

# Health And Earnings Inequality Over The Life Cycle: The Redistributive Potential Of Health Policies

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## Abstract

I study the joint dynamics of health and earnings inequality in general equilibrium. I introduce health shocks and health care spending into an incomplete markets model with idiosyncratic productivity shocks. I estimate health shock processes from data on medical conditions and match the model to survey data. Negative shocks may generate low income-low health traps, and magnify inequality along the life cycle. The health-income feedback accounts for 8.2 percent of total earnings inequality, and causes a seven-fold increase in the persistence of individual productivity. Policies that expand health care access have redistributive effects towards the bottom of the earnings distribution.

**Keywords:** Inequality, Life Cycle, Health, Income.

**JEL codes:** D1, D31, D91, E2, H31, H51, I1.

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# 1 Introduction

Health care policy discussions naturally focus on health outcomes and costs: income and health insurance status affect spending on medical care and health outcomes. However, a large empirical literature has also concluded that, at the individual level, health affects earnings.<sup>1</sup> Additionally, it is well documented that income disparities among individuals grow over time within a cohort. How important is health as a determinant of earnings inequality during the life cycle? How much of the lifetime earnings risk is produced by the feedback between health and earnings? What does this imply for the redistributive impact of policies that facilitate access to health care?

Answering these questions requires a general equilibrium framework which can generate inequality in earnings and in health over the life cycle of a cohort. For this, I introduce idiosyncratic health shocks and health care spending in an incomplete markets model with heterogeneous agents and risky earnings. In the model, the interaction between earnings and health is magnified along the life cycle. If the feedback between health and income is sufficiently strong, a sequence of adverse shocks might drive individuals into a low health-low income trap. I estimate the process for health shocks from data on medical conditions and I calibrate the model to match survey data on health status, health care spending and income. The results indicate a significant role for the health-income feedback in accounting for the dynamics of inequality over the life cycle, and an important redistributive role for health-care policies.

The point of departure for my analysis is the standard general equilibrium framework with incomplete markets where agents face shocks to labor market productivity and accumulate assets. An additional feature of my model is that individual earnings depend on the workers' amount of healthy time and agents suffer shocks that reduce their health status. As in Grossman (1972), health has a consumption value (sick days generate disutility) and a productive value (it determines available time at work). Importantly, agents can mitigate the negative impact of health shocks by paying for medical services.<sup>2</sup> For this, those who are eligible can enroll in health insurance, which reduces the price of the

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<sup>1</sup>See Section 2 for a summary of the effects found by this literature.

<sup>2</sup>Medical services in this context include all treatments, rehabilitation services and accessibility devices that contribute to increasing a person's ability at the workplace after the onset a medical condition.

health care services they purchase. Earnings risk is thus partly endogenous due to the interaction between health and earnings. Additionally, the model can distinguish the effects on the path of earnings of different types of shocks: productivity, health, and health insurance.

In the model, health shocks amplify existing inequalities and health care choices operate as an internal propagation mechanism that increases the persistence that individual productivity shocks generate on earnings. Because health and productivity are complementary for earnings, high productivity individuals have a high marginal return to their health. Therefore, they are more likely to buy health insurance and to choose a high level of medical care when hit by an adverse health shock. To the contrary, low income and low asset individuals who cannot afford a high level of medical treatment suffer earnings losses when hit by an adverse health shock. Negative shocks to both health and productivity translate into low health in the next period, propagating the persistence of productivity shocks and increasing the persistence of the earnings process. These effects amplify earnings and health inequalities amongst ex-ante identical individuals during the evolution of their lives. Because I model the interaction between health and earnings, this framework is suitable to assess the redistributive consequences of health care policies.

The interaction between health and income depends on a small number of parameters describing the trade-off between medical services and consumption, the degree of access to health insurance, and the stochastic properties of the process for health shocks. I calibrate the model using survey data on health status, health care spending and income from the Medical Expenditures Panel Survey (MEPS). The model distinguishes between health shocks (an exogenous process) and health status (an endogenous outcome that depends on agent's choices). I identify the health shocks process in the model with the age-dependent distribution of the onset of medical conditions in the data, and I estimate this process directly from the MEPS. In turn, I measure health status using a continuous, objective score available in the MEPS.

The model is calibrated to the U.S. economy before the implementation of the 2010 health care reform, when 18 percent of adults younger than age 65 were uninsured. The lifecycle dynamics of health and earnings of current adults in the U.S. are the result of the state of health insurance markets before that reform, reflecting the consequences of the high levels of uninsurance that characterized that time. Hence, this setting is ideal to

study the effects that lack of health insurance coverage on lifetime risks.

The calibrated model successfully reproduces salient features of the joint dynamics of health and earnings inequality over the life cycle that are not targeted in the calibration. Importantly, it predicts that life cycle inequality in health status is driven by a sharp decline in health for the lowest percentiles of the health distribution, as observed in the data. It also predicts an increase in the correlation between health and earnings over the life cycle, and that the lower end of the earnings distribution has the lowest average health levels.

I use the calibrated model to investigate the importance of health-income interactions for lifecycle earnings inequality. In the U.S, the variance of income almost doubles between ages 25 and 60. A key contribution of this paper is to measure how much of lifetime earnings risk is due to health risk. I find that 8.2 percent of the increase in earnings inequality over the life cycle is accounted for by health shocks, and that the long-run impact of early productivity differences is substantially magnified by the presence of health shocks.<sup>3</sup>

Then, I evaluate the redistributive impact of policies that influence access to health care. Relative to the pre-reform benchmark used to calibrate the model, the economies in the counterfactuals share some of the features introduced by the 2010 U.S. health care reform aimed at increasing health insurance coverage. The first counterfactual shows that improving the individual market for health insurance in such a way that all workers have the option to enroll in private health insurance reduces the 90 to 10 percentile earnings ratio by 14 percent. While this counterfactual scenario does not imply universal coverage, the second counterfactual looks at the effects of further increasing insurance coverage through general eligibility and health insurance premium subsidies, and the third counterfactual is an economy with social universal insurance. The degree of resulting earnings inequality declines as larger fractions of the population are covered by health insurance. An economy where everyone has health insurance coverage has a weaker correlation between health and earnings, which is 12 percent lower than in the benchmark economy.

The results of these counterfactual exercises indicate that health care policies that

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<sup>3</sup>7 percent of the observed persistence in the individual earnings process, measured as the autocorrelation coefficient, is due to the health-income feedback. This implies that the half life of an annual shock is amplified seven times.

increase health insurance coverage or make health services more affordable have redistributive effects by decreasing the correlation between health risk and earnings and improving the earnings outcomes of those at the bottom of the earnings distribution. These results are of great relevance for the current policy debate about health care reform in the U.S.

Many forces have been considered as determinants of the evolution of earnings inequality over the lifecycle: human capital accumulation and initial learning conditions as generating dispersion in earnings over the life cycle (Huggett et al., 2006, 2011), education policies (Abbott et al., 2013), job mobility (Low et al., 2010), search frictions (Kaplan, 2012) and heterogeneity in preferences for work (Heathcote et al., 2014). While all these forces are important, residual earnings inequality remains after taking them into account. Health is a natural candidate to be one of these factors.

Deaton and Paxson (1998) study the connections between health inequality and earnings inequality. They documented that health status - as measured by body mass index and self-reported health - becomes more widely dispersed within cohorts over time. They also documented that health status is positively correlated with income within cohort-sex-year cells. Cross-country empirical evidence shows that health inequality and earnings inequality are correlated at the aggregate level,<sup>4</sup> but there is no theoretical micro-founded model that generates this correlation in equilibrium.<sup>5</sup> A contribution of this paper is to provide a framework with interactions between health and earnings that is suitable to analyze the connection between health inequality and earnings inequality, and the determinants of their dynamics over the life cycle.

The model and methodology of this paper are closely related to a strand of the savings literature that considers the life cycle effects of medical expenses of the elderly on savings behavior, like Marshall et al. (2011), De Nardi et al. (2010), Poterba et al. (2017), and on the asset accumulation consequences of medical expenditures, like Hubbard et al. (1995) and Jeske and Kitao (2009). Most of those papers treat health expenditures as exogenous shocks. Unlike that literature, the focus of my project is mostly on the productivity consequences of health care decisions during the working life. Related papers that model the lifecycle evolution of health are Capatina (2015) –which assumes that the evolution of health status is exogenous– and Halliday et al. (2017) –which studies how investment

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<sup>4</sup>See Wilkinson and Pickett (2006) for a survey.

<sup>5</sup>See Deaton (2001).

in health interacts with labor supply during the life cycle, although earnings are not risky in their setup.

This paper is also related to a strand of literature concerned with welfare evaluation of health insurance policies. Some papers study health insurance in general equilibrium while taking health evolution as exogenous, such as Attanasio et al. (2010), Imrohoroglu and Kitao (2012). Papers that study the effects of health insurance policy and include endogenous health investments are Ozkan (2014), Scholz and Seshadri (2012), Ales et al. (2014), and Cole et al. (2016). Other papers do not consider the impact on labor market outcomes and earnings dispersion.<sup>6</sup> Unlike this literature, this paper is mainly focused on the interaction between health and earnings dynamics. I explicitly distinguish between health shocks and health outcomes, and I estimate health shocks from survey data. This feature allows me to study the role of wealth, earnings, and credit constraints in accounting for health outcomes and medical expenditures.

The rest of the paper is structured as follows: Section 2 describes the empirical evidence on life cycle inequality in health and earnings. Section 3 introduces the model. Section 4 describes the calibration strategy. Section 5 examines how the model performs against the data and describes the numerical results. Section 6 performs the counterfactuals. Section 7 concludes.

## 2 Health and Earnings in the U.S.

The first part of this section documents salient features of the joint evolution of inequality in health and earnings during the life cycle using data on health status, medical expenditures, health insurance coverage, income, and demographic characteristics from the MEPS.<sup>7</sup> The second part of this section briefly surveys empirical findings from the microeconomics literature related to these facts. Subsequent sections evaluate the extent to which the model can reproduce these basic patterns.

A first challenge for any analysis of this type is obtaining a reliable and comprehensive measure of health status that can be compared across individuals. Some commonly used

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<sup>6</sup>See Jeske and Kitao (2009), Attanasio et al. (2010), Jung and Tran (2016), Pashchenko and Porapakarm (2013), Feng (2012). Hansen et al. (2014) study Medicare buy-in with incomplete markets, endogenous labor and adverse selection.

