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

María José Prados[*][†]

November 15, 2012

Abstract

I study the aggregate implications of health risk and access to health care. At the individual level, health influences earnings potential, while income affects access to medical care. I investigate how this interaction shapes the joint dynamics of inequality in health and earnings over the life cycle, and I measure the redistributive impact of policies that improve access to health care. For that, I introduce health shocks and health care spending in an incomplete markets model with heterogeneous agents. Earnings risk is partially determined within the model due to the health-income feedback, and negative shocks may drive agents into a low income-low health trap, thus magnifying inequality along the life cycle. I estimate the process for health shocks and I calibrate the key parameters of the model using survey data. The calibrated model successfully reproduces the joint dynamics in health and earnings inequality in the life cycle. Like in the data, it predicts that life cycle inequality in health is driven by a sharp decline in health status for the lowest percentiles of the health distribution. I find that the health-income feedback accounts for 17 percent of total earnings inequality, and that it increases by seven times the persistence of shocks to productivity. I also find that health care policies that facilitate access to health care have redistributive effects, mostly through earnings improvements for those at the bottom of the earnings distribution.

Keywords: Inequality, Life Cycle, Health, Income.
JEL classification: E21, I14

1 Introduction

It is well documented that income disparities among individuals grow over time within a cohort. In the U.S, the variance of income almost doubles between ages 25 and 60. Understanding the source of this increase in inequality is of central relevance for macroeconomists and policy-makers alike. While many forces, such as human capital accumulation, education policies, search frictions, and heterogeneity in preferences have been considered as determinants, residual inequality remains after taking them into account.[1]

In this paper I study the role of health shocks and access to health care in shaping the dynamics of inequality in health and earnings over the life cycle. A large empirical literature documents that, at the individual level, negative health shocks affect productivity and income, while income and health insurance status affect spending on medical care and health outcomes.[2] When incorporated in a dynamic setting, this 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. This paper studies the aggregate implications of these forces. How important is health as a determinant of life cycle inequality? How much of the lifetime earnings risk is produced by the feedback between health and earnings? What is the redistributive impact of policies that facilitate access to health care?

Answering these questions requires a framework with the potential to generate inequality in both earnings and in health on the life cycle of a cohort. In addition, the magnitude of the interaction between health and income shocks must depend on parameters that can be disciplined with data. To achieve this, I introduce idiosyncratic health shocks and health care spending in an incomplete markets model with heterogeneous agents. In the model, the interaction between health and income crucially 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 directly estimate the process for health shocks and I calibrate the key parameters of the model using survey data on health status, health care spending and income from the Medical Expenditures Panel Survey (MEPS).

First, I verify that the model successfully reproduces salient features of the joint

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[1]Huggett, Ventura and Yaron (2006; 2011) study the role of human capital accumulation and initial learning conditions to generate dispersion in earnings over the life cycle, Gallipoli, Meghir, and Violante (2010) study the effects of education policies on earnings inequality, Low, Meghir, and Pistaferri (2010) find that job mobility is an important source of risk, Kaplan (2011) studies the importance of search frictions to achieve earnings dispersion, and Heathcote, Storesletten, and Violante (2009) allow heterogeneity in preferences for work.

[2]See section 2 for references and a review of this literature.

dynamics of health and earnings inequality in 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 I see in the data. It also predicts that the correlation between health and earnings increases over the life cycle, and that the lower end of the earnings distribution also has the lowest average health levels.

Second, I investigate the importance of health-income interactions for health and earnings inequality, and I evaluate the redistributive impact of policies that influence access to health care. Two key contributions of my paper are to measure how much of lifetime earnings risk is due to health risk, and to determine by how much agents can offset this risk through access to health care. Idiosyncratic income risk and incomplete insurance are central components of models with heterogeneous agents in the Aiyagari-Imrohoroglu-Huggett tradition, but in my model earnings risk is partly endogenous thanks to the interaction between health and earnings.

I find that the health-income feedback accounts for 17 percent of total earnings inequality, and that it is also responsible for 7 percent of the observed persistence in the individual earnings process.[3] I perform counterfactual exercises and find that health care policies that increase health insurance coverage or make health services more affordable have redistributive effects by improving the earnings outcomes of those at the bottom of the earnings distribution. If everyone has an option to buy health insurance, the fraction of insured workers goes up by 11 percent and the ratio between the 90 percentile of earnings and the 10 percentile of earnings - a common measure of earnings dispersion - would go down by 15 percent. If everyone has access to public health insurance, the correlation between health and earnings is weakened, and it decreases by 12 percent.

In the model, heterogeneous agents receive uninsurable shocks to labor market productivity and accumulate assets. In addition to productivity, individual earnings also depend on workers' amount of healthy time, and agents receive shocks that potentially 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). Agents can mitigate the negative impact of shocks to health by paying for medical services.[4] For this, they can also purchase health insurance, which results in a lower cost of access to medical care in case a bad health shock hits.

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[3]This fraction of persistence, measured as the autocorrelation coefficient of the process - implies that the half life of an annual shock is amplified seven times.

[4]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 suffering a medical condition.

In this setting, 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 purchase 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 shock to health. These effects amplify earnings and health inequalities amongst ex-ante identical individuals during the evolution of their lives. In addition, the accumulation of negative shocks to both health and productivity translates into a low health status 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.

To calibrate the model, I distinguish between health status and shocks to health. The first one is an endogenous outcome that depends on agent's choices, while the second one is an exogenous shock which I identify with medical conditions and whose distribution may depend on age. To measure the health status I directly observe a continuous health score which is comparable across individuals from the Medical Expenditures Panel Survey (MEPS). The MEPS also includes detailed information about medical conditions of individuals in each period. I compile this information at the individual level, as described in section 2, to obtain a measure of health-reducing shocks for individuals in different age groups.

Using the calibrated model, I argue that income-health traps help account for the extreme disparity in income and in health amongst workers. In particular, I find that: i) 25% of inequality in later phases of the life cycle is accounted for by health shocks; ii) the long-run impact of early productivity differences is magnified by the presence of health shocks; iii) 17% of the lifetime earnings risk comes from the health channel and iii) health care policies can have strong distributional impact through this channel, especially for those at the bottom of the earnings distribution. I conclude that health shocks explain a significant part of inequality in income and health in the U.S., and that health care policies have an important impact on both these outcomes.

I use the model to evaluate how policies that affect different aspects of health care impact earnings inequality and welfare. The experiments show that allowing more workers access to employer-sponsored health insurance increases the fraction of the population that buys health insurance, as well as their well-being. However, a fraction of the population would still in that case not opt into private health insurance voluntarily. Therefore, in

order to achieve complete voluntary health insurance coverage, it is not enough to improve access to insurance markets, but a subsidy to the health insurance premium needs to be put in place. The degree of resulting earnings inequality declines as larger fractions of the population are covered by health insurance.

Deaton and Paxson (1998) started an empirical literature that studies 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,[5] but there is no theoretical micro-founded model that generates this correlation in equilibrium.[6] The main contribution of this paper is to provide a framework with interactions between health and earnings that is suitable to understand 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 is 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, McGarry, and Skinner (2010), De Nardi, French, and Jones (2010), Poterba, Venti, and Wise (2010). Unlike that literature, the focus of my project is mostly on the productivity consequences of health care decisions during the working life. Also, many papers in this literature treat health expenditures as exogenous shocks, as their main focus is in the asset accumulation consequences of medical expenditures. This category includes some of the most influential contributions to the literature, like Hubbard, Skinner, and Zeldes (1995); Jeske and Kitao (2009); De Nardi, French, and Jones (2010). Other papers assume that the evolution of health status is exogenous, like Attanasio, Kitao, and Violante (2010), Imrohoroğlu and Kitao (2010) and Capatina (2011). However, as stated before, there is evidence of health status responding to income shocks and health insurance status. This channel is key for my analysis. My paper is also related to the work by Halliday, He, and Zhang (2011). They study how investment 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 recent strand of literature concerned with welfare evaluation of policies related to health insurance schemes. Those papers usually do not consider the impact on labor market outcomes and earnings dispersion, which is the main

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[5]See Wilkinson and Pickett (2005) for a survey.
[6]See Deaton (2001).

focus of this paper.[7] Unlike this literature, I am concerned with the interaction between health and earnings dynamics. I explicitly distinguish between shocks to health and health outcomes, and I estimate shocks to health form survey data. This feature allows me to study the role of wealth, earnings, and credit constraints in accounting for health outcomes and medical expenditures. Because I model the interaction between health and earnings, this framework is suitable to assess the redistributive consequences of health care policies. Also, with my model I can distinguish the effects on the path of earnings of all different types of shocks: productivity, health, and health insurance.

