

Health and Wealth In a Lifecycle Model

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Abstract

We develop a model of health investments and consumption over the life cycle where health affects longevity, provides flow utility, and health and consumption can be complements or substitutes. We solve each household's dynamic optimization problem using data from the Health and Retirement Study from 1992 through 2008 and Social Security earnings histories. Our model matches well household out-of-pocket medical expenses, self-reported health status, and wealth. The model also does a nice job matching the evolution of health status in old age and changes in wealth between 1998 and 2008. We illustrate the importance of endogenizing health investment by examining the effects on mortality and wealth of eliminating our stylized representation of Medicare. Medicare has meaningful effects on mortality, particularly at the bottom of the income distribution.

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1 Introduction

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 out-

come, 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.

Prior work that does not fully account for health in intertemporal models of consumption may yield incomplete or erroneous implications. 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, effects 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. Palumbo (1999) and De Nardi, French and Jones (2010) 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.¹ They document

¹In 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 as well as that of the income-poor.

Two other related papers model intertemporal consumption decisions and include health in the utility

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.² 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 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.³ 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, the literature including Palumbo (1999) and De Nardi, French and Jones (2010) has shown that anticipated and realized medical expenses are an important determinant of wealth decumulation patterns in old age. The focus of our work differs.

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.

² An exception is Murphy and Topel (2006) who use a utility function that features consumption-health complementarity to value improvements in health.

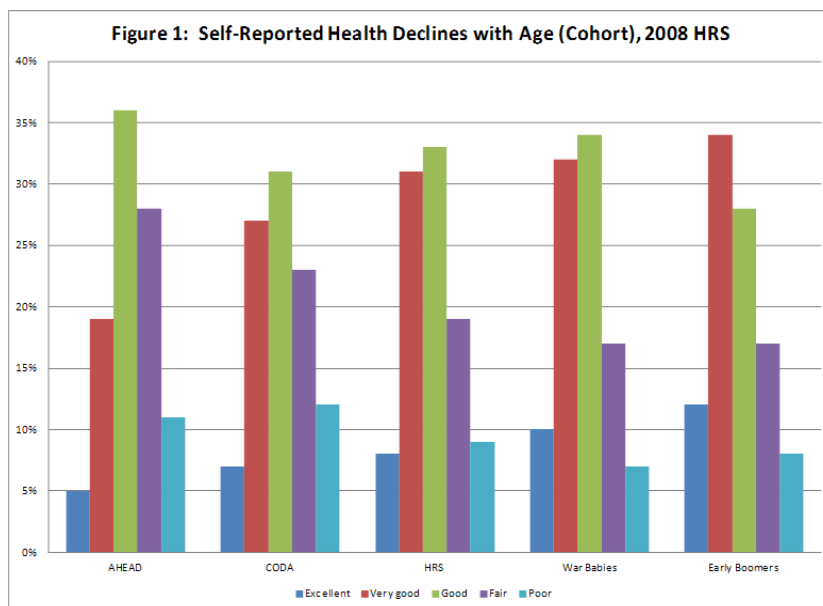
³Health is undoubtedly influenced by shocks and decisions made *in utero* and in childhood. We do not have data on these experiences, however, so lack of data and computational demands lead us to start our analysis at the beginning of working life.

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 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 tradeoff between consumption and health investments on health, longevity, and wealth offers new insights into household behavior.

After calibrating our model to match key moments for the average household, we find the model is able to match the cross-sectional variation in medical expenses, longevity and the stock of health in the Health and Retirement Study. We also match changes in wealth, health spending, and health status between 1998 and 2008. Our analysis reveals that the degree of complementarity between consumption and health capital plays a critical role in explaining various features of the data. Finally we conduct policy experiments to highlight various features of the model as well as to bring out the differences relative to a model with exogenous medical expenditures. We find that Medicare has meaningful effects on life tables, especially at the bottom of the income distribution.

2 Descriptive Facts

We use Health and Retirement Study (HRS) data from 1992 through 2008. The 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. The HRS modestly oversamples

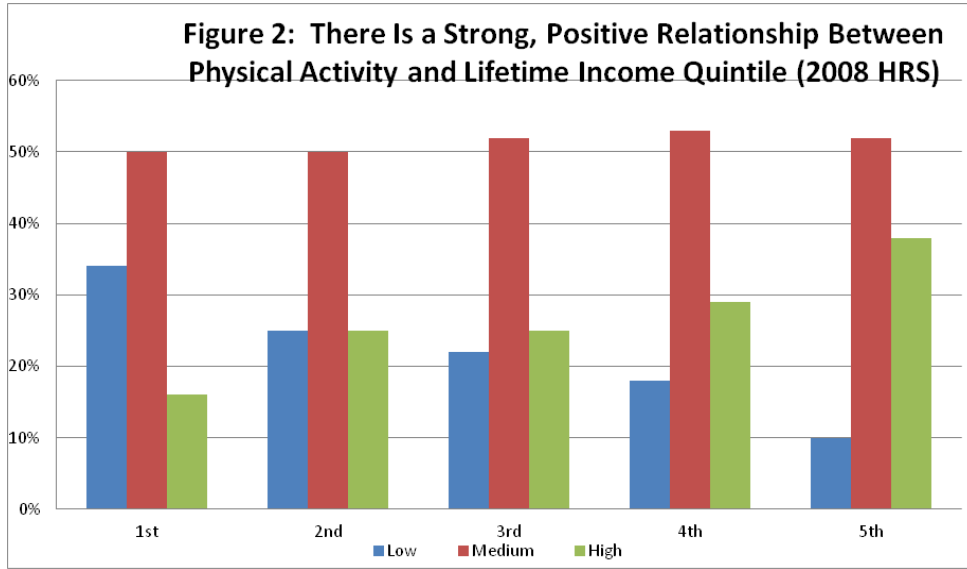


blacks, Hispanics, and Floridians.⁴

Our model must be capable of matching several descriptive facts about health and wealth. The first is perhaps obvious, but self-reported health declines with age. The HRS asks households about their self-reported health status, where households can respond on a 5-point scale (excellent, very good, good, fair, or poor). Figure 1 plots the average responses for each category 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 households reporting excellent health declines monotonically with age across cohorts. The percentage of households reporting poor or fair health rises with age across cohorts. Recognizing biological fact, health depreciates in our model of health production.

