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# Life-cycle effects of health risk

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A B S T R A C T

Health status affects individuals' labor supply, asset accumulation and welfare through four main channels: productivity, medical expenditures, time endowments and survival probabilities. Using a life-cycle model calibrated to the U.S. for different education groups, I evaluate the relative importance of each channel and quantify their interactions. The productivity and time endowment channels dominate in importance and the risks implied by them contribute significantly to income inequality and precautionary savings. Health effects are larger for the non-college than college educated and account to a large extent for the lower labor supply and higher reliance on government transfers of the non-college group.



## 1. Introduction

How important are health shocks as a source of idiosyncratic risk faced by individuals over the life-cycle and why? Using a calibrated life-cycle model with idiosyncratic risk in health, earnings and survival, this paper quantifies the effects of health status and health status risk on labor supply, asset accumulation and welfare for different education groups. To determine the specific sources of these effects, the paper evaluates the relative importance of four main channels through which health status affects individuals: (1) productivity, (2) medical expenditures, (3) time endowments and (4) survival probabilities.

I find that health shocks have large implications for the macroeconomic variables studied through all four channels. However, the productivity and time endowment channels generally dominate in importance for labor supply and welfare. The risks implied by these two channels are the most important in generating income inequality and precautionary savings during the working stage of life. They are major components of overall risk before retirement age, and they interact closely with the ability to save for risk after retirement age generated by the medical expenditures and survival channels. This highlights the importance of studying all four effects in a unified framework over the entire life-cycle.

The non-college group is subject to much larger health risks than the college group due to higher probabilities of bad health at any age, the smaller fraction of non-college graduates who have health insurance, and larger reductions in productivity and time endowments associated with bad health. In addition, at the lower income levels of the non-college group, fluctuations in incomes and time endowments imply larger utility changes, making health risk more important. Health effects account for large fractions of the differences across education groups in average wage offers, labor supply and reliance on government transfers.

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This paper contributes to the rapidly expanding life-cycle model literature incorporating health risk (e.g., Palumbo, 1999; French, 2005; Hall and Jones, 2007; De Nardi et al., 2010; Attanasio et al., 2010; French and Jones, 2011; Jung and Tran, 2011; Pashchenko and Porapakkarm, 2013; Kopecky and Koreshkova, 2014). One of the key motivations in the existing literature has been understanding how saving and retirement behaviors relate to old age medical expenditure and longevity risks. Rising health care costs and the need to finance medical care in the face of aging populations have made these issues increasingly important.

The main contribution of this paper is to study health risk over the entire life-cycle in a unified framework, and to provide a better understanding of the channels through which health status and health status risk affect individuals and their economic decisions. French and Jones (2011) and Pashchenko and Porapakkarm (2013) are the only existing papers that model all four channels studied in this paper. French and Jones (2011) focus on retirement behavior and their paper studies the effects of health on labor supply around retirement age only. Pashchenko and Porapakkarm (2013) focus on the distortions that the Medicaid program creates for labor supply decisions. Other studies incorporate some but not all four channels.[1]

Statistics indicate that all these four channels are important. For example, 8.3% of working age men report having a health problem or a disability preventing them from working or limiting the kind or amount of work. On average, men in poor health spend between 3 and 17 times as much on medical goods and services as those in good or excellent health, depending on their age group. Statistics from the 2010 American Time Use Survey show that men who purchase medical and care services spend on average 1.65 h per day in these activities, and those who engage in health related self-care (excluding exercise) spend on an average 1.5 h per day, thus limiting the time available for leisure and work. Finally, statistics on survival rates show health risk is closely linked to survival uncertainty: for example, a 65 year old male in poor health has a 10% chance of death within the year compared to only 0.5% for a male of the same age in good or excellent health.[2] In addition, the joint occurrences of these effects suggest that it is important to consider how they interact. Lower earnings caused by bad health occur at the same time as required medical expenses increase. A diminished productivity and a decrease in available time due to bad health could force individuals to take time off work, losing income and employer sponsored health insurance precisely when they need it the most.

The framework used in this paper is a standard Bewley et al. (1986) life-cycle model with incomplete markets and uninsurable income risk augmented with health shocks as previously done in French and Jones (2011). In each period, agents make a discrete work choice and a continuous consumption/savings choice. Important model assumptions are that health status and medical expenditures evolve exogenously and health affects individuals through the four channels described above but does not directly impact preferences. Since it is important to match the degree of health risk observed in the data, I model partial insurance through a consumption floor, Medicaid and Medicare programs, and employer sponsored health insurance. I calibrate the model to the U.S. using data on non-institutionalized civilian males, separately for college and non-college education groups, explicitly studying differences between them. The model approximates well life-cycle earnings, the degree of reliance on government transfers, labor supply and asset profiles observed in the data, enabling me to study the effects of health risk on these variables.

In order to assess the importance of the four channels, two sets of experiments are conducted. First, I eliminate the four health effects, individually and in combinations, by assigning all individuals the productivities, time endowments, survival probabilities and medical expenditures of those in good health. Second, I focus on the risk implied by these channels and conduct experiments removing only the variation in productivity, time endowments, survival probabilities and medical expenditures around the average levels within age-education groups.

The presence of negative health shocks over the life-cycle has very large effects on welfare, labor supply and asset accumulation, especially for the non-college education group. For this group, health induced productivity and time costs impact labor supply and asset accumulation decisions significantly during the working stage of life. The removal of these two effects leads to a 10% increase in non-college labor supply. The risk implied by health's effects on productivity and available time generates large precautionary savings. This is the case even for the lower income group because relying on the consumption floor during periods of bad health when leisure time is also low is associated with extremely low utility levels. The risk generated by these two channels accounts for 13% of asset accumulation before the age of 60 for the non-college educated. It also accounts for 4.2% of earnings inequality and for 5.8% of disposable wealth inequality among non-retirees, within the non-college group.

Health effects account for 47% of the 7 percentage point difference in labor supply between the education groups. The effect of health on productivity accounts for 4% of the college wage premium among workers, and for 10% of the college premium in wage offers in the model, before selection into the labor force. Also, I find that among middle aged individuals,

[1] For example, French (2005) does not model medical expenditures, Attanasio et al. (2010) do not model the time endowment effect, and Hubbard et al. (1995) do not model the productivity effect nor the time endowment effect. In addition, papers that study health effects before retirement do not look at the importance of individual channels. De Nardi et al. (2010) and Kopecky and Koreshkova (2014) study individual channels, but only after retirement age.

[2] The statistic on work limitations is calculated using CPS data. Medical expenditures are calculated using the Medical Expenditure Panel Survey, and survival rates are calculated using the Health and Retirement Survey. The data sets are described in detail in the Online Appendix, available at http://dx.doi.org/10.1016/j.jmoneco.2015.06.002.

7% of the non-college group and only 1% of the college group receive government transfers (i.e., rely on the consumption floor) due to the negative effects of adverse health.

Finally, health effects have extremely large impacts on welfare. When all individuals receive the productivity, time endowments and medical expenditures associated with good health throughout the entire life-cycle with certainty, the non-college group's CEV is 16.7% and the college group's is 5.8%. However, fluctuations in health status around the average health levels within age-education groups have relatively small welfare effects (the removal of health risk around average health levels leads to welfare improvements of 1.17% in terms of CEV for the non-college and 0.25% for the college educated).

## 2. The model

The framework is a standard life-cycle model based on Bewley et al. (1986), French (2005), French and Jones (2011) and Attanasio et al. (2010). Individuals face three types of uncertainty: survival uncertainty, health uncertainty, and labor earnings uncertainty. They choose consumption and make a labor force participation decision when younger than 65. They are allowed to accumulate assets but cannot borrow. The model is solved in partial equilibrium, assuming a small open economy with a fixed interest rate.

In each period, an individual's health status is either good ($G$), average ($A$) or poor ($P$).[3] Average and poor health states affect individuals by (1) lowering their productivity, (2) increasing their medical expenditures, (3) decreasing their time endowments and (4) lowering their survival probabilities relative to those in good health. Therefore, health status risk generates uncertainty through these four separate channels. There are two education groups, non-college and college, and health effects are allowed to differ across these groups.[4]

### 2.1. Demographics

Individuals enter the model at the age of 18 for the non-college group and 22 for college graduates. The college decision is exogenous. The model is written for single male individuals, abstracting from marriage decisions. All workers retire at the age of 65. Workers can simply exit the labor force any time, however, Social Security benefits can only be collected starting at the age of 65.

Individuals face survival uncertainty at every age until 100 when they die with certainty. The probability of surviving to the next period depends on age ($j$) and health status ($h$), and is given by the function $s(j,h)$.

### 2.2. Health status, medical costs and health insurance

Health status evolves stochastically according to the transition function $\Lambda_{e,j}(h,h')$ where $h \in \{G,A,P\}$. The probability of a given health state next period depends on the individual's age ($j$), education ($e$), and current health state ($h$). As in much of the closely related literature, this paper abstracts from investment in health, so individuals cannot change the health transition probabilities through health investments (i.e., French, 2005; De Nardi et al., 2010; Attanasio et al., 2010; French and Jones, 2011). The distribution of health status in the first period is given by $\Pi_e(h)$.

Medical expenditures $m(j,h)$ are modeled as negative income shocks that depend on age and health status. They must be incurred in every period in order to survive to the next but they have no effect on future health status. All medical expense uncertainty comes from health uncertainty.[5]

As in Attanasio et al. (2010) and French and Jones (2011), there are three types of medical expenditure insurance: employer-based insurance, Medicare and social assistance (Medicaid).

*Employer Provided Health Insurance*: An exogenous fraction of the population has employer-sponsored health insurance. For those younger than 65, this insurance is available only during periods when individuals participate in the labor force. It covers a fraction $k^w$ of total medical expenditures. For a fraction of these individuals, the employer sponsored health insurance extends into retirement, covering $k^{ret}$ percent of expenditures after the age of 65. Let $i \in \{0,1,2\}$ denote the employer insurance type with $i=0$ indicating no coverage, $i=1$ indicating employer sponsored coverage only when working, and $i=2$ indicating coverage when working and also when retired. Each individual's type $i$ is determined when he enters the labor force according to a random draw from the distribution $\Omega_e(i)$ which depends on education. For simplicity, the employer health insurance type remains fixed for the entire lifetime, as in Attanasio et al. (2010). Workers of type $i=1$ or

[3] Most previous papers modeling health assume only two health states (good and bad). Only Low and Pistaferri (2010) distinguish between moderate and severe work limitations (disabilities). I show it is important to model the poor health state separately because this state is associated with much larger effects through all four channels modeled.

[4] There are no statistically significant differences in survival probabilities and medical expenditures across education groups in the data, after controlling for age and health status. (The Online Appendix provides the details.) Therefore, the model is written with survival and medical expenditures independent of education.

[5] I abstract from medical expense variation within health and age groups. Previous papers that model medical expense variation around the deterministic component find that shutting down out-of-pocket medical expense risk while keeping average medical expenditures constant (conditional on all of the relevant state variables) has only small effects. De Nardi et al. (2010) and Hubbard et al. (1994) find that conditional on average medical expenses, the risk associated with the volatility of medical expenses has only a small effect on the profiles of median wealth, and Palumbo (1999) finds that eliminating medical expense risk has only small effects on consumption and assets.

