Credit, Default, and Optimal Health Insurance

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Abstract

How do defaults and bankruptcies affect optimal health insurance policy? I answer this question, using a life-cycle model of health investment with an option to default on emergency room (ER) bills and financial debts. I calibrate the model to the U.S. economy and compare the optimal health insurance policies according to whether the option to default is available. I find that the option to default induces the optimal policy to be more redistributive. Without the option to default, the optimal policy expands Medicaid for households whose income is below 30.8 percent of the average income without changing policies related to private health insurance. With the option to default, in addition to Medicaid expansion, the optimal policy offers a progressive subsidy for the purchase of private health insurance to all households whose income is above the threshold of income eligibility for Medicaid and reforms the private health insurance market by improving coverage rates and preventing price discrimination based on pre-existing conditions. This disparity implies that households rely on bankruptcies and defaults on ER bill as implicit health insurance. More redistributive reforms can improve welfare by reducing the dependence on this implicit health insurance and changing households' medical spending behavior to be more preventative.

JEL classification: E21, H51, I13, K35.

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1 Introduction

A growing body of empirical studies has recently investigated the interactions between health-related events and household finance. Many studies have found that healthcare reforms and adverse health-related events affect households' financial outcomes, such as bankruptcy, delinquency, credit scores, and unpaid debts (Gross and Notowidigdo (2011); Mazumder and Miller (2016); Hu et al. (2018); Miller et al. (2018); Dobkin et al. (2018); Deshpande et al. (2019)). Mahoney (2015) shows that bankruptcy and emergency room act as implicit health insurance because households with a lower cost of bankruptcy are reluctant to buy health insurance by relying on these institutional features. These empirical findings have been widely used to support the expansion of health insurance coverage against financial shocks due to health issues. However, there are relatively few structural approaches that examine how defaults and bankruptcies affect the design of optimal health insurance policy due to the difficulty in devising a framework that incorporates complex features of institutions for both bankruptcy and health insurance, entailing multiple trade-offs in welfare changes. In this paper, I fill this void by using a rich general equilibrium model to characterize the optimal health insurance policy according to whether an option to strategic default is available.

The assessment of health insurance policies is related to several off-setting forces in welfare changes. On the one hand, health insurance can improve welfare by mitigating health losses by providing more access to healthcare services due to a decrease in out-of-pocket medical expenses. Health insurance may induce further improvements in welfare because it reduces bankruptcies and defaults on medical bills by insuring financial risks from medical issues. On the other hand, expanding health insurance coverage can deteriorate welfare because more taxes must be levied in order to be financed. This increase in taxes increases the distortions of saving and labor supply, reducing the average income. General equilibrium effects even amplify this reduction in the average income by boosting the decrease in the aggregate supply of savings. Therefore, these trade-offs must be quantified to characterize optimal health insurance policies.

I undertake my quantitative analysis by building a model on the consumer bankruptcy framework used in Chatterjee, Corbae, Nakajima and Ríos-Rull (2007); Livshits, MacGee and Tertilt (2007) and the health capital framework of Grossman (1972, 2000, 2017). Asset markets are incomplete, and households have an option to default on their medical bills and financial debts. If a debtor defaults on his debt, the debt is eliminated, but his credit history is damaged. This default is recorded in his credit history, which hinders his borrowing in the future. The loan price differs across individual states, as it is determined by individual expected default probabilities. In the spirit of Grossman (1972, 2000, 2017), health capital is a component of individual utility and affects labor productivity and the mortality rate. Moreover, health shocks depreciate the stock of health capital, which results in reduced utility, labor productivity, and survival probability.

This model extends the standard health capital model in two directions. First, the model considers two types of health shocks: emergency and non-emergency. This setting is chosen to reflect the institutional features of the Emergency Medical Treatment and Labor Act (EMTALA), which is an important channel for defaults on medical bills, as Mahoney (2015) and Dobkin, Finkelstein, Kluender and Notowidigdo (2018) note in their empirical analyses.[1] Second, motivated by the study of Galama and Kapteyn (2011), health capital determines not the level of health but the distributions of these health shocks. This setting helps to address a well-known criticisms of the model of Grossman (1972). The model of Grossman (1972) predicts that the demand for medical services is positively related to health status, but these factors are negatively related in the actual data. With this setting, the model generates a negative relationship between the demand for medical services and health status because households who accumulate a higher level of health capital stock have a lower probability of emergency medical events and severe medical conditions. This setup additionally enables me to capture the additional preventative medical treatment effects of health insurance policies.

Using micro and macro data, I calibrate the model to the U.S. economy before the Affordable Care Act (ACA). This model performs well in matching life-cycle and cross-sectional moments on income, health insurance, medical expenditures, medical conditions, and emergency room (ER) visits. The model accounts for salient life-cycle and cross-sectional dimensions of health insurance and health inequality. Furthermore, it reproduces the untargeted interrelationships among income, medical conditions, and ER visits.[2] These strong performances are largely achieved by the extended health capital framework. The model is also good at capturing important life-cycle and cross-sectional dimensions of credit and bankruptcy.

To characterize optimal health insurance policies, this paper focuses on three health insurance policy objects: the threshold of income eligibility for Medicaid, the subsidy rule for the purchase of private individual health insurance (IHI), and a reform of the IHI market that improves its coverage rates up to those of employer-based health insurance and prevents price discrimination against pre-exiting conditions.[3] These policy components are parameterized by three parameters. This setting is sufficiently flexible to represent not only pre-existing healthcare systems around the world

[1]In the U.S., hospitals can assess the financial status of non-emergency patients before providing non-emergency medical treatment, but they cannot take this financial screening step before providing emergency medical treatment due to regulations in the EMTALA. Prior to the implementation of the EMTALA, "patient dumping", referring to refusing ER treatment due to the patients' lack of insurance and ability to pay, was allowed.

[2]Using data from the Medical Expenditure Panel Survey (MEPS), I find that the levels of health risks vary across income groups. Low-income households tend to have more severe medical conditions and to visit emergency rooms more frequently over the life-cycle.Appendix B describes the details of these empirical findings.

[3]This setting is motivated by the fact that healthcare reforms proposed in the U.S., such as the Affordable Care Act (ACA) and the American Health Care Act (AHCA), have mainly addressed policies of Medicaid and IHI.

but also alternative healthcare reforms recently proposed in the U.S. Based on this flexibility, I characterize the optimal health insurance, which is summarized by a set of these three parameters maximizing a utilitarian welfare function that values the ex ante lifetime utility of an agent born into the stationary equilibrium.

First, I use the calibrated model to investigate the effect of the option to default on the economy under the baseline health insurance system. The model predicts that the absence of the option to default induces additional precautionary motives against health risks, thereby leading to increases in medical spending, health insurance coverage, and savings. When available, households can use the option to default as implicit health insurance because they can rely on this option to insure against financial and health risks. In contrast, in the economy without the option to default, households are more cautious in managing their health and spend on healthcare to be more preventative because poor health would otherwise come at a substantial financial burden over the life-cycle. These additional precautionary motives against health risks cause households to increase their spending on healthcare services, demand for private health insurance, and assets accumulation during the working-age period. These additional precautionary motives are so quantitatively substantial as to affect the aggregate economy. Eliminating the option to default increases health insurance coverage by 6.5 percentage points, the average medical expenditure by 2.2 percent, and the capital-output ratio by 5 percent. These changes imply that the impact of implicit health insurance is sufficiently large to cause changes in the aggregate economy.

In the second set of experiments, I seek the optimal health insurance with and without the option to default. I find that the option to default makes substantial differences in the features of the optimal health insurance policies. In the economy with no option to default, the optimal health insurance policy is to expand Medicaid for households whose income is lower than 30.8 percent of the average income, while it does not change policies related to IHI. In contrast, in the economy with the option to default, the optimal health insurance system is more redistributive. This optimal health insurance policy provides Medicaid to households whose income is lower than 30.3 percent of the average income and offers a progressive subsidy for the purchase of IHI to all households whose income is above the threshold of income eligibility for Medicaid. The optimal policy reforms the IHI market by improving its coverage rates and preventing price discrimination against households with pre-existing conditions.

The disparity in these optimal policies is closely related to differences in the magnitude of the responses of medical spending and consumption to healthcare reforms, according to whether the option to default is available. Although more redistributive healthcare reforms increase the overall levels of medical spending and reduce its inequality, regardless of whether the option to default is available, the magnitude is more significant in the economy with the option to default. More redistributive health insurance policies reduce the dependence on default by providing young and low-income households with more access to healthcare services by decreasing the effective prices of health insurance. These changes bring a more considerable improvement in health and a further reduction in health inequality to the economy with the option to default.

More redistributive health insurance policies, at the same time, also play a role in reducing average consumption and in increasing consumption inequality due to more taxes to be financed, regardless of the option to default. However, the magnitude of these changes in consumption is more significant in the economy without the option to default because the precautionary savings motives are more substantial due to the lack of risk-sharing against health risks through default. These stronger precautionary motives are dissolved by the healthcare reforms, thereby leading to a further reduction in the aggregate capital. This reduction in the aggregate capital is amplified due to a more considerable increase in the risk-free interest rate in general equilibrium, thereby leading to a further decline in consumption. As a result, in the economy without the option to default, these sensitive responses of consumption and savings induce income taxes to be more distorted to finance healthcare reforms.