The second fact highlighted in Figure 2 is that exercise is positively correlated with lifetime income. This is potentially important in a model of health production as there is abundant evidence that exercise, smoking, and diet influence health and hence

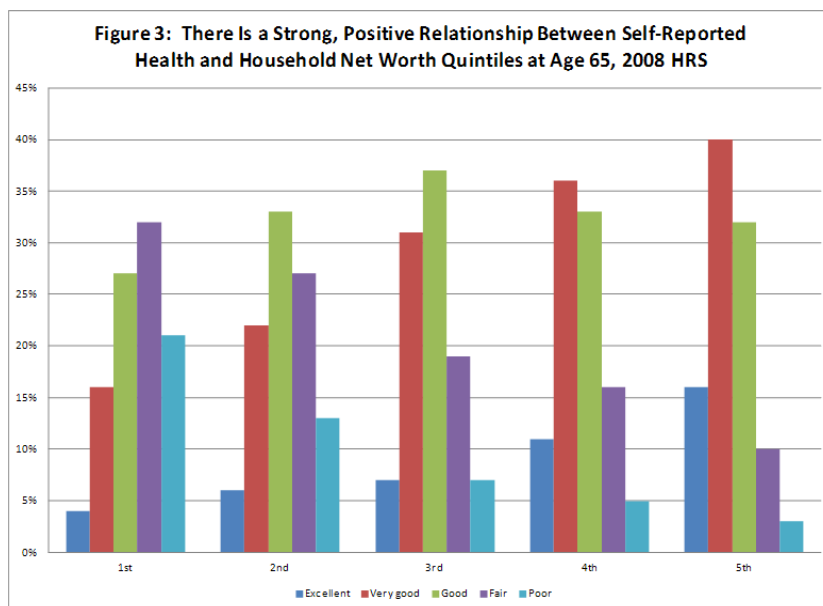
⁴Comprehensive information on the HRS is available at <http://hrsonline.isr.umich.edu/>.



longevity.⁵ Nevertheless, the computational demands that arise in solving our dynamic programming model household-by-household with endogenous consumption, health production, and retirement 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. Retirement is endogenous in our model and 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 tradeoff 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. Illuminating economic decisions over the lifecycle that result in the joint distribution of health and wealth, household-by-household, is a central challenge

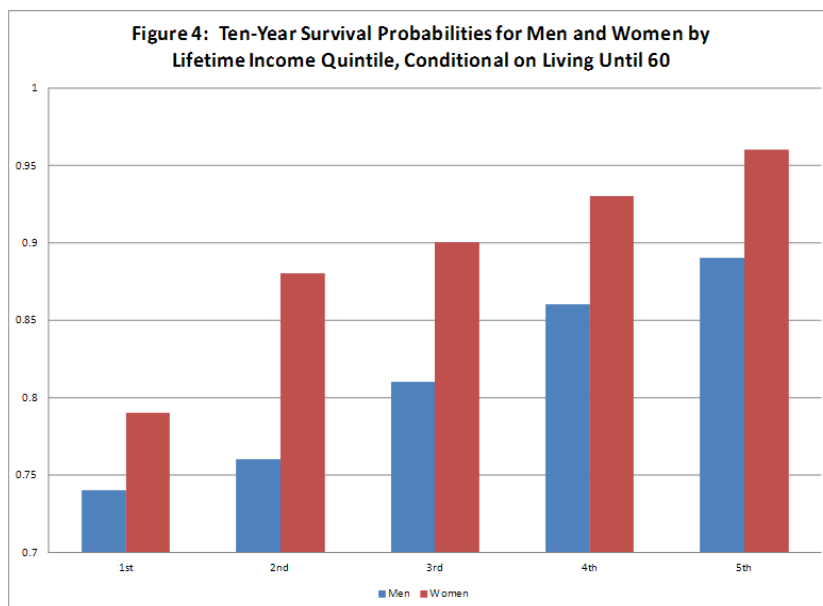
⁵See, for example, Paffenbarger et al. (1993), Willette (1994), Mokdad et al. (2004), and Warburton et al. (2006).



for this paper.

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 HRS data we have available, 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, health investments, and retirement 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

We assume a household maximizes utility by choosing consumption, health investments, and leisure. Time spent working depends on the health status of the individual (we assume that sick time is related to the health stock) and rest of the time is divided up between leisure and health investments. Retirement is endogenous. Even though adding health capital and endogenous retirement involves only two additional choice variables (relative to a standard life-cycle intertemporal consumption problem), it is a significant complication. In addition to affecting longevity, households derive direct

satisfaction from health. Lifetime utility at any age, V_j , is given by an Epstein-Zin, Kreps-Porteus formulation of recursive preferences

$$V_j = \underset{c,l,h}{Max} \left[n_j U(c_j/n_j, l_j, h_j)^{1-\gamma} + \beta (E_t V_{j+1}^{1-\theta})^{(1-\gamma)/(1-\theta)} \right]^{\frac{1}{1-\gamma}} .$$

In the above formulation, θ measures the coefficient of risk aversion, $\frac{1}{\gamma}$ is the intertemporal elasticity of substitution and $U(\cdot)^{1-\gamma}$ denotes period utility which is non-separable with the certainty equivalent of future utility. Notice that when $\theta = \gamma$, we get the standard time-additive separable case.