$i=2$ pay a premium $p^w$ deducted from their earnings and not subject to income tax. Individuals of type $i=2$ pay a premium $p^{ret}$ when retired.

*Medicare*: Starting at the age of 65, all individuals are covered by Medicare. Medicare pays for a fraction $k^{med}$ of medical expenditures and is financed through proportional payroll taxes $\tau^m$ and premiums $p^{med}$ paid by those over 65.

*Medicaid*: The Medicaid program pays the medical costs of individuals who cannot afford them or who cannot afford a minimum level of consumption after incurring the medical costs. I model Medicaid through the inclusion of a consumption floor, discussed below.

### 2.3. Social Security and social insurance

The government runs a social assistance safety net program which guarantees a minimum level of consumption $\bar{c}$ to every individual. When disposable income (net of required medical expenditures) falls below $\bar{c}$, the person receives a transfer *tr* that compensates for the difference. The Medicaid program covers any medical expenditures that consumption floor recipients cannot afford to pay.

Finally, retirees receive Social Security payments $SS(e)$ which vary with education but are independent of earning histories and are financed by proportional payroll taxes $\tau^s$ paid up to an income threshold $\bar{y}$, set to 2.5 times average earnings.

### 2.4. Preferences

Each period, individuals derive utility from consumption ($c$) and leisure ($l$). Following French (2005) and French and Jones (2011), the within period utility is assumed to take a Cobb–Douglas form over consumption and leisure

$$U(c, I_n, h) = \frac{1}{1-\sigma}[c^{\alpha}(1-\theta I_n - \Phi_1 I_{h=A} - \Phi_2 I_{h=P})^{(1-\alpha)}]^{1-\sigma}. \tag{1}$$

$c$ denotes consumption of non-medical goods. The per period time endowment is normalized to one, and the quantity of leisure consumed is $1-\theta I_n - \Phi_1 I_{h=A} - \Phi_2 I_{h=P}$. The indicator $I_n \in \{0,1\}$ denotes the discrete labor force participation choice, with $I_n=1$ indicating full time work and $I_n=0$ indicating the individual is not employed. $\theta$ captures the time cost associated with full time work. It is equal to time spent in productive work, plus a non-productive time cost stemming from preparing for work, commuting time, work related social activities and time spent thinking about work-related problems (Donald and Hamermesh, 2009).

$I_{h=A}$ and $I_{h=P}$ are indicator functions equal to 1 if the individual is in average or poor health, and $\Phi_1$ and $\Phi_2$ are the time costs associated with average and poor health states, respectively. As in French (2005) and French and Jones (2011), health does not enter the utility directly, but has an indirect effect on utility through the time costs. This modeling choice is supported by statistics from the American Time Use Survey that show that individuals spend a significant amount of time on health care activities such as purchasing medical and care services.[6]

The parameters $\theta$, $\Phi_1$, $\Phi_2$, and $\sigma$ are allowed to differ with education, but the notation is suppressed. Differences across education groups in $\theta$ may arise due to differences in types of occupations and average commuting times. Differences in $\Phi_1$ and $\Phi_2$ may arise due to different abilities to plan and follow instructions. For example, Smith (2007) finds that the less-educated have considerable difficulty in disease management using the complex treatments necessary to diminish the negative health consequences associated with diabetes.

The Cobb-Douglas preference specification allows for non-separability between consumption and leisure.[7] The parameter $\sigma$ governs the degree of non-separability. When $\sigma > 1$, consumption and leisure are Frisch substitutes, so the marginal utility of consumption is decreasing in leisure. This plays an important role in generating hump shaped consumption age profiles and in generating a drop in consumption at the age of retirement. Also, when consumption and leisure are substitutes, health shocks reduce the time endowment and increase the marginal utility of consumption (holding labor supply constant). This effect is consistent with the findings in Lillard and Weiss (1997) and Edwards (2008) that the marginal utility of consumption increases after health shocks.[8] The parameter $\sigma$ controls the extent to which the marginal utility of consumption rises in response to reductions in leisure. Higher values of $\sigma$ imply larger increases, so individuals desire to increase consumption by more when they experience negative health shocks.

The parameter $\sigma$ also represents the coefficient of relative risk aversion for total utility. Higher values imply that individuals are more risk averse, and the precautionary saving motive becomes stronger. Therefore, $\sigma$ plays an important role in determining the importance of health risk through the four channels studied.

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[6] Examples of time costs are doctor appointments (e.g., searching for a doctor, traveling to the appointment, waiting time in the office, talking to the doctor, filling out forms), undergoing tests, procedures and treatments (e.g., surgeries, physiotherapy visits), time spent buying prescribed medication, and time lost due to activity limitations (e.g., walking slower on crutches).

[7] This utility specification is based on French (2005). In sensitivity analysis, French (2005) finds that a utility function that is separable in consumption and leisure does not fit the data as well as the non-separable preference specification. Heckman (1974) and Browning and Meghir (1991) present empirical evidence consistent with non-separability.

[8] However, Finkelstein et al. (2013) conclude the opposite for the elderly and near-elderly.

### 2.5. Labor earnings

The logarithm of wages at age $j$, $\ln(W_j)$ is equal to the sum of a deterministic component $w(h,j)$ which is a function of health and age, an individual fixed effect determined at birth $\overline{\mu} \sim N(0, \sigma^2_{\overline{\mu}})$, an idiosyncratic transitory shock $\lambda \sim N(0, \sigma^2_{\lambda})$, and an idiosyncratic shock $u$ following an AR(1) process:

$$\ln(W_j) = w(h,j) + \overline{\mu} + \lambda + u. \tag{2}$$

The autoregressive component has a correlation coefficient $\rho$, and innovation $\eta$

$$u = \rho u_{-1} + \eta, \quad u_0 = 0, \quad \eta \sim N(0, \sigma^2_{\eta}). \tag{3}$$

The deterministic productivity component is a function of age, age squared and age cubed, health, and health interacted with age

$$w(h,j) = \beta_0 + \beta_1 j + \beta_2 j^2 + \beta_3 j^3 + (\beta_4 + \beta_5 j) I_{h \in \{A,G\}} + (\beta_6 + \beta_7 j) I_{h=G}. \tag{4}$$

$I_{h \in \{A,G\}}$ is an indicator equal to 1 for individuals in average or good health and equal to 0 for those in poor health, and $I_{h=G}$ is an indicator equal to one for those in good health and equal to zero otherwise. All components are allowed to vary with education, but the notation is suppressed.

### 2.6. The individual's problem

The decision problem of an individual is described using recursive language. The state of an individual younger than 65 is given by education attainment $e$, type of health insurance $i$, age $j$, health status $h$, productivity type $\overline{\mu}$, the realizations of the idiosyncratic labor income shock $u$ and of the transitory shock $\lambda$, and assets $a$ from the previous period. In each period, an individual maximizes the expected discounted lifetime utility by choosing the period consumption level $c$ and making a labor force participation decision, $I_n$.

The value of state $\{e, i, j, h, \overline{\mu}, u, \lambda, a\}$ is

$$V(e,i,j,h,\overline{\mu},u,\lambda,a) = \max_{\{c, I_n\}} \{U(c, I_n, h) + \beta s(j,h) EV(e,i,j+1,h',\overline{\mu},u',\lambda',a')\} \tag{5}$$

subject to

$$a' = x_{(j)} + tr - (1+\tau^c)c \tag{6}$$

$$\mathrm{tr} = \max\{0, (1+\tau^c)\overline{c} - x_{(j)}\} \tag{7}$$

$$c \le \frac{1}{1+\tau^c}\left(tr + x_{(j)}\right) \tag{8}$$

$$h' \sim \Lambda_{e,j}(h,h'), h_{j=1} \sim \Pi_e(h) \tag{9}$$

$$x_{(j<65)} \equiv [1+(1-\tau^r)(r-1)]a + I_n(1-\tau^w)[W_j - p^w I_{i \in \{1,2\}} - 0.5(\tau^s+\tau^m)\min\{W_j, \overline{y}\}] - (1-k^w I_n I_{i\in\{1,2\}}) m(j,h) \tag{10}$$

and Eqs. (1)–(4).

Let $x_{(j)}$ denote total available financial resources per period before any government transfers. For an individual younger than 65, $x$ equals previous period assets plus interest income (subject to a capital income tax $\tau^r$), plus labor earnings $W_j$ (net of labor income taxes $\tau^w$, Social Security taxes $\tau^s$, medicare taxes $\tau^m$, and health insurance premiums $p^w$), minus out-of-pocket medical expenditures.

$I_{i \in \{1,2\}}$ is an indicator function equal to 1 for those with employer provided health insurance ($i \in \{1,2\}$), and equal to zero otherwise ($i=0$). The premium $p^w$ and medical benefits $k^w$ apply only to workers with employer health insurance.

Constraint (6) summarizes the evolution of assets. Individuals enter the model with zero assets. Next period assets are equal to total financial resources plus a government transfer when applicable, less consumption (subject to a tax $\tau^c$). Eq. (7) describes the government transfer $tr$ that guarantees a minimum consumption level $\overline{c}$. Eq. (8) is a zero borrowing constraint. When older than 65, individuals choose only consumption given the state $\{e, i, j, h, a\}$. The value of this state is

$$V_r(e,i,j,h,a) = \max_{\{c\}}\left\{U(c,h) + \beta s(j,h) EV_r(e,i,j+1,h',a')\right\} \tag{11}$$

subject to

$$x_{(j>64)} \equiv [1+(1-\tau^r)(r-1)]a + SS(e) - [1-k^{med} - k^{ret} I_{i=2}] m(j,h) - p^{med} - p^{ret} I_{i=2} \tag{12}$$

and Eqs. (1), (6)–(9).

Total financial resources before government transfers are now equal to previous period assets plus interest income (subject to a capital income tax $\tau^r$), plus Social Security income $SS(e)$, minus out of pocket medical expenditures, minus Medicare premiums $p^{med}$. Medicare benefits cover a fraction $k^{med}$ of total medical expenditures. If individuals have employer sponsored health insurance extending into retirement (the indicator function $I_{i=2}$ equals one), they pay an additional premium $p^{ret}$ and an additional fraction $k^{ret}$ of their total medical expenditures is covered by insurance.

Most parameters vary across education groups, but the education subscripts are omitted to avoid clutter. The only parameters that are not education specific are the consumption weight in the utility function $\alpha$, the interest rate $r$, tax rates except for the labor income tax, the consumption floor, insurance premiums and coinsurance rates, medical expenditures and survival rates.

### 2.7. Health effects summary

During the working stage of life, a health shock affects an individual's working and saving decisions through the four channels in ways that may work in opposite directions. Following a negative health shock, lower productivity and higher medical expenditures reduce available financial resources and lead to lower desired consumption. On the other hand, a lower survival probability and a lower time endowment (assuming the labor supply does not change) increase desired consumption.