These differences in the extent of the responses affect the degree of off-setting forces in welfare changes. In the economy with the option to default, the reform of the IHI market and the provision of subsidies for the purchase of IHI bring further improvements in welfare from changes in health. When the option to default is available, these IHI-related policies lead to a further improvement in average health and a more significant reduction in health inequality because the responses of medical spending are more significant. In the economy with the option to default, meanwhile, the IHI-related policies bring fewer losses in welfare from changes in consumption. Since their consumption and savings are less responsive to the IHI-related policies, income taxes are less distorted to finance the policies. Put differently, in the economy without the option to default, the IHI-related policies bring fewer improvements in welfare from changes in health and more significant welfare losses from changes in consumption. This gap leads to substantial differences in optimal health insurance, according to whether the option to default is available.

These findings imply that in economies where bankruptcies and defaults are easily accessible, more redistributive healthcare reforms can bring further improvements in welfare through changes in health by reducing the use of default and bankruptcy as implicit health insurance, changing households' medical spending behavior to be more preventative.

Related Literature: This paper belongs to the stream of model-based quantitative macroeconomic literature that investigates the aggregate and distributional implications of health-related public policies.[4] Motivated by the seminal work of Grossman (1972), many of these studies have

[4] Suen et al. (2006); Attanasio et al. (2010); Ales et al. (2012); Ozkan (2014); Pashchenko and Porapakkarm (2013); Hansen et al. (2014); Yogo (2016); Jung and Tran (2016); Nakajima and Tüzemen (2017); Zhao (2017); Feng and Zhao (2018) are broadly included in this literature.

addressed health as an investment goods that is affected by the behavior of investing efforts or resources. Among them, my work is the most closely related to three papers: Zhao (2014), Jung and Tran (2016), and Cole, Kim and Krueger (2018). Zhao (2014) studied the impacts of Social Security on aggregate health spending in an endogenous health capital model. He finds that Social Security increases aggregate health spending by reallocating resources to the old whose marginal propensity to spending on health is high. The study of Zhao (2014) has a similarity to my work in the sense that both studies investigate the effect of another type of public policy on health spending, while my work focuses not on the effects of Social Security but on the impacts of defaults and bankruptcies. Jung and Tran (2016) investigated the implications of the Affordable Care Act in a general equilibrium model with investment in health capital. Although, as my work does, they examined health insurance policies in a health investment model, the focus of my work was different because their model did not consider the design of the optimal health insurance policy. Furthermore, they did not examine the effects of bankruptcies and defaults on healthcare spending. Cole, Kim and Krueger (2018) study the trade-off between the short-run benefits of generous health insurance policies and the long-run effects of health investment such as not smoking and exercising. The modeling strategy they use for health risks is similar to that used in this work, as the distribution of health shocks depends on health status. In addition, their result for the optimal health insurance policy is similar to my work in the sense that providing full insurance is sub-optional. However, Cole, Kim and Krueger (2018) did not consider risk-sharing against health risks through defaults and the accumulation of physical capital. These risk-sharing channels are formalized in my model.

This paper also contributes to the consumer bankruptcy literature based on quantitative models. In this model, defaults and bankruptcies are based on the modeling setting proposed in Chatterjee, Corbae, Nakajima and Ríos-Rull (2007) in the sense that loan prices are characterized by individual states, medical expenses represent a primary driver of default, and ex-post defaults exist in general equilibrium. Livshits, MacGee and Tertilt (2007) is also closely related to this paper, as they examined the effects of bankruptcy policies on consumption smoothing across states and over the life-cycle. In both Chatterjee et al. (2007) and Livshits et al. (2007), medical expenses are an important driving force of defaults, but neither study included the details of health insurance policies that reshape the distribution of default risks for medical reasons across households. This paper extends these studies by employing the institutional details of health insurance policies with endogenous health in the consumer bankruptcy framework.

This study is linked to a growing stream of the empirical literature addressing the relationship between health-related events and household financial well-being.[5] Among these empirical studies,

[5] These empirical studies estimated the effect of adverse health events and healthcare reforms on household financial consequences such as bankruptcy, delinquency, credit scores and unpaid debt. Gross and Notowidigdo (2011)

the most closely related paper is Mahoney (2015). He finds that ER and bankruptcy act as implicit health insurance because individuals with a lower financial cost of bankruptcy are more reluctant to purchase health insurance and make lower out-of-pocket medical payments conditional on the amount of care received. This study incorporates these institutional features in a structural model and finds that they are substantially important in designing the optimal health insurance policy because this implicit health insurance influences households' medical spending behavior.

The remainder of the paper proceeds as follows. Section 2 presents the model, defines the equilibrium, and explains the algorithm for the numerical solution. Section 3 describes the calibration strategy and the performance of the model. Section 4 presents the results of the policy analysis. Section 5 concludes this paper.

2 Model

2.1 Households

2.1.1 Household Environments

Demographics: The economy is populated by a continuum of households in J overlapping generations. This is a triennial model. They begin at age J_0 and work. They retire at age J_r, and the maximum survival age is $\bar{J}$. In each period, the survival rate is endogenously determined. The model has exogenous population growth rate n. There are 7 age groups, $j_g : 23-34, 35-46, 47-55, 56-64, 65-76, 77-91$ and $92-100$.

Preferences: Preferences are represented by an isoelastic utility function over an aggregate that is itself a constant elasticity of substitution (CES) function over consumption c and current health status h_c,

$$u(c,h_c) = \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u)h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u \tag{1}$$

empirically show that Medicaid expansion for children reduced the probability of bankruptcy. Mazumder and Miller (2016) find that the Massachusetts healthcare reform decreased bankruptcy, delinquency and the amount of debt and improved credit scores. Hu, Kaestner, Mazumder, Miller and Wong (2018) find that Medicaid expansion under the Affordable Care Act (ACA) generally improved financial well-being for low-income households. Miller, Hu, Kaestner, Mazumder and Wong (2018) empirically show that Medicaid expansion under the ACA reduced unpaid bills, medical bills, over-limit credit card spending, delinquencies and public records in Michigan. Dobkin, Finkelstein, Kluender and Notowidigdo (2018) show that hospital admission reduced earnings, income, access to credit and consumer borrowing and increased out-of-pocket medical spending, unpaid medical bills and bankruptcy. Deshpande, Gross and Su (2019) find that disability programs reduced the probability of adverse financial events such as bankruptcy and foreclosure.

where λ_u is the weight on consumption, v is the elasticity of substitution between consumption c and health status h_c, and σ is the coefficient of relative risk aversion. Following Hall and Jones (2007), B_u is a sufficiently large constant to guarantee that the value of life is positive.

Labor Income: Working households at age j receive an idiosyncratic labor income y_j given by

$$\log(y_j) = \log(w) + \log(\bar{\omega_j}) + \phi_h \log(h_c) + \log(\eta) \tag{2}$$
$$\eta' = \rho_\eta \eta + \epsilon, \quad \epsilon \sim N(0, \sigma_\epsilon)$$

where w is the aggregate market wage, $\bar{\omega_j}$ is a deterministic age term, h_c is the current health status, ϕ_h is the elasticity of labor income y_j to health status h_c and η is an idiosyncratic productivity shock. η follows the above AR-1 process with a persistence of ρ_η and a persistent shock ϵ with a normal distribution.

Health Technology: In the model, health shocks interact with health capital. First, given health capital, I demonstrate how health shocks evolve. Second, I describe how health capital is intertemporally determined.

Given the empirical importance of the effect of ER on household finance (Mahoney (2015), Dobkin et al. (2018)), the model has two types of health shocks: emergency ϵ_e and non-emergency ϵ_n. These two shocks determine current health status h_c in the following way:

$$h_c = (1 - \epsilon_e)(1 - \epsilon_n)h \tag{3}$$

where h_c is the current health status, ϵ_e is an emergency health shock, ϵ_n is a non-emergency health shock, and h is the stock of health capital. Emergency health shocks ϵ_e and non-emergency health shocks ϵ_n depreciate health capital h, and the remaining health capital becomes the current health status h_c. Note that current health status h_c is different from the stock of health capital h.

The data demonstrate that unhealthy and low-income households are more likely to visit ERs. This finding implies that a part of the probability of emergency medical events is endogenously determined. To capture this, I model emergency medical events as follows.

Households face emergency health shocks ϵ_e only when they experience an emergency medical event. The probability of emergency medical events is as follows:

$$X_{er} = \begin{cases} 1 & \text{with probability } \frac{(1-h+\kappa_e)}{A_{jg}} \\ 0 & \text{with probability } 1 - \frac{(1-h+\kappa_e)}{A_{jg}} \end{cases} \tag{4}$$

where X_{er} is a random variable of emergency medical events, and h is the stock of health capital. Regarding the probability function of emergency medical events, κ_e is the scale parameter, and

A_{j_g} is the age group effect parameter. κ_e controls the average probability of emergency room events, and A_{j_g} influences the difference in probability across age groups. Households experience an emergency medical event $X_{er} = 1$ with probability $(1 - h + \kappa_e)/A_{j_g}$. This equation implies that health capital h determines the probability of emergency medical events.[6] When a household has more health capital, it is less likely to experience emergency medical events.