There are three related reasons we chose this specification of preferences. First, it isolates the degree of risk aversion from the intertemporal elasticity of substitution. These features of preferences may have independent effects on health and other household choices. Second, as noted in Rosen (1988), with endogenous mortality, standard time-additive preferences are not invariant to affine transformations. This arises due to the fact that the household attributes zero utility to death and the agent needs to compare the utility of any optimal schedule with zero to determine whether or not it is worthwhile to live longer. Third, with common time-additive, separable CRRA preferences, $U(c) = \frac{c^{1-\sigma}}{1-\sigma}$, $\sigma < 1$ for utility to be a positive number. But most estimates and calibration exercises suggest σ exceeds one. Our formulation allows σ to exceed one.⁶

The expectation operator E_t denotes the expectation over uncertain future earnings before retirement and uncertain health shocks throughout life, β is the discount factor, j is age, c is consumption, and h is a composite stock of health for men and women in the household, and l is leisure. n_j is a household scale parameter and is a function of the number of adults, A , and children, K , in the household, so $n = g(A_j, K_j)$. Households spend an indivisible amount of time $\omega(h)$ working each period and spend the rest of their time endowment $1 - \omega(h)$ on either leisure or on activities that augment health

⁶Hall and Jones (2007), following others, use conventional CRRA preferences but add a large enough constant to guarantee that utility is positive.

investments. We assume that $\omega(h) = \bar{\omega} - s(h)$ which draws from Grossman’s formulation of sick time: households experience some loss in labor supply depending on sick time, $s(h)$, which is inversely related to their health status.⁷ Upon retirement, households split their time endowment of 1 unit between leisure and health investments.

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.⁸ 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 the positive effects of spending apply to a small subset of the conditions that lead people to show up in emergency rooms. Doyle (2010) 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. Other studies suggest that *marginal* medical expenditures have little discernible effect on health.

It is nevertheless clear that money can sometimes 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. We assume that the household

⁷In our modeling of sick time, 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 worked or the wage rate. Consequently, data limitations prevent us from disentangling the impact of bad health on labor supply from its effect 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.

⁸See, 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.

possesses a health stock and investments can improve health. The accumulation process of the stock of health is given by

$$h_{j+1} = f(m_j, i_j) + (1 - \delta_h)h_j + \varepsilon_j, j \in \{S, \dots\}$$

The stock of health at the next age, h_{j+1} , is determined by the production of health, given by $f(m_j, i_j)$. 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 $M(\cdot)$ of out of pocket medical expenses, m_j^{oop} . In the above equation, δ_h stands for the depreciation rate of health. Introducing age-dependent shocks to health is both realistic and necessary if we are interested in matching biological processes and the data. These age-dependent shocks are denoted by ε_j , which we allow to vary by gender. In typical lifecycle models, medical expenditures have only financial consequences. Here medical expenditures 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.

The probability of surviving into the next period is given by the function $\Psi(h)$. This function satisfies two properties. As h goes to ∞ , $\Psi(h)$ converges to 1. Second, $\Psi(h) = 0$ for $h \leq 0$. This ensures that as soon as h goes to zero, the household dies.

Consumption, the age of retirement, and health investments are chosen to maximize expected utility subject to the constraints.

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

$$y_j = SS \left(\sum_{j=S}^R e_j(h_j) \right) + DB(e_R(h_R)) + ra_j + T_R(e_R(h_R), \sum_{j=S}^R e_j(h_j), a_j, j, n_j), j \in \{R+1, \dots\}$$

$$c_j + a_{j+1} + m_j^{oop} = y_j + a_j - \tau(e_j(h_j) + ra_j), j \in \{S, \dots, R\}$$

$$c_j + a_{j+1} + m_j^{oop} = y_j + a_j - \tau \left(SS \left(\sum_{j=S}^R e_j(h_j) \right) + DB(e_R(h_R)) + ra_j \right), j \in \{R+1, \dots\}$$

In these expressions y is income, $e(h)$ is earnings which depends on health stock, a is assets, r is the interest rate, T is a transfer function, R is the age of retirement, and S is the age that a household member enters the labor market. Social security (SS) is a function of lifetime earnings, defined benefit pensions (DB) are a function of earnings in the last year of life, τ is a payroll and income tax function, and the transfer function for retirees (T_R) is a function of social security, defined-benefit pensions, assets, age, and family structure.

3.1 Retired Household's Dynamic Programming Problem

A retired, married household between ages R and D obtains income from social security, defined-benefit pensions, and preretirement assets. The dynamic programming problem at age j for a retired household is given by

$$V(e_R, E_R, a, j, h_h, h_w) =$$

$$\max \left\{ \begin{array}{l} nU(c/n, 1 - i, h)^{1-\gamma} + \beta \Psi(h_h) \Psi(h_w) \\ \left[\int_{\varepsilon_h} \int_{\varepsilon_w} V(e_R, E_R, a', j+1, h'_h, h'_w)^{1-\theta} d\Xi_h(\varepsilon_h) d\Xi_w(\varepsilon_w) \right]^{(1-\gamma)/(1-\theta)} \end{array} \right\}^{\frac{1}{1-\gamma}}$$

subject to

$$y = SS(E_R) + DB(e_R) + ra + T_R(e_R, E_R, a, j, n)$$

$$c + a' + m_h^{oop} + m_w^{oop} = y + a - \tau(SS(E_R), DB(e_R) + ra)$$

$$h'_h = F(M(m_h^{oop}), i) + (1 - \delta_h)h_h + \varepsilon_h$$

$$h'_w = F(M(m_w^{oop}), i) + (1 - \delta_h)h_w + \varepsilon_w$$

$$h = \Delta(h_h, h_w)$$

In the above equation the value function, $V(e_R, E_R, a, j, h_h, h_w)$, denotes the expected present discounted value of maximized utility from age j until the date of death, the $'$ superscript denotes the corresponding value in the following year; and, as noted before, $\Psi(h)$ denotes the probability of survival between ages j and $j + 1$ for the husband and the wife respectively. m^{oop} are out of pocket medical expenses for the husband and wife. 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. We integrate over the distribution of health shocks facing the husband and wife in the married couple.