The four health channels affect decisions in a complex way due to the labor force participation decision and the availability of employer sponsored health insurance to a fraction of workers. Lower productivity and a reduction in the time endowment caused by adverse health make labor force participation less attractive. On the other hand, there is a greater incentive to work in order to offset the negative effect of higher medical expenditures on the budget through labor earnings. Individuals who receive employer sponsored health insurance only if they work potentially face strong work incentives, especially if their expected medical expenditures are high.

Health effects depend crucially on the modeling choices. For example, in an alternative model without a labor force participation decision where earnings are equal to a fraction of the time endowment multiplied by productivity, the effect of adverse health would be that the lower time endowment, lower productivity and higher medical expenditures reduce the available budget together in an isomorphic fashion. The labor force participation decision enriches the model and enables it to capture the complex interactions between different health channels. For example, the budget of a high productivity worker could change relatively little in response to a health shock as long as he remains in the labor force, but a lower time endowment could lower the incentive to work enough to induce the individual to exit the labor force and hence experience a large decrease in income.

## 3. Data

An ideal data set for this study would be a representative panel of individuals observed over several years containing information on demographics, health status, medical expenditures, health insurance, earnings and assets, consumption, and employment status. Unfortunately, no such comprehensive survey exists, so I utilize several data sets which together enable me to estimate the required parameters and statistics: (1) Health and Retirement Survey (HRS), (2) Medical Expenditure Panel Survey (MEPS), (3) Current Population Survey (CPS), (4) Panel Study of Income Dynamics (PSID) and (5) Consumer Expenditure Survey (CEX). The Online Appendix describes the data sets in detail, presents information on the variables used in the analysis, and discusses issues of comparability across data sets.

While most of these surveys extract some information related to health, the HRS and MEPS surveys contain the most detailed variables on health, insurance and medical expenditures. An advantage of the MEPS survey is that it includes individuals of all adult ages. However, MEPS includes relatively few observations for ages above 70. The HRS is a national panel survey of individuals aged 51 and above and contains detailed information on the elderly. Data from the PSID is used in estimating wage process parameters which requires a longer panel dimension. I also use the PSID Wealth Surveys for data on assets. I use the CPS for aggregate statistics that do not require a panel structure due to its large sample size. The CEX is used since it is the best survey available to study consumption over the life cycle.

Table A.1 in the Online Appendix presents the number of observations in each data set and shows how sample restrictions affect sample size. Statistics are calculated using sampling weights and are averages across all cohorts and years. The Online Appendix presents information on cohort and time effects in selected variables and discusses their implications for the model results. Labor supply statistics are calculated using full time workers only, defined as workers who are not self-employed and who work more than 30 h per week and at least 48 weeks per year. Part-time and part-year workers are classified as not employed. Wage statistics are calculated using only full time workers with hourly wages greater than half of the minimum wage in the corresponding year. All dollar amounts are CPI adjusted to 2006 U.S. dollars.

## 4. Calibration

The benchmark model is calibrated to match the US economy during the time period 1996–2010, for civilian, non-institutionalized males who are not attending school. The calibration is conducted separately for the two education groups in the model. The non-college group includes those with a high-school degree and no years of college, and the college group includes all those with four or more years of college.[9]

[9] I focus on these two education groups since they are the largest in the adult male population (32% and 29%, respectively). High school and college dropouts are very different from high school and college graduates so they cannot be combined. High school dropouts have significantly worse health

The strategy used is to estimate some of the parameters directly from the data and to simultaneously calibrate others by matching specific moments on labor supply, earnings, consumption and assets observed in the data. The parameters that can be estimated directly from the data are the parameters summarizing health insurance coverage and premiums, health status transitions, medical expenditures, and survival probabilities. The parameters that need to be calibrated by matching moments are the parameters of the utility function (except $\alpha$), all the parameters determining the wage process, and the time discount factor. Table 1 provides a summary of the tax and Social Security environment, and lists the fixed parameters taken as given in the model.

*Model period and time endowments*: The model period is set to be a year. The time endowment is set to 5200 h per year (100 h per week).

*Health status*: Health is measured by respondents' perceived health status, rated consistently on a scale from 1 to 5 in all data sets containing this variable.[10] I group these five states into three: the good health state (G) corresponds to a self-reported health status of excellent or very good; the average health state (A) corresponds to a self-reported health status of good or fair; and the poor health state (P) corresponds to a self-reported health status of poor.[11]

*Survival probabilities*: Mortality rates by health status and age are estimated using the HRS Tracker files. The HRS reports the exact death dates of individuals who die during each past or current wave of interview. Mortality probabilities at ages younger than 53 are assumed to follow a linear trend from zero to the estimated death probability at the age of 53. It is assumed that death occurs with certainty at age 100. Fig. 1 presents the estimated mortality probabilities, revealing that mortality rates increase greatly as health status deteriorates, especially at old ages. There are no statistically significant differences in mortality rates across education groups, conditional on health status and age.

*Health status transitions*: Health transition probabilities by education and age are estimated using the MEPS data. I use a logistic regression model that includes age, age squared and age cubed. Since the MEPS data set contains relatively few observations for individuals older than 80, transition probabilities at these ages are predicted out of sample. Fig. 2 shows selected health transition probability age profiles. As expected, the probability of deteriorating health increases with age and the college educated group is less likely to transition to bad health states at almost all ages.

*Health insurance*: Table 2 reports the fraction of the working male population by employer health insurance type, estimated from the CPS. Since I abstract from modeling individually purchased health insurance, the statistics are calculated assigning those who buy insurance privately in the "no insurance group".[12] The college group contains a smaller fraction of uninsured workers and a significantly higher percentage of workers whose insurance extends into retirement.

The annual Medicare part B premium is set to $854, obtained from an average of CPI adjusted premiums over the sample period. The annual single coverage employer-sponsored health insurance premium is $3,548 for an active worker, and $3,497 for a retired worker over 65. The employee share of this premium is 18 percent for active workers, and 45 percent for retirees. The statistics for active workers are calculated using the MEPS Insurance Component data set. The statistics for retired workers are taken from Buchmueller et al. (2006). I take the health insurance coinsurance rates from Attanasio et al. (2010) who estimate that Medicare, employer health insurance while working, and employer health insurance extending into retirement cover on average 50%, 70% and 30% of total medical expenditures, respectively.

*Medical expenditures*: Average total health expenditures by age and health status are estimated from MEPS and are reported in Table 3. These expenditures include out-of-pocket expenditures plus what is covered by insurance, but they do not include insurance premiums since these are accounted for separately. Since MEPS does not collect information for the institutionalized population, nursing home costs are not included in total expenditures. Nursing home costs are part of regular consumption in the model.[13] In addition, MEPS might not capture late life medical expenses associated with any serious illness that results in a quick death. The sample size of individuals over 70 is relatively small in MEPS, so this requires relatively broader age groups in order to maintain a large enough sample of individuals. There are no statistically significant differences in medical expenditures across education groups, conditional on health status and age.

(*footnote continued*)
outcomes than high school graduates based on CPS data. College dropouts have better outcomes than high school graduates but significantly worse than college graduates.

[10] The validity of the self-reported health status measure has been discussed extensively in previous literature (e.g., Benìtez-Silva and Ni, 2008; Crossley and Kennedy, 2002; Baker, 2004; Hurd and McGarry, 1995). The general finding is that this measure is subject to both positive and negative biases arising from endogeneity and measurement error.

[11] The grouping is based on observed similarities in earnings and labor supply. The Online Appendix provides a discussion of potential biases introduced by the aggregation and how they likely affect the model results.

[12] French and Jones (2011) note that this categorization is appropriate because private health insurance is a poor substitute for employer-provided coverage, as high administrative costs and adverse selection problems can result in prohibitively expensive premiums. Also, private insurance usually does not cover pre-existing medical conditions. Therefore, those with private health insurance usually still face very high health care costs. The percentage of individuals not offered employer sponsored insurance who buy it privately is 4.6% for the non-college and 6.2% for the college group, respectively.

[13] The model generates higher consumption levels in poor health than in good health states in the wealthy elderly group because the marginal utility of consumption is higher in bad health states due to the decrease in leisure time. The wealthy old also consume more in poor health states since poor health is associated with very high probabilities of death at old ages. If we consider only the consumption value of nursing homes, then the model could endogenously generate high consumption of nursing homes among the elderly.

**Table 1**
Model parameters.

| Parameter | Description | Values | | |
|---|---|---|---|---|
| $\alpha$ | Consumption weight (utility) | | 0.4 | |
| $r$ | Interest rate | | 1.04 | |
| **Taxes %** | | | | |
| $\tau^r$ | Capital income tax | | 40.0 | |
| $\tau^c$ | Consumption tax | | 5.7 | |
| $\tau^s$ | Social Security tax | | 6.2 | |
| $\tau^m$ | Medicare tax | | 1.45 | |
| | | Non-college | | College |
| $\tau^w$ | Labor income tax | 16.0 | | 19.0 |
| **Social Security and social insurance** | | | | |
| $\overline{c}$ | Consumption floor | | \$4,114 | |
| $SS$ | Social Security income | \$12,325 | | \$13,513 |

*Notes*: The consumption floor is set at 10% of the average earnings of males observed in CPS data. Social Security income figures are estimated using CPS data.

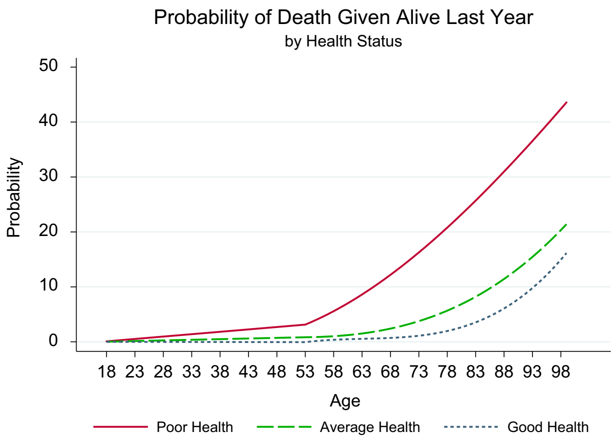


**Fig. 1.** Mortality probabilities given alive last year, by health status and age. *Data source*: HRS. Note: Probabilities at ages lower than 53 are imputed, and follow a linear trend from zero to the estimated probability at age 53.

*Consumption floor*: The consumption floor is set to 10% of male average earnings, as in Attanasio et al. (2010) and consistent with the estimates in French and Jones (2011).[14]

*Calibration of time discount factor, labor productivity, and preference parameters*: I jointly calibrate the time discount factor $\beta$, the earnings process parameters $\beta_0 - \beta_7, \rho, \sigma^2_{\overline{\mu}}, \sigma^2_{\eta}, \sigma^2_{\lambda}$, the parameters in the utility function associated with the time costs of work and bad health $\theta, \Phi_1$ and $\Phi_2$, and the coefficient of relative risk aversion for total utility, $\sigma$.

The calibration targets key moments on labor supply, earnings, and savings observed in the data. Specifically, the calibration minimizes the sum of the squared differences between the targets in the data and their counterparts in the simulated data, weighting all targets equally. All calibrated parameters are allowed to vary with education, and all targets are education specific. The model is simulated using 300 grid points for assets (constructed specific to each individual state), 2 grid points for the individual fixed productivity effect $\overline{\mu}$, 5 grid points for the idiosyncratic transitory shocks $\lambda$, 15 grid points for the idiosyncratic shocks $u$, and 9 grid points for the innovation shocks $\eta$.