Conditional on an emergency medical event, $X_{er} = 1$, emergency health shocks ϵ_e evolve as follows:

$$\epsilon_e = \begin{cases} \epsilon_{se} & \text{with probability } p_{se} \text{ conditional on } X_{er} = 1 \\ \epsilon_{ne} & \text{with probability } 1 - p_{se} \text{ conditional on } X_{er} = 1 \end{cases} \tag{5}$$

where

$$0 < \epsilon_{ne} < \epsilon_{se} < 1 \quad \text{and} \quad 0 < m_e(\epsilon_{ne}) < m_e(\epsilon_{se})$$

where (ϵ_{ne}) ϵ_{se} is a (non-) severe emergency health shock, p_{se} is the probability of the realization of a severe emergency health shock ϵ_{se} and $(m_e(\epsilon_{ne}))$ $m_e(\epsilon_{se})$ is the medical cost of a (non-) severe emergency medical shock. A severe emergency health shock is larger than a non-severe emergency health shock. Examples of severe emergency health shocks include ER events such as heart attacks and car accidents. Non-severe emergency health shocks imply less serious ER events such as allergies or pink eye. These emergency health shocks incur emergency medical costs $m_e(\cdot)$. Note that emergency medical costs $m_e(\cdot)$ are not a choice variable; rather they are a function of emergency health shock $\epsilon \in \{\epsilon_{ne}, \epsilon_{de}\}$. Severe emergency health shocks incur higher medical costs than non-emergency health shocks, $m_e(\epsilon_{ne}) < m_e(\epsilon_{se})$.

It is worth discussing the assumptions of this setting for emergency medical events. First, the model assumes that the probability of emergency room events is negatively related to health status, which might cause one to be concerned about the unrealistic prediction that unhealthy households more often have serious emergency medical events such as car accidents and gun wounds. This prediction is inconsistent with that of the model because the probability of emergency medical events depends not only on health status h but also on the scale parameter κ_e. This setting implies that the probability of some types of emergency events, such as car accidents and gun wounds, is independent of individuals' health status, whereas that of other types of emergency events, such as heart attacks and strokes, is relevant.

Second, the model assumes that spending on emergency medical treatments is given as a shock, which makes one be worried whether it fails to capture the moral hazard behavior of low-income

[6] For example, let us assume that $A_{j_g} = 1$ and $\kappa_e = 0$, and I compare two households: household A with $h = 0.5$ and household B with $h = 0.8$. Then, the probability of emergency medical events for household A is 0.5, while that for household B is 0.2.

households in the usage of emergency rooms. Note that frequent usage might be due not only to moral hazard behavior but also to adverse selection stemming from poor health status. If the impact of moral hazard behavior is quantitatively the main driving force behind the income ingredient of ER visits, the ER cost might systematically differ across income groups, for example, because either the rich or the poor spend more on ER healthcare conditional on visiting an ER. However, using data from the Medical Expenditure Panel Survey (MEPS), I find that the amount charged for ER events is unrelated to income level conditional on visiting an ER.[7] This finding suggests that adverse selection is quantitatively important in driving the income gradient of ER visits, which supports the choice of the ER setting.[8]

Non-emergency health shock ϵ_n evolves as follows:

$$\epsilon_n \sim TN\left(\mu = 0, \sigma = \frac{((1/h) - 1 + \kappa_n)^{\alpha_n}}{B_{j_g}}, a = 0, b = 1\right) \tag{6}$$

where $TN(\mu, \sigma, a, b)$ is a truncated normal distribution on bounded interval $[a, b]$, for which the mean and standard deviation of its original normal distribution are μ and σ, respectively. Let us denote σ as the dispersion of the distribution of non-emergency health shocks. The dispersion σ is a function of health capital h with three parameters: κ_n, α_n and B_{j_g}. Regarding the dispersion of the distribution of non-emergency health shocks, κ_n is the scale parameter, α_n is the curvature parameter, and B_{j_g} is the age group effect parameter. κ_n controls the overall size of non-emergency health shocks, α_n determines the extent to which differences in health capital affect the level of dispersion σ, and B_{j_g} influences the extent to which the level of dispersion σ differs across age groups.

Health capital determines the distribution of non-emergency health shocks through its dispersion σ. Figure 1 illustrates how health capital determines the distribution of non-emergency health shocks. The horizontal axis indicates the size of non-emergency health shocks, and the vertical axis indicates the value of the probability density function of non-emergency health shocks. Given values of parameters κ_n, α_n and B_{j_g}, the dispersion of non-emergency health shocks, $\sigma = \frac{((1/h)-1+\kappa_n)^{\alpha_n}}{B_{j_g}}$, decreases with health capital h. Thus, the probability density function of non-emergency health shocks tends to be concentrated more around 0 if the level of health capital h is high, as the left-hand side graph in Figure 1 shows. This concentration means that those who accumulate a larger stock of health capital are less likely to confront a large non-emergency health shock. On the other hand, if a household has a low stock of health capital, the dispersion of the distribution of non-emergency health shocks is high, as the right-hand side graph in Figure

[7]This result is presented in Appendix A.

[8]The model succeeds in generating the gap in ER visits across income groups, which will be presented in the section on Model Performance.

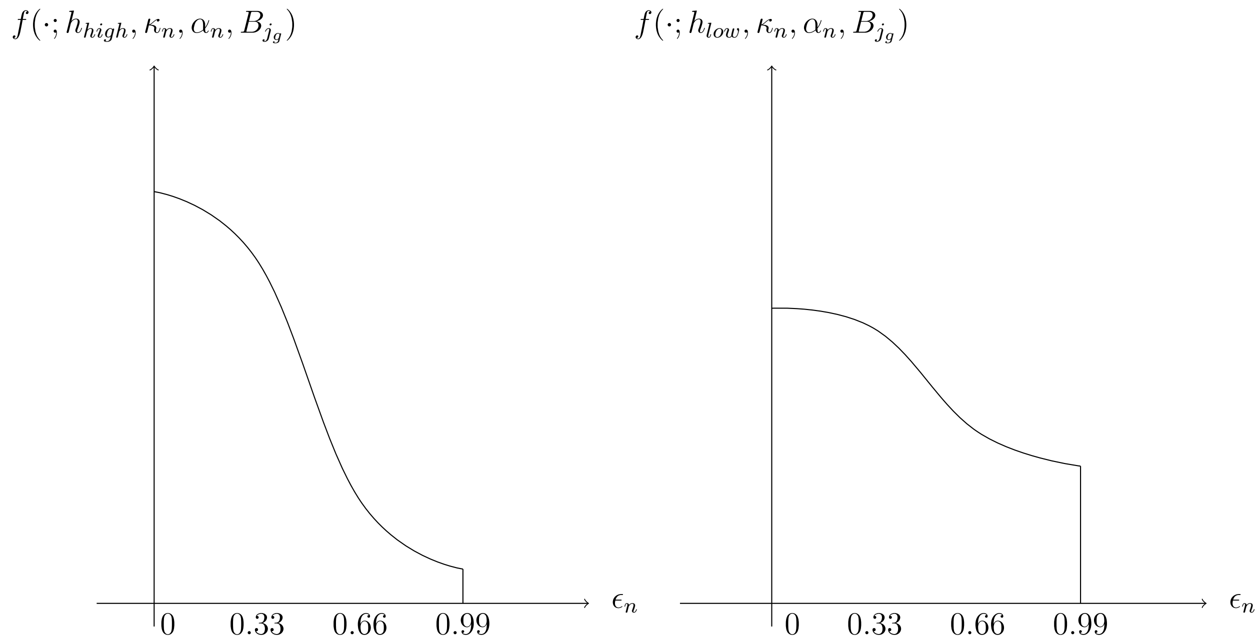

Figure 1: Distribution of Non-emergency Health Shocks across Levels of Health Capital ($h_{high} > h_{low}$)

1 shows. This dispersion means that this agent is more likely to face a substantial non-emergency health shock.

The merit of the setting for non-emergency medical events is worth noting: it enables a well-known criticism of the model of Grossman (1972) to be addressed. His model predicts that the demand for medical and health service is positively related to health, while their relation is negative in the actual data. In the model, motivated by Galama and Kapteyn (2011), health capital affects the distribution of health shocks such that when a person has more health capital, he is less likely to experience severe or emergency medical events. This prediction implies that healthier households spend less on medical and health services, which is consistent with the empirical findings. Additionally, this setting makes it possible to account for salient interrelations between income and health risks observed in micro data. The data show that levels of health risks are negatively related to income, which is endogenously generated by the model due to the setting of non-emergency medical events.[9]

To model health technology, I modify the health capital model of Grossman (1972, 2000, 2017). In the spirit of his work, health capital evolves as follows:

$$h^{'} = h_c + \psi_{j_g} m_n^{\varphi_{j_g}} = (1 - \epsilon_e)(1 - \epsilon_n)h + \psi_{j_g} m_n^{\varphi_{j_g}} \tag{7}$$

[9] Appendix B describes the details of this finding.

where $h^{'}$ is the stock of health capital in the next period, h_c is the current health status, ϵ_e represents emergency health shocks, ϵ_n represents non-emergency health shocks, h is the stock of health capital in the current period, ψ_{j_g} is the efficiency of non-emergency health technology for age group j_g, and φ_{j_g} is the curvature of the non-emergency medical expenditure function. Households invest in health capital through non-emergency medical expenditures m_n. Then, households' total medical expenditures m are given by

$$m = m_n + m_e(\epsilon) \tag{8}$$

where m_n and $m_e(\epsilon_e)$ are non-emergency and emergency medical expenditures, respectively.