3.2 Working Household's Dynamic Programming Problem

A working single household between the ages S and R obtains income from labor earnings and preretirement assets.⁹ The dynamic programming problem at age j for a working household is given by

$$W(e, E_{-1}, a, j, h) = \max \left\{ \begin{array}{l} nU(c/n, 1 - \omega(h) - i, h)^{1-\gamma} + \beta\Psi(h) \\ \left[\int_{\varepsilon} \int_{e'} W(e', E, a', j + 1, h')^{1-\theta} d\Xi(\varepsilon) d\Omega(e') \right]^{(1-\gamma)/(1-\theta)} \end{array} \right\}^{\frac{1}{1-\gamma}}$$

subject to

$$y = e(h) + ra + T(e(h), a, j, n)$$

⁹For brevity, we do not write down the dynamic programming problem for single retired and married working households.

$$c + a' + m^{oop} = y + a - \tau(e(h) + ra)$$

$$h' = F(M(m^{oop}), i) + (1 - \delta_h)h + \varepsilon$$

$$E = E_{-1} + e(h)$$

$V(e, E_{-1}, a, j, h)$ denotes the expected present discounted value of lifetime utility at age j . E_{-1} are cumulative earnings up to the current period. We integrate over health and non-health-related earnings shocks. As noted earlier, health shocks also affect earnings through their effect on sick time. The other variables are defined above.

As noted earlier, the age at which the household retires is endogenous. The decision problem at this age is much the same as the working household's decision problem with one exception, the continuation value is what the household will realize upon retiring, given by the value function $W(e, E_{-1}, a, j, h)$. The irreversible retirement decision is affected by changes in social security, defined benefit pensions, and by the incidence of health shocks as the household ages. We compute the optimal retirement age by solving the household decision problem for various choices of the (discrete) retirement age and then choosing the retirement age that maximizes lifetime utility.

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 average household to data on wealth accumulation, medical expenses, retirement age 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: Recall that preferences are recursive. We assume that momentary household utility has a constant relative risk-averse form. We further assume the subutility function over consumption and health has a constant elasticity of substitution. Hence the period utility takes the form

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

The elasticity of substitution between the consumption-leisure composite and health is $1/(1-\rho)$. The parameter γ is the inverse of the intertemporal elasticity of substitution. The discount factor (β) is set at 0.96, a value similar to the 0.97 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 θ , the coefficient of risk aversion equal to 3, a value commonly used in many studies including Hubbard, Skinner, and Zeldes (1995). We calibrate γ .

Health aggregator: Our analysis of consumption and wealth accumulation is naturally at the household level. But health is clearly individual. We model *individual* investments in health that we then aggregate to the household level using a simple CES function

$$h = \Upsilon(h_h, h_w) = [\vartheta (h_h)^v + (1-\vartheta) (h_w)^v]^{\frac{1}{v}}.$$

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 indicate 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: We model an exogenous, time-varying, progressive income tax that takes a form used by Gouveia and Strauss (1994, 1999)

$$\tau(y) = a(y - (y^{-a_1} + a_2)^{-1/a_1}),$$

where y is in thousands of dollars. We estimate parameters a , a_1 , and a_2 using information on taxes paid and incomes by income class drawn from Statistics of Income volumes (produced by the Internal Revenue Service) available electronically through the Boston Public Library. The function characterizes U.S. effective, average household income tax rates between 1950 and 2008.

Earnings and Earnings Expectations: Earnings data through 2007 come from three sources: Social Security Administration Summary Earnings files, SSA earnings detail files (W2 information), and HRS self-reports.

Earnings in the Summary Earnings files are top-coded. Starting in 1978 we have un-top-coded W2 data for many individuals. Starting in 1992 we have HRS self-reports of earnings. If available, we use W2 data or self-reports to address top-coding. For top-coded observations from 1951 to 1977, we estimate a censored regression model to predict true earnings for top-coded observations.¹⁰ For the remaining top-coded observations from 1978 to 2007 we use a similar empirical model, adding labor force status to the covariates after 1992. We set missing earnings to zero in years following

¹⁰The empirical model includes the following covariates: gender, education, birth year, race, census region, marital status, average percentile in the earnings distribution over the previous 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 wealth over the HRS study years (1992,1994,...2008). The non-time-varying covariates are drawn from the first wave the respondent appears in the HRS.

the respondent’s last year of work or retirement year, for respondents who report never having worked, and for respondents younger than age 17. We impute the remaining missing earnings using a variant of our empirical earnings model: rather than using the respondent’s percentile in the earnings distribution, we use the respondent’s average real earnings in the past/next five years.

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.¹¹ 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

$$\log e_j = \alpha^i + \beta_1 AGE_j + \beta_2 AGE_j^2 + u_j$$

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

where, as mentioned above, e_j is the observed earnings of the household i at age j in 2008 dollars, α^i is a household specific constant, AGE_j is age of the head of the household, u_j is an AR(1) error term of the earnings equation, and ϵ_j is a zero-mean i.i.d., normally distributed error term. The estimated parameters are α^i , β_1 , β_2 , ρ and σ_ϵ .

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).¹² Estimates of the persistence parameter, ρ , across groups

¹¹Due 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.

¹²The 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

range from 0.69 to 0.82.

Assuming a 40 hour workweek and 112 hours of non-sleeping time per week, we set the value of full-time work, \bar{w} , to 0.36.

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

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

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} 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.¹³ These 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

20 percent of the lifetime earnings of the household.

¹³See <http://www.ukcpr.org/AvailableData.aspx>

work and the fraction of household earnings earned by the male and the fraction earned by the female.

Health production: We assume that the production of health is given by $F(M(m), i) = A_t (m^\chi i^{1-\chi})^\xi$, where total medical expenses are a function of out-of-pocket expenses, $m = M(m^{oop})$ and health is also produced with time, i . We assume A_t grows at 3 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 this function takes the form, $m = \begin{cases} m^{oop} + c, & \text{shock} \\ m^{oop}, & \text{no shock} \end{cases}$. In the absence of a health shock, health care expenditures come directly out of the uninsured household's pocket. In the event that the uninsured household suffers an adverse health shock, a baseline level of care, c , 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."¹⁴ The average total medical spending for the insured (under age 65) in the

¹⁴See, for example, Currie and Gruber (1997), Currie and Thomas (1995), Haas and Goldman (1994),

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 $0.6\bar{m}_i = \bar{m}_u = \bar{m}_u^{oop} + \bar{c}$ we recover the average value of charity care in the event of an adverse health shock, $\bar{c} = \$1,400$.