The paper is structured as follows: Section 2 describes the 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 policy exercises. Section 7 includes robustness exercises. Section 8 concludes.

2   Health and Earnings in the U.S.

In this section, I document salient features of the joint evolution of inequality in health and earnings during the life cycle. To do this, I use data on health status, medical expenditures, health insurance coverage, income, and demographic characteristics from the Medical Expenditure Panel Survey (MEPS).[8] Then, I briefly survey empirical findings from the microeconomics literature related to these facts. In subsequent sections, I evaluate to which extent the model can reproduce these basic patterns.

A first challenge for any analysis of this type is obtaining a reliable measure of health status that can be compared across individuals. Some commonly used measures are either not comparable across individuals, or capture very narrow aspects of health.[9] In contrast, the MEPS includes a summary score for health called Physical Component Summary (PCS). The PCS score provides a summary measure from a broad physical

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[7]See Jeske and Kitao (2009), Attanasio, Kitao, and Violante (2010), Jung and Tran (2011), Pashchenko and Porapakkarm (2010), Feng (2012). Hansen, Hsu, and Lee (2012) study Medicare buy-in with incomplete markets, endogenous labor and adverse selection. Papers that include endogenous investments in health to study the effects of health insurance policy are Ozkan (2011), Scholz and Seshadri (2010), and Cole, Kim, and Krueger (2012).

[8]See Appendix A for a description of MEPS and the data.

[9]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*. A less commonly used proxy for health in the literature has been the body mass index. The obvious drawback of this measure is that it captures a very narrow aspect of health.

health perspective. It weights answers to a short questionnaire which targets different measures of general health and of physical and mental limitations in different activities.[10] As a result, PCS summarizes various 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.[11] In my quantitative analysis, I interpret this score as the fraction of time that can be effectively applied to productive activities.

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.

The main facts emerge from the analysis are as follows: 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 through a worsening in the health status of individuals in the lowest twenty percentiles 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.

2.1 Facts
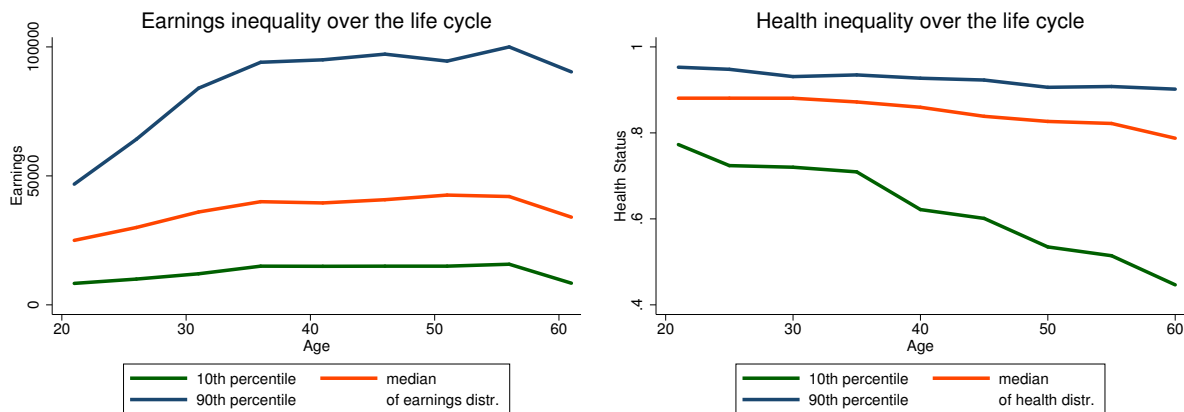
Inequality in Health and Earnings during the Life Cycle

In figure 1, I document the evolution of the dispersion in both earnings and health during the life cycle, using the PCS measure for health status.[12] The figure includes individuals ages 20 to 64 years old, grouped in five-year age groups which are indicated by the lowest age in each one. The left panel shows the 90th, 50th and 10th percentiles of the earnings distribution within each age group. In turn, the right panel shows the 90th, 50th and 10th percentiles of the health distribution for these age groups.

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[10]See Appendix A for more information on PCS and the questionnaire from which it is computed.

[11]Feng (2011) also uses the PCS as measure of health status for his calibration exercise.

[12]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.

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 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 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.

Source: own from MEPS

Figure 1: Health and earnings inequalities over the life cycle

Relation between Health and Earnings

I document additional features of the joint distribution of health and earnings that will inform the quantitative analysis. The literature that studies the causality aspects of this behavior at the individual level is surveyed in sub-section 2.2 below.

Figure 2 displays the cross-sectional correlation between health status and earnings over the life cycle. Two characteristics are noteworthy. 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 health status deteriorates for all. This pattern for the correlation between health and earnings by age groups parallels the concavity of the earnings profile.
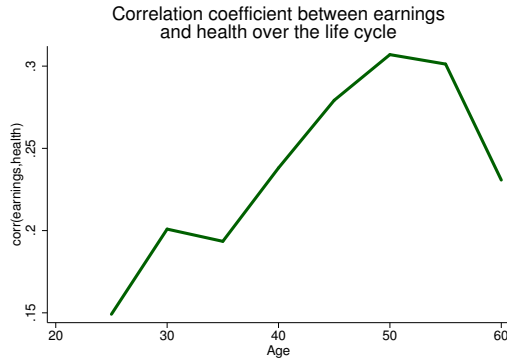
8

Figure 2: Health and earnings over the life cycle

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. Also, 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.
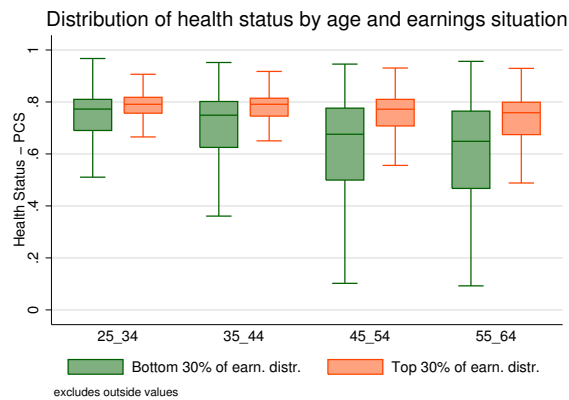

Figure 3: Health status distribution by age and earnings group

Health Insurance and Earnings

Another important dimension of inequality is given by the access to medical services. Health insurance status determines what kind of medical treatment an individual can afford. In the U.S., 18.7% of adults aged 21 to 65 years old in 2008 did not hold private health insurance and did not qualify for public health insurance. Access to health insurance is an important determinant of health outcomes, and it is also correlated with earnings. The group of uninsured workers has on average 43% lower earnings than those insured, controlling for all observables in a Mincer-type regression. 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. Figure 4 shows the fraction of uninsured workers by percentiles of earnings. 44% of individuals in the first decile of the earnings distribution was uninsured in 2008, while this figure is less than 5% of those in the last quartile of the earnings distribution.
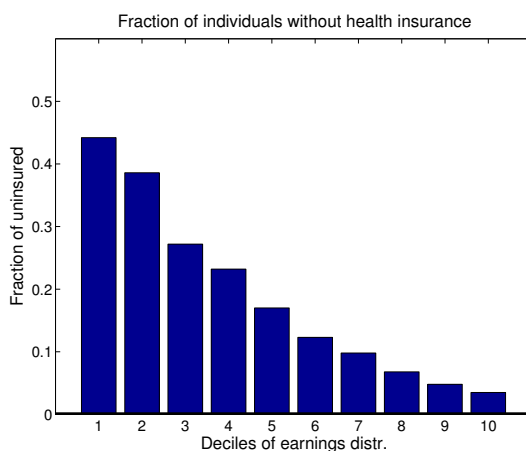
Figure 4: Fraction of uninsured, over percentiles of earnings.

2.2 Measuring Shocks to Healthy Time

In the model, I distinguish between two 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 the data.

I use the *medical conditions files* in MEPS, that 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 discard conditions that were diag-

nosed 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 disability, understood as some decrease in the physical and mental strength and energy an individual has, and in the number and complexity of tasks that can be performed. 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*[13] 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).[14]

More precisely, the interpretation of these disability weights is the following: if a medical condition implies a certain potential disability d, the resulting health status is reduced by this fraction, so the new health status is $health * (1 - d)$. A measure of the health shock received by an individual must account for all conditions that appear in the period. Therefore, the disability weights for all conditions the individual gets that period must be aggregated. When there are J conditions, the cumulative effect on health is given by the shock s, defined as follows

$$(1 - s) = \Pi_{j=1}^{J}(1 - d_j) \tag{1}$$

Using this method, I compute the total disability weight for the total of each individual's medical conditions 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.

For the quantitative analysis, I feed this distribution of health shocks (adjusted to the length of the period) into the model, and the optimal solution to each individual's problem generates the evolution of his health status, conditional on his history of shocks.