Table 4 lists a subset of the targets used in the calibration along with their respective data sources. In addition to these, the calibration targets (1) average wage age profiles, by education and health status, (2) the average labor force participation rates between ages 30 and 50, by education and health status, and (3) median assets age profiles between ages 30 and 50, by education. These are presented in Figs. 4, 5 and 6, respectively. While all calibrated model parameters jointly affect all the estimated moments, some parameters are relatively more important for a subset of moments. The identification of each parameter is discussed in detail below.

[14] As noted in Hubbard et al. (1995), measuring the means-tested consumption floor is difficult since potential payments from social insurance programs differ dramatically according to the number of children, marital status, age, and even the recipient's state or city. Also, I model Medicaid through the consumption floor, yet under the Medicaid eligibility rules prior to 2010, males with incomes below the poverty level were unlikely to be covered by Medicaid if they had no disabilities and no children. However, a consumption floor of 10% of average earnings is approximately 59% lower than the federal poverty level, increasing the likelihood that individuals with such low incomes are covered by Medicaid in reality as well.

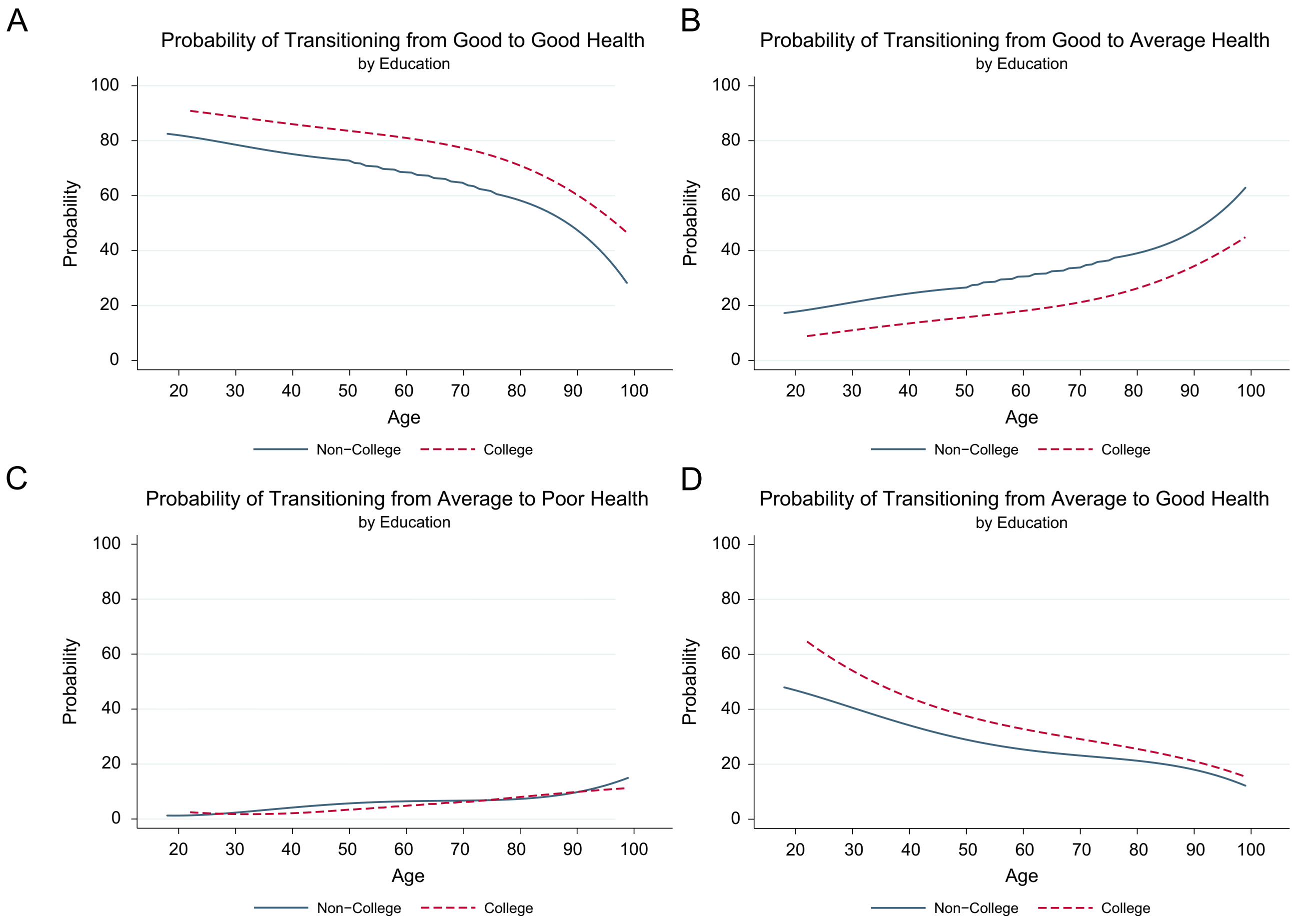


**Fig. 2.** Selected health transitions by education and age. *Data source*: MEPS.

**Table 2**
Health insurance summary.

| **% Workers by Employer Provided Health Insurance (EPHI)**[a] | | | |
|---|---|---|---|
| | **Non-college** | | **College** |
| No insurance | 19 | | 8 |
| Insurance while working only | 47 | | 48 |
| Insurance while working and in retirement | 34 | | 44 |
| **Insurance premiums**[b] (annual, single coverage) | **Total** | | **Employee share** |
| Medicare premium (part B) | | $854 | |
| EPHI Premium (workers) | $3548 | | $652 (18%) |
| EPHI Premium (retirees) | $3497 | | $1574 (45%) |
| **% of total medical expenditures paid for by different insurance types**[c] | | | |
| Medicare | | 50% | |
| EPHI, ages $<65$ | | 70% | |
| EPHI, ages $\geq 65$ | | 30% | |

[a] *Notes*: Author's calculations from CPS.
[b] *Source for Medicare premium*: Centers for Medicare and Medicaid Services http://www.cms.gov. *Source for EPHI premium (workers)*: MEPS Insurance Component. *Source for EPHI premium (retirees)*: Buchmueller et al. (2006).
[c] Figures are taken from Attanasio et al. (2010).

**Table 3**
Average annual health expenditures.

| Age group | **Health** | | | | | |
|---|---|---|---|---|---|---|
| | **Poor** | | **Average** | | **Good** | |
| 18–29 | 4,933 | (144) | 1,458 | (3554) | 636 | (9498) |
| 30–39 | 17,818 | (294) | 2,226 | (4877) | 1,026 | (11025) |
| 40–49 | 15,835 | (561) | 3,220 | (5948) | 1,412 | (10056) |
| 50–59 | 16,338 | (693) | 5,689 | (5425) | 2,433 | (7331) |
| 60–64 | 19,990 | (284) | 7,645 | (1943) | 3,634 | (2493) |
| 65–74 | 23,154 | (428) | 7,946 | (2708) | 4,023 | (2987) |
| 75–82 | 22,541 | (263) | 10,548 | (1340) | 5,384 | (1158) |
| 83+ | 21,043 | (115) | 10,444 | (424) | 6,854 | (347) |

*Notes*: Author's calculations from MEPS. Figures are in 2006 U.S. dollars. Number of observations in parenthesis.

**Table 4**
Calibration targets and model results.

| **Moments to match** | **Non-college** | | **College** | | **Data source** |
|---|---|---|---|---|---|
| | **Data** | **Model** | **Data** | **Model** | |
| $\hat{\sigma}^2_{\mu}$ | 0.09 | 0.10 | 0.07 | 0.08 | PSID |
| $\hat{\rho}$ | 0.89 | 0.89 | 0.96 | 0.97 | PSID |
| $\hat{\sigma}^2_{\eta}$ | 0.03 | 0.03 | 0.02 | 0.02 | PSID |
| % Working 2 consecutive years, ages 30–55 | 91.3 | 91.2 | 93.3 | 92.8 | CPS |
| Ratio of median assets to median labor income, ages 30–50 | 0.62 | 0.60 | 1.52 | 1.71 | PSID |

*Note*: Please see the Online Appendix for details on the estimation of targets.

The time discount factor $\beta$ and the coefficient of relative risk aversion for total utility $\sigma$ are identified by targeting moments on assets estimated using data from the PSID Supplemental Wealth files.[15] The value of $\beta$ is set so that the model

[15] Assets in the data are equal to total wealth excluding home equity. Mortgages are not included. (The Online Appendix provides more details). This is appropriate since the model does not allow for borrowing, and buying a home usually requires large mortgages. Excluding home equity may lead to a downward bias in $\beta$, and the model may therefore underestimate precautionary savings against possible serious health shocks late in life. Individuals may in fact accumulate wealth through housing to self insure against these shocks.

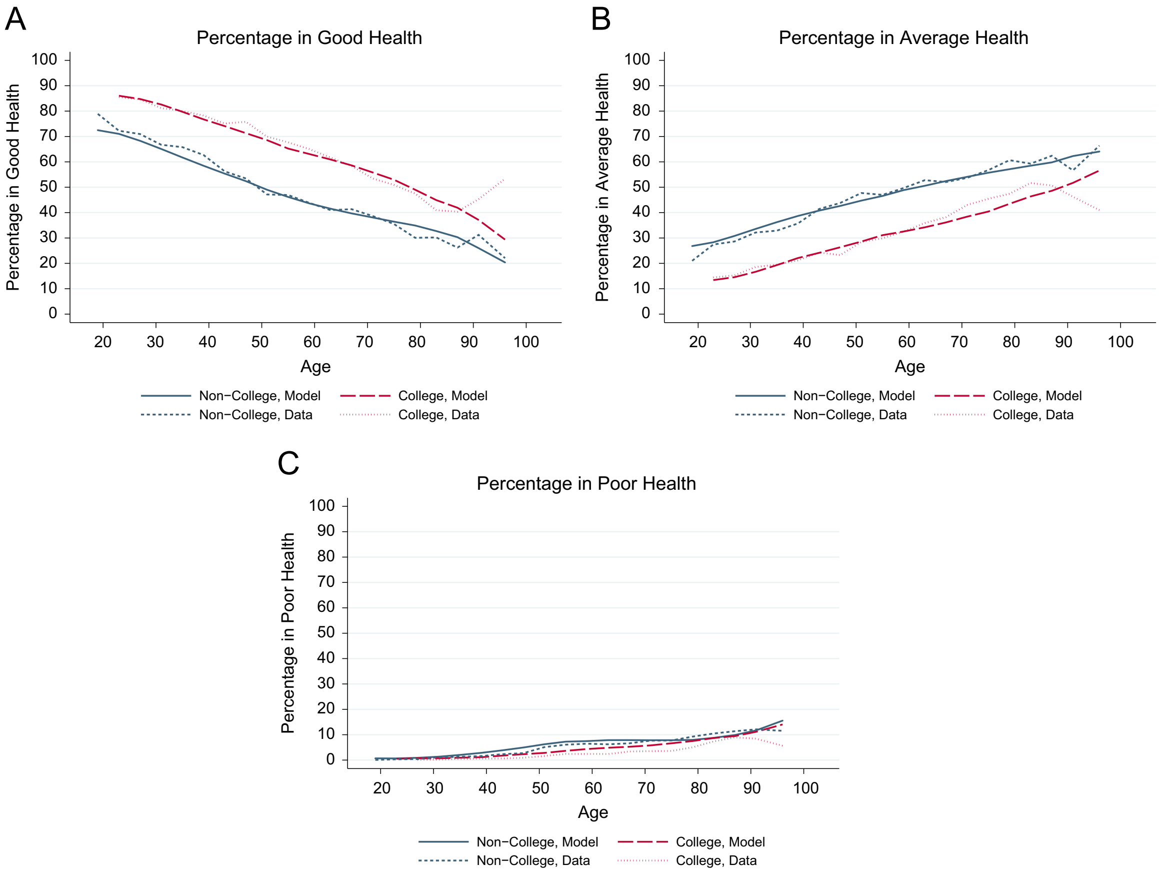


**Fig. 3.** Distribution of health in the population, by education, model and data. *Data sources*: MEPS and HRS. MEPS data was used to construct the profiles for ages 18 to 52. Profiles for ages 53 to 70 are simple averages of the profiles obtained with MEPS and HRS data. For ages 71 and above, the profiles are constructed using HRS data only.