To calibrate the “generosity parameter,” ζ , 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 $\zeta_i = \frac{m_i^{oop} - D_i}{(m_i - D_i)}$, $i \in \{1, 2, \dots, 5\}$. 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 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 $\Psi(h) = 1 - \exp(-\psi h^\sigma)$.

Health Shocks: At each age, we assume that there are two possible values for the health shocks: ε_h and ε_l . The first shock ε_h corresponds to being healthy and is set to zero. The magnitude of the health shock ε_l can vary by age and gender and is determined by the calibration procedure: $p_{55}, p_{65}, p_{75}, p_{85}$ and p_{100} refer to 5-year probabilities of an adverse health shock between the ages of 0-55, 55-65, 65-75, 75-85 and 85+ respectively.

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

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, retirement age, life tables and

Long, Marquis, and Rodgers (1997), and Tilford *et al.* (1999) who provide information on medical care use for the insured and uninsured.

medical expenses for the average household in the HRS to pin down these parameters. The parameters we calibrate are λ , the utility weight on consumption relative to health; ρ , which determines the elasticity of substitution between consumption and health; ϑ and v , the parameters governing the aggregation of the husband and the wife's stock of health to determine the household's health stock; γ , the inverse of the intertemporal elasticity of substitution; ψ , the coefficient on health in the survival function; σ , the curvature of the survival function with respect to health; ξ , the curvature of the health production function; ε_l , the magnitude of the adverse health shock; χ , the share parameter in health production between monetary and time inputs; δ_h , the annual depreciation rate of health; α , the elasticity of sick time with respect to health status; and p_{55} , p_{65} , p_{75} , p_{85} and p_{100} , the probabilities of bad health shocks occurring at different age intervals separately for males and females.

To calculate these remaining parameters, we solve the dynamic programming problem for married, single male, and single female "average" households, where average 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 the adverse 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:¹⁵

1. Mean net worth in 1998 for married couples (husband age 63.2, wife age 60.9) is \$508,904
2. Mean net worth in 2008 for married couples is \$628,599
3. Mean net worth in 1998 for single males (age 64.1) is \$295,486
4. Mean net worth in 1998 for single females (age 66.7) is \$193,064
5. The probability of dying between ages 50-54 for males: 3.08%
6. The probability of dying between ages 70-74 for males: 13.76%
7. The probability of dying between ages 80-84 for males: 31.69%
8. The probability of dying between ages 90-94 for males: 60.70%
9. The probability of dying between ages 50-54 for females: 1.834%
10. The probability of dying between ages 70-74 for females: 9.57%
11. The probability of dying between ages 80-84 for females: 23.94%
12. The probability of dying between ages 90-94 for females: 52.05%
13. Average annual total medical expenses for married women age 19-44: \$4,454

¹⁵Moments 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/. The data on sick hours come from the PSID.

14. Average annual total medical expenses for married women age 50-54: \$5,743
15. Average annual total medical expenses for married women age 60-64: \$7,747
16. Average annual total medical expenses for married women age 70-74: \$12,417
17. Average annual total medical expenses for married women age 80+: \$17,896
18. Average annual total medical expenses for single women age 70-74: \$12,479
19. Average annual total medical expenses for married men age 70-74: \$13,225
20. Average annual total medical expenses for single men age 70-74: \$13,474
21. Sick hours relative to total work hours at age 40: 0.015
22. Retirement Age: 62

The model with each calibrated parameter generates 22 non-linear equations with 22 unknowns. We obtained an exact match between the model predictions and the moments listed above. The resulting parameter values are given below.

Parameter	λ	ρ	ϑ	v	γ
Value	0.71	-4.1	0.49	0.73	0.78
Parameter	ψ	σ	ξ	ε_l	χ
Value	.0012	1.53	0.69	-14.4	0.49

Parameter	p_{55}	p_{65}	p_{75}	p_{85}	p_{100}	δ_h
Value	0.06	0.11	0.139	0.197	0.245	0.042
Parameter	$p_{55,f}$	$p_{65,f}$	$p_{75,f}$	$p_{85,f}$	$p_{100,f}$	α
Value	0.04	0.09	0.119	0.168	0.229	0.17

The value of γ is equal to 0.78, which implies an intertemporal elasticity of substitution ($1/\gamma$) of 1.28. This number is not comparable with the Euler equation based

estimates of the IES since most studies estimating the IES use standard time additively separable preferences. The elasticity of substitution between consumption/leisure composite and health is $\frac{1}{1-\rho} = 0.2$. Consumption and health are complements and our calibrated value is very close to the estimates in Finkelstein, Luttmer, and Notowidigdo (forthcoming). In a married household, the male and the female's health are very good substitutes as reflected by $v = 0.73$. The rate of depreciation of health is 4.2 percent per year. The share of goods in the production of health χ is 0.49, suggesting that time and goods are both important in the production of health. The bad health shock, ε_l , takes on the value -14.4 (recall that the good health shock ε_h is set to 0). Finally, note that the 5-year realization probability of the bad health shock increases from 6 percent for men (4 percent for women) below 55 years of age to 11 percent (9 percent for women) for men between 55 and 65, to 13.9 percent (11.9 percent for women) for men between 65 and 75, to 19.7 percent (16.8 percent for women) for households between 75 and 85, and to 24.5 percent (22.9 percent for women) for men above the age of 85.

As mentioned above, we match 22 data moments with the model to identify these 22 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 ρ will lead to a higher level of assets in 1998. In addition, a lower value of ρ 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 ρ .

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 both utility as well as mortality. The importance of health in utility (λ) 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 health aggregator in preferences. A change in the parameters governing the health aggregator for married households (ϑ, v) will affect both the wealth of the married household 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. 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. We then use the decision rules and the observed earnings and medical expenses to obtain the model's predictions for wealth, health, medical expenses and mortality at a given age. Where we do not have annual data on medical expenses

or earnings, we use the distributions of earnings shocks or health shocks to integrate out expected medical expenses and earnings.