Survival Probability: A Household's survival probability is given by

$$\pi_{j+1|j}(h_c, j_g) = 1 - \Gamma_{j_g} \cdot \exp\left(-\nu h_c\right) \tag{9}$$

where $\pi_{j+1|j}(h^{'}, j_g)$ is the survival probability of living up to age $j+1$ conditional on surviving at age j in age group j_g with current health status h_c, Γ_{j_g} is the age group effect parameter of the survival probability, and ν is the curvature of the survival probability with respect to current health status h_c. The age group effect parameter of the survival probability Γ_{j_g} controls overall age effects up to death. Older age groups have a higher value of Γ_{j_g}. The curvature parameter of the survival probability ν captures differences in households' survival rate by current health status h_c.

Health Insurance: The health insurance plans in the benchmark model resemble those in the U.S. For working-age households, the choice set of health insurance plans is given by

$$i \in \begin{cases} \{NHI, MCD, IHI, EHI\} & \text{if } y \leq \bar{y} \text{ \& } \omega = 1 \\ \{NHI, MCD, IHI\} & \text{if } y \leq \bar{y} \text{ \& } \omega = 0 \\ \{NHI, IHI, EHI\} & \text{if } y > \bar{y} \text{ \& } \omega = 1 \\ \{NHI, IHI\} & \text{if } y > \bar{y} \text{ \& } \omega = 0 \end{cases} \tag{10}$$

where i is health insurance status, NHI indicates no health insurance, MCD is Medicaid, IHI is private individual health insurance, EHI is employer-based health insurance, y is individual income, $\bar{y}$ is the income threshold for Medicaid eligibility, and ω is the offer of employer-based health insurance.

Medicaid MCD is available only for low-income working-age households. Thus, if a household's income is below the income threshold for Medicaid eligibility $\bar{y}$, it can take Medicaid. Otherwise, Medicaid MCD is not available as an insurance choice.[10] Individual private health

[10] Pashchenko and Porapakkarm (2017) find that asset testing for the eligibility of Medicaid has important welfare

insurance IHI is available to every working-age household. Households do not have any requirement to buy it.

Employer-based health insurance EHI is available only to those who have an offer ω from their employers. Jeske and Kitao (2009) show that the offer rate of employer-based health insurance EHI tends to be higher in high-salary jobs. Thus, I assume that the offer of employer-based health insurance EHI is randomly determined, and the probability of an offer of employer-based health insurance increases with households' persistent component of idiosyncratic labor productivity shock η because it may capture more information on employers rather than individual health. Explicitly, the likelihood of an offer of employer-based health insurance EHI is given by $p(EHI|\eta)$, where η is the persistent component of the idiosyncratic shock to earnings. Following Jeske and Kitao (2009), the offer probability $p(EHI|\eta)$ increases with η.

The price of private health insurance is given by

$$p_{i'}(h_c, j_g) = \begin{cases} 0 & \text{if } i' = NHI \text{ or } i' = MCD \\ p_{IHI}(h_c, j_g) & \text{if } i' = IHI \\ p_{EHI} & \text{if } i' = EHI \end{cases} \tag{11}$$

where $p_{i'}(\cdot,\cdot)$ is a premium for health insurance i' for the next period, h_c is the current health status, and j_g is the age group. $p_{IHI}(h_c, j_g)$ is the health insurance premium of private individual health insurance IHI for an insured individual whose health status is h_c within age group j_g, and p_{EHI} is the premium for employer-based health insurance.

Individual private health insurance IHI and employer-based health insurance EHI differ in the price system. Individual health insurance has premiums $p_{IHI}(h_c, j_g)$, where h_c and j_g are the current health status and age group, respectively. This setting is based on the individual private health insurance market in the U.S. before the ACA. Individual private health insurance providers are allowed to differentiate prices by considering customers' pre-existing conditions, age and smoking status. Contrary to the separating equilibrium of individual health insurance IHI, employer-based health insurance EHI has a single premium p_{EHI}. This price is independent of any individual state, which reflects that in the U.S., the providers of employer-based health insurance cannot discriminate against employees based on their pre-existing conditions due to the Health Insurance Portability and Accountability Act (HIPAA). In addition, a fraction $\psi_{EHI} \in (0, 1)$ of the premium p_{EHI} is covered by employers, so insurance holders pay $(1 - \psi_{EHI}) \cdot p_{EHI}$.

All health insurance plans provide coverage $q_i \cdot m$, and $(1-q_i)m$ becomes an out-of-pocket medical expenditure for an insured household. For example, for Medicaid holders, Medicaid MCD

implications because 23 percent of Medicaid enrollees do not work to be eligible. This channel is not captured in this model because the labor supply is set to be inelastic due to its computational burdens.

covers $q_{MCD} \cdot m$, and $(1 - q_{MCD}) \cdot m$ represents their out-of-pocket medical expenditures.

Retired households use Medicare. Medicare is public health insurance for elderly households. I assume that all retired households use Medicare and do not access the private health insurance market.

Default: The model has two types of default based on the source of debt: financial default and non-financial default. Following Chatterjee et al. (2007), Livshits et al. (2007) and Nakajima and Ríos-Rull (2019), financial default is modeled to capture the procedures and consequences of Chapter 7 bankruptcy.[11] Non-financial default is modeled to reflect the features of the EMTALA.

Households have either a good credit history or a bad credit history. Good credit history means that the credit record has no bankruptcy. Bad credit history implies that the household's credit record has a bankruptcy. The type of credit history determines the range of feasible actions of households in the financial markets.

Households with a good credit history can either save or borrow through unsecured debt. They can default on both financial and medical debts by filing for bankruptcy. In the period of filing for bankruptcy, these households can neither save nor dis-save. They have a bad credit history in the next period. If a household with a good credit history either has no debt or repays its unsecured debt, it preserves its good credit history in the next period.

Households with a bad credit history pay a cost for having a bad credit history that is as much as χ portion of their earnings for each period. Households with a bad credit history can save assets but cannot borrow from financial intermediaries. Because of the absence of financial debt, they do not engage in financial default. However, they can default on emergency medical expenses, as the EMTALA requires hospitals to provide emergency medical treatment to patients on credit regardless of patients' ability to pay the emergency medical costs. In the period when defaulting on emergency medical expenses, these households cannot save, and they preserve the bad credit history in the next period. Unless they default, with an exogenous probability λ, their bad credit history changes to a good credit history in the next period.

Tax System and Government Budget: Taxes are levied from two sources: payroll and income. On the one hand, Social Security and Medicare are financed through payroll tax. τ_{ss} is the payroll tax rate for Social Security, and τ_{med} is that for Medicare. On the other hand, income tax covers government expenditure G, Medicaid q_d and the subsidy for employer-based health insurance ψp_e. I choose the progressive tax function from Gouveia and Strauss (1994), which has been widely

[11] Chapter 7 covers 70 percent of household bankruptcies. The other type of household bankruptcy is Chapter 13, which I do not address here.

used in the macroeconomic policy literature. The income tax function $T(y)$ is given by

$$T(y) = a_0\{y - (y^{-a_1} + a_2)^{-1/a_1}\} + \tau_y y \tag{12}$$

where y is taxable income. a_0 denotes the upper bound of the progressive tax as income y goes to infinity. a_1 determines the curvature of the progressive tax function, and a_2 is a scale parameter. To use Gouveia and Strauss's (1994) estimation result, I take their estimates in a_0 and a_1. a_2 is calibrated to match a target that is the fraction of total revenues financed by progressive income tax, which is 65 percent (OECD Revenue Statistics 2002). τ_y is chosen to balance the total government budget.

2.1.2 Dynamic Household Problems

Households experience two phases of the life-cycle: working and retirement. For each period, households have either good or bad credit history. Bad credit history means that the household has a record for a bankruptcy filing in its recent credit history. Good credit history implies that the household has no such record. Here, I focus on explaining the choice problem of working-age households with good credit history because their choice problem is so informative as to understand decisions all the other types of households can make. Appendix C describes all types of the dynamic household problems in recursive form.