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[13] *http://www.who.int/bulletin/volumes/88/12/10-084301/en/*

[14] For discussions of this measure see Murray and Lopez (1996), Essink-Bot et al. (2002) and Mont (2007) on using disability weights.
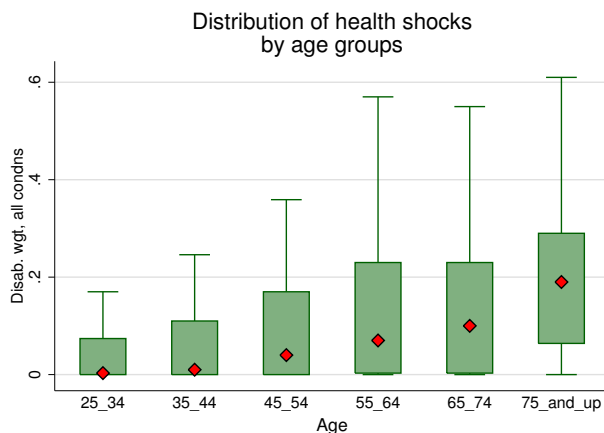
Figure 5: Distribution of health shocks

2.3 Literature on Causality between Health and Earnings

The health economics literature has documented that several measures of health and different measures of socio-economic status are positively correlated at the individual level.[15] 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).[16] The effects of income and wealth on health materialize through access to health insurance, and medical treatment.[17]

This two-way interaction between health on 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, Kitao, and Violante (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. Moreover, he finds that these effects are persistent in time. Other studies focus on particular medical conditions. For example, Pincus, Mitchell, and Burkhauser (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

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[15]See Cutler, Lleras-Muney, and Vogl (2008).

[16]For a survey, see Currie and Madrian (1999).

[17]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).

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.

At the same time, earnings and wealth affect health through access to health insurance as well as through access to medical treatment. Newhouse and Group (1993) and Dow et al. (1997) find evidence from the RAND Experiment that shows that people with access to health insurance achieve better health outcomes,[18] while Currie and Gruber (1996, 2001) find health benefits from increased health insurance eligibility. Doyle (2005) finds better outcomes from hospital treatment due to automobile accidents for those with insurance. Finkelstein et al. (2011) find that insurance increases utilization and health outcomes in the Oregon Experiment.[19]

In addition to the effects of health insurance, the demand for health care is elastic with respect to income and price. Newhouse et al (1993) have found that the use 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 positive price coefficient. Acemoglu, Finkelstein, and Notowidigdo (2009) use oil price shocks to instrument income effects, and find evidence of positive income elasticity of health care consumption.[20]

In my model, people with higher earnings or wealth are more likely to choose health insurance and get more medical care, reinforcing the effect of earnings and health shocks during the life cycle.

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[18]The RAND Health Insurance Experiment was an experimental study of health care costs, utilization and outcomes in the United States, which assigned people randomly to different kinds of plans and followed their behavior, from 1974 to 1982.

[19]The Oregon Health Study, conducted since 2008, was the first randomized controlled experiment to examine the causal effects of having some type of insurance versus having no insurance at all on access to and utilization of health care, family finances, and ultimately health status.

[20]Disentangling the direct effect of earnings or wealth status on health is a difficult task, which many papers in the literature have tried to accomplish. In order to account for the potential endogeneity of wealth and earnings, wealth shocks have been used as instrumental variables (Meer, Miller and Rosen (2003), Michaud and Van Soest (2008); Smith (2005)) with different results with respect to causation. Adams et al. (2004) and a follow up work with extended data and cohorts by Stowasser, Heiss, and McFadden (2011) apply a system of non-causality and invariance tests to rule out causality channels. The reanalysis with fresher and more encompassing data by Stowasser, Heiss, and McFadden (2011) suggests that direct causal links from SES to health can be ruled out for much fewer health conditions than in the Adams et al. (2004) study. Therefore, there is still no consensus about definite results in this part of the literature.

3 Model

I start from a standard life-cycle model with incomplete markets and idiosyncratic risk. I augment this setting incorporating health status in the individual 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 total or partially offset the negative impact of health shocks on their productivity by seeking medical treatment; iv) agents can purchase health insurance and if so, reduce the cost of medical expenditures if a negative health shock hits.

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 agents are born as old agents die. At birth, each agent draws a fixed effect for his process of latent productivity. 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. Agents face borrowing constraints.

Figure 6: Timeline
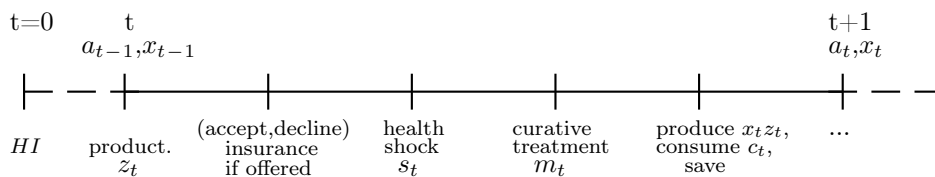
The timing of decisions is shown in figure 6. At the beginning of his working life, the individual randomly becomes eligible to access health insurance or not. Then, in the beginning of each period, agents receive a shock to their productivity. If eligible, given

14

their assets and their productivity level, they decide whether to accept of decline the health insurance contract. 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.

3.1.2 Earnings and the Role of Health

Health status x_t is normalized to 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 disability or impairment. A value of zero means death, and since there is no mortality in the model health only takes strictly positive values: $0 < x_t \leq 1$. Health is valued because it has an instrumental value: it allows individuals to perform at 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" $n(x_t)$. This flow determines the maximum amount of time available for market activities. Each unit of healthy time is transformed in the market into z_{it} 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. Medical treatment only serves to cure a condition. Absent a negative health shock, there is no role for medical treatment since there is no accumulation of health beyond the maximum level of 1.

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

$$x_t = x_{t-1}(1 - s_t) + m_t,$$

where s_t is a disabling health shock, or a measure of health loss. The shock to health s_t is uncorrelated over time, and its distribution is age-dependent. I assume medical care m helps to partially or totally restore the health status only in case of a bad health shock, so $0 \leq m \leq s_t x_{t-1}$. This assumption captures 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 of ten years. For this reason it is sensible to assume that health loses that are not treated and restored in past periods cannot be

15

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 to disability 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 disability is computed using equation (1), reproduced here:

$$(1 - s_J) = \Pi_{j=1}^{J}(1 - d_j)$$

This implies that the disability due to comorbidity increases with more diseases but is less than the sum of individual disability weights for all conditions. In the specification of the model, s_t enters the law of motion for health x_t in this way to be consistent with this.

The linear specification of the effect of m_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.[21] It is further assumed that there is no possibility to invest in health beyond 100% healthy state $x_i = 1$, so $x_{i,t} = x_{i,t-1}$ if $s_t = 0$.

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, and the fraction of healthy time $n(x)$ 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). Also, due to credit constraints some workers are not able to achieve their desired level of health when hit by a bad health shock.

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[21]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. I am currently working on robustness exercises with respect to a more general functional form $x_t = x_{t-1}(1 - s_t) + m_t^{\varphi} x_t^{\nu}$.

The underlying productivity level $z_{i,t}$ follows a stochastic process that depends on a worker's initial level of productivity, his age, and has a transitory and a persistent component.[22] 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

$$y_{i,t} = wn(x_{i,t})z_{i,t},$$

where w is the market wage.

3.1.3 Health Insurance

At the beginning of their working lives, individuals randomly become eligible for private health insurance or not. This status is assumed to be permanent. However, each period those who are eligible decide if they contract health insurance or not. Health insurance eligibility is correlated to an individual's innate productivity level (as suggested by the data, described in the calibration in section 4). These assumptions constitute a stylized way of modeling access to private health insurance in the U.S.[23]

The insurance contract considered in this model captures one of the main components of current regular health insurance contracts in the U.S., it provides a discount on medical services.[24] There is only one type of health insurance contract in this economy. 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 pocket. The rest is covered by the insurer.[25] I assume that the health insurance sector is competitive,

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[22]Explained to more detail in the calibration section 4 below.

[23]In the U.S., most people obtain health insurance from their employers. However, many people work for firms that do not offer this option -usually smaller firms- or are self-employed. In spite of this, only 5% of workers get health insurance in the individual market. The pervasiveness of employer-sponsored health insurance is due to important differences between the group and individual health insurance markets. In group health insurance contracts, the worker is not subject to health screening and the premium does not depend on age. Also, medical underwriting is not permitted by large firms, therefore their premiums are generally based in community rating. Also, if a worker takes group health insurance, the premium is tax deductible. On the contrary, the tax benefit is lost with individual insurance, and moreover, the individual market for private health insurance is problematic due to asymmetric information. In this market, medical underwriting is allowed and many individuals with pre-existing conditions are denied coverage. Therefore, modeling private health insurance eligibility as a random event, correlated to earnings ability, allows me to capture these deficiencies in insurance markets.