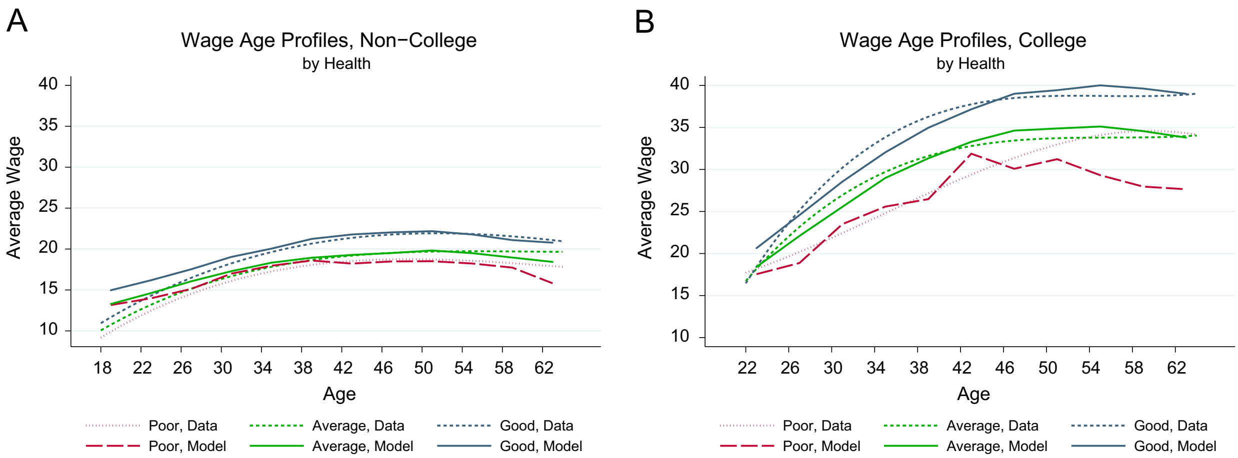


**Fig. 4.** Wage age profiles, by education and health, model and data. *Data source*: CPS.

delivers the ratio of median assets to median labor income observed in the data between ages 30 and 50. The value of $\sigma$ is set to match the growth in median assets between ages 30 and 50. The remaining parameters are identified by targeting moments on earnings and labor supply.

A major issue with observed earnings in the data is selection bias. We observe only the earnings of those who choose to work. The data reveals a strong selection effect into the labor force by education, age and health status: on average, the college group, the healthy groups and the age group 30–50 supply the most labor to the market (Fig. 5). Suppose we

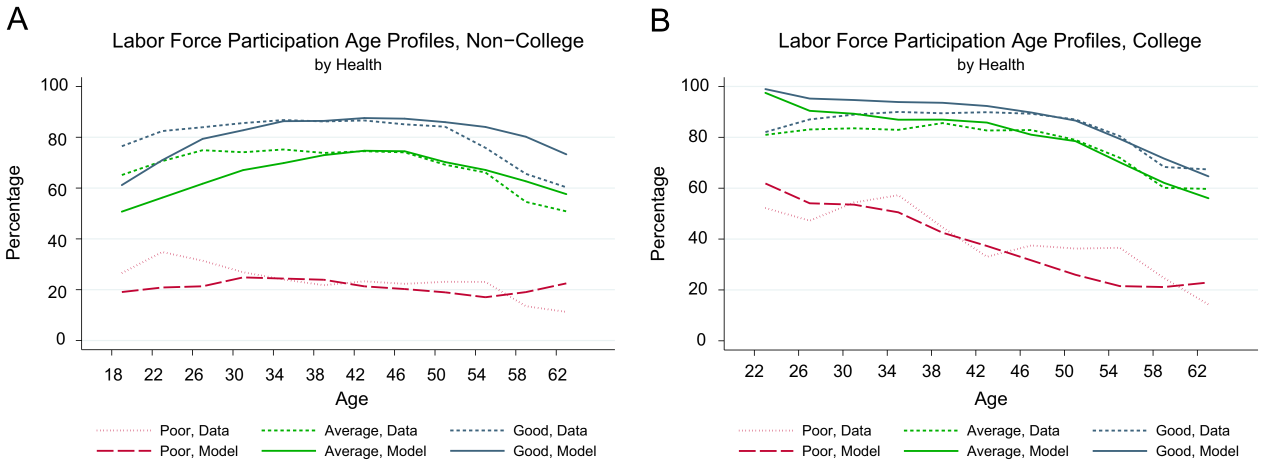


**Fig. 5.** Labor force participation, by education and health, model and data. *Data source*: CPS.

**Table 5**
Calibrated parameters.

| Parameter | Description | Values | |
|---|---|---|---|
| | | Non-college | College |
| $\Phi_1$ | Time cost of average health | 0.025 | 0.0 |
| $\Phi_2$ | Time cost of poor health | 0.21 | 0.14 |
| $\theta$ | Fixed time cost of work | 0.48 | 0.53 |
| $\beta_0$ | Constant | 0.732 | 1.29 |
| $\beta_1$ | Age coefficient | 0.074 | 0.082 |
| $\beta_2$ | Age squared coefficient | −0.00095 | −0.00112 |
| $\beta_3$ | Age cubed coefficient | 0.0000024 | 0.0000032 |
| $\beta_4$ | Avg. or Good health coefficient | 0.232 | 0.17 |
| $\beta_5$ | Avg. or Good health∗ age coefficient | 0.0 | 0.0005 |
| $\beta_6$ | Good health coefficient | 0.21 | 0.088 |
| $\beta_7$ | Good health∗ age coefficient | 0.0 | 0.0015 |
| $\rho$ | Autoregressive coefficient | 0.95 | 0.979 |
| $\sigma_{\eta^2}$ | Variance of the innovation | 0.0136 | 0.02 |
| $\sigma_{\bar{\mu}^2}$ | Variance of individual fixed effect | 0.23 | 0.04 |
| $\sigma_{\lambda^2}$ | Variance of transitory shocks | 0.0195 | 0.02 |
| $\beta$ | Time discount factor | 0.974 | 0.9782 |
| $\sigma$ | Coefficient of relative risk aversion | 2.8 | 2.8 |

*Notes*: $\theta$ includes productive time (assumed to be equal to 0.4 in the model, and equivalent to 40 h per week) plus other time costs associated with work. $\beta_0-\beta_7$ are the parameters of the deterministic component of earnings. Parameters $\rho, \sigma_\eta^2, \sigma_{\bar{\mu}}^2$, and $\sigma_\lambda^2$ are the remaining parameters of the earnings process.

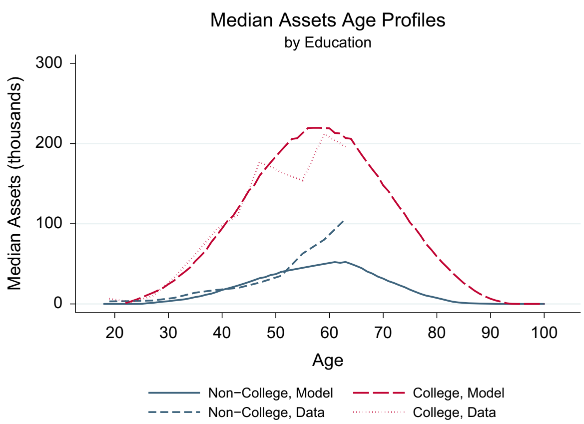


**Fig. 6.** Asset accumulation age profiles, model and data. *Data source*: PSID wealth surveys.

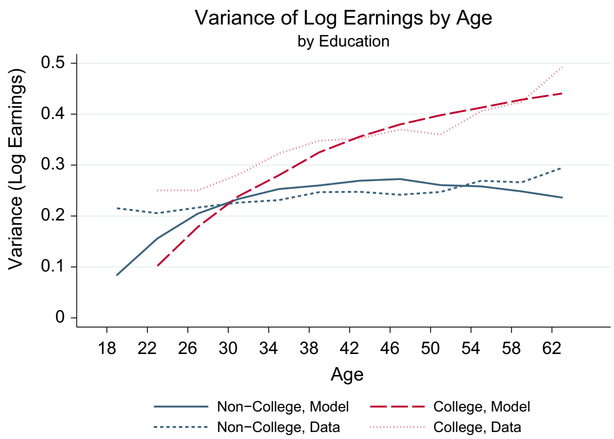


**Fig. 7.** Variance of earnings age profiles, model and data. *Data source*: CPS.

attempted to estimate the deterministic component of wages $w(j, h)$ from Eq. (4) by running a regression of log hourly wages on the corresponding age and health variables in the equation. It is likely that only workers with very good wage shocks choose to work in poor health states. This implies a negative bias on the coefficient $\beta_4$ measuring the effect of average health on wages, relative to poor health. All other coefficients are biased for similar reasons.

To solve this problem, I calibrate the model parameters $\beta_0 - \beta_7$, iterating on them until the average wage age profiles (by health status and education) of workers in the simulated data match the same profiles estimated using CPS data (Fig. 4). I assume that the bias in the earnings profiles of workers is the same in both actual and simulated data. The differences in average earnings profiles across workers of different health status help identify the effects of health on workers' productivities.

The parameters $\sigma^2_{\overline{\mu}}, \rho$ and $\sigma^2_{\eta}$ are identified similarly. Using both the model simulated data and PSID data, I run regressions of log wages on age, age squared, age cubed, health and health interacted with age. The residuals from these regressions are used to estimate the empirical (biased) counterparts of these parameters, denoted by $\hat{\sigma}^2_{\overline{\mu}}, \hat{\rho}$ and $\hat{\sigma}^2_{\eta}$. I iterate on the parameters entered in the model until the estimates from the simulated data match those estimated using the PSID.