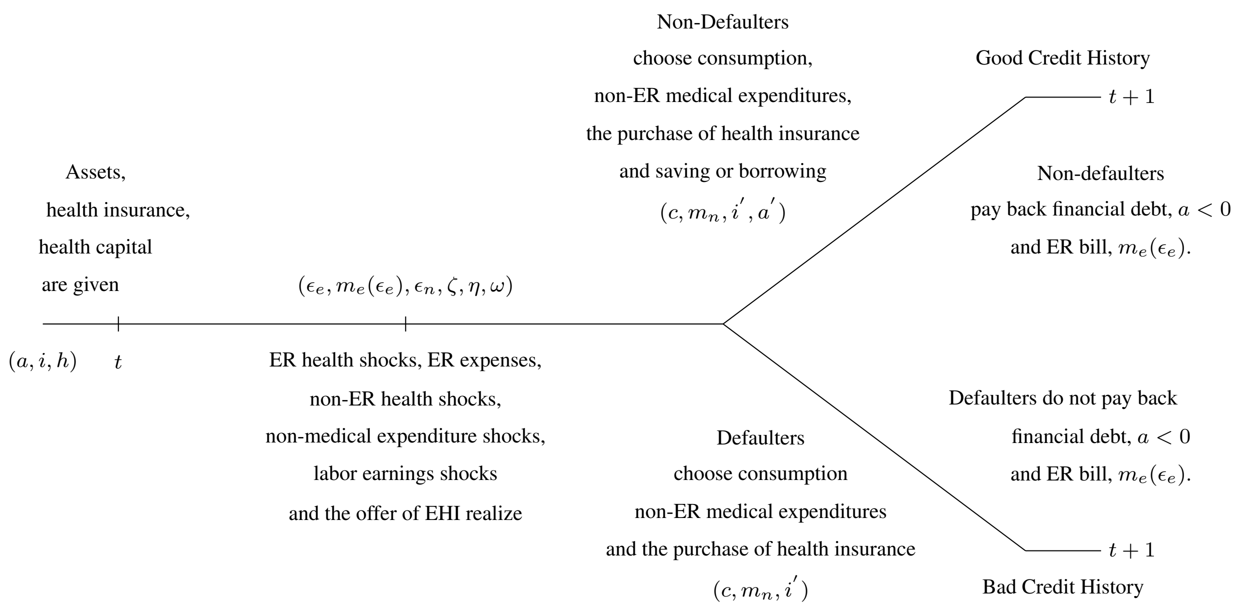

Figure 2: Time-line of Events for Working-age Households with a Good Credit History

Figure 2 shows the time-line of events for working-age households with a good credit history.

Each period consists of two sub-periods. At the beginning of sub-period 1, assets a, health insurance status i and stock of health capital h are given from the previous period. Then, emergency health shocks ϵ_e, non-emergency health shocks ϵ_n, non-medical expenditure shocks ζ, uninsurable idiosyncratic shocks to the efficient units of labor η and an offer of employer-based health insurance ω are realized. These health shocks affect households' utility, labor productivity and mortality. Emergency health shocks ϵ_e incur specific sizes of non-discretionary medical costs $m_e(\epsilon_e)$.[12] Non-medical expenditure shocks ζ capture all possible reasons for filing for bankruptcy other than medical bills and bad luck in the labor market.[13] ζ follows a uniform distribution of $U[0, \bar{\zeta}]$.

Let $V_j^G(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$ denote the value of working-age households with a good credit history in sub-period 1. They solve

$$V_j^G(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega) = \max\left\{v_j^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \eta, \zeta, \omega), v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)\right\} \tag{13}$$

where $v_j^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ is the value of non-defaulting with good credit history and $v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ is the value of defaulting with a good credit history. The defaulting value, $v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$, does not depend on the current assets, a, and non-medical expenditure shocks, ζ, because all debts are eliminated with the default decision.

In sub-period 2, the available choices differ with default decision in sub-period 1. Non-

[12] This setting means that the amount of emergency medical costs is independent of households' income. This setting is supported by evidence in micro data. Using data from the MEPS, I find that, conditional on the use of emergency rooms, the amount of emergency room charges is unrelated to households' income. Further details are presented in Appendix A.

[13] Although medical expenses and shocks from the labor market are the main driving forces of bankruptcy, other motives also play a role. For example, Chakravarty and Rhee (1999); Chatterjee et al. (2007) note that marital disruption and lawsuits/harassment are also important factors to account for individuals' bankruptcy filing decision.

defaulting working-age households with a good credit history at age j in age group j_g solve

$$v_j^{G,N}(a,i,h,\epsilon_e,\epsilon_n,\zeta,\eta,\omega) = \max_{\{c,\,a',\,i',\,m_n\geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u$$
$$+ \beta\pi_{j+1|j}(h_c,j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h',\epsilon_n'|h',\eta'|\eta,\omega'|\eta',\zeta'} \left[V_{j+1}^G(a',i',h',\epsilon_e',\epsilon_n',\zeta',\eta',\omega')\right] \tag{14}$$

such that

$$c + q(a',i',h';j,\eta)a' + p_{i'}(h_c,j_g)$$
$$\leq (1-\tau_{ss}-\tau_{med})\, w\bar{\omega}_j h_c^{\phi_h}\eta + a + \kappa$$
$$-(1-q_i^n)\,m_n - (1-q_i^e)\,m_e(\epsilon_e) - \zeta - T(y)$$

$$\zeta \sim U[0,\bar{\zeta}]$$
$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$
$$y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$$

the feasible set of health insurance choice i follows (10) , and

the health insurance premium $p_{i'}(h_c,j_g)$ follows (11).

Non-defaulting working-age households with a good credit history make decisions on consumption c, savings or debt a', the purchase of health insurance for the next period i' and non-emergency medical expenditures m_n. They earn labor income $w\bar{\omega}_j h_c^{\phi_h}\eta$ and accidental bequest κ. They pay out-of-pocket medical costs, the amount of which differs based on insurance status. If a household purchased health insurance in the previous period, the insurance company covers a part of its medical expenditure, $q_i^n m_n + q_i^e m_e(\epsilon_e)$ where q_i^n (q_i^e) is the fraction of non-emergency (emergency) medical expenditure health insurance i covers.[14] The rest of the medical expense is the household's out-of-pocket medical expenditure, $(1-q_i^n)\,m_n + (1-q_i^e)\,m_e(\epsilon_e)$. If a household did not purchase health insurance in the previous period, the total medical expenditure is the same as the household's out-of-pocket medical expenditure, $q_i^n = q_i^e = 0$. They also pay costs incurred by non-medical expenditure shocks, ζ, which follows a uniform distribution of $U[0,\bar{\zeta}]$. These households pay a progressive tax $T(\cdot)$ based on their income y. They preserve their good credit history to the next period.

[14]The fraction of medical expenses covered by health insurance differs between emergency and non-emergency treatments. According to the MEPS, the coverage rates of health insurances are larger for the case of emergency medical treatments. More details are described in Section 3 (calibration).

Health insurance plays both roles. First, health insurance decreases the marginal cost of investing in health capital by reducing the out-of-pocket medical expenses for non-emergency treatment. Second, health insurance partially insures the risk of emergency medical expense shocks. Since physical capital a can also play the same roles, how the relative price of health capital h to physical capital a changes is a key to determining the allocation of these two types of capital. Health insurance policies alter this relative price. If a health insurance policy subsidizes the purchase of health insurance to poor households, they face a lower relative price of health capital h to physical capital a than rich households and decide to increase their medical spending. This individual change in medical spending behavior results in a reallocation of health h and physical capital a over households.

Defaulting working-age households with a good credit history at age j in age group j_g solve

$$
\begin{aligned}
v_j^{G,D}(i,h,\epsilon_e,\epsilon_n,\eta,\omega) = & \max_{\{c,\, i',\, m_n \geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u \\
& + \beta \pi_{j+1|j}(h_c, j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h',\epsilon_n'|h',\eta'|\eta,\omega'|\eta',\zeta'} \left[V_{j+1}^B(0,i',h',\epsilon_e',\epsilon_n',\zeta',\eta',\omega')\right] \qquad (15) \\
& \text{such that} \\
& c + p_{i'}(h_c, j_g) = (1-\tau_{ss}-\tau_{med}) w \bar{\omega}_j h_c^{\phi_h} \eta - (1-q_i^n) m_n - T(y) + \kappa \\
& h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e) h + \varphi_{j_g} m_n^{\psi_{j_g}} \\
& y = w \omega_j h_c^{\phi_h} \eta \\
& \text{the feasible set of health insurance choice } i \text{ follows (10) , and} \\
& \text{the health insurance premium } p_{i'}(h_c, j_g) \text{ follows (11).}
\end{aligned}
$$

Defaulting working-age households with a good credit history make decisions on consumption c, health insurance i' for the next period and non-emergency medical expenditures m_n, but they can neither save nor dis-save in this period, $a' = 0$. As non-defaulting households do, the out-of-pocket medical expenses depend on their health insurance status. However, contrary to the case of non-defaulting households, these households do not repay emergency medical expenses $m_e(\epsilon_e)$ because they have an exemption. They also have exemptions from the unsecured financial debt $a < 0$ and costs incurred by non-medical expenditure shocks ζ. The exemptions from those debts are given at the cost of their credit record. Their credit history will become bad in the next period.

Although a majority of the decision-making problems of working-age households with bad credit history are nearly identical to those of non-default households with good credit history, there are a few differences. Non-defaulters with a bad credit history are not allowed to borrow, $a \geq 0$, and pay a pecuniary cost of having a bad credit history equal to some fraction of their earnings, $\xi w \bar{\omega}_j h_c^{\phi_h} \eta$. In addition, their credit history is randomly determined in the next period. Defaulters with bad credit history pay a pecuniary cost of having a bad credit history equal to some fraction of their earnings, $\xi w \bar{\omega}_j h_c^{\phi_h} \eta$. They can neither save nor dis-save, $a^{'} = 0$, and they make decisions on consumption c, health insurance for the next period $i^{'}$ and non-emergency medical expenditures m_n. Defaulters with bad credit history also do not repay emergency medical costs ϵ_e and non-medical expenses ζ, so $(1-q_i^n)m_n$ becomes their out-of-pocket medical cost.[15] They maintain bad credit history in the next period.

