households into lifetime income quintiles.<sup>13</sup> In Table 2 we present a comparison of the cross-sectional implications of the model in 1998 and in 2008. The 1998 cross-section is made up of the household heads from all birth cohorts that participated in the 1998 HRS interview ( $n = 9,041$ ) and likewise for the 2008 cross-section ( $n = 11,172$ , our full HRS sample). The vast majority of the difference (2,131 households) are households in the “early boomers” cohort who were added to the HRS in 2004 and hence are not a part of the 1998 cross-section.

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<sup>13</sup>Lifetime income is defined within four roughly equal-sized age groups: under 60, 60 to 65, 66 to 75, and over 75.



TABLE 2

MEDIAN NET WORTH AND OOP MEDICAL EXPENSES, 1998 AND 2008

Lifetime Income	Median Net Worth (\$)		Median OOP Medical Expenses (\$)	
	Data	Model	Data	Model
1998				
Lowest Quintile	33,588	31,456	413	421
Second Quintile	60,717	53,483	646	729
Middle Quintile	97,212	93,708	904	967
Fourth Quintile	180,859	163,695	1098	1081
Highest Quintile	340,144	353,129	1,219	1,235
2008				
Lowest Quintile	15,495	16,394	370	356
Second Quintile	63,900	61,304	775	844
Middle Quintile	136,000	132,453	1,083	1,137
Fourth Quintile	238,000	248,120	1,425	1,413
Highest Quintile	443,000	432,230	1,795	1,735

There are two striking features of Table 2. First, while we calibrate the model to the average household in 1998, the model does a good job matching the wide variation in wealth across low and high lifetime income households in 1998. In particular, the correlation of actual and optimal net worth in 1998 is 0.71. Scholz, Seshadri, and Khitatrakun (2006) report a correlation between model predications and net worth in the HRS of 0.86 in 1992. There are a number of differences between our earlier work and this paper. The most important is that health affects utility and longevity, households make endogenous health investments, we model the health decisions of spouses, new cohorts have been added to the data and we now look at a more recent period, and we have new estimates of the earning process, which show somewhat more volatility in

earnings than our previous estimates, among other changes. Despite these differences our earlier qualitative conclusion still holds: Most Americans appear to be preparing for retirement in a manner consistent with our life-cycle model given the current policy environment.

Predicted median out-of-pocket medical expenses also match actual expenses fairly closely. For instance, in 1998, the out of pocket medical expenses rise from \$421 for the lowest lifetime income quintile to \$1,235 for the highest income quintile. This tracks the data pretty closely. Richer households spend more out of pocket (despite possessing better health on average at the same age) and these investments affect both flow utility as well as longevity. The household-by-household correlation between actual out-of-pocket medical expenditures and optimal out-of-pocket medical expenditures in the model is 0.47.

The second striking feature of Table 2 is the degree to which we match the dispersion of median net worth and out-of-pocket medical expenditures by lifetime income quintile at a later date (2008). We use only one net worth moment for 2008 (the net worth of married couples): health expenses are for 2004 (due to the timing of the National Health Expenditure Accounts). Yet the behavioral model augmented with preference parameters calibrated to the average household in 1998, data on changes in household composition, and earnings realizations (for those still in the labor market) is able to closely match the 2008 distribution of median net worth and out-of-pocket health spending.

## 5.2 Health Status

Another feature of the HRS are questions on self reported health status, which we used in Figures 1 and 3. Households report this on a 5 point scale ranging from poor to excellent. In the model, the stock of health is a continuous variable and hence to compare with the data, we turn the continuous health variable into a discrete one. In the HRS data, 13



Figure 5: Self-Reported Health Status in 1998: Model vs Data

percent of the sample report excellent health, 28 percent report very good, 30 percent report good, 19 percent report fair and 9 percent report poor. We choose the cut-off points in the continuous distribution so that these percentages are what we observe in the HRS. Figures 5 and 6 depict the relationship between model and data for 1998 and 2008 in greater detail.