Similar to Erosa et al. (2011), I calibrate the variance of transitory shocks $\sigma^2_{\lambda}$ by targeting the fraction of workers observed to be employed in two consecutive years in the CPS. As noted in their paper, the larger the variance of transitory wages, the less likely it is that individuals work in consecutive periods.[16]

Finally, the time costs associated with work ($\theta$) and with average and poor health ($\Phi_1$ *and* $\Phi_2$) are identified by targeting the average labor supply between the ages of 30 and 50 of different health status groups, estimated using CPS data (Fig. 5). $\theta$ includes both productive time (time spent earning wages) and other non-productive time costs associated with work such as travel. Individuals who participate in the labor force are assumed to spend 40 h out of the total 100 h of time endowment per week in productive work, so the lower bound for $\theta$ is 0.4. The additional non-productive time costs associated with work are identified by matching the labor supply profiles of those in good health. Next, $\Phi_1$ and $\Phi_2$ are identified by targeting the labor supply of those with average and poor health. The productivity costs associated with adverse health states already reduce these groups' labor supply, but not by enough to match the data. Positive time costs are needed to further decrease it to the observed levels.

## 5. Calibration results

The calibrated parameters are presented in Table 5. The time costs of poor health are large, equal to 21% and 14% of total available time for non-college and college groups, respectively. The time costs associated with average health are much smaller, approximately 3% for the non-college group, and zero for the college educated.

The effects of poor and average health on productivity are also very large. Averaging across age groups younger than 65, the percentage reductions in wages associated with average and poor health are 19% and 36%, respectively, relative to being in good health, for the non-college educated. The reductions in the wages of the college educated are smaller, equal to 14% and 28%, respectively.

Even though the calibration allows for different values of the coefficient of relative risk aversion for total utility $\sigma$ for the two education groups, the calibrated value of $\sigma$ is 2.8 for both groups. Identical preferences across education groups simplify the analysis of health risk.

[16] This method is preferred to targeting the variance of transitory shocks observed in the data since the estimated variation in the transitory component of observed wages may be too large due to the presence of measurement error in hours worked and earnings, as argued in Erosa et al. (2011).

**Table 6**
Government transfers, model and data, ages 30–55 .

| **% Receiving transfers** | | |
|---|---|---|
| | **Model** | **Data** |
| Non-college | 19 | 21 |
| College | 4 | 9 |
| **% Transfer recipients who are in poor or average health** | | |
| | **Model** | **Data** |
| Non-college | 61 | 65 |
| College | 40 | 44 |

*Notes*: *Data source*: CPS, single males only. Respondents are classified as government transfer recipients if they received any income from various public assistance programs or health insurance through Medicaid, SCHIP, or other public insurance.

### 5.1. *Performance of the model*

The calibrated model matches the targets closely and performs well in matching other statistics in the data. First, the estimated health transition probabilities and survival probabilities result in a demographic structure closely approximating the data, even for age intervals where probabilities were predicted out of sample. Fig. 3 shows the percentage of individuals in each health group by age and education, and compares the profiles in the model with those observed in the combined MEPS and HRS data. The average lifespan is 75 for the non-college and 79 for the college educated in the simulated data, consistent with U.S. life tables by education.

The model performs well in matching the targeted wage and labor force participation age profiles, by health status and education, for the majority of the working life-cycle (Figs. 4 and 5). It is extremely important to closely match these profiles since a main interest of the paper is to evaluate the impact of health effects on the labor supply of different groups. The model has difficulties in matching some of these profiles only at young ages and just before retirement.[17] In addition, the model matches very well the additional wage and labor supply moments listed in Table 4 that identify the parameters associated with the non-deterministic components of the wage process. As a result, the model performs well in matching the variance of earnings over the life cycle observed in the CPS (Fig. 7), with the exception of young ages.

The key parameters that enable the model to match labor supply profiles by health status are the fixed time costs $\theta, \Phi_1$ and $\Phi_2$, and the productivity costs associated with average and poor health states. A large time cost of poor health is required to match the very low labor supply of the poor health group. Productivity costs account for most differences in labor supply between average and good health states, so the time costs associated with average health are very low. The productivity and time costs associated with average and poor health states are higher for the non-college than college group, enabling the model to match the relative differences in average labor supply and wage profiles across education groups.

The model approximates very well the asset to income ratio of the 30–50 age group and the growth in median assets of both education groups up to age 52 (Table 4 and Fig. 6). To note is that even though asset growth up to this age is much steeper for the college than the non-college group, the model matches this with a value of $\sigma$ equal to 2.8 for both groups and very similar values of $\beta$. It is mainly differences in incomes, income shocks and heath shocks that account for the different asset growth rates across education groups, and not differences in preferences.

Since the model successfully matches earnings and asset profiles, it also performs well in matching consumption statistics. The model produces a hump shaped average consumption age profile for both education groups, generated by non-separable utility, borrowing constraints, uncertain lifetimes in the absence of annuity markets and income uncertainty (e.g., Heckman, 1974; Bullard and Feigenbaum, 2007; Hansen and Imrohoroglu, 2008; Thurow, 1969; Attanasio et al., 1999; Keane and Wolpin, 2001; Gourinchas and Parker, 2002). Consumption peaks at the age of 50 for the non-college and 54 for the college group, very close to the peaks observed in the data. Average consumption rises much faster in the college group, by 52.0% between the ages of 25 and 50, versus 32.8% for the non-college, closely matching the growth rates observed in the CEX data of 52.1% for the college and 31.4% for the non-college, and consistent with previous findings (e.g., Carroll and Summers, 1991; Guvenen, 2007).

[17] One reason why the model is not able to match these profiles at young and old ages might be that preferences for leisure are not constant throughout the life-cycle, but increase with age. The time costs associated with poor and average health states might also increase with age. This would explain the relatively low labor supply when young and high labor supply when old of the non-college in the model, compared with the data.

**Table 7**
Health and labor supply.

| Percentage change in average labor supply relative to benchmark | | | | | |
|---|---|---|---|---|---|
| **Health effect removed** | **Non-college** | **College** | **Non-college, by health** | | |
| | | | **Poor** | **Average** | **Good** |
| All | 10.8 | 1.7 | | | |
| Medical expenditures | −0.9 | −2.2 | −62.0 | −0.9 | 0.2 |
| Survival | 0.2 | 0.6 | 25.1 | 0.8 | 0.0 |
| Productivity | 7.4 | 2.2 | 129.4 | 17.8 | −0.2 |
| Time endowment | 3.3 | 0.9 | 172.6 | 4.2 | 0.1 |
| Productivity and time endowment | 9.7 | 2.5 | 257.2 | 20.5 | −0.2 |

*Notes*: The table presents the percentage changes in average labor supply relative to the benchmark as a result of assigning all individuals the medical expenditures, survival probabilities, productivity, and/or time endowments of those in good health.

**Table 8**
Health and asset accumulation.

| Percentage change in average assets for different age groups relative to benchmark | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Health channel** | **(A) Removing health effects** | | | | **(B) Removing health risk** | | | |
| | **Ages** $< 60$ | | **Ages** $\geq 60$ | | **Ages** $< 60$ | | **Ages** $\geq 60$ | |
| | **NC** | **C** | **NC** | **C** | **NC** | **C** | **NC** | **C** |
| All | 8.5 | 12.0 | 47.2 | 48.8 | −11.9 | −0.3 | −6.7 | 0.1 |
| Medical expenditures | −2.0 | −2.2 | −13.9 | −8.1 | 1.4 | 0.4 | −3.4 | −2.1 |
| Survival | 20.6 | 16.5 | 42.8 | 52.3 | 0.5 | 5.1 | 0.9 | 7.0 |
| Productivity | −1.9 | 0.5 | 15.4 | 5.8 | −8.9 | −1.7 | −4.2 | −1.1 |
| Time endowment | −9.8 | −1.8 | −3.4 | −1.3 | −6.9 | −0.3 | −3.6 | −0.9 |
| Productivity and time endowment | −8.5 | −0.4 | 13.3 | 6.0 | −12.9 | −0.8 | −8.3 | −0.2 |
| Productivity and medical expenditures | −4.8 | −1.0 | 0.0 | −1.2 | −8.3 | 0.0 | −7.7 | −1.7 |
| Productivity, time and med. exp. | −14.1 | −2.3 | −0.9 | −1.5 | −13.4 | −0.4 | −9.6 | −1.3 |
| Medical expenditures = 0, ages $\geq 65$ | −10.5 | −6.5 | −31.3 | −18.2 | – | – | – | – |
| Medical expenditures = 0, ages $< 65$ | 7.3 | 2.4 | 7.6 | 1.4 | – | – | – | – |
| Medical expenditures = 0, all ages | −3.8 | −3.3 | −26.9 | −16.8 | – | – | – | – |
| All, transitory earnings shocks removed | – | – | – | – | −16.1 | −3.0 | −7.8 | −2.8 |
| All, consumption floor is 50% of original | – | – | – | – | −16.3 | −1.7 | −16.0 | −2.3 |

*Notes*: NC and C represent the non-college and college groups. The table presents the percentage changes in mean assets for different age groups relative to the benchmark as a result of removing health effects and health risks generated through various channels. Column A presents the results of assigning all individuals the medical expenditures, survival probabilities, productivity, and/or time endowments of those in good health. Medical expenditures are also eliminated entirely for retirees, non-retirees and for all ages. Column B presents the results of eliminating health risk by giving all individuals in a given age–education group the average medical expenditures, survival rates, productivity and/or time endowments in that group. In the last two rows, all health induced risk is eliminated in the absence of transitory earnings shocks and a consumption floor that is half of the original. The numbers are percentage changes relative to new "benchmark" economies in which transitory earnings shocks are absent and the consumption floor is 50% lower.

The model also performs well in matching statistics in the data that have not been explicitly targeted in the calibration. An important aspect of the model is the degree of social insurance available to individuals through the consumption floor because this provides partial insurance against health shocks. Therefore, it is crucial to generate the same degree of reliance on government transfers in the model as in the data. Table 6 shows that the model approximates well the percentage of people receiving transfers observed in the data. It also closely matches the fraction of recipients who are in average or poor health, 65% for the non-college and 44% for the college group. The success of the model in matching these statistics supports the assumption of a 10% consumption floor level as a fraction of average earnings.

### 5.2. Importance of model assumptions

*Absence of a spouse*: The model assumes individuals are single, but approximately 75% of working age men are married and have their spouse present in the household. Partners represent a form of insurance against health shocks since they can adjust their assets and labor supply and provide care during periods of bad health. In addition, the partner's health shocks are also sources of risk. Finally, marriage and divorce may depend on health. Gallipoli and Turner (2009) show that

**Table 9**
Health and welfare.

| % Consumption Equivalent Variation (CEV) relative to benchmark | | | | |
|---|---|---|---|---|
| **Health channel** | **(A) Removal of effect** | | **(B) Removal of risk** | |
| | **Non-college** | **College** | **Non-college** | **College** |
| Medical expenditures | 3.1 | 2.0 | 0.7 | 0.4 |
| Productivity | 8.6 | 3.2 | 0.3 | −0.1 |
| Time endowment | 5.1 | 0.9 | 0.7 | 0.2 |
| Productivity and Time endowment | 14.2 | 4.3 | 1.2 | 0.2 |
| Productivity and medical expenditures | 11.4 | 5.0 | 0.7 | 0.2 |
| Productivity, time endowment and med. exp. | 16.7 | 5.8 | 1.2 | 0.3 |

*Notes*: Column A presents the % CEV of eliminating the health effects by assigning individuals the medical expenditures, productivity, and/or time endowments of those in good health. Column B presents the % CEV of eliminating the risks generated through these channels by giving all individuals in a given age–education group the average medical expenditures, productivity and/or time endowments in that group.

following disability shocks, there are increased transfers of time between spouses. Husbands (main-earners) tend to transfer consumption to wives (second-earners) who in exchange transfer their time to husbands in periods of need. This is important because it allows the husband to smooth labor supply and achieve greater levels of human capital accumulation and earnings. Therefore, married men experience smaller swings in labor supply than single men due to disability. In light of this result, abstracting from marriage implies a negative bias in the estimated time costs associated with bad health since these time costs are mainly identified by targeting the average labor supply by health status, and without the partners' time transfers, labor supply would be lower during periods of bad health.