It is worth noting the difference between filing for bankruptcy and defaulting. The bankruptcy system of this model is to capture the features of the Chapter 7 Bankruptcy in the U.S. Since refilling bankruptcy is not allowed on average for ten years in the U.S., I assume that only those who have a good credit history can file for bankruptcy. However, this does not mean those who have a bad credit history cannot default on debts. Households with a bad credit history are allowed to default on non-financial debts such as ER bills and costs from divorce.

Retired households do not have any labor income but receive Social Security benefits. Borrowing is not allowed for them, $a^{'} \geq 0$. I assume that all retired households have Medicare and do not use any private health insurance. At the beginning of each period, retired households face non-medical expenditure shocks ζ, emergency health shocks ϵ_e, and non-emergency health shocks ϵ_n. They make decisions on consumption c, savings or debt $a^{'}$, and non-emergency medical expenditures m_n. They pay out-of-pocket medical costs, $(1-q_{med}^n)m_n + (1-q_{med}^e)m_e(\epsilon_e)$.

2.2 Firm

The economy has a representative firm. The firm maximizes its profit by solving the following problem:

$$\max_{K,N} \{zF(K,N) - wN - rK\} \tag{16}$$

where z is the total factor productivity (TFP), K is the aggregate capital stock, N is aggregate labor, and r is the capital rental rate.

2.3 Financial Intermediaries

There are competitive financial intermediaries, and loans are defined by each state. This system implies that with the law of large numbers, ex post-realized profits of lenders are zero for each type

[15]They do not have any debt via the financial sector, as those with bad credit cannot borrow regardless of their default decision.

of loan. The lenders can observe the state of each borrower, and the price of loans is determined using good credit-status households' default probability and the risk-free interest rate.[16]

Specifically, the default probability of a household with a good credit history G, total debt $a^{'}$, insurance purchase status $i^{'}$, health capital for the next period $h^{'}$, current age j and current idiosyncratic earnings shock η in the next period is given by

$$d(a^{'}, i^{'}, h^{'}; j, \eta) = \tag{17}$$
$$\sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}, \zeta^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \pi_{\eta^{'}|\eta} \pi_{\omega^{'}|\eta^{'}} \pi_{\zeta^{'}} \mathbb{1}_{\{v^{G,N}(a^{'}, i^{'}, h^{'}, \epsilon_e^{'}, \epsilon_n^{'}, \eta^{'}, \omega^{'}, j+1) \leq v^{G,D}(i^{'}, h^{'}, \epsilon_e^{'}, \epsilon_n^{'}, \eta^{'}, \omega^{'}, j+1)\}}$$

where $\pi_{\epsilon_e^{'}|h^{'}}$ is the probability of an emergency health shock $\epsilon_e^{'}$ in the next period conditional on health capital $h^{'}$ for the next period, $\pi_{\epsilon_n^{'}|h^{'}}$ is the probability of a non-emergency health shock ϵ_n in the next period conditional on health capital $h^{'}$ for the next period, $\pi_{\eta^{'}|\eta}$ is the transitional probability of idiosyncratic shocks on earnings $\eta^{'}$ in the next period conditional on the current idiosyncratic shocks on earnings η, and $\pi_{\omega^{'}|\eta^{'}}$ is the probability of the offer of employer-based health insurance in the next period conditional on the idiosyncratic shock to earnings $\eta^{'}$ in the next period.

The zero-profit condition of the financial intermediaries that make a loan of amount $a^{'}$ to households with age j, current idiosyncratic labor productivity η, health capital $h^{'}$ for the next period, and health insurance $i^{'}$ for the next period is given by

$$(1 + r^{rf})\ q(a^{'}, i^{'}, h^{'}; j, \eta)\ a^{'} = (1 - d(a^{'}, i^{'}, h^{'}; j, \eta))\ a^{'} \tag{18}$$

where r^{rf} is the risk-free interest rate and $q(a^{'}, i^{'}, h^{'}; j, \eta)$ is the discount rate of the loan price.[17] Then, the discount rate of the loan price $q(a^{'}, i^{'}, h^{'}; j, \eta)$ is

$$q(a^{'}, i^{'}, h^{'}; j, \eta) = \frac{1 - d(a^{'}, i^{'}, h^{'}; j, \eta)}{1 + r^{rf}}. \tag{19}$$

[16]Note that households with a bad credit history cannot access the financial market.

[17]Financial intermediaries consider both households' health insurance $i^{'}$ and health capital $h^{'}$ for the next period to price loans. This assumption is necessary to solve the model, as no pooling equilibrium exists under symmetric information between lenders and borrowers. Solving default models under asymmetric information is beyond the scope of this paper.

2.4 Hospital

The economy has a representative agent hospital. For convenience, I denote household state s as $(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ and credit history as $\upsilon \in \{G, B\}$; the hospital earns the following revenue:

$$m_n(\mathbf{s}, j) + (1 - g_d(\mathbf{s}, j))\ m_e(\epsilon_e) + g_d(\mathbf{s}, j)\ \max(a, 0) \tag{20}$$

where $m_n(\mathbf{s}, j)$ is the decision rule for non-emergency medical expenditures for households of state s at age j. $m_e(\epsilon_e)$ is emergency medical expenses for emergency health shocks ϵ_e, and $g_d(\mathbf{s}, j)$ is the decision rule for defaulting for households of state s at age j. All households always pay non-emergency medical expenditures m_n, regardless of whether they default, as the hospital can assess patients' financial abilities before providing non-emergency medical treatment. However, the payment amount for emergency medical treatments $m_e(\epsilon_e)$ depends on individual default decisions. This is because the EMTALA requires hospitals to provide emergency medical treatment regardless of whether the patients can pay their emergency medical bills. Non-defaulters repay all of their emergency medical expenditures to the hospital, but defaulters provide their assets instead of paying emergency medical expenses. If the asset level of these individuals is below 0 (debt), the hospital receives no payment.

For each period t, hospital profits are given by

$$\begin{aligned}\sum_{j=J_0}^{\bar{J}} \int \{ & [m_n(\mathbf{s}, j) + (1 - g_d(\mathbf{s}, j))\, m_e(\epsilon_e) + g_d(\mathbf{s}, j)\ \max(a, 0)] \\ & - \frac{(m_n(\mathbf{s}, j) + m_e(\epsilon_e))}{\zeta} \} \mu(\mathbf{ds}, j)\end{aligned} \tag{21}$$

where ζ is the mark-up of the hospital, and $\mu(\mathbf{s}, j)$ is the measure of households at age j of state s. Following Chatterjee et al. (2007), mark-up ζ is adjusted to ensure zero profits in equilibrium.[18]

Note that the mark-up of the hospital ζ is an instrument through which I can evaluate the efficiency of healthcare policies in terms of healthcare providers, because the size of the hospital's mark-up ζ increases with unpaid medical debt.

2.5 Equilibrium

Appendix E defines a recursive competitive equilibrium.

[18]Note that the object of default is here only emergency medical expenditures, while that in Chatterjee et al. (2007) is all medical expenditures.

2.6 Numerical Solution Algorithm

Here, I describe the key ideas of the numerical solution algorithm. Appendix G demonstrates each step of the algorithm with details.

Substantial computational burdens are involved in solving the model. The model has a large number of individual state variables, and loan prices depend on the state of individuals due to the endogenous default setting. Moreover, the model has many parameters that must be adjusted to match cross-sectional and life-cycle moments in the model with those in the data.

To solve the model, I apply an endogenous grid method to the variable of asset holdings $a^{'}$ for the next period and discretize the variables of health capital $h^{'}$ for the next period and health insurance $i^{'}$ for the next period because the variation of asset holdings $a^{'}$ is the largest among endogenous state variables. The endogenous grid method I use is an extension of Fella's (2014) method. Fella (2014) develops an endogenous grid method to solve models with discrete choices under an exogenous borrowing limit. One of the main contributions of Fella (2014) is an algorithm identifying concave regions over the solution set, to which Carroll's (2006) endogenous grid method is applicable. However, Fella's (2014) endogenous grid method is not directly applicable to models with default options, as these models do not have any predetermined feasible set of solutions. Based on the theoretical findings of Arellano (2008); Clausen and Strub (2017), I add a numerical procedure for finding the lower bound of feasible sets for the solution to Fella's (2014) algorithm that identifies concave regions over the solution sets, which allows me to use the endogenous grid method to solve this model.

Definition 2.6.1. For each $(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$, $a^{'}_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ is ***the risky borrowing limit*** if

$$\forall a^{'} \geq a^{'}_{rbl}(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta),$$
$$\frac{\partial q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) a^{'}}{\partial a^{'}} = \frac{\partial q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta)}{\partial a^{'}} a^{'} + q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) > 0.$$

I numerically compute the risky borrowing limit for each state and take it as the lower bound of feasible sets for solution $a^{'}$. To use the endogenous grid method, a first-order condition (FOC) is required. The following proposition guarantees the existence of an FOC and provides the form of the FOC, which is needed to use the endogenous grid method.