5 Results

As emphasized in the previous discussion, we calibrate key model parameters to the average (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. We summarize results for household wealth and out-of-pocket medical expenses by showing median values, breaking households into lifetime income quintiles.¹⁶

Table 1: Median Net Worth and Out-of-Pocket Medical Expenditures, Model and Data, 1998 and 2008				
1998	Median Net Worth		Median OOP Medical Expenses	
Lifetime Income	Data	Model	Data	Model
Lowest Quintile	\$33,588	\$23,596	\$708	\$735
Second Quintile	60,717	47,506	904	845
Middle Quintile	97,212	94,503	995	956
Fourth Quintile	180,859	151,203	930	982
Highest Quintile	340,144	322,309	1,023	1,012
2008				
Lowest Quintile	\$15,495	\$15,283	\$640	\$632
Second Quintile	63,900	57,495	1,080	921
Middle Quintile	136,000	127,503	1,200	1,146
Fourth Quintile	238,000	253,991	1,384	1,323
Highest Quintile	443,000	422,405	1,680	1,589

¹⁶Lifetime income is defined within four roughly equal-sized age groups: under 60, 60 to 65, 66 to 75, and over 75.

There are two striking features of Table 1. 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. The correlation of actual and optimal net worth in 1998 is 0.69. 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, retirement is endogenous, preferences are not time-additively separable, new cohorts have been added to the data and we now look at a much 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 seem to be preparing well for financially secure retirements.

Predicted out-of-pocket median medical expenses also match actual expenses fairly closely. For instance, in 1998, the out of pocket medical expenses rise from \$735 for the lowest lifetime income quintile to \$1,012 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 0.50.

The second striking feature of Table 1 is the degree to which we match the dispersion of median net worth and out-of-pocket medical expenditures by lifetime income quintile in 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.

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 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. Table 2 depicts the connection between the model and data for 1998 and 2008 in more detail.

Table 2: Self-reported Health Status, Model and Data, 1998 and 2008										
	Fraction of Households by Self Reported Health Status									
Lifetime Income	Excellent		V. Good		Good		Fair		Poor	
1998	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model
Bottom Quintile	7	7	17	15	28	29	28	29	19	18
Second Quintile	10	9	20	21	28	26	26	27	16	17
Middle Quintile	12	12	23	22	33	34	21	20	11	12
Fourth Quintile	13	14	29	28	34	33	18	19	7	6
Highest Quintile	18	19	36	35	30	29	12	12	4	5
2008										
Bottom Quintile	5	6	18	19	28	27	31	30	18	18
Second Quintile	7	7	22	21	31	30	26	27	13	15
Middle Quintile	9	10	26	24	33	32	23	24	9	10
Fourth Quintile	10	10	32	31	33	32	19	19	7	8
Highest Quintile	12	12	37	34	33	33	13	14	5	7

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 3 gives the fit between model and data on retirement age.

Table 3: 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	60	61	61	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	63	62	63	62	62	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.

5.1 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 4 we take all 60 year olds. These households face many different patterns of potential health shocks (ε_l 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 the table under the column "Model."

Table 4: Ten-Year Survival Probabilities, Model and Data				
Survival Probabilities	Age 60		Age 75	
	Data	Model	Data	Model
Bottom Lifetime Income Quintile	0.77	0.75	0.54	0.49
Second Quintile	0.83	0.80	0.54	0.51
Middle Quintile	0.86	0.83	0.52	0.54
Fourth Quintile	0.90	0.85	0.62	0.56
Highest Lifetime Income Quintile	0.92	0.88	0.64	0.60

The model does a strikingly good job matching survival patterns in the underlying data, though we note that seven of the 14 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.

5.2 Complementarity

The degree of complementarity between consumption and health in the utility function plays a central role in understanding our results. In Table 5 we illustrate the effect of setting ρ to zero (which would make the consumption-leisure composite and health separable in the utility function) on optimal net worth.

Table 5: The Effect of Complementarity on Optimal Wealth Accumulation, 1998		
	Median Net Worth	
	Baseline Model ($\rho = -4.1$)	$\rho = 0$
Bottom Quintile	\$23,596	\$48,485
Second Quintile	47,506	104,507
Middle Quintile	94,503	157,120
Fourth Quintile	151,203	322,346
Highest Quintile	322,309	532,340

When consumption and health are complements in the utility function, households anticipate that as health declines late in life, so will consumption. This phenomenon is absent when consumption and health are separable in preferences. Hence the model

with complementarity will, all else equal, imply less asset accumulation than when ρ equals zero. Other moments are also affected. To illustrate this, we set ρ to zero and re-calibrate the model. We ignore the 2008 wealth moment and solve 21 equations in 21 unknowns. We then re-do simulations for all households in the sample. We report below the fit of the model (baseline in parenthesis)

1. The correlation between model and data for net worth in 1998: 0.48 (0.69)
2. The correlation between model and data for out-of-pocket medical expenses in 1998: 0.31 (0.50)
3. The model correctly predicts the exactly stock of health (on a 5-point scale) for 48 (72) percent of the population in 1998

Complementarity has an important effect on the fit of the model for net worth, out-of-pocket medical expenses, and the stock of health.

Another way to illustrate the importance of consumption-health complementarity is to examine *changes* in wealth between 1998 and 2008. As individuals age, health deteriorates. A sceptic might be worried that this deterioration in health might be associated with too steep a change in wealth when health and consumption are complements. To examine this, we compute the ratio of wealth in 2008 to wealth in 1998 for each household that is alive in 2008. We then proceed to arrange them by lifetime income quintile and report the median ratio in Table 6.

Table 6: The 2008-1998 Change in Net Worth Under Different Model Specifications				
	Median Ratio of (NW in 2008)/(NW in 1998)			
	Data	$\rho = -4.1$	$\rho = 0$	Exogenous
Bottom Quintile	0.77	0.78	0.68	0.74
Second Quintile	0.92	0.94	0.85	0.78
Middle Quintile	1.06	1.08	0.91	0.83
Fourth Quintile	1.08	1.12	0.94	0.87
Highest Quintile	1.17	1.21	0.96	0.90

The variation in the ratio of 2008 net worth to 1998 net worth in the data is steep across lifetime income quintiles: poor households experience a substantial decline in wealth while their richer counterparts experience a 17 percent increase in wealth. The baseline model with $\rho = -4.1$ tracks this pattern very well. For poor households, who are closer to death than a comparable rich household, it is optimal for them to run down their assets. For richer households complementarity implies that as health deteriorates, consumption declines. This results in an increase in asset accumulation, in part because richer households have longer expected lifetimes than poor households.