<sup>7</sup>See appendix ?? for a description of the MEPS and the data.

measures are either not comparable across individuals, or capture very narrow aspects of health.<sup>8</sup> To avoid this, I use the Physical Component Summary (PCS), available in MEPS. The PCS score is a measure of health-related quality of life and it provides a summary measure of health. It weights answers to a short questionnaire which targets different measures of general health and of physical and mental limitations in different activities.<sup>9</sup> As a result, PCS summarizes objective characteristics of the health status of an individual, and it is comparable across different age groups. Moreover, its continuous nature provides a scale suitable for numerical analysis. In the quantitative analysis, I interpret this score as the fraction of time that can be effectively applied to productive activities.<sup>10</sup>

A second challenge to discipline the quantitative analysis is to distinguish between health status (a stock) and health shocks (a flow). After presenting the main facts, I present the measure of health shocks that I estimate from the data and feed into my model. Finally, I briefly survey empirical findings from the microeconomics literature related to these facts.

These main facts emerge from the analysis: i) health status, access to health insurance and earnings are strongly correlated within groups of individuals with similar observable characteristics; ii) inequalities in health and earnings grow larger as a cohort ages; iii) the increase in health inequality during the life cycle is mainly driven by a worsening in the health status of individuals in the lowest quintile of the distribution of health status; iv) the correlation between health and earnings across individuals increases over the life cycle; and v) uninsured individuals have lower health and more dispersion in both health and earnings than insured individuals within age groups.

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<sup>8</sup>A commonly used measure of health, which is collected in several surveys, is the self-reported, five-states health status. Given its subjective nature, this measure is imperfectly comparable across individuals. In addition, its discreteness makes it of limited suitability for quantitative analysis. For example, the health loss that drives this measure from *excellent* to *very good* need not be the same health loss that turns a *fair* into *bad*.

<sup>9</sup>See appendix ?? for more information on PCS and the questionnaire used.

<sup>10</sup>A few waves of the MEPS also include another measure of health-related quality of life, the EQ-5D instrument, which is based on a shorter instrument than the one used for PCS. Both measures are positively and significantly correlated.

## 2.1 Facts

### Inequality in Health and Earnings over the Life Cycle

Figure 1 documents the evolution of the dispersion in annual earnings and health status over the life cycle, using the PCS measure for health status.<sup>11</sup> The figure includes individuals ages 20 to 64 years old, grouped in five-year age groups. Panel (a) shows the 90th, 50th and 10th percentiles of the earnings distribution within each age group. In turn, panel (b) shows the 90th, 50th and 10th percentiles of the health distribution for these age groups.

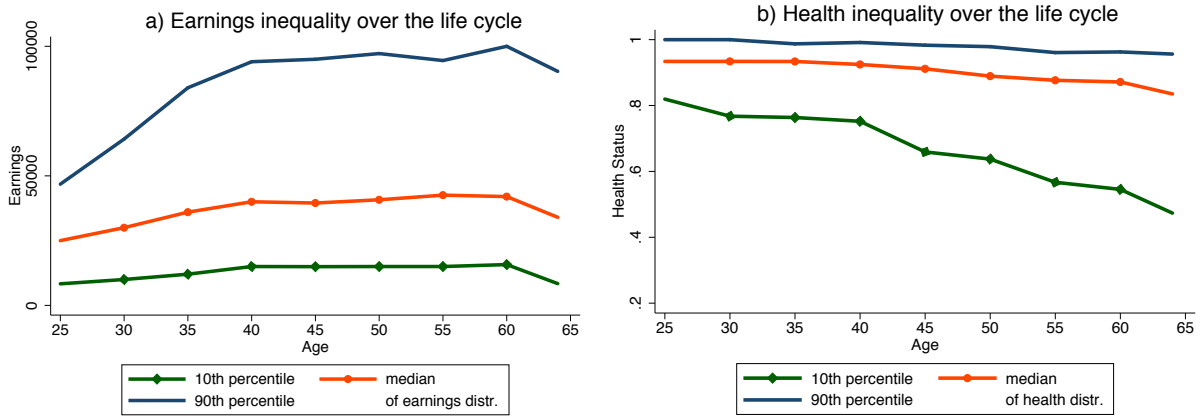


Figure 1: INEQUALITY IN EARNINGS AND HEALTH STATUS OVER THE LIFE CYCLE

Source: Author's calculations using MEPS

Earnings inequality increases over the life cycle, in particular through the increase of the higher percentiles of the distribution. Health inequality also increases over the life cycle. Contrary to what occurs with earnings, the divergence in health status over the life cycle is driven by the decline at the bottom of the health distribution. The average ability to perform productive tasks for very healthy individuals is slightly lower at age 60 than at age 20 (it declines by less than 1%), implying that on average health declines for all individuals over time. However, the health level of the most unhealthy individuals is

<sup>11</sup>Deaton and Paxson (1998), as part of their well-known series of papers on inequality patterns, document similar patterns in earnings and health. In their analysis, they use self-reported health status and body mass index to measure health.



much lower at age 60 than at age 20 (the 10th percentile of health between ages 60 and 65 is 43% lower than between ages 20 and 25). This evidence is suggestive of persistence in health status of negative shocks over time.

## Relation between Health and Earnings

The additional features of the joint distribution of health and earnings documented here will inform the quantitative analysis in later sections. The literature that studies the causality aspects of this behavior at the individual level is surveyed in Section 2.3.

Figure 2 displays the cross-sectional correlation between health status and earnings over the life cycle. Two facts emerge. First, the correlation is always positive, hence people with higher earnings consistently also score better levels of health. Second, on average, the correlation between these two variables increases over the life cycle. It is weakest for those in their 20s and early 30s, but increases with age until it reaches a maximum of 0.31 for those in their early 50s. The correlation sharply weakens during the early 60s as two factors become relevant: health status deteriorates with age for all and survival bias weakens the correlation. This pattern for the correlation between health and earnings by age groups parallels the concavity of the earnings profile.

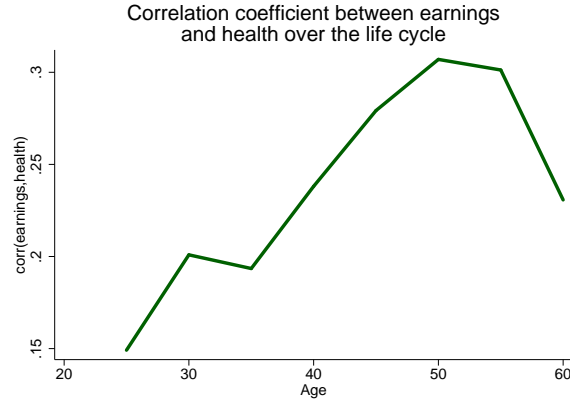


Figure 2: HEALTH AND EARNINGS OVER THE LIFE CYCLE

*Source:* Author's calculations using MEPS

Figure 3 displays the distribution of health status for different age groups before retirement. Within each age group, the figure shows the distribution of health for the

bottom 30% and the top 30% of the earnings distribution. With age, average health level declines and dispersion in health levels increases in both earnings groups. However, both effects are stronger for the poorest than for the higher earnings workers. The mean health status of those in the top 30% of the earnings distribution is higher than that for those in the bottom 30% of the earnings distribution. For example, the difference in average health between these two earnings groups is 15% at age 45. The differences in mean health status across earnings bins are larger for older individuals. The standard deviation of health status amongst those at the bottom of the distribution is twice as high as the standard deviation for those at the top of the earnings distribution at that age.

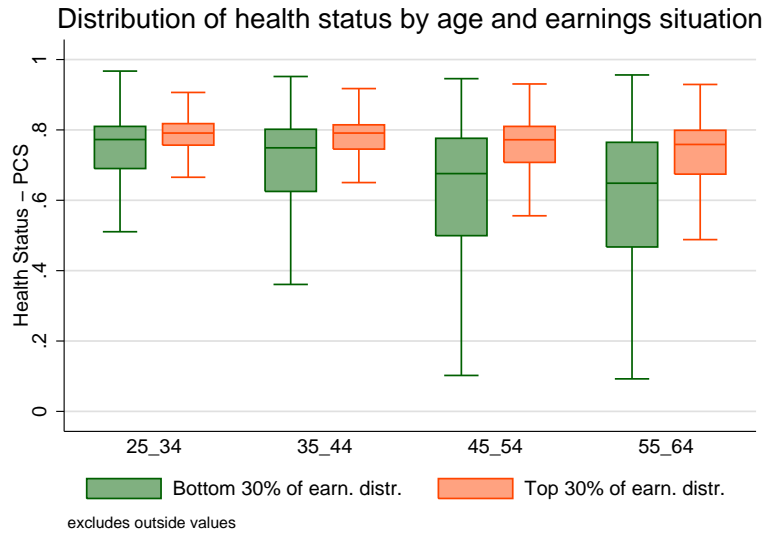


Figure 3: HEALTH STATUS DISTRIBUTION BY AGE AND EARNINGS GROUP

*Note:* This graph represents the distribution of health status by age and earnings groups. The edges of each box indicate the values of the lower and upper quartiles of the health status for that age and earnings group, and the whiskers represent the 5th and 95th percentiles. The median value of health status for the different groups is indicated by the line dividing each box.

## Health Insurance and Earnings

Another important dimension of inequality is given by health insurance coverage. Health insurance status determines the price of medical care that an individual faces, and hence influences what kind of medical treatment an individual can afford. 18.7% of adults ages 21 to 64 were not covered by any kind of private or public health insurance in the U.S. in

2008.<sup>12</sup> Health insurance – an important determinant of the demand for health care and of health outcomes, as explained in Section 2.3 – is also correlated with earnings. Pierce (2001) shows that firms that offer higher wages typically also offer better non-monetary perks like employer-sponsored health insurance.

Figure 4 shows the fraction of uninsured workers by percentiles of earnings. 44% of individuals in the first decile of the earnings distribution were uninsured in 2008, while this figure is less than 5% of those in the last quartile of the earnings distribution.

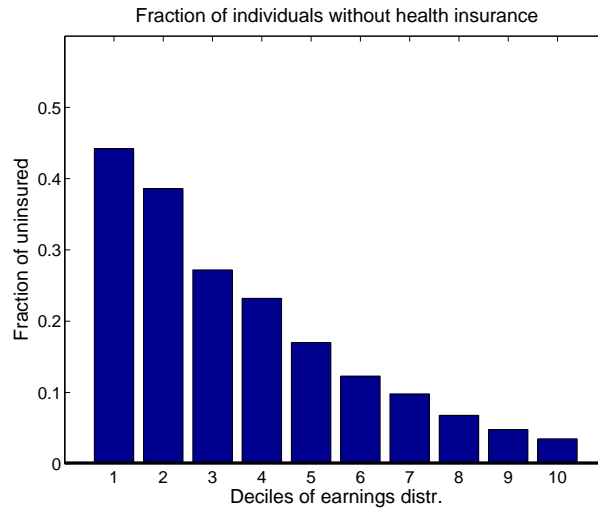


Figure 4: FRACTION OF UNINSURED ADULTS, OVER PERCENTILES OF EARNINGS

I look at the differences in earnings by insurance status controlling for all observables in a Mincer-type regression. The earnings of uninsured workers are on average 43% lower than the earnings of those insured. In addition, the group of uninsured workers is more heterogeneous than the insured in terms of earnings and hours worked. The residual dispersion of log-earnings, a typical measure of labor market risk, is 60% higher for the uninsured.