*Absence of an intensive margin of labor supply*: Results in previous literature indicate that health has the largest effects on labor supply through the extensive margin. French (2005) documents small effects of health on hours worked but relatively larger effects on labor force participation. Yet, some workers do switch from full-time to part-time work in response to health shocks, and continue receiving income and possibly the employer health insurance. The fraction of part-time workers is relatively small (7% and 6% of the non-college and college groups' labor force), but there are differences across health groups: the fraction of part-time workers is 6% among those in good health, 9% among those in average health, and 20% among those in poor health.[18] Therefore, the model might slightly overestimate the effects of bad health by omitting the intensive margin of labor supply.

*Exogenous health transition probabilities and medical expenditures*: In reality, health outcomes are determined by both exogenous factors such as genes, environment and random events, and choice variables such as lifestyles, time spent exercising and health care expenditures. Since the existing literature is inconclusive in assessing the relative importance of these factors, I follow the literature most closely related to my paper in modeling health transition probabilities as exogenous (i.e., French, 2005; De Nardi et al., 2010; Attanasio et al., 2010; French and Jones, 2011). The model best approximates reality when exogenous factors dominate in relative importance. If choice variables played a large role, the model would fail to capture the tradeoffs between allocating resources to health production and allocating resources to work, leisure, asset accumulation and consumption.

The model in fact accounts for the largest sources of heterogeneity in health outcomes by allowing health transitions to differ by education. Smith (2007) shows that education is the primary influence through which socioeconomic status impacts future health outcomes, not financial resources. Health behaviors such as smoking are important, but again, these behaviors have a strong correlation with education.[19]

Another important assumption is that medical expenditures are income shocks. In reality, some health expenditures such as annual checkups and blood pressure medication costs are discretionary. Moral hazard also leads to heterogeneity in health expenditures across groups with and without health insurance, and the model does not account for this. Unfortunately, it is not possible to estimate discretionary and non-discretionary expenditures separately with the available data.

*Exogenous retirement age*: An exogenous retirement age could be problematic if in reality individuals adjust the age of retirement to better prepare financially for possible medical expenditures later in life. However, these effects are likely to be small. For example, French and Jones (2011) find a significant but small effect of health insurance on retirement. In reality, individuals can also apply for and start receiving Social Security benefits at the age of 62, so a large fraction of workers retires at this age. The model might overpredict the degree of health risk at ages just prior to 65 since it does not allow individuals to withdraw Social Security benefits early in the advent of bad health that makes working more painful.

[18] Only the fraction for those in poor health differs by education, and equals 22% for the non-college and 17% for the college group. Since the fractions of part-time workers are similar across education groups, the comparison between education groups is not biased by the composition effects of part time work.

[19] Health outcomes differ with education due to selection effects, unobserved factors influencing both education and health, or the contribution of skills learned in college to health. See for example Grossman et al. (1997), Cutler and Lleras-Muney (2006), Gan and Gong (2007), and Smith (2007).

However, this problem is likely minor. French (2005) finds that the tax structures of Social Security and pensions are the key determinants of the high observed job exit rates at 62 and 65, and that health plays only a minor role.

## 6. Quantitative experiments

The calibrated model is used in the next sections to assess the quantitative importance of the four health channels. In Section 6.1, I eliminate the four health effects (individually and in combinations) by assigning individuals the productivities, time endowments, survival probabilities or medical expenditures of those in good health. In these experiments, there are two effects: (1) an elimination of health risk (elimination of fluctuations around mean earnings, mean available time, mean survival and mean medical expenditures across individuals of different health states), and (2) a level effect from higher average earnings, time endowments, survival and average disposable incomes when the productivity, time, survival and medical expenditures channels are shut down, respectively. In Section 6.2, I study the effects of health risk independent of level effects by removing only the variation in productivity, time endowments, survival probabilities and medical expenditures around the average levels.

### *6.1. Health effects on labor supply, asset accumulation, and welfare*

The following experiments are conducted to determine the importance of health effects for aggregate labor supply, asset accumulation and welfare: (1) I study each effect's individual outcome on these variables by eliminating each one separately (for example, all individuals are given the productivities of those in good health) ; (2) I consider the importance of the effects at different stages of the life cycle (for example, I eliminate medical expenditures only before or after retirement age); (3) I study the effects of removing a combination of health channels simultaneously; and (4) I estimate the total effect of health by considering an environment where everyone is in good health with certainly for the entire lifetime. In each experiment, I compare the results to those of the benchmark model, defined as the calibrated model where all four health channels operate. The results are summarized in Tables 7–9.

Each effect considered separately is important for at least one variable, but the productivity and time endowment channels stand out as the most important for labor supply and welfare, especially in the non-college group. Lower productivity and available time associated with poor and average health states greatly decrease non-college labor supply, especially for those in poor health. In the absence of the productivity effect, non-college labor supply would be 7.4% higher, and in the absence of the time endowment effect, 3.3% higher (Table 7). In the college group, these numbers are only 2.2% and 0.9%, respectively.[20] On the other hand, the presence of medical expenditures leads to slightly higher labor supply because workers in poor health with employer provided health insurance are more likely to keep working when faced with high medical expenditures.[21] The welfare costs implied by health effects are large, particularly those generated through the productivity and time endowment channels: in their absence, welfare would be 8.6% and 5.1% higher in terms of CEV for the non-college group, respectively, and 3.2% and 0.9% higher for the college group (Table 9, column A).[22]

Asset accumulation is influenced by all health channels but the most important is survival (Table 8, column A). Lower survival rates associated with bad health imply higher future discount rates which significantly reduce average asset accumulation: if all individuals had the survival rates of the healthy, asset accumulation would be 21% higher for the non-college group before the age of 60 and 43% higher after 60, while for the college educated, asset accumulation would be 17% and 52% higher respectively.

I find it is important to model health effects over the entire life-cycle, especially when studying how medical expenditures affect asset accumulation. Even though medical expenditures are highest among the elderly, medical expenditures before retirement are important because they significantly decrease disposable incomes and the ability to save for late life expenditures. Table 8 shows the effects of eliminating all medical expenditures before retirement, after retirement, and for the entire life-cycle on asset accumulation. Both education groups accumulate more assets due to old age medical expenditures. In their absence, the non-college group's average assets before the age of 60 would be 10.5% lower. However, eliminating medical expenditures before retirement age leads to higher disposable incomes and an increase in average asset accumulation before the age of 60 of 7.3% for the non-college group. Eliminating all medical expenditures at all ages lowers asset accumulation for the non-college by only 3.8% before the age of 60 due to the combined effects of higher disposable incomes and less savings needed to insure against medical expenditure risk. Taking into account health effects

[20] Since the model matches labor supply age profiles in the data extremely well only between the ages of 30 and 60, I check whether the results are sensitive to restricting the sample to only 30–60 year olds, and find they change very little. The majority of the numbers presented in Table 7 increase slightly when we consider only 30–60 year olds.

[21] In the benchmark economy, the average labor supply of non-college workers with employer insurance is only 5 percentage points higher than that of workers with no insurance. In the data, this difference is 27 percentage points. In reality the provision of employer insurance is positively correlated with wages and job tenure (e.g., Dey and Flinn, 2005; Fang and Gavazza, 2011). Workers with no insurance have relatively low wages and are observed to work less, while those with insurance have high wages and work more.

[22] Welfare is defined as in Conesa et al. (2009) to equal the ex-ante expected lifetime utility of a new-born agent. Welfare changes are measured in terms of consumption equivalent variation (CEV) : switching from a consumption-labor allocation of $(c_0; l_0)$ to $(c^*; l^*)$ results in a welfare change given by $\mathrm{CEV} = \left[\frac{W(c*,l*)}{W(c_0,l_0)}\right]^{1/(\alpha(1-\sigma))} - 1$. Note that this measure cannot be used to evaluate the welfare effects of changes in survival probabilities since period utility is negative and higher survival rates lead to a lower expected lifetime utility and a negative CEV.

**Table 10**
Health risk effects on earnings and wealth inequality.

| % Change in the variance of log earnings and log disposable wealth relative to the benchmark (Ages < 65) | | | | |
|---|---|---|---|---|
| **Health risk removed** | **Earnings** | | **Disposable wealth** | |
| | **Non-college** | **College** | **Non-college** | **College** |
| All | −4.7 | −1.7 | −5.3 | −0.6 |
| Medical expenditures | −0.1 | 0.2 | 0.2 | −0.5 |
| Survival | −0.8 | 1.2 | 1.3 | 0.8 |
| Productivity | −2.9 | −2.0 | −3.5 | −1.5 |
| Time endowment | −1.2 | 0.1 | −3.5 | −2.1 |
| Productivity and time endowment | −4.2 | −1.4 | −5.8 | −2.4 |
| Productivity and medical expenditures | −3.8 | −0.9 | −3.7 | −3.0 |
| Productivity, time endowment and med. exp. | −5.0 | −2.1 | −5.2 | −2.5 |

*Notes*: Health risk is eliminated by giving all individuals in a given age-education group the average medical expenditures, survival rates, productivity and/or time endowments in that group. The variance of log annual (pre-tax) earnings is calculated keeping workers only. The variance of disposable wealth is calculated keeping all individuals younger than 65. “Disposable wealth” is equal to the total amount available to the individual to consume and save from every period.

during the pre-retirement stage is important because as the example above shows, these effects play a big role in explaining why individuals may appear to save too little for old age medical expenditures.

Finally, in an economy where all individuals are always in good health with certainty, or where health has no effects, labor supply and welfare increase substantially, especially for the non-college group. Non-college labor supply is 11% higher than in the benchmark economy in the absence of health effects, while college labor supply is only 2% higher. The non-college group's CEV is 16.7% in the absence of productivity, time and medical costs associated with bad health and the college group's CEV is 5.8%.[23]

### 6.1.1. *Differences across education groups*

The above experiments have revealed consistently that health effects are much larger for the non-college group. One reason for this is that the non-college group faces higher probabilities of bad health at any age. As a result, for example, at the age of 45, the percentage of individuals in good health is only 54% among the non-college group versus 73% among the college educated.