Proposition 2.6.1. *Given a pair of* (ϵ_e, ϵ_n)*, for any* $(\bar{i}^{'}, \bar{h}^{'}, j, \eta)$ *and for any* $a^{'} \geq a^{'}_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$*,*
(i) the FOC of asset holdings $a^{'}$ *exists, and*
(ii) the FOC is as follows:

$$\frac{\partial q(a^{'},\bar{i}^{'},\bar{h}^{'};j,\eta)a^{'}}{\partial a^{'}}\frac{\partial u(c,(1-\epsilon_e)(1-\epsilon_n)\bar{h})}{\partial c}=\frac{\partial W^G(a^{'},\bar{i}^{'},\bar{h}^{'},\eta,j+1)}{\partial a^{'}} \tag{22}$$

where W^G is the expected value of working-age households with a good history.

Proof. See Appendix D. □

For each of the grid points for asset holdings $a^{'}$ for the next period, endogenous grid methods computes the endogenously-driven current assets $a(a^{'})$ by using the FOC in Proposition 2.6.1. Note that since the endogenously-driven current assets $a(a^{'})$ is located on an endogenous grid of the current assets a, the decision rule and values on the exogenous grid must also be computed. The monotonicity of decision rules and value functions allows endogenous grid methods to use interpolations to compute those on the exogenous grid for the current assets a.

I modify this interpolation step as follows. For each of the grid points for asset holdings $a^{'}$ of which value is above zero, I use a linear interpolation as other endogenous grid methods do. However, for each of the grid points for asset holdings $a^{'}$ whose value is below zero, I use the grid search method to avoid potentially unstable solutions due to numerical errors in calculating the derivative of loan rate schedules $\frac{\partial q(a^{'},\bar{i}^{'},\bar{h}^{'};j,\eta)a^{'}}{\partial a^{'}}$. Although Proposition 2.6.1 proves that these loan rate schedules are differentiable, as Hatchondo et al. (2010) noted, the accuracy of the solution is sensitive to the method used to compute the derivative of loan rate schedules $\frac{\partial q(a^{'},\bar{i}^{'},\bar{h}^{'};j,\eta)a^{'}}{\partial a^{'}}$. I use the grid search method only for asset holdings $a^{'}$ of which value is below zero. Despite the inclusion of this grid search method, this hybrid method substantially reduces computational time because the method does not search the whole range of the assets grid. This grid search is operated only between the risky borrowing limit and zero assets. Moreover, using the monotonicity, I can repeatedly narrow the range of the feasible set of solutions in grid search.

3 Calibration

I calibrate the model to capture cross-sectional and life-cycle features of the U.S. economy before the ACA, because the period of the ACA is too brief to be considered as the steady state of the U.S. healthcare system. To reflect these features, I take information from multiple micro data sets. In particular, I use the MEPS to capture salient cross-sectional and life-cycle dimensions on the use of emergency rooms, medical conditions, and medical expenditures.[19]

To calibrate the model, I separate parameters into two groups. The first set of parameters is determined outside the model. I choose the values of these parameters from the macroeconomic

[19]The details of the data selection process are provided in Appendix A.

literature and policies. The other set of parameters requires solving the stationary distribution of the model to minimize the distance between moments generated by the model and their empirical counterparts. Table 1 shows the values of parameters resulting from the calibration, Table 2 summarizes the targeted aggregate moments and the corresponding moments generated by the model, and Figure 3 shows the targeted life-cycle moments and the corresponding model-generated moments.

Table 1: Benchmark Parameter Values

Parameter	Description	Internal	Value
Demographics			
J_0	Initial age	N	23
J_r	Retirement age	N	65
$\bar{J}$	Maximum length of life	N	100
π_n	Population growth rate (percent)	N	1.2%
Preferences			
λ_u	Weight on consumption	Y	0.604
v	Elasticity of substitution b.w c and h_c	Y	0.54
σ	Risk aversion	N	3 (De Nardi et al. (2010))
β	Discount factor	Y	0.7659
B_u	Constant in the utility	Y	3004.29
Labor Income			
$\bar{\omega}_j$	Deterministic life-cycle profile	N	{0.0905,-0.0016}*
ϕ_h	Elasticity of labor income to health status	N	0.594
ρ_η	Persistence of labor productivity shocks	Y	0.851
σ_ϵ	Standard deviation of persistent shocks	Y	0.579
Health Technology			
κ_e	Scale of ER health shocks	Y	0.309
A_{j_g}	Age group effect on ER health shocks	Y	{1, 1.330, 1.494, 1.586, 1.266, 1.037}
p_{se}	Probability of drastic ER health shocks	N	0.2
κ_n	Scale of non-ER health shocks	Y	0.019
α_n	Dispersion of non-ER health shocks	Y	0.543
B_{j_g}	Age group effect of non-ER health shock	Y	{1, 0.711, 0.459, 0.295, 0.172, 0.012}
ψ_{j_g}	Efficiency of health technology	Y	{0.440, 0.427, 0.503, 0.587, 0.670, 0.639}
φ_{j_g}	Curvature of health technology	Y	{0.286, 0.205, 0.260, 0.264, 0.275, 0.4}
Survival Probability			
Γ_{j_g}	Age group effect on survival rate	Y	{0.004, 0.01, 0.02, 0.026, 0.112, 0.297, 0.605}
ν	Elasticity of survival rate to health status	N	0.226 (Franks et al. (2003))
Health Insurance			
$\bar{y}$	Income threshold for Medicaid eligibility	Y	0.048
(q^n_{MCD}, q^e_{MCD})	Medicaid coverage rates	N	(0.7,0.8)
(q^n_{IHI}, q^e_{IHI})	IHI coverage rates	N	(0.55,0.7)
(q^n_{EHI}, q^e_{EHI})	EHI coverage rates	N	(0.7,0.8)

Table 1 continued from previous page

Parameter	Description	Internal	Value
(q^n_{med}, q^e_{med})	Medicare coverage rates	N	(0.55,0.75)
p_{med}	Medicaid premium	N	0.021
$p(EHI\|\eta)$	EHI offer rate	N	Appendix H
ψ_{EHI}	Subsidy for EHI	N	0.8
ξ_{IHI}	Markup for IHI	Y	1
ξ_{EHI}	Markup for EHI	Y	1
Default			
ξ	Cost of having a bad credit history	Y	0.55
λ	1/Duration of having a bad credit history	N	0.333
$\bar{\zeta}$	Non-medical expense shocks $\zeta \sim U[0, \bar{\zeta}]$	Y	0.052
Tax and Government			
ss	Social Security benefit	N	0.256
τ_{ss}	Social Security tax	Y	0.08
τ_{med}	Medicare payroll tax	Y	0.053
G	Government spending/ GDP	N	0.18
a_0	Upper bound of the progressive tax fnc	N	0.258 (Gouveia and Strauss (1994))
a_1	Curvature of the progressive tax fnc	N	0.768 (Gouveia and Strauss (1994))
a_2	Scale of the progressive tax fnc	Y	1.31
τ_y	Proportional tax rate	Y	0.098
Firm			
z	Total factor productivity	Y	0.557
θ	Capital income share	N	0.36
δ	Depreciation rate	N	0.24
Hospital			
ζ	Mark-up of hospital	Y	1.039

The model period is triennial . One unit of output in the model is the U.S. GDP per capita in 2000 ($\$36,245.5$).

Demographics: The model period is triennial. Households enter the economy at age 23 and retire at age 65. Since the mortality rate is endogenous, life spans differ across households. Their maximum length of life is 100 years. These values correspond to $J_r = 15$ and $\bar{J} = 26$. The chosen population growth rate π_n is 1.2 percent, which is consistent with the annual population growth rate in the U.S.

Preferences: Preferences are represented by a power utility function over a CES aggregator over consumption and health status. λ_u is the weight of non-medical consumption on the CES aggregator in the utility function. λ_u is chosen to match the ratio of the total medical expenditures to output of 0.163 in the National Health Expenditure Accounts (NHEA). v is the elasticity of substitution between non-medical consumption and current health status, which is chosen to target

Table 2: Targeted Aggregate Moments

Moment	Empirical value	Model value
Risk-free interest rate (percent)	4	4
AVG of bankruptcy rates (percent)	1.122	1.128
Fraction of bankruptcy Filers with Medical Bills	0.62	0.63
Total medical expenditures/GDP	0.163	0.167
CV of medical expenditures	2.7	2.52
Corr b.w. consumption and medical expenditures	0.158	0.158
Autocorrelation of earnings shocks	0.952	0.952
STD of log earnings	1.29	1.292
Fraction of ER users aged b.w. 23 and 34	0.125	0.126
AVG of health shocks b.w. ages of 23 and 34	0.116	0.121
Individual health insurance take-up ratio	0.11	0.106
Employer-based health insurance take-up ratio	0.685	0.669
Working-age households' Medicaid take-up ratio	0.044	0.044

The model period is triennial . I transform triennial moments into annual moments. One unit of output in the model is the U.S. GDP per capita in 2000 $(\$36,432.5)$.

the correlation between non-medical consumption and medical expenditures, which is 0.158 in the PSID. The value of v is 0.54, which implies that consumption is complementary with health. This result is consistent with the empirical findings of Finkelstein et al. (2013). σ is the coefficient of relative risk aversion, according to De Nardi et al. (2010). β is the discount factor of households, which is selected to match an equilibrium risk-free interest rate of 4 percent. Following Hall and Jones (2007), B_u is chosen to guarantee the positive value of life. Its value is larger than usual values in the literature to prevent negative values of living in extremely bad cases. For example, if a household pays a pecuniary cost of having a bad credit history and experiences extremely bad health events with bad luck in the labor market, its life value can be positive only when B_u is substantially large.[20]

Labor Income: To obtain the deterministic life-cycle profile of earnings $\bar{\omega}_j$, I take the following steps. First, in the MEPS, I choose the Physical Component Score (PCS) as the counterpart of health status in the model.[21] I normalize the PCS by dividing all of the observations by the highest score in the sample. Second, exploiting the panel structure of the MEPS data, I regress the difference in log labor income on differences in age squared, education, sex and the PCS.[22] I choose the summation of the age and age-squared terms as the deterministic life-cycle profiles of

[20]The value of B_u is 66.27 in the model of Hall and Jones (2007), which does not address borrowing and default.