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<sup>12</sup>Because unemployment can affect health insurance coverage, I use data from before the rise in unemployment rates during the Great Recession.

## 2.2 Measuring Shocks to Healthy Time

The model includes two distinct concepts: health status and shocks to health. The previous section described the evolution of the measure of health status over the life cycle. Here, I describe the measure of health shocks that I generate from the data.

For this I use the *medical conditions files* in MEPS, which provide information describing medical conditions for each individual reported by households in each wave of the survey. Households are surveyed five times over two years. I only consider the incidence of disease in each period: I discard conditions that were diagnosed before the relevant survey period and I compile for each individual the new medical conditions that appeared over the course of the survey.

Each medical condition affects health status and has the potential to generate some level of health impairment or disability, understood as a decrease in the physical and mental strength and energy an individual has and in the number and complexity of tasks that he can perform. To measure the severity of the health shock, I weight each of these medical conditions by the respective disability weight computed by the World Health Organization (WHO). The WHO's *Global Burden of Disease 2004 Update*<sup>13</sup> provides the list of disability weights, which is a set of numerical weights attached to the wide array of non-fatal consequences from different diseases and injuries. A disability weight is a weight factor that reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death).<sup>14, 15</sup>

More precisely, the interpretation of these disability weights is the following: if a medical condition implies a potential health limitation or disability  $d$ , the resulting health status is reduced by this fraction, so the resulting health status is  $health * (1 - d)$ . A measure of the health shock suffered by an individual must account for all the new medical conditions that he developed. Therefore, the disability weights for all conditions the individual gets that period must be aggregated. When individual  $i$  suffers  $J_{i,t}$  conditions

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<sup>13</sup><http://www.who.int/bulletin/volumes/88/12/10-084301/en/>

<sup>14</sup>For discussions of this measure see Murray and Lopez (1996), Essink-Bot et al. (2002) and Mont (2007) on using disability weights.

<sup>15</sup>See appendix ?? for more information about the disability weights.

in period  $t$ , the cumulative effect on health is given by the shock  $s_{i,t}$ , defined as follows:

$$(1 - s_{i,t}) = \prod_{j=1}^{J_{i,t}} (1 - d_j) \quad (1)$$

Using this method, I compute the total disability weight corresponding to all medical conditions each individual suffers over the period.

The box plot in Figure 5 shows the median (diamond), 25th and 75th percentiles (box), and 5th and 95th percentiles (whiskers) of the distribution of health shocks by age group. As expected, the shocks to health become more severe with age, and the variance increases. Additionally, the incidence of bad shocks ( $Pr(s > 0)$ , not shown in this figure) also increases with age. In the quantitative analysis, I feed this distribution of health shocks (adjusted to the length of the period) into the model. The optimal solution to each individual's problem generates the evolution of his health status, conditional on his history of shocks.

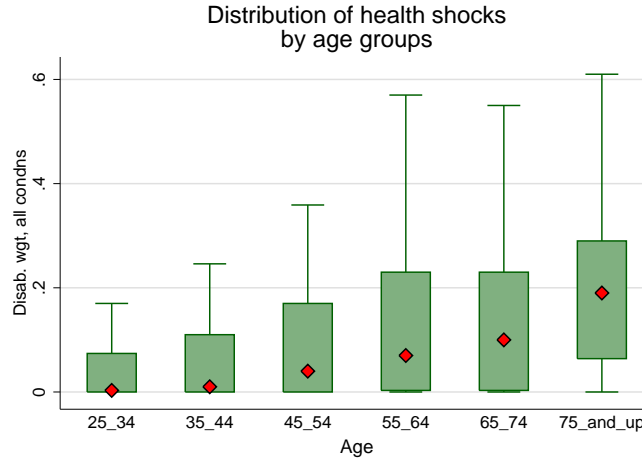


Figure 5: DISTRIBUTION OF HEALTH SHOCKS

*Note:* This graph represents the distribution of health shocks measured by total disability weight, by age group. The median value of health status for the different groups is indicated by the red diamond dividing each box. The edges of each box indicate the values of the lower and upper quartiles of the health status for that age group, and the whiskers represent the 5th and 95th percentiles.

## 2.3 Literature on Health and Earnings

The health economics literature has consistently documented that several measures of health and different measures of socio-economic status are positively correlated at the individual level.<sup>16</sup> In particular, there is evidence of a two-way interaction between health and earnings. Health losses have negative effects on earnings and in labor supply (both through the intensive and extensive margins).<sup>17</sup> The effects of income and wealth on health materialize through access to health insurance and medical treatment, although the size of these effects are more controversial in the literature.<sup>18</sup>

This two-way interaction between health and earnings poses a challenging identification problem. For this reason, and given the diversity of health measures and health shocks studied, the estimated effects in the literature cover a wide range: Attanasio et al. (2010) find that individuals who report a deterioration of (subjective) health status from *good* to *bad* experience an average fall in hourly wages of 15%, while Smith (1999) estimates that a severe (moderate) health event implies a per period reduction of about 4 hours (1.5 hours) per week and a 15 (5) percentage point decline in the probability of remaining in the labor force. Other studies focus on particular medical conditions: Pincus et al. (1989); Mitchell and Burkhauser (1990) find that arthritis reduces earnings by between 19 and 27%; Kahn (1998) finds that the labor force participation of diabetic males is about 80% that of non-diabetic males, and Famulari (1992) finds an average loss of 22% in wages for people with epilepsy. In my analysis, the effect of health on earnings is within this broad range estimated in the literature.

The evidence clearly indicates that the demand for health care is elastic with respect to income and price.<sup>19</sup> However, the evidence about the direct effect of income or health insurance on health outcomes is more elusive and there is no clear consensus in the literature. Evidence from the RAND Health Insurance Experiment shows that health insurance coverage reduced mortality rates of high-risk patients and in some cases improved

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<sup>16</sup>See Cutler et al. (2011).

<sup>17</sup>For a survey, see Currie and Madrian (1999).

<sup>18</sup>Income levels have also been linked to differences in risky health behaviors, but the causality is not clear in this case. See Cawley and Ruhm (2011).

<sup>19</sup>Newhouse (1993) found that the usage of medical services responds unequivocally to changes in the amount paid out of pocket, and Akin et al. (1998) control for ill bias and also find a significant price coefficient. Acemoglu et al. (2013) use oil price shocks to instrument income effects, and find evidence of positive income elasticity of health care consumption.

health outcomes,<sup>20</sup> while in the Oregon Health Insurance Experiment Medicaid coverage increased health care utilization and improved self-reported health and mental health, but it had no effects on mortality.<sup>21</sup> Doyle (2005) finds better outcomes from hospital treatment due to automobile accidents for those with health insurance. There is evidence that Medicaid coverage during childhood has medium and long term health benefits.<sup>22</sup>

Evans and Garthwaite (2014) find improvements in self-reported health and biomarkers for mothers who were benefited from expansions of the Earned Income Tax Credit. Ettner (1996) finds that increases in income significantly improve mental and physical health. In order to account for the potential endogeneity of wealth and earnings, wealth shocks have been used as instrumental variables<sup>23</sup> and a system of non-causality and invariance tests have been used to rule out causality channels<sup>24</sup>, with conflicting results with respect to causation.

### 3 Model

The baseline is a standard life-cycle model with incomplete markets and idiosyncratic risk. I augment this setting incorporating health status in the individual's production function and utility, and health risk. The main features of my model are that: i) agents face uninsurable earnings and health risk; ii) an agent's health status affects his amount of available time for productive activities; iii) agents can totally or partially offset the negative impact of health shocks on their productivity by seeking medical treatment; iv) agents can purchase health insurance and, by doing so, reduce the cost of their medical expenditures whenever they demand medical care.

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<sup>20</sup>The RAND Health Insurance Experiment was a randomized controlled trial which randomized people into health insurance plans with different coinsurance rates. Health outcomes like blood pressure, anemia, vision, dental health and mortality improved for the poorest participants that were assigned to the free care group. (Newhouse, 1993).

<sup>21</sup>The Oregon Health Insurance Experiment was a Medicaid expansion for low-income, uninsured adults that occurred via random assignment. See Finkelstein et al. (2012) and Baicker et al. (2013). Finkelstein et al. (2012) argue that the impact of Medicaid among a low-income population may be lower than that of private insurance or insurance among higher income individuals.

<sup>22</sup>See Currie and Gruber (1996, 2001), Wherry and Meyer (2015) and Wherry et al. (2016) .

<sup>23</sup>See Meer, Miller and Rosen (2003), Michaud and Van Soest (2008) and Smith (2005)

<sup>24</sup>Adams et al. (2004) and Stowasser et al. (2011).

## 3.1 Setup

### 3.1.1 Population Dynamics and Timing

The economy is populated by a constant measure of households who live for  $T$  periods. Agents enter the labor force in the first period of their lives. They work until period  $\underline{t} - 1$  and in period  $\underline{t}$  they retire. During periods  $\underline{t}$  to  $T$  agents consume out of their savings and a social security transfer they receive from the government. In each period, as many new young agents enter the workforce as old agents die.

At the beginning of his working life, each agent draws a fixed effect for his process of latent productivity and for health insurance eligibility. All agents start with the same stock of health. During their lives, individuals face shocks to their productivity levels and their health. Shocks to the health stock are reversible through medical treatment if it is received during the same period. There are borrowing constraints.

The timing of decisions within a period is shown in Figure 6. In the beginning of each period  $t$ , agents receive a shock to their productivity. If eligible, given their assets and their productivity level, they decide whether to enroll in a health insurance plan or not. After that, they are hit by a health shock. At that point, agents choose how much medical treatment to get, at a cost that depends on whether they have health insurance in that period or not. Finally, they produce, earn income, consume, and save for the next period at a risk-less rate.