There is a very tight link between lifetime income and the self-reported health status and the model does an excellent job tracking the variation in the data. Various model features come into play here - as households age, they receive adverse shocks with greater intensity. Their ability to buffer these shocks depends largely on health investments they had made in the past (which determines their current health status) as well as their income. The pace with which health deteriorates in older ages also affects consumption (recall that consumption and health are complements) which in turn affects wealth accumulation. The fact that the model is able to match the extent to which health worsens between 1998 and 2008 adds to our confidence that the model provides

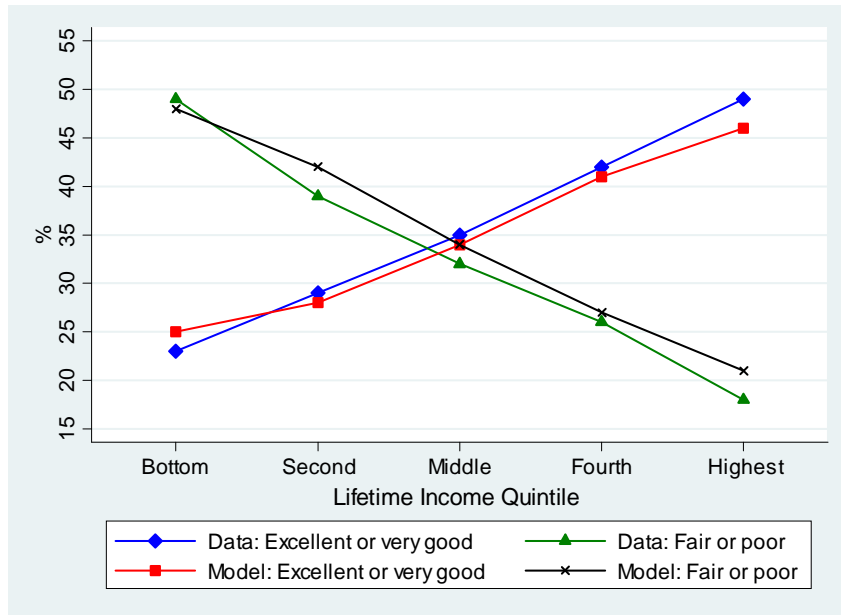


Figure 6: Self-Reported Health Status in 2008: Model vs Data

a reasonable description of the evolution of health by lifetime income.

Our model makes predictions not just during the retirement phase but also throughout the working phase of the life-cycle. Unfortunately, the HRS data begin in 1992 and consequently we do not have information on the behavior of these households while they are working. Nevertheless, it is instructive to compare model predictions with best available data.

### 5.2.1 Health During the Working Phase

The Panel Study of Income Dynamics (PSID) also contains information on a self-reported health status (5 point scale) much like the HRS data. Measures of the distribution of health by age and income come from the 2009 wave of the PSID. The PSID is a longitudinal panel that began in 1968. By 2009 the sample size has grown to include more than 9,000 families. The analysis in this subsection will compare model simulations with responses from 13,055 PSID respondents in 2009. The health measure gives

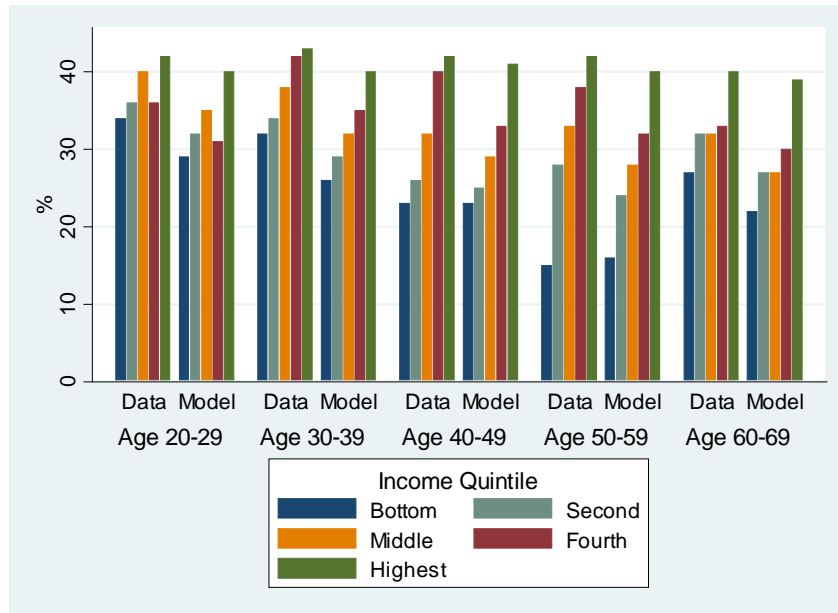


Figure 7: Percent Reporting "Very Good" Health Status: Model vs PSID Data

respondents' perceived health on a Likert scale (excellent, very good, good, fair, poor). Income quintiles are defined using the household head's 2008 labor, business, and farm income.