[24]I abstract from catastrophic health insurance plans. Catastrophic health insurance plans are high deductible, low premium health insurance policies. These plans usually do not pay for regular medical services but covers major medical expenses. Absent bankruptcy and mortality in my model, and given that medical expenditures are bounded above, there is no relevance for these plans in this setting.

[25]I abstract from access to public health insurance for now, but I am working on a version of the

and the premium is actuarially fair.

Therefore, the characteristics of the unique health insurance contract are summarized in the parameters (p, γ). Health care policy can also change the share of individuals that are eligible for health insurance.

3.1.4 Retirement Period

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

After period $\underline{t}$ workers retire. Worker's receive social security payments in the form of a transfer b from the government when they retire. Additionally, all retirees are automatically enrolled in Medicare and pay a premium $p_{MediCare}$. Medicare covers a fraction γ of their medical expenditures.[26] The weight of health in their utility is higher to reflect the importance of old age medical expenditures and the increased need to buy comfort-enhancing services when old.[27] These 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 $\mathbf{1}_{ins} \in 0, 1$. Agents maximize the expected present value of their lifetime utility, which depends on their level of consumption and their health status.[28] 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 else individuals value in life, and disease and disability generate disutility because they prevent them from doing so. Because of this feature, this problem is not analog to a human capital problem. Additionally, given that health is bounded above at 1 and that in the model everyone starts life with perfect

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model with an option of public insurance that, like Medicaid, is means-tested.

[26]In this setting, Medicare is analog to the private health insurance during the working life. The only differences are that everyone is enrolled in Medicare, and that the premium is subsidized.

[27]See De Nardi, French, and Jones (2010) and Palumbo (1999)

[28]There is evidence that health status has a positive effect on the marginal utility of consumption, as found by Palumbo (1999) and Finkelstein, Luttmer, and Notowidigdo (2008), and several papers in the literature include health in the utility function.

health, this formulation implies that if health declines below maximum level 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 expected lifetime utility. The decision problem for a worker who has been given the chance to contract health insurance is stated in problem (1) below, where c indicates consumption, m medical services, and $ins \in 0, 1$ indicates the decision to contract health insurance if eligible.

$$\max_{\{c_t, m_t, ins_t\}} E \sum_{t=1}^{T} \beta^t u_t \left(c_{i,t}, x_{i,t} \right) \tag{2}$$

subject to:

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

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

An individual who does not have the option to contract health insurance solves the same problem, except that in this case $\mathbf{1}_{ins,i} = 0$ every period.

During their working lives, agents receive labor earnings, which is taxed at rate τ. After they retire, they receive the fix pension payment b.

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 τ_y, that is used to finance some level of government spending G. The revenues from taxing labor earnings at rate τ_{ss} are used to finance social security, and the revenues from taxing labor earnings at rate τ_{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 χ, such that:

   i) Individual decisions solve the optimization problem given in (1), given prices.

   ii) Aggregate quantities result from individual decisions and factor markets clear:

$$K = \int_X a(\chi)d\mu(\chi)$$

$$L = \int_X n(\chi)zd\mu(\chi)$$

 where L are units of effective labor, which includes 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 med-

20

ical 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:

$$w = (1 - \alpha) A \left(\frac{K}{L} \right)^\alpha$$

$$r = \alpha A \left(\frac{L}{K} \right)^{1-\alpha}$$

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

$$\int_X \tau_y y(\chi | t < \underline{t}) d\mu(\chi | t < \underline{t}) = G$$

$$\int_X \tau_{ss} y(\chi | t < \underline{t}) d\mu(\chi | t < \underline{t}) = b \int_X d\mu(\chi | t \geq \underline{t})$$

$$\int_X \tau_{MC} y(\chi | t < \underline{t}) d\mu(\chi | t < \underline{t}) = G_{MediCare} \int_X d\mu(\chi | t \geq \underline{t})$$

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:

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

From the FOCs on medical treatment, when $s_t > 0$, the following equation describes

21

the intertemporal evolution of x_t:

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

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

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

where $\zeta_{a,t}$ 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 - such as entering the next period with higher health, which increases their expected earnings - but if they hit the borrowing constraint, they will not be able to get the optimal level of treatment.

Even if experiencing a low productivity period, the asset rich have enough of a buffer to allow them to pay this cost and regain their earnings path. Consumption is less sensible to shocks for high levels of accumulates 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.

We can go an extra step, including the Euler equation for consumption (3) in equation (5):

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

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.

Borrowing constraints and uncertain earnings imply an inefficiently high level of sav-

ings. 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 tradeoff between two different technologies to access 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 contract 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 contract health insurance is a static choice for an eligible individual, so it can be solved within the period. Also, the relevant "technology" to buy medical services will only appear in their budget constraint. Therefore, the optimal choice of technology 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.

There is a cutoff value $\overline{m}$ 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: $\max_{s_t} m_t^*(a_t, x_t; z_t, s_t) \leq \overline{m}$. Figure 7 shows a graphical proof of this result.
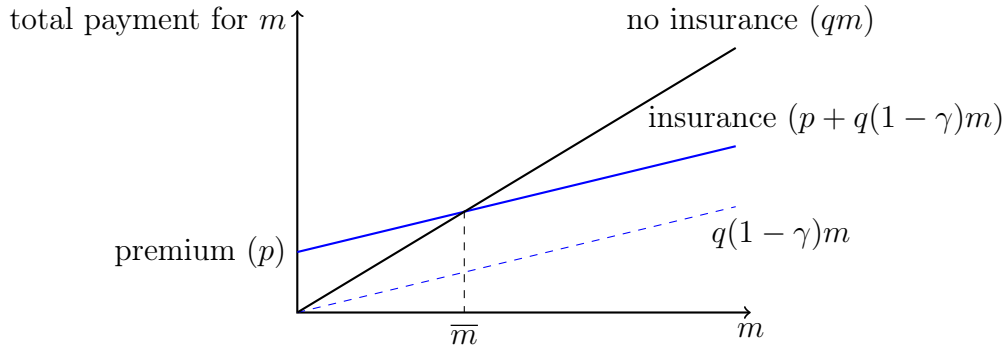

Figure 7: Optimal health insurance choice depends on optimal level of medical care

4 Calibration

The calibration strategy is as follows. First, a number of parameters are taken directly from the literature or set equal to their direct empirical counterparts. Second, parameters describing the process of health shocks are estimated directly from the data. Finally, the

key parameters describing the interaction between health and income are calibrated to match some of the key data moments.

4.1 Parameters Set Outside of the Model

Preferences and time

Individuals in the model are born at age 25, retirement happens at age 65, and they live until age $T = 85$. The model time period is 10 years.[29]

For the period utility I assume the following functional form: $u(c_{i,t}, x_{i,t}) = \frac{\left(c_{i,t}^{1-\lambda} x_{i,t}^{\lambda}\right)^{1-\sigma}}{1-\sigma}$. 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. [30]

I set a coefficient of relative risk aversion $\sigma = 0.9$ and an annual discount rate β of 0.975.

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 $\tau_y = 15\%$, which corresponds to the average tax rate in the U.S. in 2008.

Production function

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

Health-related variables

I assume initial health is 1 for everyone. As explained in section 3.1.2, $x_t \in (0, 1]$ 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. I measure the probability $1 - \pi$ of receiving a bad health shock $(s_t | s_t > 0)$. I compute the empirical distribution of

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[29]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).

[30]See Finkelstein, Luttmer, and Notowidigdo (2008) and Palumbo (1999).

24

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.

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, which is shown in figure 8.
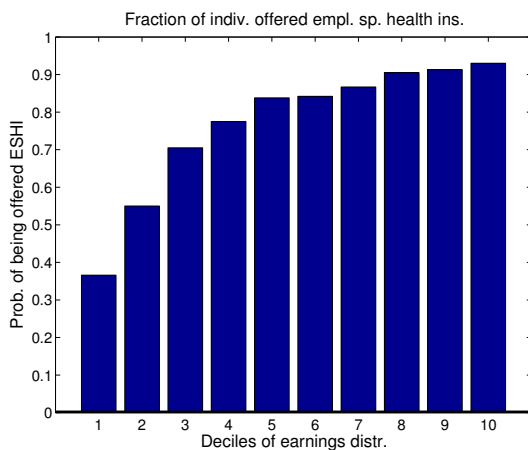

Figure 8: Access to employer-sponsored health insurance by deciles of earnings

The parameter for coinsurance is taken to be 1 minus the average fraction of medical expenditures γ 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.