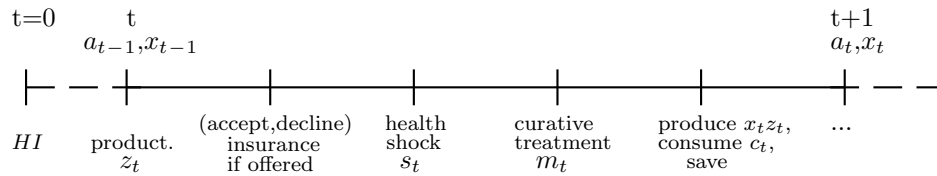


Figure 6: TIMELINE

### 3.1.2 Earnings and the Role of Health

The health status  $x_{i,t}$  of agent  $i$  at time  $t$  can take a maximum value of 1. A value of 1 indicates a perfectly healthy individual, whereas a value close to zero indicates a large



level of health impairment. There is no mortality before age  $T$ , therefore health only takes strictly positive values:  $0 < x_{i,t} \leq 1$ . (A value of health equal to zero would mean death.) I assume imperfect substitutability between consumption and health to capture the vital role of health status. Health is valued because it enters the utility function and because it has an instrumental value: it allows individuals to perform their job and activities. In this sense, and following the work of Grossman (1972) in a stylized way, health has a consumption value (sick days generate disutility) and a productive value (it determines income levels). Health status generates a “flow of healthy time”  $n(x_{i,t})$ . This flow determines the maximum amount of time available for market activities. Each unit of healthy time is transformed in the market into  $z_{i,t}$  units of labor input.

An important departure from Grossman’s setting is that instead of assuming a deterministic depreciation rate for health, I incorporate uncertainty about the evolution of health. In each period, health is struck by a debilitating shock. If the shock takes a value of zero, it has no impact on health, otherwise it has the potential to decrease the flow of healthy time. Medical treatment and services help treat the condition and restore health. There are no health-enhancing shocks and there is no accumulation of health beyond the maximum level of 1. Moreover, medical treatment is only effective to cure or mitigate the consequences of a current medical condition (negative health shock).

At any stage in their lives, health status evolve according to the following transition equation:

$$x_{i,t} = x_{i,t-1}(1 - s_{i,t}) + m_{i,t},$$

where  $s_{i,t}$  is a debilitating health shock, or a measure of health loss. The shock to health  $s_{i,t}$  is uncorrelated over time, and its distribution is age-dependent. Because I assume medical care  $m$  helps to partially or totally restore the health status only in case of a bad health shock, medical expenditures are bounded above by the damage inflicted by the shock:  $0 \leq m_{i,t} \leq s_{i,t}x_{i,t-1}$ , and  $x_{i,t} = x_{i,t-1}$  if  $s_{i,t} = 0$ . This assumption helps capture the persistence of the health process. Due to the characteristics of health-related processes, the model is set up for low frequency analysis. In the calibration, the model period is ten years. For this reason it is sensible to assume that health losses that are not treated and restored in past periods cannot be recovered in subsequent periods. This captures the fact that health deteriorates by aging too if it is not duly taken care of.

This way of modeling the impact of shocks on health has a natural correspondence

with the definition of the variables I use in the data, as explained in Section 2. Namely, the measure of health shock captures the fraction of health status that is potentially lost because of the medical conditions suffered. The method adopted to compute the shocks from the data is a multiplicative adjustment method that implies that the increase in disability due to comorbidity is proportional, and total health shock is computed using equation (1), reproduced here:  $(1 - s_J) = \prod_{j=1}^J (1 - d_j)$  This implies that the size of the health shock increases with comorbidity of more diseases but is less than the sum of individual disability weights for all conditions.

In the specification of the model,  $s_{i,t}$  enters the law of motion for health  $x_{i,t}$  in a way consistent with this. The linear specification of the effect of  $m_{i,t}$  implies that a unit of medical treatment is defined in units of health status. The implied elasticity of health status with respect to medical treatment is within the bounds set in the literature.<sup>25</sup>

Workers supply labor inelastically, so the labor market earnings for an individual equal the product of a rental rate of human capital services  $w$ , the agent's potential productivity level  $z_{i,t}$ , and the fraction of healthy time  $n(x_{i,t})$  he has available that period. The agent's productivity level and his available healthy time constitute his level of effective human capital. Both components of effective human capital are risky, but workers can only affect the health status. This means that they chose a health status level that provides some insurance for the future. The optimal level of insurance achieved through maintaining a good health status depends on the individual's characteristics (age, productivity, level of assets). Additionally, borrowing constraints affect how much health workers can recover when hit by a bad health shock.

The underlying productivity level  $z_{i,t}$  follows a stochastic process that depends on a worker's initial level of productivity and his age, and has a transitory and a persistent component.<sup>26</sup> The initial level of individual productivity can be interpreted as differences in education, skills, ability, and health that are present at the beginning of the adult working life. Earnings for an individual are given by:  $y_{i,t} = wn(x_{i,t})z_{i,t}$ .

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<sup>25</sup>Grossman (1972) and the subsequent literature that builds on that model, assumed constant returns to scale for medical services in the health production function. Galama et al. (2012) fail to find evidence of decreasing returns to scale from medical services. Halliday et al (2011) and Ozkan (2011) estimate the elasticity of health with respect to medical expenditures in the presence of shocks to be 1 and between 0.8 and 1.25, respectively.

<sup>26</sup>This process is explained in more detail in the calibration Section 4.

### 3.1.3 Health Insurance

As previously noted, the assumptions of the benchmark model constitute a stylized way of modeling access to private health insurance in the U.S. before the 2010 health care reform.<sup>27</sup> The rationale for this is that the lifecycle dynamics of health and earnings of current adults in the U.S. are the long-term result of how access to health insurance worked before that reform, reflecting the consequences of the high levels of uninsurance that characterized health insurance markets during that time.<sup>28</sup> In this setting, health care policy affects access to health care by changing health insurance coverage in the population.

The model assumes that individuals randomly become eligible for private health insurance or not at the beginning of their working lives.<sup>29</sup> This status is assumed to be permanent. However, each period those who are eligible decide if they enroll in health insurance or not. Health insurance eligibility is correlated with an individual's innate productivity level.<sup>30</sup>

The insurance contract considered in this model captures one of the main components of current regular health insurance plans in the U.S.: it provides a discount on medical services. A health insurance plan consists of a premium  $p$  and a coinsurance rate  $(1 - \gamma)$ , which indicates the fraction of the total medical charges,  $qm$ , that the worker pays out of

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<sup>27</sup>The health care reform took shape with the signature of the Patient Protection and Affordable Care Act (shortened to the Affordable Care Act) in 2010. The provisions in the Affordable Care Act were scheduled to gradually take effect between 2010 and 2020, although most took effect on January 1, 2014.

<sup>28</sup>In the U.S., most working-age individuals obtain health insurance from their employers. Group health insurance premiums are tax deductible and generally based in community rating. Those who work for small firms that do not offer employer-sponsored health insurance or are self-employed can use the individual market for private health insurance. However, before the implementation of the Affordable Care Act in 2010 only 5% of workers got health insurance in this market. Before the reforms, this market suffered from adverse selection, medical underwriting, and coverage could be denied due to pre-existing conditions.

<sup>29</sup>This version of the model abstracts from public health insurance before retirement. Before the implementation of the Affordable Care Act, most able-bodied adults with no children would not qualify for public health insurance through Medicaid regardless of how low their income. The eligibility requirements vary by state and only some states adopted the Medicaid expansion proposed by the Affordable Care Act. In general, Medicaid is not currently a good substitute for private insurance for adults. Because of restrictions to reimbursement rates, a limited set of health care providers accept Medicaid patients. As a result, access to medical care for individuals enrolled in Medicaid is more difficult and the care they receive is of lower quality than for those enrolled in private health insurance.

<sup>30</sup>Pierce (2001) finds that firms where wages are higher are more likely to offer non-monetary perks like health insurance. The calibration in Section 4.1 is in line with this.

pocket. The rest is covered by the insurer. I assume no deductibles, a competitive health insurance sector, and actuarially fair premium. Therefore, the characteristics of the unique health insurance plan are summarized by the parameter pair  $(p, \gamma)$ . For simplicity, there is only one type of health insurance plan in this economy.<sup>31</sup>

### 3.1.4 Retirement Period

The focus of this model is on the interaction between health and earnings during the working life. However, the inclusion of a stylized retirement period is crucial for the model to adequately capture the dynamics of worker's incentives to save and to invest in health.

After period  $\underline{t}$ , workers retire. Retirees receive social security payments in the form of a transfer  $b$  from the government during their retirement. Additionally, all retirees are automatically enrolled in Medicare and pay a premium  $p_{MediCare}$ . Medicare covers a fraction  $\gamma$  of their medical expenditures.<sup>32</sup> The weight of health in their utility can be higher than during the working years, to reflect the importance of old age medical expenditures and the increased need to buy comfort-enhancing services when old.<sup>33</sup>

The last periods of life after retirement capture in a stylized way the relevant aspects of the retirement period (all risks comes from the shocks to health) for the behavior of savings during the life cycle.

### 3.1.5 Individual's Problem

Individuals are heterogeneous in six dimensions: age  $t$ , assets carried over from the previous period  $a$ , health status resulting from the previous period  $x$ , idiosyncratic labor productivity  $z$ , shock to healthy time  $s$ , and health insurance eligibility status indicated by  $\mathbf{1}_{ins} \in \{0, 1\}$ .

The model assumes that agents derive utility from their level of consumption and

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<sup>31</sup>The model does not allow for other, less prevalent types of health plans, like catastrophic health insurance plans (high deductible, low premium health insurance policies). These plans usually do not pay for regular medical services but cover major medical expenses. Absent bankruptcy and mortality, and given that medical expenditures are bounded above, there is no relevance for these plans in this model.

<sup>32</sup>In this setting, Medicare is analog to the private health insurance during the working life. The only differences are that, after retirement, everyone is enrolled in Medicare and the premium is subsidized.

<sup>33</sup>See De Nardi et al. (2010) and Palumbo (1999)

their health status.<sup>34</sup> The rationale behind this assumption is that health has intrinsic value, but moreover it has a largely instrumental value. Health is necessary to pursue most of what individuals value in life, and disease generates disutility because it prevents them from doing so. Because of this feature, this problem is not analog to a human capital problem. This formulation implies that whenever health declines it has a negative effect on their utility as well as their productivity (if the individual is in productive years), and when hit by an adverse health shock they face a trade-off between medical treatment and consumption.