Before proceeding with the comparison, it is useful to note that while the PSID data are for the 2009 cross-section, the model simulations we present are for cohorts born much earlier. Consequently, the policies and opportunities faced by these households are quite different from the current cross-section and hence there could have been large differences in the distribution of health status by age. In the interests of space, we report the comparison between model and data for one of the self-reported health status: "very good". The results are in Figure 7.

The Figure presents a comparison between self-reports of "very good" in the PSID with its model counterpart at various ages for 5 income quintiles (these are income levels at that age and not lifetime income). While the fit is far from perfect, the model is able to track the declines in health by age as well as evolution of health with income. The

fit is a better at higher income levels and among those aged 40-49 and 50-59.

### **5.3 Consumption in Retirement**

One other feature of our data set is the availability of consumption data. While consumption data are not available for the entire sample under study, hence making it impossible to compare model and data household by household, consumption data are available for a sub-sample of the population. Wave nine of the Consumption and Activities Mail Survey (CAMS) was completed by 3,587 individuals on behalf of their household. CAMS respondents report 2009 household spending in 39 categories of nondurables and durable goods. We calculate total household spending on these categories weighted using CAMS household weights that adjust for both sample design and non-responses to both the HRS as well as the CAMS survey. The household spending is thus representative of American households aged 50 and above in 2009.

We normalize the consumption of an average household in the third quintile to 1 and report in Table 3 the consumption levels of households in the 5 different lifetime earnings quintiles for each of the self-reported health status for the cross-section of households in 2008. As can be seen from Table 3, consumption rises with income for each health status and consumption rises with health status for each income quintile. The fit between model and data is fairly good and the fact that consumption co-moves with health status in the cross-section is attributable to consumption-health complementarity in preferences.

TABLE 3

MEAN CONSUMPTION BY HEALTH STATUS AND LIFETIME EARNINGS

Earnings	Bottom Quintile		Second Quintile		Middle Quintile		Fourth Quintile		Highest Quintile	
	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data
Excellent	0.95	0.93	1.04	1.02	1.16	1.15	1.24	1.29	1.54	1.68
Very Good	0.79	0.75	0.93	0.91	1.12	1.20	1.20	1.23	1.44	1.55
Good	0.71	0.69	0.91	0.88	1.01	1.00	1.15	1.13	1.36	1.38
Fair	0.65	0.64	0.84	0.73	0.92	0.87	1.05	1.04	1.31	1.29
Poor	0.60	0.61	0.76	0.71	0.83	0.79	0.96	0.92	1.28	1.24

## 5.4 Medical Expenses During Working Years

We have information on the distribution of out-of-pocket medical expenses by age and income from the 2008 Household Component of the Medical Expenditure Panel Survey (MEPS). MEPS is nationally representative for the U.S. civilian noninstitutionalized population. The calculations shown in Table 4 under the columns labeled ‘Data’ were derived using the MEPSnet Query Tools and public use file HC121 with sample size 12,696 (2008 Full Year Consolidated Data File). The medical expenditure variable includes the total amount paid by the individual or their family for: medical provider visits, hospital outpatient visits, hospital emergency room visits, hospital inpatient stays, dental visits, home health care, vision aids, other medical equipment and services, and prescribed medicines. Income is a comprehensive measure of person-level income.

The same caveat that applied to the comparison between model and data for health during working years applies here as well - the data are from a cross-section while the model simulations are for the HRS cohorts. The model is able to track the rise in medical spending by age as well as the variation by income. Rather interestingly, the model’s fit for the age range 60-69 is quite a bit better than for the other ages. We attribute it to the fact that the households we simulate are roughly in the 60-69 age range in 2008.