Process for productivity

The process for the exogenous productivity is of the form:

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

where

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

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

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

and $g(t)$ is a deterministic age productivity profile.[31]

I take from Storesletten, Telmer, and Yaron (2004) the variance of the productivity fixed effect $\sigma_\alpha^2 = 0.21$ and the variance of the transitory shock $\sigma_\varepsilon^2 = 0.06$.[32] The remaining parameters from the latent productivity process ρ and σ_η 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 ρ 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 takes the following values:

Table 1: Deterministic age labor-efficiency profile, from Hansen (1993)

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

4.2 Parameters Calibrated to Match Moments from the Data

The calibrated parameters are the weight of health in the utility function λ, the unit price of medical treatment q, and the persistence ρ and variance σ_η^2 of the persistent productivity shock. The values are shown in table 2.

To calibrate these values, I match the moments in table 3, which are 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.

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[31]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.

[32]To adjust the periodicity of the stochastic variables to that of the model, I follow Livshits, MacGee and Tertilt (2007).

Table 2: Calibrated parameters

	Parameter	Value
λ_{worker}	Weight of health in utility, young	0.7
$\lambda_{retired}$	Weight of health in utility, retired	0.5
q	Price of medical treatment	0.015
ρ	Persistence of productivity shock (annual)	0.92
σ_η^2	Variance of innovation to productivity shock	0.18

(*) Values for annual frequency

Table 3: Matched moments

Moment	Data	Model
$mean(x_{\underline{t}-1})/mean(x_1)$	1.10	1.10
$mean(qm_{working\,age})/mean(y_{working\,age})$	0.147	0.141
$mean(qm_{retired})/mean(y_{working\,age})$	0.25	0.22
$autocorr(\log y_{res})$	0.967	0.964
$var(\log y_{res})$	9.566	9.527

5   Numerical Results

Table 4 and figure 9 show how the model performs with respect to some moments not used in the calibration. The model under-predicts the fraction of people who buy private health insurance. This is a natural outcome given that there is only one type of health insurance contract in the model, 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 contracts because there are many nuances in the health insurance market that are not captured by this model. The model matches an increase in correlation between health and earnings over the life cycle, although it does not capture the full degree of correlation at its maximum level for the 45-50 years old age group.
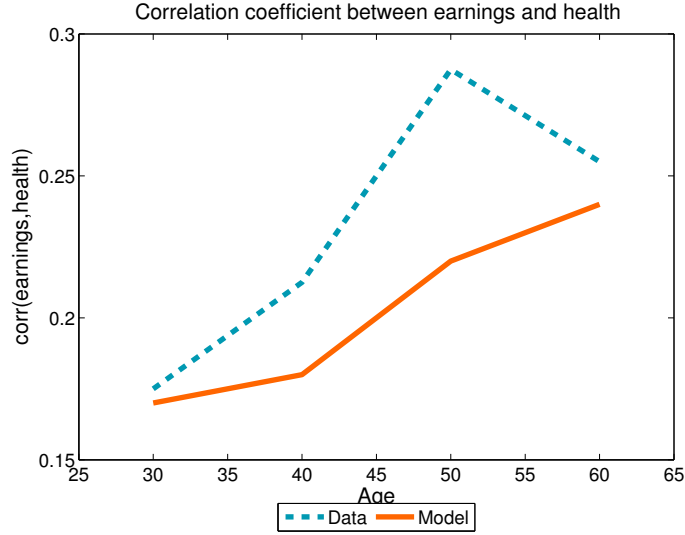
Figure 9: Correlation between earnings and health in the model and in the data

Table 4: Performance with respect to other moments (not used to calibrate the parameters)

Moment	Data	Model
Health insurance premium	0.085	0.062
$\frac{Med.\,Exp.\,Uninsured}{Med.\,Exp.\,Insured}$	0.38	0.39
Fraction insured	any ins.:0.81; priv. ins.: 0.77	0.69
Avg. health, working age	0.81	0.86
Avg. health, retired	0.70	0.73

Figure 10 shows 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.
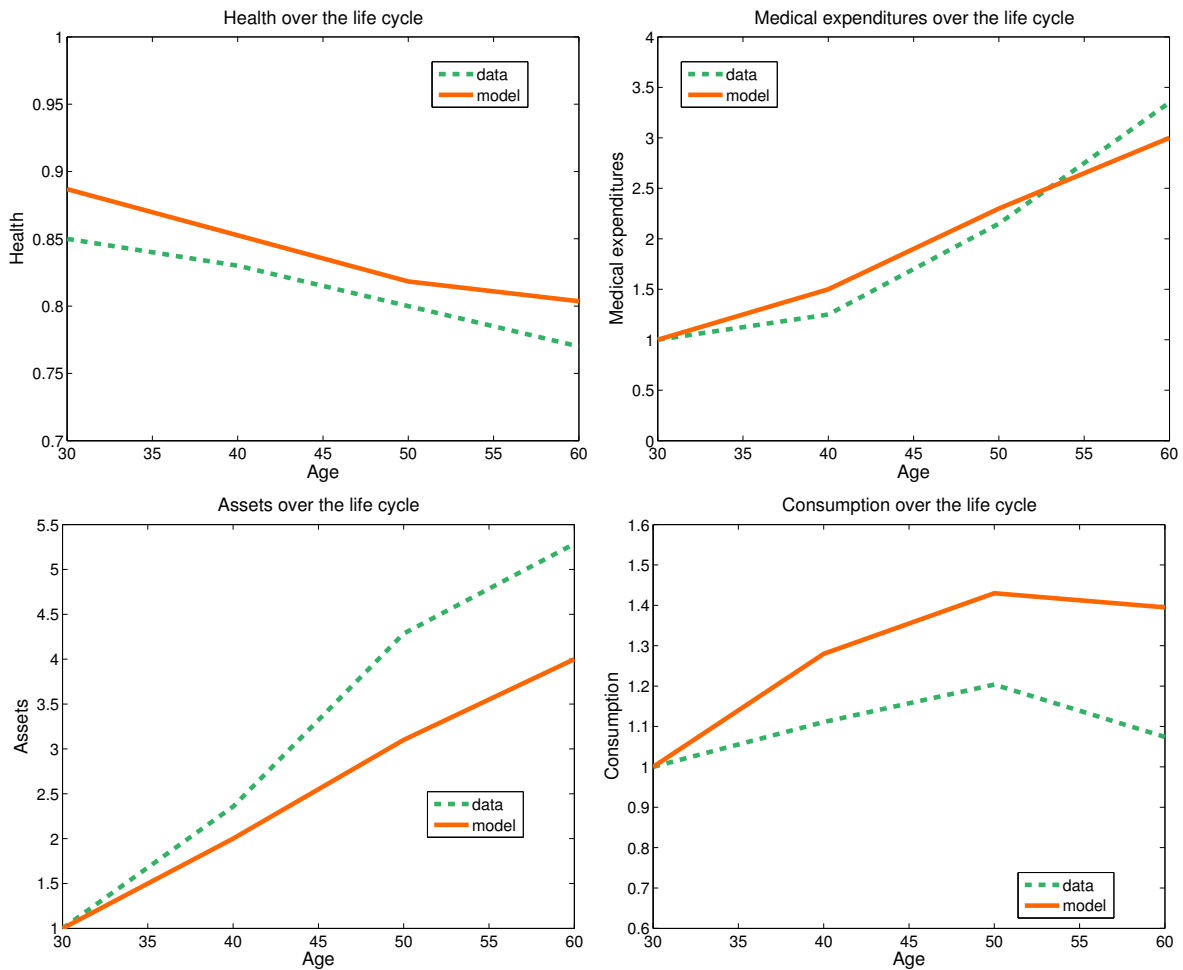
Figure 10: Life cycle profiles of health, medical spending (as fraction of earnings), assets and consumption