Agents maximize the expected present value of their discounted utility. The optimization problem for a worker who is eligible to enroll in health insurance is stated in problem (2) below, where  $c$  indicates consumption,  $m$  medical services, and  $ins \in \{0, 1\}$  is the decision to enroll in health insurance.

$$\max_{\{c_{i,t}, m_{i,t}, ins_{i,t}\}} E \sum_{t=1}^T \beta^t u_t(c_{i,t}, x_{i,t}) \quad (2)$$

subject to:

$$c_{i,t} + a_{i,t+1} + (1 - \mathbf{1}_{ins,i} \gamma) q m_{i,t} + \mathbf{1}_{ins,i} (1 - \tau) p = (1 - \tau) y_{i,t} + (1 + r) a_{i,t}$$

$$\begin{aligned} y_{i,t} &= \begin{cases} w n_{i,t} z_{i,t} & \text{if } t < \underline{t} \\ b & \text{if } t \geq \underline{t} \end{cases} \\ n_{i,t} &= n(x_{i,t}) \\ x_{i,t} &= x_{i,t-1} (1 - s_{i,t}) + m_{i,t} \\ 0 &\leq m_{i,t} \leq s_{i,t} x_{i,t-1} \\ c_{i,t}, a_{i,t+1} &\geq 0 \\ s_t &= \begin{cases} 0 & \text{w/prob. } \pi \\ \sim G_t & \text{w/prob. } (1 - \pi) \end{cases} \\ z_{it} &\sim \text{exogenous process} \end{aligned}$$

An individual who is not eligible to enroll in health insurance solves the same problem, except that in this case (2) is modified so that  $ins_i$  is not a control variable for him and

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<sup>34</sup>There is evidence that health status has a positive effect on the marginal utility of consumption, as found by Palumbo (1999) and Finkelstein et al. (2013), and several papers in the literature include health in the utility function.

$\mathbf{1}_{ins,i} = 0$  is fixed for all periods.

During their working lives, agents receive labor earnings, which is taxed at rate  $\tau$ . After they retire, they receive the fix pension payment  $b$ . The health insurance premium  $p$  is tax-deductible.

The choice of medical treatment not only depends on the level of productivity but also on the persistence of the exogenous productivity shocks. When a worker's health is hit by a health shock, he can get treatment  $m$ . The marginal benefit of recovering his health consists of the marginal utility from health, the marginal utility of the extra earnings, and the marginal future benefit of higher health in the next period. The marginal cost of seeking treatment is given by the price of treatment in terms of forgone consumption. There is a trade-off between health and savings (future consumption smoothing) because health status has inter-temporal consequences.

### 3.1.6 Government

The government collects taxes on earnings. There is an income tax  $\tau_y$ , that is used to finance some level of government spending  $G$ . The revenues from taxing labor earnings at rate  $\tau_{ss}$  are used to finance social security, and the revenues from taxing labor earnings at rate  $\tau_{MC}$  are used to subsidize Medicare (Medicare subsidies are called  $G_{MediCare}$ ). The combined income and payroll tax is  $\tau = \tau_y + \tau_{ss} + \tau_{MC}$ .

### 3.1.7 Firms

Firms organize effective labor and capital assets to produce the final good, so that  $Y = f(K, L)$ . The final good  $Y$  can be used as consumption good  $C$  or transformed at a linear rate  $q$  into medical treatment  $M$ .

## 3.2 General Equilibrium and Optimal Policies

### 3.2.1 Equilibrium

An equilibrium is a collection of cohort-specific policy functions  $\{c(\chi), m(\chi), a(\chi), h(\chi), ins(\chi)\}$  that depend on the individual idiosyncratic state  $\chi = \{t, a, x, z, s, \mathbf{1}_{ins}\}$ , factor prices  $w$

and  $r$ , health insurance premium  $p$ , and a measure  $\mu(\chi)$  of agents across states  $\chi$ , such that:

- i ) Individuals solve the optimization problem given in (2), given prices.
- ii) Aggregate quantities result from individual decisions and factor markets clear:  $K = \int_X a(\chi) d\mu(\chi)$  and  $L = \int_X n(\chi) z d\mu(\chi)$ , where  $L$  are units of effective labor, which depends on the levels of productivity  $z$  and healthy time  $x$  for each worker.
- iii) Wage, interest rate and health insurance premiums are determined in competitive markets. Private premium payments (left-hand side) equal the fraction of expected medical expenditures of working-age individuals that is covered by the insurance company:

$$p \int_X d\mu(\chi|t < \underline{t}) = \gamma q \int_X m(\chi|t < \underline{t}) d\mu(\chi|t < \underline{t})$$

Collected Medicare premiums plus the government's subsidy to Medicare equal the fraction of expected medical expenditures of retirees covered by Medicare:

$$(p_{MediCare} + G_{MediCare}) \int_X d\mu(\chi|t \geq \underline{t}) = \gamma q \int_X m(\chi|t \geq \underline{t}) d\mu(\chi|t \geq \underline{t})$$

The resulting wage and interest rate are:  $w = (1 - \alpha)A \left(\frac{K}{L}\right)^\alpha$  and  $r = \alpha A \left(\frac{L}{K}\right)^{1-\alpha}$

- iv) The government's budget constraint is satisfied, and each tax revenue matches its purpose:

$$\begin{aligned} \int_X \tau_y y(\chi|t < \underline{t}) d\mu(\chi|t < \underline{t}) &= G \\ \int_X \tau_{ss} y(\chi|t < \underline{t}) d\mu(\chi|t < \underline{t}) &= b \int_X d\mu(\chi|t \geq \underline{t}) \\ \int_X \tau_{MC} y(\chi|t < \underline{t}) d\mu(\chi|t < \underline{t}) &= G_{MediCare} \int_X d\mu(\chi|t \geq \underline{t}) \end{aligned}$$

- v) Resource feasibility is met:  $AK^\alpha L^{1-\alpha} = C + qM + G$ , where  $C = \int_X c(\chi) d\mu(\chi)$ ,  $M = \int_X m(\chi) d\mu(\chi)$

### 3.2.2 Optimal Policies

#### Consumption and Medical Services

The first order conditions when  $s_{i,t} > 0$  imply the following conditions for optimal policies. I omit the  $i$  indexes below for simplicity and, to save notation, I normalize  $w = 1$ . Absent health insurance, the Euler equation for consumption is:

$$u_{c,t} = (1 + r)\beta E u_{c,t+1} + \zeta_a \quad (3)$$

From the FOCs on medical treatment, when  $s_t > 0$ , the following equation describes the intertemporal evolution of  $x_t$ :

$$u_{x,t} + \frac{z_t - q}{q} \xi_{x,t} + \beta E(1 - s_{t+1}) \xi_{x,t+1} = \zeta_{x,t} \quad (4)$$

Lastly, the implied relationship between health and consumption is also dynamic because of the dynamic nature of  $x$  and  $a$ :

$$u_{x,t} + (z_t - q) [u_{c,t} + q(1 + r)\beta E(1 - s_{t+1})u_{c,t+1}] = \zeta_{x,t} \quad (5)$$

$\zeta_{a,t}$  and  $\zeta_{x,t}$  are the Kuhn-Tucker multipliers for the borrowing constraint and the upper bound on health, and  $\xi_{x,t}$  is the shadow value of health in period  $t$ .

In the case of bad health shocks, individuals can pay to reposition themselves on a good earnings path. For high productivity individuals, the marginal cost of treatment is overcompensated by the immediate productivity gain. Since this happens within the period, they can afford to get treatment. For other workers, their productivity is low when compared to the cost of treatment. There are future benefits from treatment - entering the next period in better health, which increases their expected earnings - but the existence of borrowing constraint affects the level of treatment they will be able to get.

Even if experiencing a low productivity period, the asset rich have enough of a buffer to allow them to pay the cost of medical care and regain their earnings path. Consumption is less sensible to shocks for high levels of accumulated assets. When the level of accumulated assets is low, the marginal utility of consumption is high, and so consumption is



a steep function of wealth. In these cases, the optimal choice of medical treatment may imply incomplete recovery, even though maximum recovery would imply higher expected earnings in the future.

Including the Euler equation (3) in equation (5) results in:

$$u_{x,t} + z_t u_{c,t} + q(1+r)\beta E(1-s_{t+1})u_{c,t+1} = q u_{c,t} + \zeta_x$$

This means that the optimal level of health depends positively on the current marginal utility from health, the current productivity of health, valued according to the marginal utility of consumption; and the expected marginal gain in future consumption from health as an input in the production of health the next period. The marginal cost is related to the value of the foregone consumption that allows investment in health in the current period.

As usual in this class of models, borrowing constraints and uncertain earnings imply an inefficiently high level of savings. Some individuals who receive a negative earnings shock would like to borrow to smooth consumption but they are constrained. Consumption is a concave function of income, and the propensity to consume out of wealth is higher for richer individuals.

## Insurance Decision

In this setting, private health insurance works as a trade-off between two different cost functions for access to health care. Individuals without health insurance pay the market price  $q$  for medical services, and have no fixed costs associated with their health. On the other hand, individuals who are enrolled in a health insurance plan pay a discounted price  $(1-\gamma)q$  for medical services, and have a fixed cost, which is the tax deductible insurance premium.

In the individual's problem, the decision to sign up for health insurance is a static choice for an eligible individual, so it can be solved within the period. The relevant cost function for medical services will only appear in their budget constraint. Therefore, the optimal choice with respect to insurance can be studied as a function of the optimal policies under each case (insurance vs no insurance). The following standard result can be readily derived.

**Proposition 1** *There is a cutoff value  $\bar{m}$  for medical services that determines the health insurance decision by an individual. Health insurance is always rejected when the level of optimal medical services for any realization of the health shock  $s_t$  is too low, that is when:  $\max_{s_t} m_t^*(a_t, x_t; z_t, s_t) \leq \bar{m}$ .*

Figure 7 shows a graphical proof of this result. It shows the total cost of health care decisions in a period as a function of medical care. In the case of a worker with health insurance, the total cost of health care is the sum of discounted medical services  $((1-\gamma)qm)$  and premium payment  $p$ , while for an uninsured worker it is simply the full-price cost of medical services,  $qm$ . For consumption of medical services below  $\bar{m}$ , the total cost is lower for the uninsured. When medical services are  $m > \bar{m}$ , the total cost is lower for the insured. Therefore, the individual rejects health insurance when  $\max_{s_t} m_t^*(a_t, x_t; z_t, s_t) \leq \bar{m}$ . There is no general result when the condition in Proposition 1 does not hold.