Table 6 also reports what happens with separable utility, where $\rho = 0$. With separable utility the model has difficulty generating increases in wealth between 1998 and 2008 - even the rich households decumulate wealth at older ages (although at a much slower pace than poorer households). Finally, for a sceptic who thought that endogenizing health might not have been all that critical to understand the changing behavior of health, we also report the same statistics for the conventional modelling of consumption and health in a lifecycle model. Specifically we show results from a model where lifetime budgets are subject to medical expense shocks that proxy for health shocks. With exogenous health, the variation in the change (across time) in net worth between rich and poor households is smaller than in the separable utility case since

medical expenses do not influence longevity.¹⁷ We conclude that the assumed degree of complementarity is reasonable and plays an important role in explaining the behavior of mortality, health, medical expenses as well as health for older households.

5.3 Medicare and Longevity

Policy simulations are another way to gain insight into behavior and the way our model works. In Table 7 we examine the effect of removing our stylized version of Medicare, the universal social insurance program that was established in 1965 to provide health insurance to the elderly. Our modeling of this change is extreme: instead of being eligible for a Government-provided insurance program upon reaching age 65, households are uninsured.¹⁸ There are several reasons why we focus on this policy. First, Medicare is a massive social insurance program costing \$325 billion in fiscal year 2006. Second, end-of-life health shocks have been shown by several authors to have significant effects on asset accumulation. Third, Finkelstein and McKnight (2008) show in the first 10 years following the establishment of Medicare, there was no discernible effect on mortality, though Chay *et al.* (2010) challenge this conclusion. The effects of policy changes on mortality and asset accumulation in the short- and long-run are issues the model is nicely designed to address.

Suppose that Medicare were instantly eliminated in 1998 and the change was not an-

¹⁷Indeed, even the recent work of Denardi *et al.* (2010) has a difficult time rationalizing the increase in asset holdings of rich singles. While their model does a very nice job explaining the behavior of the bottom quintiles, the top quintile experiences an increase in assets late in life while their model generates a decline over the same time period. Recall that our sample also includes married households who are richer on average than single households. This, in large measure, explains why even our average household experiences an increase in asset holdings while in their sample, the average household does not.

¹⁸As noted earlier, medical care for insured households is $m = \underbrace{D + \zeta(m - D)}_{\text{OOP}} + \underbrace{(1 - \zeta)(m - D)}_{\text{insurance}}$. Total medical expenditures for the uninsured are $m = \begin{cases} m^{oop} + c, & \text{shock} \\ m^{oop}, & \text{no shock} \end{cases}$. This policy experiment is extreme in the sense that institutions would undoubtedly evolve to provide insurance opportunities for the elderly.

anticipated. All assets and health capital held by households had been accumulated under the assumption that Medicare would exist. Medicare is financed by taxes on earned income and so when Medicare is eliminated, we rebate annually back to the household all future Medicare tax payments. After eliminating Medicare, we can recompute the model and examine the effects on 10-year survival probabilities.

Table 7 shows the short-run effect on mortality (under the "No Med" column) of eliminating Medicare are sizeable. Since most accumulation of health capital and wealth occurs well before retirement, health status is largely fixed by age 60-65. Eliminating Medicare, therefore, has little effect on health in the years immediately following its repeal. Nevertheless, Medicare provides insurance against health shocks and given that Medicare was eliminated unexpectedly, households did not have an opportunity to increase their savings in order to self insure.

Table 7: Short- and Long-Run Effects of Eliminating Our Stylized Medicare Program						
	Age 60			Age 75		
Lifetime Income	Baseline	No Med	LR	Baseline	No Med	LR
Bottom	0.75	0.71	0.66	0.49	0.45	0.40
Second	0.80	0.74	0.71	0.51	0.46	0.43
Middle	0.83	0.79	0.77	0.54	0.50	0.48
Fourth	0.85	0.81	0.81	0.56	0.53	0.52
Highest	0.88	0.84	0.85	0.60	0.57	0.58

There are three primary effects of removing Medicare. The first is the insurance effect, the fact that Medicare provides insurance against health shocks. The second is the investment effect, the idea that individuals are more likely to invest more in health when young if they know there is insurance available at older ages. Finally, there is the income effect: removing Medicare means that Medicare taxes are rebated back to the household which results in more income available for health investments. In the short run ("No Med") experiment, only the first effect is at play.

The long-run effects of repealing our stylized Medicare program are even larger as all three effects come into play. As before, when we repeal Medicare, the Medicare tax on earnings is rebated back to the household. In the long-run analysis, households go through their entire working lives without Medicare. In the lowest and middle lifetime income quintiles there is a moderate adverse effect on survival probabilities. In the long-run, a forward-looking household with low lifetime income will recognize they have no health insurance program in retirement. They also correctly anticipate the lifecycle pattern of health shocks and the cumulative effects of health depreciation, so old-age health will be worse than health when young. Because health and consumption are complements, the life-cycle pattern of consumption mirrors the lifecycle pattern of health. Low lifetime income households will therefore invest less in health, trading off a shorter expected lifespan for greater consumption in younger ages when the marginal utility of consumption is high relative to later in life. High lifetime income households can mitigate these effects by self-insuring: they engage in buffer stock saving and invest in health capital.