5.1 Dynamics of Health and Earnings Inequality over the Life Cycle

Figure 11 shows the evolution of mean health by earnings percentiles and age groups. The left panel is the outcome from the model, while the right panel shows the data. We see that the model reproduces a few facts: the health of those in the 10th percentile of earnings is much lower than average health of those with median earnings, and the difference in average health between those in the percentile 90th of earnings and those with median earnings is not too high.
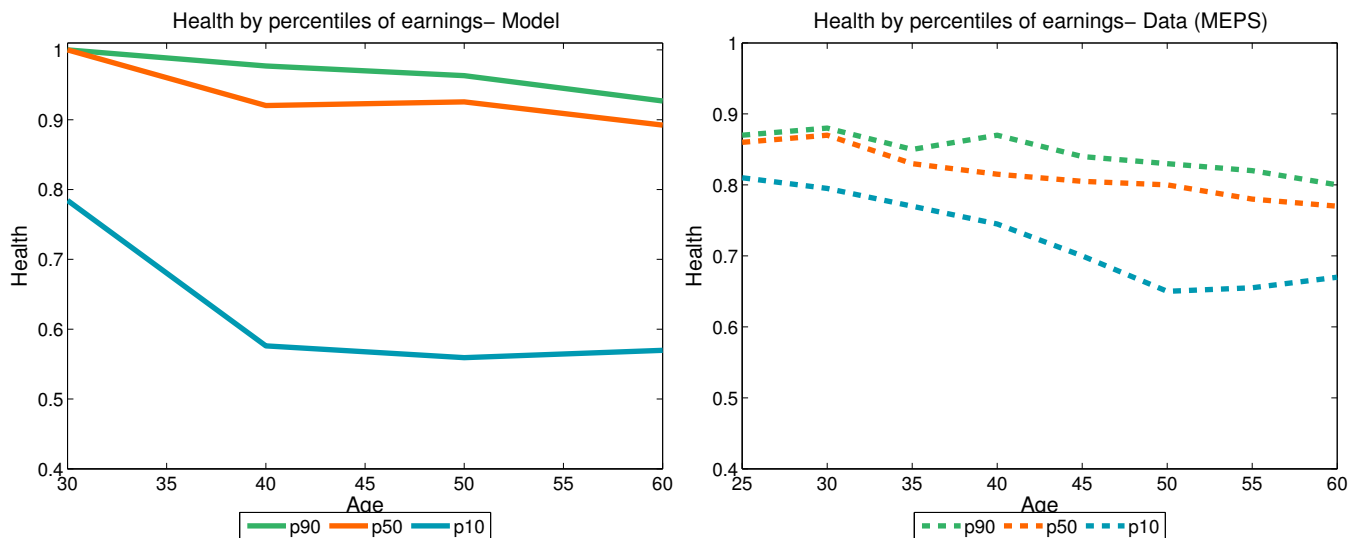
Figure 11: Health by percentiles of earnings and age, model (left) and data (right)

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 variance of earnings to variance of productivity process for all age groups. The dispersion of the residual earnings profile is amplified on average by 14% over the life cycle. The peak of this amplification happens for the group of workers between 45 and 55 years old, when it is 25%.

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 132% higher in an economy with productivity shocks alone. In such an economy, earnings of the bottom half of the earnings distribution are 46% higher. Given these figures, non-surprisingly, the 90/10 ratio declines by 73% but the 90/50 ratio declines only by 4.7%. The coefficient of variation declines by 17% when shocks to health are removed from the model.

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 is difference indicates that health risk is an important determinant of lifetime risk.
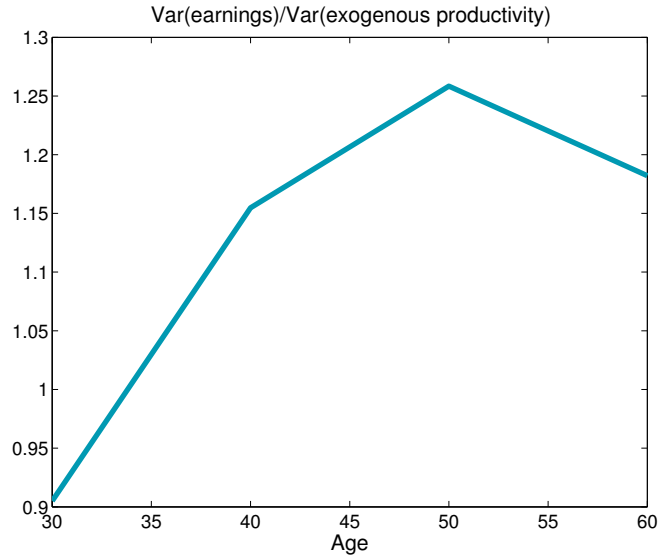

Figure 12: Additional earnings inequality due to health channel

5.3   Lifetime Earnings Risk

Figure 13 shows how the standard deviation of earnings evolves over the life cycle for different types. The higher line is the average individual in the economy. The lower line shows the evolution of earnings volatility for an individual who is always healthy. In this case, earnings volatility is lower over the entire life cycle. The largest difference with the average individual is of 37% during the last period. On average, 17% of the dispersion of earnings is due to health risk.

5.4   Effect of early shocks

Differences in innate productivity   Early shocks are amplified over the life cycle. Since low earning workers can afford less medical care in case of bad health shocks, this implies that health insurance makes a larger difference for these workers than for high earning individuals.

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).

31

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 23% difference in expected lifetime utility by insurance status, conditional on getting hit by bad health shock in first period.
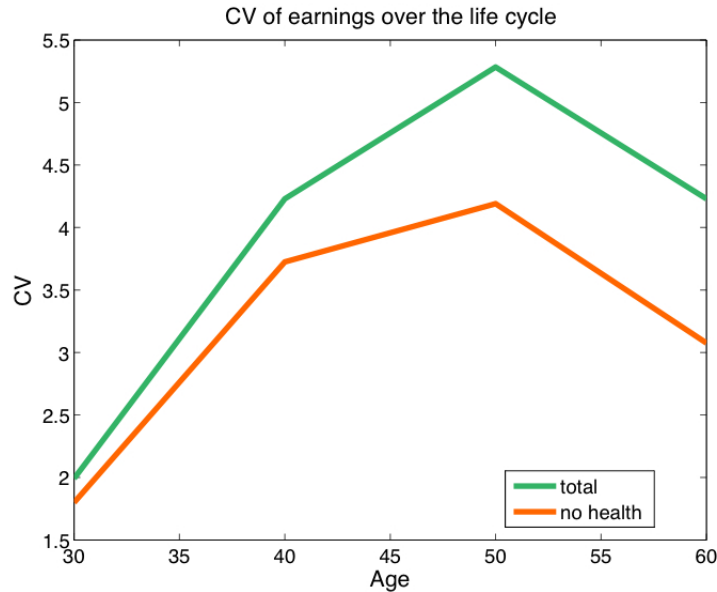
Figure 13: Contribution of health to the evolution of earnings risk for different types of workers

Table 5: Effect of early health shocks: average shock

	earnings
On average	-6%
1st quintile of earn. distr.	-7.8%
top 60% of earn. distr.	-4.1%
Insured	-3.1%
Uninsured	-8.2%

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 exercises is laid out in increasing degrees of policy effectiveness for increasing access to health insurance.

These experiments provide insight on the effects of some of the key components of the health care reform law signed in 2010 as the Patient Protection and Affordable Care Act. While the model is not designed to incorporate all of the changes that this reform puts in place, it is adequate to study the effectiveness and consequences of policies aiming at increasing health insurance coverage. And one of the goals of the 2010 health care reform is to increase the number of people covered with health insurance. Amongst other aspects of the reform, new insurance regulations aim to achieve this. The Affordable Care Act implements measures to increase access to health insurance. One such measure is to forbid insurance companies to deny coverage due to pre-existing conditions. This allows everyone to be able to enter a health insurance contract with an insurance company. In order to prevent the market from breaking down due to adverse selection, the law puts in place an individual mandate by which every individual must acquire some health insurance plan. Lastly, in order to make this requirement feasible for everyone, the Affordable Care Act will provide low income households with financial support to buy health insurance.

The first exercise studies the effects of generalizing access to health insurance, in the sense that everyone is eligible to buy private health insurance. This experiment goes in line with one goals 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.

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

The third experiment studies one particular instance of universal health care: health insurance is provided by the government but individuals pay a coinsurance rate just like in the private health insurance case. This would work as a plain subsidy of medical services. The results of these policy experiments are explained below.[33]

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[33]This version of policy exercises is computed in partial equilibrium. I am currently working on the general equilibrium version of the experiments.

6.1 General Access to Employer-Sponsored Health Insurance

In this exercise, I study the case where everyone is allowed to purchase the private health insurance plan. But workers still decide in each period whether they want to purchase it or not. Table 6 below shows the results of this policy. Access to health insurance affects the entire life cycle path of outcomes.