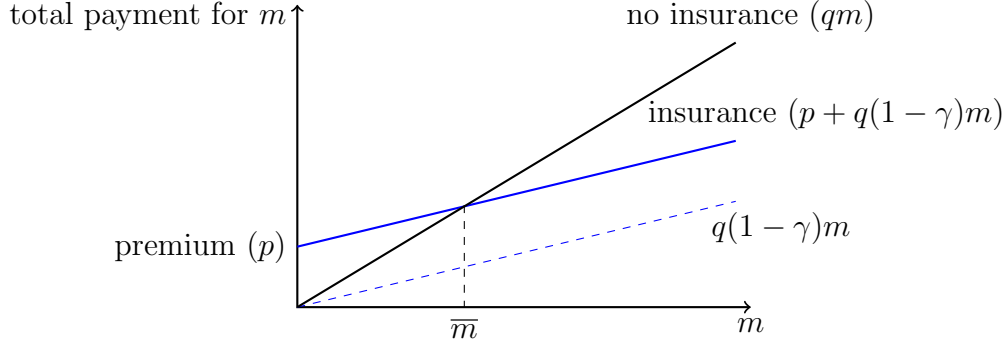


Figure 7: OPTIMAL HEALTH INSURANCE CHOICE DEPENDS ON OPTIMAL LEVEL OF MEDICAL CARE

## 4 Calibration

First, a number of parameters are borrowed from the literature or set equal to their direct empirical counterparts. Second, parameters describing the process of health shocks are estimated from the data on health conditions. Finally, the key parameters describing the interaction between health and income are calibrated to match some of the key data moments. Appendix ?? describes the computational algorithm used to solve the model.

## 4.1 Parameters Set Outside of the Model

### Production function

I assume a Cobb-Douglas aggregate production function:  $Y = K^\alpha L^{1-\alpha}$ , with  $\alpha = 0.36$ .

### Preferences and time

For the period utility I assume the following functional form:  $u(c_{i,t}, x_{i,t}) = \frac{(c_{i,t}^{1-\lambda} x_{i,t}^\lambda)^{1-\sigma}}{1-\sigma}$ . I assume imperfect substitutability between consumption and health to capture the instrumental role of health that goes beyond its effect on productivity. Absent mortality in the model, this captures the vital role of health status. Non-separability between consumption and health is consistent with the empirical evidence that finds an effect of health on the marginal utility of consumption.<sup>35</sup>

I set a coefficient of relative risk aversion  $\sigma = 0.9$  and an annual discount rate  $\beta$  of 0.975. Individuals enter the model at age 25, retirement happens at age 65, and they live until age  $T = 85$ . A period in the model is 10 years.<sup>36</sup>

### Health-related variables

I assume that the initial level of health is 1 for everyone. As explained in Section 3.1,  $x_t \in (0, 1]$  since medical treatment does not enhance health in absence of an adverse health shock. I assume the flow of healthy time is given by  $n(x_{i,t}) = x_{i,t}$ .

I compute health shocks as described in Section 2.2, and I estimate the probability of receiving a bad health shock as  $1 - \pi = Pr(s_t > 0)$ . I compute the empirical distribution of health shocks directly from the data for each of six age groups, as shown in Figure 5. I approximate this distribution of shocks with 3 states for each age group.

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<sup>35</sup>See Finkelstein et al. (2013) and Palumbo (1999).

<sup>36</sup>Due to the dynamics of health, treatment and medical conditions, studying the evolution of variables at a low frequency serves better the objective of the model. All reported parameter values are annual, and are adjusted to account for the longer period like in Livshits et al. (2007).

## Health insurance

In the model, agents are randomly eligible for private health insurance. The probability that they become eligible at the beginning of their lives is correlated with their initial distribution of productivity. I calibrate this initial-productivity dependent probability to match the probability of being eligible for private health insurance by deciles of earnings in MEPS, shown in Figure 8.

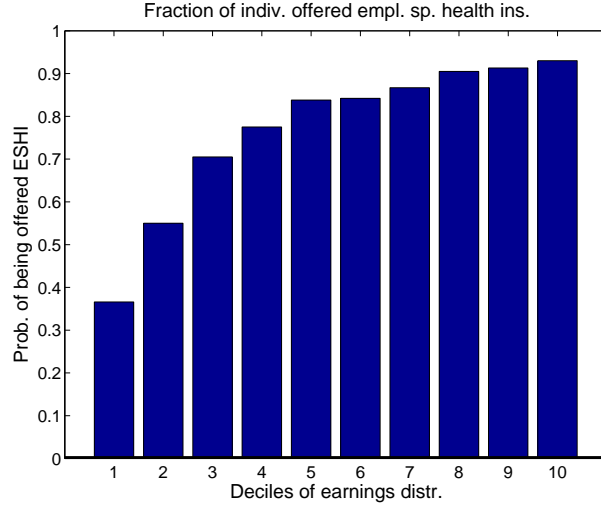


Figure 8: OPTION OF EMPLOYER-SPONSORED HEALTH INSURANCE BY EARNINGS

*Note:* Fraction of individuals ages 25-64 who are eligible for employer-sponsored health insurance, by deciles of the earnings distribution, regardless of whether they are actually enrolled or not.

The parameter for coinsurance is taken to be 1 minus the average fraction of medical expenditures  $\gamma$  that the insurance pays. In MEPS, the insurance company covers on average 70% of total medical expenses (including medical services and prescription drugs). The annual Medicare premium for Part B was \$1,156.8 in 2008, and average earnings in 2008 were \$41,325, so I set  $p_{MediCare}$  to be 2.8% of mean earnings.

## Taxes

Payroll tax rates are set to equal their counterparts in the U.S.: social security tax rate is  $\tau_{ss} = 10.4\%$  and Medicare tax rate is  $\tau_{MC} = 2.9\%$ . The income tax rate is set to the average tax rate in the U.S. in 2008:  $\tau_y = 15\%$ .

## Process for individual productivity

The process for the exogenous productivity is of the form:

$$\log(z_{i,t}) = \alpha_i + g(t) + \tilde{z}_{i,t-1} + \varepsilon_{i,t}$$

where

$$\tilde{z}_{i,t} = \rho \tilde{z}_{i,t-1} + \eta_{i,t}$$

$$\eta_{it} \sim N(0, \sigma_\eta)$$

$$\varepsilon_{i,t} \sim N(0, \sigma_\varepsilon)$$

and  $g(t)$  is a deterministic age productivity profile.<sup>37</sup>

I take from Storesletten et al. (2004) the variance of the productivity fixed effect  $\sigma_\alpha^2 = 0.21$  and the variance of the transitory shock  $\sigma_\varepsilon^2 = 0.06$ .<sup>38</sup> The remaining parameters from the latent productivity process,  $\rho$  and  $\sigma_\eta$ , are calibrated. Since effective earnings in this model are a function of health as well as productivity, the model generates a different observed persistence and variance of shocks than the original process for productivity shocks it is fed, so the calibrated value of  $\rho$  is lower than the estimate in the literature.

Following the life cycle literature, the age productivity profile  $g(t)$  is taken from Hansen (1993). This index is interpolated to in-between years, normalized to average one during the working life, and it is shown in Table 1.

Table 1: DETERMINISTIC AGE LABOR-EFFICIENCY PROFILE

Age group	$g(t)$
25-34 years old	0.9249
35-44 years old	1.0328
45-54 years old	1.0559
55-64 years old	0.9865

*Source:* Hansen (1993)

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<sup>37</sup>Hansen and İmrohoroğlu (2009) show that under certain assumptions the quantitative and theoretical implications of using these exogenous efficiency weights are the same as if the human capital accumulation were endogenously generated by on-the-job training à la Ben-Porath.

<sup>38</sup>To adjust the periodicity of the stochastic variables to that of the model, I follow Livshits et al. (2007).

## 4.2 Parameters Calibrated to Match Data Moments

The calibrated parameters are the weight of health in the utility function  $\lambda$ , the unit price of medical treatment  $q$ , and the persistence  $\rho$  and variance  $\sigma_\eta^2$  of the persistent productivity shock. The values are shown in Table 2.

Table 2: CALIBRATED PARAMETERS

	Parameter	Value
$\lambda_{worker}$	Weight of health in utility, young	0.63
$\lambda_{retired}$	Weight of health in utility, retired	0.5
$q$	Price of medical treatment	0.016
$\rho$	Persistence of productivity shock (annual)	0.93
$\sigma_\eta^2$	Variance of innovation to productivity shock	0.03

(\*) Values for annual frequency

To calibrate these values, I match the moments in Table 3: the slope of the health status profile over the life cycle, the average medical spending with respect to average earnings for workers (individuals in productive life), the average medical spending of retirees with respect to average earnings, the autocorrelation of residual log-earnings, and the variance of residual log-earnings.

Table 3: MATCHED MOMENTS

Moment	Data	Model
$mean(x_{t-1})/mean(x_1)$	1.10	1.10
$mean(qm_{working\ age})/mean(y_{working\ age})$	0.147	0.14
$mean(qm_{retired})/mean(y_{working\ age})$	0.25	0.22
$autocorr(\log y_{res})$	0.967	0.96
$var(\log y_{res})$	9.566	9.53

## 5 Results

Table 4 shows the model performance with respect to some moments not used in the calibration. The model assumes actuarially fair health insurance premiums, which predictably turns out to be lower than the average premium in the data. The model under-predicts

the fraction of people who buy private health insurance. This is a natural outcome given the assumption that there is only one type of health insurance plan in the model, which is actuarially fair, while there are several types of health insurance contracts in reality, which offer different degrees of coverage and imply different costs for individuals. The value to the consumer may differ across these types of plans because there are many nuances in the health insurance market that are not captured by this model. The model generates slightly stronger correlation between health and earnings than the data on residual earnings and residual health.

Table 4: PERFORMANCE WITH RESPECT TO MOMENTS NOT TARGETED IN CALIBRATION

Moment	Data	Model
Health insurance premium	0.085	0.06
$\frac{Med. Exp. Uninsured}{Med. Exp. Insured}$	0.38	0.39
Fraction insured (private)	0.77	0.69
Avg. health, working age	0.81	0.86
Avg. health, retired	0.70	0.73
Corr(health, earnings)	0.14	0.17

Figures 9 and 10 show the evolution of health, consumption, medical spending as fraction of earnings, and assets over the working life, as generated by the model and in the data. The points over the life cycle are indicated by the midrange of the age group. For example, in the graphs, the age group labeled as 30 indicates the group aged 25 to 34 years old.

As in the data, the model predicts that medical expenditures increase over the life cycle, and health monotonously deteriorates with age. The model replicates the concave profile of consumption and the increasing profile of assets. After retirement, consumption goes down and assets are run down. The model does not incorporate any bequest motives, so all agents have zero level of assets by the end of their lives.