TABLE 4

MEDIAN OUT-OF-POCKET MEDICAL EXPENSES (\$) BY AGE AND INCOME

Income	Bottom Quintile		Second Quintile		Middle Quintile		Fourth Quintile		Highest Quintile	
Age	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data
20-29	131	197	145	206	156	221	198	283	202	300
30-39	177	228	168	226	182	253	231	270	208	295
40-49	199	268	201	336	213	315	274	333	234	354
50-59	285	446	267	438	342	585	365	529	312	514
60-69	652	678	635	669	647	636	701	722	671	749

## 5.5 Mortality

A novel feature of our economic model is that it allows us to examine the effects of policy changes on mortality. But the confidence readers have with our mortality results will depend, in part, on the ability of the model to reproduce mortality patterns in the HRS. To examine this, we take 10-year mortality probabilities in the HRS for two groups – those who are 60 years old and those who are 75 years old. Specifically, we restrict the sample to people first observed in the HRS before (or when) they reach age 60 and who, conditional on survival, would have been at least 70 in 2008. We make similar calculations for the age 75 sample. The entries in the table below under "Data" give the survival probabilities by lifetime income quintile.

The mortality calculations implied by the model require considerable calculation. For example, in the first two columns of Table 5 we take all 60 year olds. These households face many different patterns of potential health shocks ( $\varepsilon_{j,g}$  paths). We integrate out over all potential sequences between the ages 60 and 70 and calculate the mass of survivors. These calculations require, of course, the optimal decision rules over the lifetime of households. We make similar calculations for households age 75. The



survival rates implied by the model are given in Table 5 under the column "Model."

TABLE 5  
TEN-YEAR SURVIVAL PROBABILITIES, MODEL vs DATA

Lifetime Income	Age60		Age 75	
	Data	Model	Data	Model
Bottom Quintile	0.77	0.76	0.54	0.52
Second Quintile	0.83	0.81	0.54	0.53
Middle Quintile	0.86	0.84	0.52	0.55
Fourth Quintile	0.90	0.87	0.62	0.60
Highest Quintile	0.92	0.89	0.64	0.62

The model does a strikingly good job matching survival patterns in the underlying data, though we note that seven of the 19 moments that we use to calibrate the model tie down mortality probabilities by age for households with average lifetime incomes. This does not, however, imply that we would expect the model to reproduce survival patterns for high- or low-lifetime income quintile households. Both at age 60 and 75, there are substantial deviations between the survival data and predictions for households in the highest lifetime income quintiles. These are likely to be the households that are most efficient in producing health capital. At age 75 there is also a substantial deviation between data and model in the lowest lifetime income quintile. This is the pattern we expect to see as unobservable efficiency in health investment should make low-income households in the HRS who survive to age 75 healthier than the average low-income households in the model.

### 5.5.1 Mortality During Working Years

In our model, health shocks get increasingly likely as households age. What does our model say about mortality at younger ages? The National Office of Vital Statistics

publishes life tables and these tables are available for the cohort born between 1939-41. In Table 6 we present the 10 year survival probabilities for this cohort and compare that with the model-implied survival probabilities for the HRS cohort born between 1931 and 1941 for men and women. Recall that men and women draw health shocks from different distributions. Before age 65, these shocks do not vary by age. The main age effect is the depreciation in health capital that induces different investments in health capital as individuals age and hence makes individuals more susceptible to health shocks as they age. Table 6 presents the comparison between model and data. The model implied survival probability closely tracks the life tables for the cohort born at approximately the same time adding further credibility to our modeling of health.

TABLE 6  
TEN-YEAR SURVIVAL PROBABILITIES, MODEL vs DATA

Age	Men		Women	
	Model	Data	Model	Data
20	0.98	0.97	0.99	0.98
30	0.95	0.96	0.97	0.97
40	0.91	0.92	0.93	0.94
50	0.84	0.83	0.89	0.88

NOTE.-Model moments are for HRS cohort. Data moments come from United States Life Tables and Actuarial Tables, 1939-1941.

[http://www.cdc.gov/nchs/data/lifetables/life39-41\\_actuarial.pdf](http://www.cdc.gov/nchs/data/lifetables/life39-41_actuarial.pdf)

## 6 The Effect of Health Insurance on Retirement

There is a very tight link between lifetime income and the self-reported health status and the model does an excellent job at tracking the variation in the data. Various model features come into play here - as households age, they receive adverse shocks

with greater intensity. Their ability to buffer these shocks depends largely on health investments they had made in the past (which determines their current health status) as well as their income. The pace at which health deteriorates in older ages also affects consumption (recall that consumption and health are complements) which in turn affects wealth accumulation. The fact that the model is able to match the extent to which health worsens between 1998 and 2008 adds to our confidence that the model provides a reasonable description of the evolution of health by lifetime income.