Table 6: Results from general eligibility to contract health insurance

insurance rate	82%
lifetime consumption of the newly included in ESHI	+2.03%
lifetime health of the newly included in ESHI	+3.58%
lifetime earnings of the newly included in ESHI	+2.8%
variance of earnings of newly included in ESHI	-1.01%
90/10 earnings ratio	-15%

As a counterfactual exercise, figure 14 shows the life cycle evolution of earnings dispersion for the group of people who were denied access to health insurance in the benchmark model. The figure shows two paths, everything else constant: one path corresponds to the no eligible for health insurance case, and the other corresponds to the case when there is general access to the health insurance option.
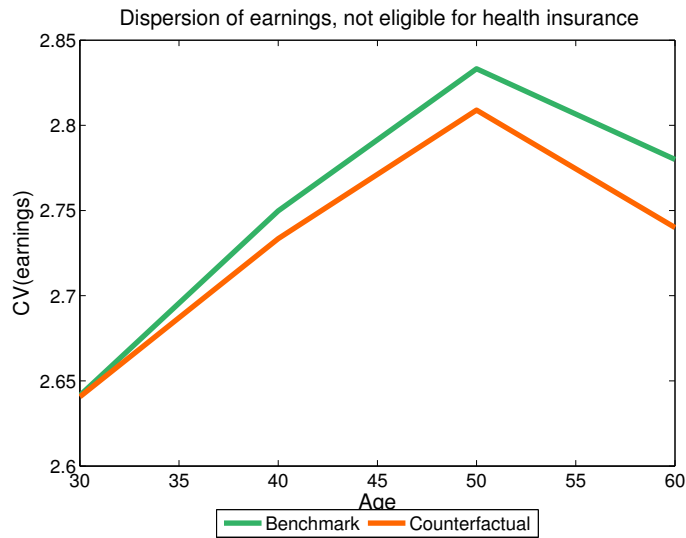

Figure 14: Dispersion of earnings for the group of ineligible for insurance, when ineligible (benchmark) and when made eligible (counterfactual)

It is worth noting that a fraction of people within this group will not accept health insurance in the general access case, so the aggregate differences in the group are derived

from those who do contract health insurance. The lower dispersion in earnings is a result not only of better health outcomes. The lifetime correlation between earnings and health goes down from .202 to .195 with generalized voluntary access to health insurance.

6.2   Private Health Insurance Subsidies

An individual mandate seeks to achieve large coverage in the population by making health insurance compulsory. This can be accompanied by subsidies for the premium or not. The Affordable Care Act puts in place an individual mandate with subsidized health insurance premium.

In the context of the model, I have shown in the previous section that the take up rate of the only health insurance plan is lower than 100% when everybody is eligible for private 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 pass on the health insurance being offered to them. 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, which is the subsidies to health insurance premium. I fist study the effectiveness of a flat subsidy to achieve larger coverage, and then I will make subsidies depend on income levels.

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%. The young and those at the bottom of the earnings distribution are most likely to pass on insurance and remain uninsured. 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 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   Robustness

7.1   Health in the Utility Function

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

If I remove health from the utility function of the workers, by setting $\lambda_{worker} = 0$, then the effect 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, He, and Zhang (2011). Figure 15 illustrates the case with both $\lambda_{worker} = 0$ and $\lambda_{retired} = 0$.
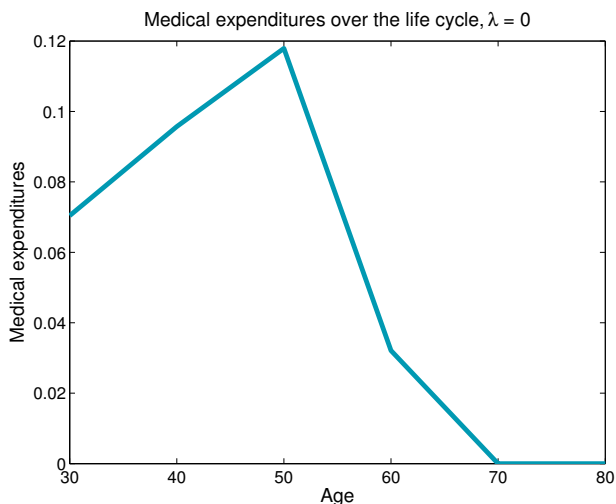
Figure 15: Life cycle profile of medical expenditures, $\lambda = 0$ case.

8 Conclusions

In this paper, I have incorporated health risk into an income fluctuation model of the life cycle with heterogeneous agents and idiosyncratic uncertainty. In the model, agents choose consumption, medical services and health insurance. Access to health care is affected by income and wealth, but earnings are affected by health shocks. Thus, the model includes interactions between health and earnings consistent with findings from empirical studies.

I estimated the process for shocks to health directly from survey data, and calibrated the model using disaggregated data on medical expenditures, health status and earnings. The, I used the calibrated model to study the role of health in generating earnings inequality over the life cycle, and to evaluate alternative health policy interventions.

I find that the health channel explains around 17% of the increase in earnings dispersion over the life cycle and 23% of earnings inequality at retirement age. Also, 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.

37

The policy exercises 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. Subsidies are needed to achieve larger effects in terms of coverage, because even facilitating access to health insurance for everyone would leave 18% of individuals not contracting health insurance. Therefore it is only through a subsidized premium that greater coverage be achieved. 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.

Appendix A: Data

The MEPS consists of a series of national surveys, structured as panels where a representative sample of households is interviewed five times over the course of two years. This survey has been conducted since 1996 by the U.S. Agency for Health Care Research and Quality. The MEPS includes standard demographic and economic variables and a comprehensive set of health-related variables: measures of health status (physical component summary from Short-Form 12 Version 2, and self-reported health status), health insurance status each month of the year, health insurance (broad) type, employer offered health insurance or not, several categories of medical expenditures, and detailed medical conditions.

The sample comprises all non-institutionalized adults ages 25 and above. To calibrate the steady state of the model, I use the waves corresponding to the years 2007 and 2008. 2009 is an atypical year because of the great recession, with big fluctuations in earnings and employment that would contaminate the estimates without explicitly taking them into account. The data for the 2010 survey will be available at the end of 2012.

Physical Component Summary

PCS is computed in MEPS using the data from the Short-Form 12 Version 2 (SF12) of the 2007 Self-Administered Questionnaire. The SF12 and the 36 questions version (SF36) were constructed to survey health status in the Medical Outcomes Survey. These questionnaires were designed for use in clinical practice and research, health policy evaluations, and general population surveys. The SF36 includes one multi-item scale that assesses eight health concepts: limitations in physical activities because of health problems, limitations in social activities because of physical or emotional problems, limitations in usual role activities because of physical health problems, bodily pain, general mental health, limitations in usual role activities because of emotional problems, vitality (energy and fatigue), and general health perceptions. The designers of PCS built the measure applying principal component analysis to obtain weights for questions in each of these categories.

For the history and development of SF36 see Ware Jr and Sherbourne (1992), for details about construction and validity tests of PCS: McHorney, Ware Jr, and Raczek (1993); Ware Jr et al. (1995). Ware et al. (1995); Ware, Kosinski, and Keller (1996) and McDowell (2006) describe SF12 and evaluate the validity of PCS using SF12.

Expenditures and insurance related variables Table 2 shows the means by age groups for yearly labor earnings (wagep), total medical and prescriptions expenditures (by individual and insurance) as a fraction of earnings (totexp_wagep), fraction of people who are insured during at least 9 months per year (pri_ins), and the health status measured by PCS (pcs_norm).

Table 7: Variable means by age groups

Age groups	(1) wagep07x	(2) totexp_wagep	(3) pri_ins_07	(4) pcs_norm
1	33,982.24	0.17	0.62	0.85
	(30,541.27 - 37,423.20)	(0.13 - 0.21)	(0.57 - 0.68)	(0.84 - 0.87)
2	43,741.12	0.13	0.72	0.83
	(38,955.96 - 48,526.29)	(0.07 - 0.18)	(0.68 - 0.77)	(0.82 - 0.84)
3	44,408.37	0.19	0.77	0.80
	(43,207.03 - 45,609.71)	(0.11 - 0.27)	(0.76 - 0.77)	(0.79 - 0.81)
4	43,236.90	0.43	0.79	0.77
	(38,492.71 - 47,981.10)	(-0.13 - 1.00)	(0.78 - 0.81)	(0.76 - 0.79)
5	31,682.76	0.77	0.09	0.74
	(30,090.95 - 33,274.56)	(0.22 - 1.31)	(-0.06 - 0.23)	(0.70 - 0.78)
6	22,739.25	1.87	0.02	0.67
	(19,663.07 - 25,815.42)	(-0.95 - 4.69)	(-0.02 - 0.06)	(0.60 - 0.74)
Observations	12,433	12,433	12,433	12,433

ci in parentheses

1: 25_34years, 2: 35_44years, 3: 45_54years, 4: 55_64years. Source: MEPS

Employer sponsored health insurance

Figure 16 shows the fraction of insured individuals by source of private insurance (employer or union sponsored (ESHI) vs individual insurance) and deciles of earnings. The columns don't add up to one, the rest is public insurance.
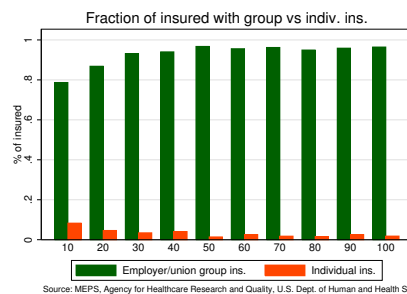