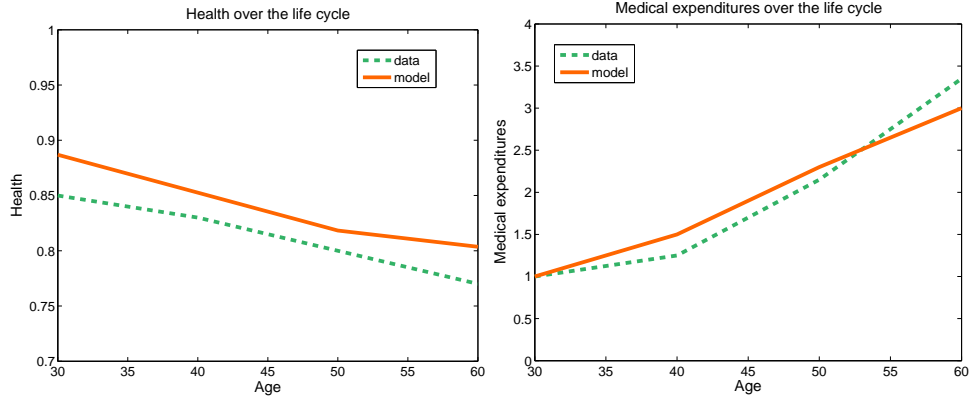


Figure 9: DATA AND SIMULATED LIFE CYCLE PROFILES OF HEALTH AND MEDICAL SPENDING (AS FRACTION OF EARNINGS)

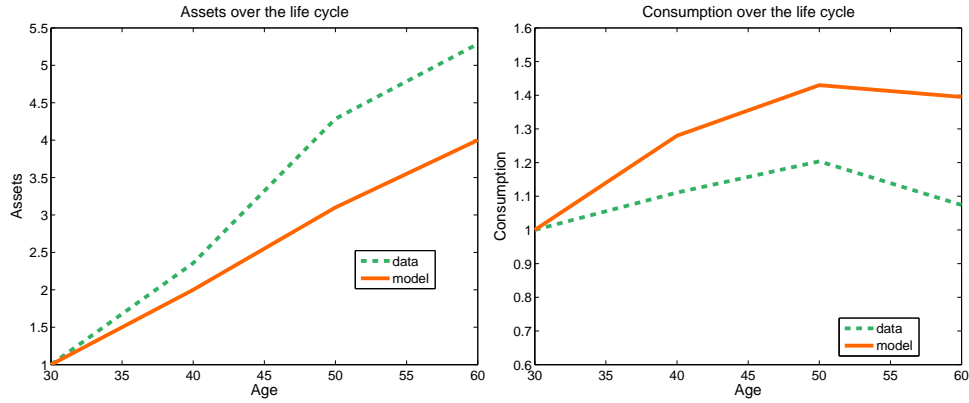


Figure 10: DATA AND SIMULATED LIFE CYCLE PROFILES OF ASSETS AND CONSUMPTION

## 5.1 Dynamics of Health and Earnings Inequality over the Life Cycle

I check how the model performs in terms of the joint evolution of health and earnings over the life cycle. Figure 11 shows the evolution of the average level of health by earnings deciles and age groups. The left panel is the outcome from the model, while the right panel shows the data. The model reproduces a few facts from the data: the health of those in the top decile of earnings remains high during the entire life cycle, the difference in average health between those in the deciles six and ten of earnings is not too high, and individuals with low earnings have much lower average health than those with higher



earnings. The model predicts a more abrupt deterioration in average health of individuals in the second decile of earnings, and too little difference between health of those in the sixth decile versus those in the tenth decile of earnings.

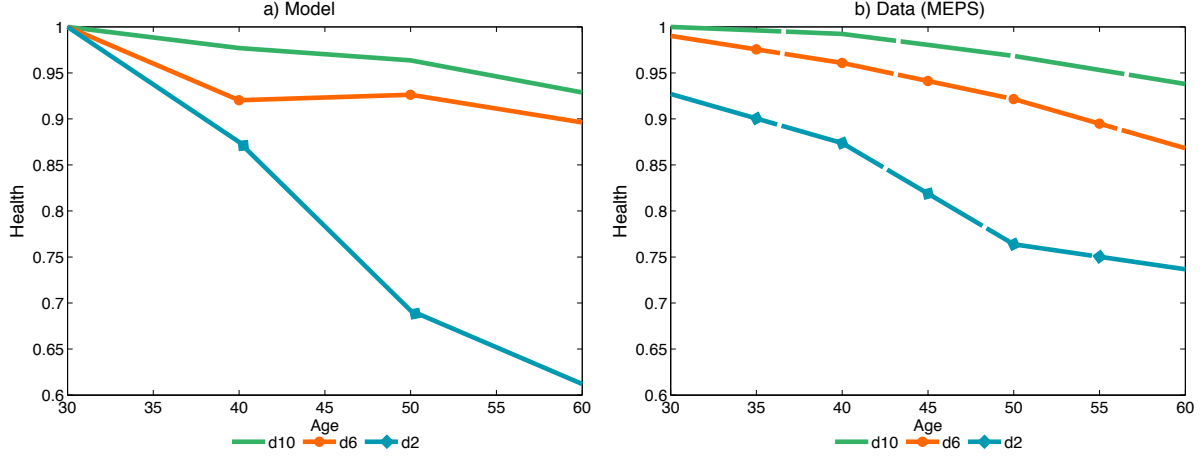


Figure 11: HEALTH BY DECILES OF EARNINGS AND AGE, MODEL (A) AND DATA FROM MEPS (B)

When comparing the model output to the data, it is important to keep in mind that there are sources of insurance that the model does not include, like Medicaid for the very poor and support that may come from relatives inside or outside the household.<sup>39</sup> Also, the model assumes that everyone works as much as they can, given their health status, whereas it is possible that I have not been able to exclude from the sample all the people who are earning less than their market potential for reasons other than health. These aspects can help explain the discrepancy between the model and the data, especially for the poorest individuals.

<sup>39</sup>Medicaid is the government health insurance program for low resources families. Before the Affordable Care Act, Medicaid covered low-income children, pregnant women, elderly and disabled individuals, and some parents, but excluded other low-income adults. Because of this, Medicaid would not be a fundamental force in this model. However, if the model included a Medicaid-like public insurance, only those adults with a very low level of  $h$  and income would qualify, hence it would not prevent the big drop in health but may act as a cushion and prevent health from dropping further, which could help explain the disparity in health for the second decile between the model and the data. As mentioned before, the Affordable Care Act expanded Medicaid eligibility and this framework could be modified to study the effects of this expansion.

## 5.2 Health as Determinant of Earnings Dynamics

This model provides a way to compute how much of the dynamics of the earnings process is accounted for by the health channel. The first result along this dimension concerns the dispersion of earnings. As it was discussed in Section 2, the interaction between health and productivity shocks generates extra dispersion over what comes from the productivity process. Figure 12 shows the ratio of the coefficient of variation of earnings to the coefficient of variation of the exogenous productivity process in the model for all age groups. The dispersion of the residual earnings profile is amplified on average by 5% over the life cycle. The peak of this amplification happens for the group of workers in their last working period before retirement, when it is 8.2%.

The biggest effect of absence of health shocks happens at the bottom of the earnings distribution: Earnings of the first decile of earnings distribution are 120% higher in an economy with productivity shocks alone and the 90/10 ratio declines by 71%. In such an economy, earnings of the bottom half of the earnings distribution are 40% higher. The coefficient of variation declines by 13% when shocks to health are removed from the model.

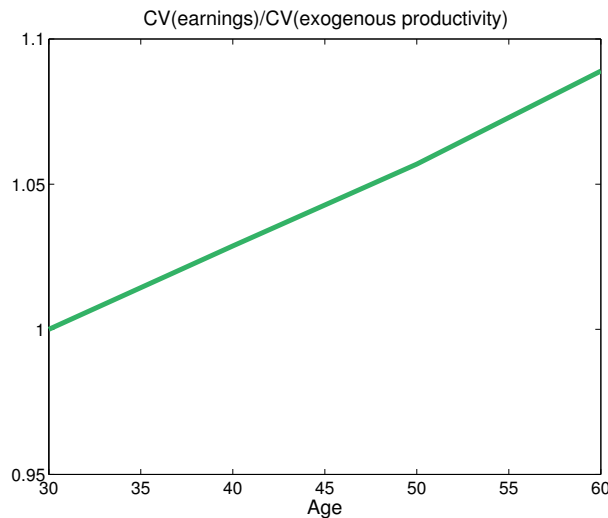


Figure 12: ADDITIONAL EARNINGS INEQUALITY DUE TO HEALTH CHANNEL

The second result about the characteristics of the earnings dynamics concerns the persistence of the productivity process. The observed persistence of residual earnings can

be measured through the autocorrelation coefficient of the process, which is 0.989. The calibrated persistence of the productivity process is much lower, with an autocorrelation coefficient of 0.92. The difference in persistence between these two processes can be better assessed computing the half life of a shock. In the case of residual earnings, the half life of the process is 62.6 years, whereas for the productivity process it is only 8.31 years. This difference highlights health as an important determinant of lifetime risk.

### 5.3 Effect of early shocks

#### Differences in innate productivity

Early shocks are amplified over the life cycle. Low earning workers obtain less medical care in case of bad health shocks, which implies that health insurance makes a larger difference for these workers than for high earning ones.

#### Early health shocks

When the worker receives a bad health shock early in life, it implies lower earnings on average over the life (see Table 5). There is a difference in outcomes between a worker who gets hit by a bad health shock early in life by the insurance status at the time. There is a 22% difference in expected lifetime utility by insurance status, conditional on getting hit by bad health shock in first period.

Table 5: EFFECT OF EARLY HEALTH SHOCKS: AVERAGE SHOCK

	Earnings
On average	-5.6%
1st quintile of earn. distr.	-7.3%
top 60% of earn. distr.	-4.0%
Insured	-3.1%
Uninsured	-8.1%

## 5.4 Robustness: Health in the Utility Function

In this exercise I explore the effects of not including health as an argument in the utility function. Removing health from the utility function of the retirees, by setting  $\lambda_{retired} = 0$ , means there is no motive for the retirees to buy any kind of medical services. This would be counterfactual.

Removing health from the utility function of the workers, by setting  $\lambda_{worker} = 0$ , implies that the role of health becomes more similar to a human capital model, and there is a point of optimal disinvestment in human capital-producing health before it renders useless at the retirement age. Therefore, the profile of medical expenditures would be concave instead of convex. This would be counterfactual. This is consistent with findings in Halliday et al. (2017). Figure 13 illustrates the case with both  $\lambda_{worker} = 0$  and  $\lambda_{retired} = 0$ .

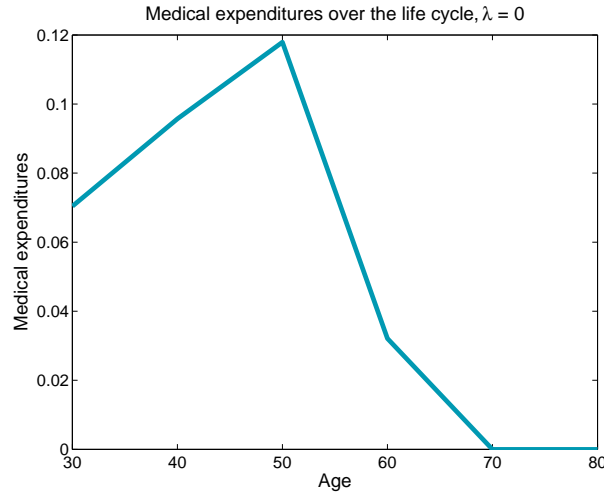


Figure 13: LIFE CYCLE PROFILE OF MEDICAL EXPENDITURES,  $\lambda = 0$  CASE.