A final feature of our model is retirement. Recall that the decision to retire is endogenous. Table 7 provides the fit between model and data on retirement age.

Table 7: Retirement Age, Model Prediction and HRS Data										
	Median Retirement Age by Self Reported Health Status									
Lifetime Income	Excellent		V. Good		Good		Fair		Poor	
	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
Bottom Quintile	61	61	61	60	60	59	57	58	54	55
Second Quintile	60	61	63	62	62	61	61	61	57	57
Middle Quintile	62	62	62	62	62	62	60	61	60	59
Fourth Quintile	62	62	62	62	62	62	62	61	61	60
Highest Quintile	63	63	63	63	63	63	63	63	63	63

In the data, low lifetime income households with poor health status retire early (age 54) while the majority of households retire at 62. The early retirement of poor households is triggered by the early onset of bad health shocks. These households typically have low earnings options and hence choose to retire early. Richer households who have better health expect to live longer and hence choose to retire later, partly to finance a longer retirement period.

There are many reasons why scholars and policy-makers are interested in the effect of health insurance on retirement. Most health insurance in the United States is provided by employers until eligibility for public health insurance for the elderly (Medicare) begins

at age 65. Some employer health insurance plans provide coverage for retired workers, but others do not. Reform proposals that would make health insurance coverage independent of employment status could increase the already-high rate of retirement before age 65, which could increase financial pressure on Medicare and Social Security.

We used our model to study the interplay of wealth accumulation, health accumulation, health insurance status and retirement decisions. We will now examine how health shocks and health insurance affect retirement decisions. With a clear understanding of the influence of these factors in the model, we will then examine how workers in our model would optimally respond to various policy changes – changes in Social Security benefits as well as changes to the normal retirement age. The model also provides an excellent framework for understanding the effects of a health shocks between ages 55 and 65 on health status and the decision to retire early. The model can be used to analyze whether and how the availability of Medicare interacts with the decision to claim benefits, particularly for low income individuals.

Our analysis reveals several interesting findings. While health shocks lead to retirement well before age 62, our findings reveal that around 85% of early retirees at age 62 are in good health. This is consistent with the findings of Burkhauser, Couch, and Phillips (1996) and Smith (1999). Burkhauser et al (1996) compare the health and financial assets of those who took early benefits and those who did not and find that the great majority of people who take early benefits are in good health, a result that is consistent with the currently established view that most retirements are essentially voluntary responses to financial incentives. They report that fewer than 10 percent of men who take early benefits are in poor health and have no other source of pension income beyond Social Security benefits. The comparable figure for women is 20 percent. Smith (1999) confirms the basic finding of Burkhauser and others (1996) using several panels of the SIPP. He concludes that most retirees who take early benefits do not report health problems that limit work.

Next, we examine the impact of the availability of retiree health insurance on the decision to retire early. Empirical studies uniformly find a large positive association between retiree health insurance and early retirement. On the other hand, structural models that analyze the effects of retiree health benefits on early retirement factor health insurance into the budget constraint based on the average cost of insurance and find retirement behavior is similar to behavior that arises when ignoring health insurance, implying a small effect of retiree health insurance on retirement. Blau and Gilleskie (2001) estimate a structural model of joint retirement by married couples and find little effect of retiree health insurance when health insurance only enters the budget constraint and a larger effect when health insurance is allowed to influence utility directly. Our simulations reveal that there are two opposing effects at work. On the one hand, the availability of health insurance in retirement makes retirement more attractive thereby making it optimal to retire earlier. On the other hand, investments in health are complementary with the availability of health insurance. The fact that this health insurance is available at a later date makes additional investments in health more attractive. These investments are costly and to defray these costs, the household finds it optimal to delay retirement. The former dominates the latter for households who are 60 or older and for whom retirement is imminent. On the other hand, for households who are younger and hence have more time to respond to changes in policy, the two effects might well cancel. Clearly, the interplay between these forces depends on the age of the household when the policy change is being enacted. If for instance, the household knew at age 20 that retirement health insurance was available, they will invest more in health and possess a higher health stock than an otherwise identical household without access to retirement health insurance. We perform an experiment where we remove post-retiree health insurance for households with such coverage - we assume that this is known to the household at the beginning of working life. On average we find that the first effect dominates and the availability of postretirement health insurance induces households to

retire about 3 months earlier than their counterparts without such insurance.