Figure 16: Insurance through employer vs individual market

Appendix B: Disability Weights

The World Health Organization computes measures of the burden of disease in order to set its program goals and evaluate health policies. Their measure consists in disability-adjusted life-years (DALY), which includes mortality measures (years of life lost to illness, or YLL) and morbidity measures (years lived with disabilities, or YLD). The morbidity measure YLD of each medical condition depends on the incidence of the disease and how disabling the diseases is, which is measured through disability weights. I follow the same principle to measure how disabling each condition is, by using the disability weights computed by the WHO and other health researchers. Table 4 includes WHO's disability weights by condition (the adjusted version by Melse et al. (2000); Stouthard, Bonsel et al. (2000), annualized to account for the average duration of acute conditions). [34]

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[34]*http://www.who.int/bulletin/volumes/88/12/10-084301/en/*

Table 8: Disability weights by condition

Condition	Disab. Wgt.	Condition	Disab. Wgt.
Tuberculosis	0.23	Aortic, peripheral, and visceral artery aneurysms	0.29
Bacterial infection, unspecified site	0.04	Aortic and peripheral arterial embolism	0.29
Mycoses	0.00	Other circulatory disease	0.13
Hiv infection	0.57	Phlebitis, thrombophlebitis and thromboembolism	0.13
Hepatitis	0.08	Pneumonia (except that caused by tuberculosis or sexual	0.04
Viral infection	0.01	Influenza	0.01
Other infections, including parasitic	0.02	Acute and chronic tonsillitis	0.00
Sexually transmitted infections (not HIV or hepatitis)	0.07	Acute bronchitis	0.00
Cancer of head and neck	0.20	Other upper respiratory infections	0.00
Cancer of stomach	0.33	Chronic obstructive pulmonary diseas	0.23
Cancer of colon	0.22	Asthma	0.23
Cancer of rectum and anus	0.22	Pleurisy, pneumothorax, pulmonary collapse	0.23
Cancer of liver and intrahepatic bile duct	0.20	Respiratory failure, insufficiency, arrest	0.23
Cancer of pancreas	0.20	Lung disease due to external agents	0.04
Cancer of bronchus, lung	0.43	Other lower respiratory disease	0.04
Cancer of bone and connective tissue	0.06	Other upper respiratory disease	0.00
Melanomas of skin	0.06	Intestinal infection	0.02
Other non-epithelial cancer of skin	0.06	Gastroduodenal ulcer (except hemorrhage)	0.02
Cancer of breast	0.27	Gastritis and duodenitis	0.02
Cancer of uterus	0.10	Appendicitis and other appendiceal conditions	0.46
Cancer of cervix	0.08	Regional enteritis and ulcerative collitis	0.02
Cancer of ovary	0.10	Intestinal obstruction without hernia	0.02
Cancer of other female genital organs	0.10	Diverticulosis and diverticulitis	0.20
Cancer of prostate	0.34	Peritonitis and intestinal abscess	0.20
Cancer of testis	0.09	Nephritis, nephrosis, renal sclerosis	0.09
Cancer of bladder	0.09	Acute and unspecified renal failure	0.09
Cancer of kidney and renal pelvis	0.09	Chronic renal failure	0.10
Cancer of brain and nervous system	0.09	Urinary tract infections	0.01
Cancer of thyroid	0.09	Hyperplasia of prostate	0.04
Hodgkin's disease	0.06	Inflammatory diseases of female pelvic organs	0.33
Non-hodgkin's lymphoma	0.31	Endometriosis	0.10
Leukemias	0.09	Prolapse of female genital organs	0.10
Cancer, other and unspecified primary	0.09	Ovarian cyst	0.10
Secondary malignancies	0.75	Female infertility	0.11
Malignant neoplasm without specification of site	0.09	Ectopic pregnancy	0.55
Neoplasms of unspecified nature or uncertain behavior	0.09	Skin and subcutaneous tissue infection	0.07
Maintenance chemotherapy, radiotherapy	0.09	Other inflammatory condition of skin	0.07
Benign neoplasm of uterus	0.09	Chronic ulcer of skin	0.07
Other and unspecified benign neoplasm	0.09	Other skin disorders	0.07
Diabetes mellitus without complication	0.20	Rheumatoid arthritis and related disease	0.53
Diabetes mellitus with complications	0.20	Osteoarthritis	0.19
Nutritional deficiencies	0.03	Spondylosis, intervertebral disc dis	0.06
Gout and other crystal arthropathies	0.13	Joint disorders and dislocations, trauma related	0.07
Deficiency and other anemia	0.05	Fracture of neck of femur (hip)	0.19
Sickle cell anemia	0.05	Spinal cord injury	0.73
Meningitis (except that caused by tuberculosis or std)	0.31	Skull and face fractures	0.43
Parkinson's disease	0.68	Fracture of upper limb	0.19
Multiple sclerosis	0.53	Fracture of lower limb	0.19
Paralysis	0.57	Other fractures	0.19
Epilepsy, convulsions	0.11	Sprains and strains	0.06
Headache, including migraine	0.03	Intracranial injury	0.36
Cataract	0.10	Crushing injury or internal injury	0.22
Retinal detachments, defects, vascular occlusion and reti	0.10	Open wounds of head, neck, and trunk	0.17
Glaucoma	0.10	Open wounds of extremities	0.17
Blindness and vision defects	0.10	Superficial injury, contusion	0.17
Otitis media and related conditions	0.02	Burns	0.16
Other ear and sense organ disorders	0.07	Poisoning by other medications and d	0.17
Other nervous system disorders	0.50	Poisoning by nonmedicinal substances	0.17
Heart valve disorders	0.13	Other injuries and conditions due to	0.17
Peri-, endo-, and myocarditis, cardiomyopathy	0.32	Nausea and vomiting	0.00
Essential hypertension	0.25	Abdominal pain	0.00
Hypertension with complications and secondary hyperte	0.25	Malaise and fatigue	0.00
Acute myocardial infarction	0.15	Allergic reactions	0.00
Coronary atherosclerosis and other heart disease	0.29	Adjustment disorder	0.02
Pulmonary heart disease	0.13	Anxiety disorder	0.17
Other and ill-defined heart disease	0.13	Attention-deficit, conduct, and disruptive behavior disor	0.17
Conduction disorders	0.13	Delirium, dementia, and amnestic and other cognitive di	0.71
Cardiac dysrhythmias	0.13	Developmental disorders	0.02
Cardiac arrest and ventricular fibri	0.15	Impulse control disorders	0.13
Congestive heart failure, nonhyperte	0.15	Mood disorders	0.23
Acute cerebrovascular disease	0.61	Personality disorders	0.66
Occlusion or stenosis of precerebral arteries	0.61	Schizophrenia and other psychotic disorders	0.66
Other and ill-defined cerebrovascular disease	0.61	Alcohol-related disorders	0.55
Transient cerebral ischemia	0.61	Substance-related disorders	0.55
Late effects of cerebrovascular dise	0.61	Suicide and intentional self-inflict	0.23
Peripheral and visceral atherosclero	0.29		

Source: Mathers, Fat, and Boerma (2008); Melse et al. (2000); Stouthard, Bonsel et al. (2000)

Appendix C: Computational Algorithm

The main structure of the algorithm is as follows - more details below -: for a given set of prices and parameters, I solve the individual problem, I aggregate it and compute equilibrium values. Adjust prices to reflect the equilibrium values and compute the individual problem again, and repeat until prices used as input generate the same equilibrium values. Then, I compute model moments and compare to the data moments. Adjust parameter values to decrease the distance between them, and solve individual problem and equilibrium again. Iterate until moments from the model match the chosen moments from the data.

The individual life cycle model is solved using grids for each endogenous state (assets and health), and discretizing the exogenous states (shocks to productivity and shocks to health). The persistent productivity shock is discretized using the algorithm by Tauchen (1991). The shock to health is discretized from the empirical distribution in the data. Given that it is a finite life model, the optimal solution is found by backwards induction of the value function, which will depend on age. By discretizing the exogenous states, I have a discrete set of shock realizations in the algorithm. I thus compute the set of optimal policies for each of the possible history of stochastic shocks.

I aggregate the economy for a given set of parameter values and compute the equilibrium values of health insurance premium p, wages w and interest rate r iterating on the prices on individual problem and aggregated economy. I then measure the distance of the model generated moments to their empirical counterpart and adjust the parameters. I do this in two separate blocks: one for health, which is governed by the parameters λ and q in the model, and the other for productivity, which involves the iteration on the parameters governing the evolution of the persistent shock: ρ and σ_η. I then iterate until the data moments are matched by the corresponding ones generated by the model.

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