The effects of this experiment on wealth and out-of-pocket spending are shown in Table 8. With Medicare eliminated and many elderly people paying for all medical care out of pocket, some households engage in additional buffer stock saving, self-insuring in the absence of Medicare (some still have insurance provided by Medicaid, employer-provided plans, or VA-Champus). Indeed, we see greater wealth accumulation throughout the lifetime income distribution. We also see fewer medical expenditures. The tables illustrate a central insight into the lifecycle model with endogenous health. Long-run adjustments to changes in the institutional environment will be made on two margins: first, households will consume less and do more buffer stock saving. Second, private health investment will decrease. The result is that households will both consume less and die earlier in a world without Medicare. But relative to a standard lifecycle model of consumption without endogenous health production, the consumption responses will

be smaller, since a portion of the response occurs through a diminution of health capital. With less health capital, households correctly anticipate that they will die younger and hence they need to accumulate less wealth to finance consumption in retirement. Thus, the model with endogenous health mitigates the effects of changes in social insurance on consumption relative to standard lifecycle models.

1998	Median Net Worth		Median OOP Medical Exp.	
Lifetime Income	Baseline	No Medicare-LR	Baseline	No Medicare-LR
Bottom Quintile	\$23,596	\$39,203	\$735	\$327
Second Quintile	47,506	68,924	845	652
Middle Quintile	94,503	118,674	956	791
Fourth Quintile	151,203	171,488	982	869
Highest Quintile	322,309	341,294	1,012	965

Endogenous versus Exogenous Health The consumption and out-of-pocket spending responses to eliminating the stylized Medicare program shown in Table 8 are fairly modest, which results in the moderate reduction in survival probabilities for low- and moderate-income households in the model. This result is quite different than what would arise from the standard modeling approach such as Scholz *et al.* (2006), where medical expenses follow an exogenous stochastic process and there is no health-consumption complementarity.

Hubbard, Skinner and Zeldes (1995) argue that means-tested transfer programs have a large effect on wealth accumulation. More recently, De Nardi, French and Jones (2010) make a similar point finding large effects of Medicare on the evolution of net worth at older ages. In Table 9, we demonstrate the impact on net worth from removing Medicare in model presented above as well as in a world in which medical expenses follow an AR(1) process similar to Scholz *et al.* (2006) and where health is not an argument in

preferences.

Table 9: Long Run Effects of Eliminating Medicare on Net Worth, Endogenous vs. Exogenous				
1998	Median Net Worth			
	Endogenous Health		Exogenous Health	
Lifetime Income	Model	No Medicare-LR	Model	No Medicare-LR
Bottom Quintile	\$23,596	\$39,203	\$23,864	\$117,540
Second Quintile	47,506	68,924	47,213	159,342
Middle Quintile	94,503	118,674	87,548	226,673
Fourth Quintile	151,203	171,488	148,124	307,235
Highest Quintile	322,309	341,294	323,575	553,124

The asset response to eliminating the stylized Medicare program is enormous in an economy in which medical expenses are exogenous. In this economy households will try to self-insure by accumulating substantial wealth. In contrast, in our model there are two channels that mitigate this response. First, when medical expenses are endogenous, when hit with a bad health shock, households can choose not to spend on medical care later in life. This option is not available in models where medical expenses are exogenous. Second, consumption-health complementarity implies optimal consumption profiles decline as health depreciates. Hence, households will optimally accumulate fewer late-in-life assets than would identical households in a model that does not recognize these complementarities. Comparing a society with social insurance and one without, we would be hard pressed to find poor households in poor economies building up large asset stocks. Hence, the fact our model implies a much smaller effect of social insurance programs on wealth accumulation than other frameworks is a desirable result.

6 Sensitivity Analyses

In what follows we briefly report the effect of altering some of the exogenously set parameter values on goodness of fit. The upshot is that the fit between the model and the data is preserved with reasonable perturbations of the parameter values. We also report the fit of the model when we use standard time-additive separable utility.

Parameter	R ² (Health)	R ² (Med. Exp.)	R ² (Wealth)
Baseline - recursive utility	0.72	0.50	0.69
$\beta = 0.9$	0.58	0.43	0.58
$\beta = 0.99$	0.74	0.41	0.63
$r = .01$	0.66	0.39	0.58
$r = .07$	0.55	0.42	0.72
$\theta = 1$	0.55	0.36	0.54
$\theta = 5$	0.64	0.46	0.57
$\eta = 0.2$	0.71	0.45	0.70
$\eta = 0.6$	0.67	0.52	0.65
Time additive separable utility	0.48	0.33	0.48

When beta is lower than the baseline, households discount the future more and this causes them to save less for old age. The fit worsens along all dimensions - they care less about future health and wealth. When beta rises, households place more weight on the future. The results indicate that model fits better along the health dimension but the R² for wealth is lower.

When $\theta = 1$, preferences become closer to time additively separable. This worsens the fit along all dimensions. Indeed the last row represents the fit of the model when we move all the way to time additively separable preferences ($\theta = \gamma = 0.78$), the fit worsens even more. Clearly, this suggests that recursive utility and the delineation between risk aversion and IES plays a major role in explaining differences in health and wealth across

households.

Finally, the elasticity of consumption versus leisure in utility has a fairly small impact on the goodness of fit when we vary the value between 0.2 and 0.6.

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 novel features: household build health capital with investments of both time and money; insurance affects the transformation of out-of-pocket medical expenses to total medical expenses; retirement is endogenous; the health status of two spouses in a marriage evolve distinctly; we employ recursive utility to get around some issues that arise with time additively separable utility when mortality is endogenous; health affects earnings 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, retirement, mortality, and medical expenses for the average HRS married and single households, calibrating 22 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 22 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, the degree of complementarity between consumption and health capital is critical in explaining various features of the data. Complementarity helps explain the time path of wealth decumulation late in life. While some previous authors relied on differences in discount factors and preferences to account for the steeper decline in consumption after age 50 for the less educated, we find that this decline is synchronous with the decline in health and the complementarity between consumption and health helps explain this steeper fall in consumption for poorer households relative to their richer counterparts.

Third, we find that the effect of policy in a framework in which health is endogenous is quite different from the standard framework in which medical expenses follow an exogenous stochastic process. For instance, means-tested transfer programs such as Medicaid have a much smaller effect on asset accumulation than in models without endogenous health investment. This is consistent with the available evidence.

Fourth, policy can have meaningful effects on life tables especially in the bottom few deciles of the income distribution. Further work exploring the effects of policy on life tables and longevity is an exciting area for future work.

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