## 7 Conclusion

In this paper we describe a lifecycle model of consumption with endogenous investments in health. Health affects longevity as well as utility and we find that consumption and health are complementary inputs in the utility function. The model has many features: households build health capital with investments of both time and money; insurance affects the transformation of out-of-pocket medical expenses to total medical expenses; the health status of two spouses in a marriage evolve distinctly, and health affects time endowment and labor supply and earnings affect health. We solve the model household-by-household using data from the HRS. We force the model to match moments on wealth, mortality, and medical expenses for the average HRS married and single households, calibrating 19 parameters. We take these parameters as primitives for all households and vary the circumstances of the households based on observables in the HRS data such as earnings and medical expense realizations, insurance status, marital status, and demographic variables. We then ask whether this framework with the 19 parameters identified by the typical household can account for the microeconomic variation in health, wealth, mortality and retirement across the 11,172 households we analyze. We find that it can. Our study makes several contributions.

First, the model successfully accounts for the variation in medical expenses and longevity across households. In addition, the fit between the model and data on health status is excellent. We conclude that the model can rationalize a significant fraction of the variation in health across households.

Second, while health shocks lead to retirement well before age 62, our findings reveal that around 85% of early retirees at age 62 are in good health. This is consistent with the findings in the literature

Third, isolate the effects in play when households consider whether to respond to the availability of retiree health insurance by retiring early. We perform an experiment where we remove post-retiree health insurance for households with such coverage. On average we find that the availability of postretirement health insurance induces households to retire about 3 months earlier than their counterparts without such insurance.

## 8 Appendix

### 8.1 PSID Labor Supply

We use the Panel Study of Income Dynamics (PSID) to estimate the association between health status and other individual characteristics with labor supply. The long observation window of the PSID makes it well suited to studying the labor supply of individuals over the lifecycle. In order to match the household characteristics in lifecycle model, we used age, marital status, sex, self report of health, wealth, current earnings, and union status to predict annual hours worked. These data were available in a subset of the PSID observation years (1984, 1989, 1994, 1999, 2001, 2003, 2005, 2007, and 2009). The analysis sample is described in table A1 and the OLS estimation results are found in table A2. Most of the predictor variables are highly significant and all take the expected sign.



TABLE A1  
PSID SAMPLE

	Mean	Std. Dev.
Age	43.6	15.9
Current Earnings	\$31,353	\$54,437
Net Worth	\$246,886	\$1,375,000
	Percentage	
Female	54%	
Union Member	9%	
Health		
Excellent	22%	
Very Good	33%	
Good	29%	
Fair	12%	
Poor	4%	
Marital Status		
Married	69%	
Never Married	13%	
Widowed	6%	
Divorced	9%	
Separated	4%	
N	106,619	

TABLE A2  
MODEL OF ANNUAL LABOR SUPPLY (HOURS)

	Coefficient	Robust S.E.
Age	46.73***	3.15
Age <sup>2</sup>	-0.67***	0.03
Female	-458.74***	21.41
Union Member	250.17***	15.28
Current Earnings (\$1, 000)	5.26***	1.05
Net Worth (\$1,000)	-0.03***	0.01
<i>Health</i>		
(Excellent)		
Very Good	5.15	9.71
Good	-80.76***	15.52
Fair	-343.09***	25.62
Poor	-674.96***	32.86
<i>Marital Status</i>		
(Married)		
Never Married	-20.96	13.39
Widowed	114.95***	17.11
Divorced	165.59***	14.90
Separated	31.33	18.74
Constant	1022.92***	32.44
R-squared	0.39	
N	106,619	

NOTE.-Standard error adjusted for 24,819 individual clusters

\* p<0.05, \*\* p<0.01, \*\*\* p<0.001

Dollar amounts are in year 2008 dollars.

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