Second, the effect of health on productivity is larger for the non-college group. For example, at the age of 45 when labor supply is generally highest, average health reduces wages by 19% relative to good health for the non-college group, versus only 14% for the college group. Poor health reduces wages by 37% relative to good health for the non-college group, versus only 29% for the college educated.

Third, the time endowment effect associated with poor health is larger for the non-college, at 21% relative to only 14% for the college group. This can make a big difference in terms of utility since many individuals in poor health also have low assets and incomes and cannot compensate for drops in leisure by increasing consumption. Also, in general, at the lower income levels of the non-college group, fluctuations in incomes and time endowments caused by health imply larger utility changes, making health risk relatively more important.

Overall, health effects account for 47% of the 7 percentage point difference in labor supply observed in the data between education groups. This is calculated for ages 25–62 where the labor supply in the model best matches the data. The productivity and time endowment effects play the biggest roles since together, they decrease non-college labor supply by 9 percentage points while lowering college labor supply by only 2 percentage points.

The college wage premium is 45% in the benchmark economy, close to the 49% observed in the CPS data. The effect of health on productivity (which is greater for the non-college group) accounts for 4% of this premium. This figure is relatively small because the wage premium is calculated for workers, and large fractions of those in average and poor health stay out of the labor force, especially in the non-college group. Health in fact accounts for 10% of the 59% college premium in wage offers before selection into the labor force.

Finally, health effects account for 39% of the percentage difference in government transfer recipiency rates across education groups in the model. The fraction of the non-college educated group receiving government transfers is 19% in the benchmark model versus 4% for the college group (Table 6). Eliminating all health effects lowers these fractions to 12% and 3%, respectively. Since the model slightly overestimates the difference between education groups in the fractions receiving transfers, health accounts for only 32% of the percentage difference in government transfer recipiency across education groups in the data.

[23] This welfare gain would be even greater when accounting for the extra years of life gained when health has no effect on survival. As mentioned previously, this cannot be captured by the CEV measure.

### 6.2. The importance of health risk

Previous literature has extensively studied precautionary savings and the welfare costs of idiosyncratic risk, but no previous paper has estimated the importance of health risk in a life-cycle model that incorporates all four channels through which health affects individuals. This section extends this literature and shows that health risk accounts for very large fractions of accumulated assets, especially for the non-college group, mainly due to the generated productivity and time endowment risk.

In order to assess the role of health risk alone, this section presents the results of experiments where only the variation around an average effect is eliminated. The productivity risk associated with changes in health status is eliminated by giving all individuals of a particular age and education the average deterministic component of wages in that age-education group.[24] The time endowment, medical expenditure and survival risks are eliminated similarly, by giving all individuals the average time endowment, medical expenditures and survival probabilities within age-education groups.

First, to shed light on the magnitude of health risk, I study its impact on earnings and disposable wealth inequality among non-retirees (Table 10).[25] Health risk accounts for 5.3% of disposable wealth inequality for the non-college group, and only 0.6% for the college educated. Medical expenditure risk has only a small effect, while health induced productivity risk and time endowment risk each account for 3.5% of disposable wealth inequality in the non-college group. Productivity risk is the most important for earnings inequality accounting for 3% of inequality among non-college workers and 2% among college workers.

Individuals can protect themselves from health risk only through the accumulation of precautionary savings. In the non-college group, health risk accounts for 12% of average asset accumulation before the age of 60, and for 7% after age 60 (Table 8, column B). Medical expenditures risk has a modest effect before the age of 60, but accounts for 3.4% of asset accumulation after age 60. On the other hand, health induced productivity and time endowment risks are very important before the age of 60, accounting for 9% and 7% of asset accumulation, respectively, and together accounting for 13%.[26] This is explained by the large drops in utility associated with low consumption combined with low leisure in poor health states. The productivity and time endowment effects are very large for the non-college group. If individuals choose to work, they enjoy very little leisure while productivity and earnings are also low, and if they stop working, they receive no earnings while leisure is still relatively low due to the time costs associated with bad health.

This highlights the point that the interactions between channels are complex, mainly due to the labor force participation decision. For workers who continue participating in the labor force after a health shock, time endowment reductions, medical expenditures and productivity losses are each more painful due to the presence of the other effects. The interactions between these lead to additional precautionary savings against the possibility of their joint occurrence. However, productivity risk is relevant only for workers. Time endowment reductions push a fraction of workers out of the labor force, making any productivity losses irrelevant. For this group, the effects of the productivity and time endowment channels do not amplify each other.

In the case of the non-college group, precautionary savings overall increase due to the joint occurrence of these adverse health effects. The elimination of the time endowment effect leads to 6.9% lower average asset accumulation before age 60, but when the time endowment effect is eliminated in the absence of the productivity effect, asset accumulation declines by only 4%. Additional savings are required to self insure against the joint occurrence of these effects, indicating that on average, they are more painful when they occur together.

An important factor in the assessment of health risk is its interaction with the social insurance safety net (consumption floor). Hubbard et al. (1995) have shown that in a model with medical expenditures, survival and earnings risks, the consumption floor discourages savings, especially for low income individuals. It reduces uncertainty and effectively taxes savings 100% when shocks force individuals to rely on the consumption floor. Similarly, I find that the consumption floor has a large negative effect on asset accumulation, especially for the lower education group. In an experiment where the consumption floor is half of its original value, average asset accumulation before the age of 60 increases by 18.2% relative to the benchmark for the non-college and by 7.4% for the college group.

The consumption floor also leads to lower levels of precautionary savings against health risk for both education groups. When the consumption floor is reduced by half, the percentage of asset accumulation accounted for by health risk is 16.3% and 1.7% before the age of 60 for the non-college and college groups, respectively, compared to only 11.9% and 0.3% when the consumption floor is at its original level (Table 8, column B). It is interesting to note that despite the presence of the consumption floor, the non-college group accumulates much higher fractions of precautionary savings against health risk

[24] The average is taken over wages before selection into the labor force takes place. Post-selection, average earnings may not be the same in this experiment as in the benchmark.

[25] Disposable wealth is equal to the total amount available to the individual to consume and save from every period. It equals the sum of assets from the previous period, after tax returns on assets, after tax earnings, government transfers minus health insurance premiums and medical expenditures.

[26] A comparison of columns A and B in Table 8 reveals the distinction between level effects associated with the four channels and the effects of risk. For example, health induced productivity risk is an important precautionary savings motive for the non-college, accounting for 8.9% of average asset accumulation before age 60. However, when all productivity costs associated with bad health are eliminated, asset accumulation declines by only 1.9% before the age of 60 for the non-college group relative to the benchmark. This is because the reduction in savings generated by the elimination of risk is largely offset by a positive income effect from higher average earnings.

than the college educated. The presence of health risk slightly reduces the gap in asset accumulation between education groups.[27] The time endowment channel makes the consumption floor a less attractive insurance option during periods of poor health since utility levels become extremely low when consumption is at a minimum and also leisure is low due to poor health.

It is important to note that people self insure through asset accumulation for a variety of reasons. Transitory earning shocks are important to model because in their presence, individuals already accumulate a large amount of assets to self insure. Since the timing of adverse health shocks need not coincide with negative transitory shocks, individuals are already insured to some extent against health shocks. Omitting the transitory earnings variation would lead to an overestimation of the effect of health risk on asset accumulation. The removal of all health risk in the absence of transitory shocks leads to a 35% larger decline in average asset accumulation for the non-college group before the age of 60 than when these shocks are present and 16% larger decline after the age of 60.

The simultaneous elimination of productivity, available time and medical expenditure risk leads to a welfare increase of 1.2% in terms of CEV relative to the benchmark for the non-college, and 0.3% for the college educated (Table 9, column B). The time endowment risk has the largest effect on welfare for the non-college (0.74%), followed by medical expense risk (0.65%).[28] The welfare changes associated with the removal of health risk are very small compared to the welfare improvements associated with the complete elimination of health effects (17% in terms of CEV for the non-college and 6% for the college group). Fluctuations around the mean health levels within age-education groups do not have large welfare implications, but the negative effects associated with the mean health levels relative to good health are actually very important.

## 7. Conclusion

Health risk is a major component of overall risk and a big determinant of welfare, labor supply and asset accumulation, especially for the non-college education group. Health affects individuals' decisions through productivity, available time, medical expenditures and survival probability effects, and due to interactions between these, it is important to model them in a unified framework. The productivity and time endowment channels dominate in importance when studying labor supply and welfare and the risks implied by these two channels are the most important in generating income inequality and precautionary savings during working life.

The results highlight the importance of health effects for the working age population relative to retirees. Even though the probability of bad health is relatively low before the retirement age, health effects during the working life-cycle are extremely important for welfare, and contribute significantly to income inequality, both between and within education groups. Health has larger effects for the non-college than college educated, and accounts to a large extent for the lower labor supply and higher reliance on government transfers observed in the non-college group relative to the college.

The policy debate has focused greatly on medical expenditures insurance. Yet, I show that in general, health has much larger effects through the productivity and time endowment channels than medical expenditures. A growing literature studying the disability insurance program is providing new findings on how this program can be reformed to increase welfare (e.g., Low and Pistaferri, 2010). There are several other ways to lower the importance of the productivity and time endowment channels. First, laws that guarantee workers a minimum number of paid sick days or leave could go a long way in insuring productivity losses. The U.S. does not currently have such a law, while countries such as Norway and Finland have very generous paid sick leave systems. Second, it would be interesting to study how government skill training programs could be used to help increase the productivity of workers who are no longer able to work in their previous jobs or occupations due to health shocks. Third, policies that improve the efficiency of the health care system could also be important in diminishing the importance of the time endowment channel.

The results suggest that good health has a very large welfare value for the non-college group due to its benefits through the productivity and time endowment channels. Therefore, it would be interesting to incorporate these in endogenous health models that study individuals' incentives to invest in health over the life-cycle. Hall and Jones (2007) show that good health is increasingly valuable as incomes rise since health allows people to increase the quantity and quality of life by lowering mortality probabilities. Accounting for productivity and time endowment effects in addition to the survival effect would be interesting.

Finally, it would be interesting to study the contribution of health risk to personal bankruptcy decisions in a model incorporating not only medical expenditures, but also productivity and time endowment effects. There is a relatively large personal bankruptcy literature modeling or documenting the importance of medical expense shocks (e.g., Gross and Notowidigdo, 2011; Livshits et al., 2010). However, health induced productivity and time endowment risks are the most

[27] In the experiment where all health risk is removed, the difference in average asset accumulation between education groups is $104,702 before the age of 60 and $94,336 after age 60 compared to only $98,599 before the age of 60 and $91,547 after age 60 in the benchmark model.

[28] The elimination of health induced productivity risk leads to slightly lower welfare for the college group. In this experiment, individuals receive the average deterministic component of wages in their age-education group. This average is taken over both workers and non-workers. Since a large fraction of those in poor and average health with lower wages do not work, this average is lower than the average taken over workers only. Therefore, the average earnings of workers is lower in the absence of the health induced productivity risk than in the benchmark economy. This negative income effect is large enough for the college group to offset the gains in welfare derived from the elimination of health induced productivity risk.

important in generating income inequality, so health shocks may overall play a relatively larger role in bankruptcy decisions than previously estimated.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.jmoneco.2015.06.002.

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