## 6 Policy Experiments

In this section, I study the implications for earnings distribution and for other variables like consumption, health, and earnings, of policies that affect different components of access to health care. Exploiting the interaction between health and earnings in the model, I also use it to look at the redistributive effects of these health care policies. The policy

experiments studied here address different aspects of health insurance. The ingredients of health insurance in the model are eligibility, insurance premium, and coinsurance rate, and in this section I focus on eligibility and insurance premium. The set of counterfactuals is laid out in increasing degrees of policy effectiveness for increasing health insurance coverage.

These counterfactual exercises provide insight on the effects of some key provisions of the health care reform law signed in 2010, the Affordable Care Act, most of which went into effect in 2014.<sup>40</sup> While the model is not designed to incorporate all of the changes that this reform put in place, it is adequate to study the effectiveness and consequences of policies aiming at increasing health insurance coverage. One of the goals of the 2010 health care reform was to get closer to universal health insurance coverage. New insurance regulations aim to achieve this, amongst other aspects of the reform. One such regulation forbids insurance companies to deny coverage or adjust premiums due to pre-existing conditions. This means everyone has the option to enroll in a health insurance plan in the individual market.<sup>41</sup> In order to prevent the market from breaking down due to adverse selection, the law put in place an individual mandate which requires that every eligible individual enrolls in some health insurance plan. Lastly, to make this requirement affordable for everyone, the law implemented a series of health insurance premium subsidies. The Affordable Care Act also included a mandate for large employers to offer employer-sponsored health insurance to their employees.

The first counterfactual exercise studies the effects of generalized access to health insurance, in the sense that everyone is eligible to enroll in private health insurance. In this case, health insurance obtained through the individual market looks the same as employer-sponsored health insurance. This experiment goes in line with one goal of the Affordable Care Act, which is to expand coverage providing individuals with new insurance opportunities, although the exercise does not incorporate all of the mechanisms the Affordable Care Act puts into place to achieve this.

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<sup>40</sup>There are ongoing political efforts to repeal and replace the Affordable Care Act. Even if this law is finally repealed, the exercises carried out in this Section are helpful to understand the potential impact of any policy aimed at increasing health insurance coverage.

<sup>41</sup>The Affordable Care Act put in place state-wide health insurance exchanges to replace the failed individual market. It also regulated the basic benefits that health insurance should provide, thus making health insurance plans in the individual market more similar to employer-sponsored plans.

The second exercise also targets an expansion of health insurance, but adding a subsidy to the health insurance premium. The Affordable Care Act also provides individuals and families with financial support to buy health insurance. Tax credits for the purchase of health insurance, also called premium subsidies, are available to people based on their income.

The third counterfactual studies a social health insurance case: health insurance is universal and the premiums paid for by the government yet medical care is not free, as individuals must pay a coinsurance rate for the medical care they consume.<sup>42</sup> In the mode, this works as a plain subsidy of medical services. The results of these policy experiments are explained below.

## 6.1 General Eligibility for Private Health Insurance

In this counterfactual exercise, I study the case where everyone is eligible for private health insurance and, in each period, individuals decide whether to enroll or not. Table 6 shows the results of this policy. Access to health insurance affects the entire life cycle path of outcomes: it increases consumption, health status, and earnings of the newly insured. The variance of earnings of the newly insured cohorts goes down and inequality goes down in the new equilibrium.

Table 6: RESULTS FROM GENERAL ELIGIBILITY TO ENROLL IN PRIVATE HEALTH INSURANCE

Variable	Result
Insurance rate	82%
Variable	Change
Lifetime consumption of the newly included in ESHI	+2.0%
Lifetime health of the newly included in ESHI	+3.5%
Lifetime earnings of the newly included in ESHI	+2.5%
Variance of earnings of newly included in ESHI	-1.01%
90/10 earnings ratio	-14%

Figure 14 shows the life cycle evolution of earnings dispersion for the group of people

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<sup>42</sup>This social health insurance system is similar to the Bismarck model, implemented in Germany and followed by other European countries and Japan during the last century.

who were ineligible for health insurance in the benchmark model and for that same group in the counterfactual scenario. The figure shows two paths, everything else constant: one path corresponds to the benchmark case (when the group is ineligible for health insurance), and the other corresponds to the counterfactual case when there is a health insurance enrollment option for everyone in that group.

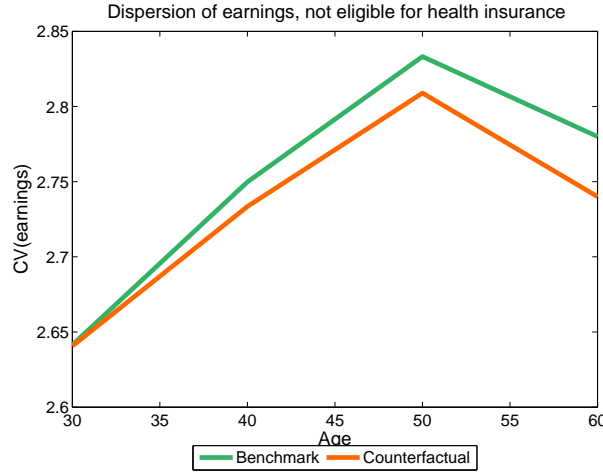


Figure 14: DISPERSION OF EARNINGS FOR THE GROUP OF INELIGIBLE FOR INSURANCE, WHEN INELIGIBLE (BENCHMARK) AND WHEN MADE ELIGIBLE (COUNTERFACTUAL)

A fraction of people will choose not to enroll in health insurance in the general eligibility case, so any aggregate differences between the two groups are derived from those who do enroll in the health insurance plan only. The lower dispersion in earnings is a result not only of better health outcomes. The lifetime correlation between earnings and health goes down from 0.202 to 0.195 with generalized voluntary access to health insurance.

## 6.2 Subsidies to Health Insurance Premium

An individual mandate seeks to achieve universal coverage in the population by making health insurance compulsory. In principle, this can be accompanied by subsidies for the premium or not. In the context of the model, I have shown in the previous section that the take-up rate of the health insurance plan is lower than 100% when everybody is eligible for private health insurance. This implies that putting in place an individual mandate

without subsidizing the health insurance premium would impose a disutility cost on those who find it optimal to not enroll in health insurance. Additionally, given that there is no adverse selection in the model, nobody would have a utility gain from an individual mandate. Therefore, its effects are limited.

For these reasons, I study the role of another component of the Affordable Care Act that is complementary to the individual mandate: subsidies to health insurance premium. In the model, a subsidy of 50% the insurance premium drives the take-up rate to 89% and reduces the 90/10 earnings ratio by 18.5%.<sup>43</sup> The young and those at the bottom of the earnings distribution are most likely to choose to remain uninsured. Given the set of parameters used, in order to achieve 100% coverage, the subsidy rate must be of 78%.

### 6.3 Universal Health Care

In this exercise, I assume a form of universal health care that consists on government-sponsored health insurance for everyone. Everyone has access to health insurance and no premium payment is required. Individuals pay coinsurance for the medical services they consume, and the government covers the rest. This system works in practice just as if the government provided a subsidy for all medical services.

I assume this form of universal health care is put in place financed through proportional taxation. The coinsurance rate is the same as in the private health insurance case of the benchmark model.

As a result of this policy, there are positive effects in health and consumption: Average health goes up by 4.4%, and average consumption goes up by 0.05% (average consumption goes up for the bottom 50 percentiles or the earnings distribution, and it goes down slightly for the top 50 percentiles of the earnings distribution). Average medical expenditures also increase by 5.4% and average earnings increase by 1.63%.

The main effect of equal access to subsidized medical treatment for everyone is that the connection between health outcomes and earnings is weakened. The correlation between health status and earnings is 0.1781 on average across age groups, while it was

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<sup>43</sup>In 2017, the average subsidy was around 40% and 10.5% of the non-elderly population remained uninsured in the U.S, which is roughly in line with the magnitudes of this counterfactual. However, it is worth noting that the provisions in the Affordable Care Act went into effect in 2014. Thus, given the recency of the health care reform in the U.S, the current situation is arguably a transition and not a new equilibrium yet, hence it is not directly comparable to the counterfactual results.



0.2025 in the benchmark model.

In terms of welfare, the utilitarian measure of welfare indicates that welfare goes up by 1.02 percent. The largest increase in welfare amongst age groups occurs for the 45-54 age group, that experiences an increase of 1.23 percent with respect to the benchmark economy. Utility goes up for everyone below the 90 percentile of the earnings distribution.

## 7 Conclusions

The findings in this paper are potentially of great relevance for the present debates about earnings inequality and about the consequences of access to health care. By accounting for the joint evolution of health and earnings, I show that health care policies can affect the distribution of labor earnings in the economy. Moreover, I find that the health channel explains around 9% of the increase in earnings dispersion over the life cycle. The interaction between health and earnings increases the persistence of the effects from all shocks: productivity, health and insurance eligibility. I find that the accumulation of bad shocks in both health and productivity dimensions translates in a low health outcome in some states. This low level of health is carried on to the next period, propagating the persistence of productivity shocks and increasing the persistence of the earnings process. Therefore, the interaction between health and earnings can create low earnings-low health outcomes since most additional dispersion in earnings and health happens at the bottom of the earnings distribution.

The policy exercises in this paper imply that health care policies that increase health insurance coverage or provide subsidized health care have redistributive consequences because they can affect and prevent the poverty traps aforementioned. Generalizing health insurance eligibility to everyone reduces inequality and increases lifetime consumption, earnings and health, even though a fraction of individuals still chooses not to enroll in health insurance. In that setting, subsidies are necessary to increase coverage. Universal health insurance coverage reduces the correlation between earnings and health and increases welfare. The main redistributive effect of these health care policies is through increasing the earnings of the lower ability-lower health workers. Subsidized expansions of health insurance would mostly benefit those at the bottom of the earnings distribution.

An important avenue for future research is to investigate what these joint dynamics

between earnings and health imply for related problematics of the current economy, like disability claiming and early retirement.

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# Appendix

See online appendix in [www-bcf.usc.edu/~prados/Prados\\_Health\\_OnlineAppendix.pdf](http://www-bcf.usc.edu/~prados/Prados_Health_OnlineAppendix.pdf)