[21]The PCS is a continuous health measure between 0 and 100 that indicates individual physical condition.

[22]This setting absorbs individual fixed effects. Further, one might be concerned about endogeneity due to reverse causality from labor income to health, but empirical studies including Currie and Madrian (1999) and Deaton (2003) show that it is difficult to find a direct effect of labor income on health.

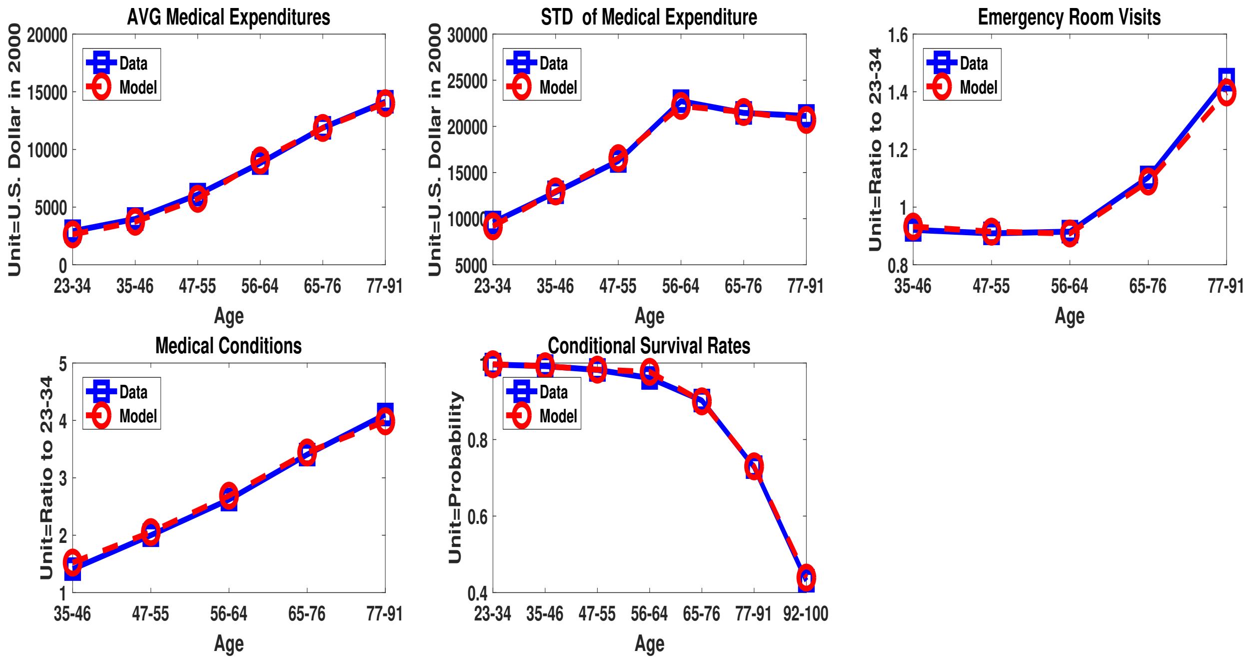

Figure 3: Targeted Life-cycle Moments

earnings $\bar{\omega_j}$. ϕ_h is set based on the estimate of the coefficient of the PCS. ρ_η is chosen to match the autocorrelation of the idiosyncratic component $\phi_h \log(h_c) + \log(\eta)$ with the autocorrelation of earnings shocks without the health component of 0.957 in Storesletten, Telmer and Yaron (2004). σ_ϵ is chosen such that the model generates a standard deviation of 1.29 for the log earnings (labor income) in the Survey of Consumer Finance (SCF) (Díaz-Giménez, Glover and Ríos-Rull (2011)).

Health Technology: I choose the scale parameter of the function for emergency health shocks κ_e to target the average fraction of emergency room users aged between 23 and 34, which is 0.125 in the MEPS. A_g governs differences in emergency room visits by age group. It is chosen to match the ratio of the fraction of emergency room visits for each age group to that of households aged between 23 and 34. The upper-right panel of Figure 3 shows that these ratios observed in data are close to those generated by the model. p_{se} is the probability of an extreme emergency medical event conditional on the occurrence of an emergency medical event. I model these extreme emergency medical events as emergency events that incur the top 20 percent of emergency medical expenses. κ_n is chosen to target the average health shocks of households aged between 23 and 34, which is 0.125 in the MEPS. α_n determines the degree of differences in health shocks across levels of health capital. It is selected to target the coefficient of variation of medical expenditures of 2.67 in the MEPS. B_{j_g} is set to match the ratio of the average of medical conditions transformed by health shocks for each age group to that of households aged between 23 and 34. The lower-left panel of Figure 3 shows that the model generates a similar age profile of medical conditions. ψ_{j_g}

is set to match the average of medical expenditures for each age group. φ_{j_g} is chosen to target the standard deviation of medical expenditures for each age group. The upper-left and upper-middle panels of Figure 3 show that the life-cycle profiles of the mean and standard deviation for medical expenditures in the data are close to those generated by the model.

Survival Probability: Γ_{j_g} controls the disparities in survival rates across age groups. Γ_{j_g} is chosen to target the average survival rate for each age group, which is calculated based on Bell and Miller (2005). ν governs the predictability of the PCS for the survival rate. I choose ν based on the estimate of Franks, Gold and Fiscella (2003). They use a somewhat different type of health measure from the MEPS. Whereas the MEPS uses the SF-12 as its PCS, Franks, Gold and Fiscella (2003) choose the SF-5 as their PCS. Although the types of PCS differ, Østhus, Preljevic, Sandvik, Leivestad, Nordhus, Dammen and Os (2012); Lacson, Xu, Lin, Dean, Lazarus and Hakim (2010); Rumsfeld, MaWhinney, McCarthy Jr, Shroyer, VillaNueva, O'brien, Moritz, Henderson, Grover, Sethi et al. (1999) find that different types of PCS are highly correlated. Based on their finding, I use the estimate of Franks, Gold and Fiscella (2003) by transforming their five-year result to a three-year value and rescaling the 0-100 scale into the relative scale of the model. Recall that, in the model, health status is represented by a health status relative to the healthiest in the economy.

Health Insurance: The income threshold for Medicaid eligibility $\bar{y}$ is chosen to match the percentage of Medicaid takers among working-age households, which is. 4.4 percent in the MEPS.[23] Health insurance coverage rates, q[24]$^{e}_{MCD}$, q^{e}_{IHI}, q^{e}_{EHI} and q^{e}_{med}, (q^{n}_{MCD}, q^{n}_{IHI}, q^{n}_{EHI} and q^{n}_{med}), are chosen to match the fraction of (non-) emergency out-of-pocket medical expenditures among the total medical expenditures for each type of health insurance. The Medicare premium p_{med} is set to 2.11 percent of GDP per capita, which is based on the finding in Jeske and Kitao (2009). The offer rates of employer-based health insurance $p(EHI|\eta)$ are set to target the offer rates across earnings levels in the MEPS. Appendix H demonstrates the details. For each age group j_g, I calculate the conditional offer rates given a level of earnings in the data. Then, I map the offer rate in the data onto the stationary distribution of earnings shocks in the model and calculate the conditional offer rate $p(EHI|\eta)$. I use not the level of earnings but the persistent part of earnings shocks because the latter captures more features of employers. The subsidy for employer-based health insurance ψ_{EHI} is chosen such that employer-based health insurance takers pay 20 percent of the premium. ξ_{IHI} and ξ_{EHI} are set to the take-up ratios of individual private health insurance and employer-based health insurance, respectively.

[23] Pashchenko and Porapakkarm (2017) find that asset testing for the eligibility of Medicaid has important welfare implications because 23 percent of Medicaid enrollees do not work to be eligible. This channel is not captured in this model because the labor supply is set to be inelastic due to the computational burdens.

[24] This model does not address asset testing that has important implications in welfare

Default: The cost of bad credit history ξ is chosen to match the average Chapter 7 bankruptcy rate in Nakajima and Ríos-Rull (2019). λ is chosen to match the average duration of exclusion, which is 10 years for Chapter 7 bankruptcy filing.

Tax and Government: ss is chosen to match a replacement rate of 40 percent. Social Security tax τ_{ss} is chosen to balance the government budget for Social Security. τ_{med} is set to balance the government budget for Medicare. Non-medical government spending is set at 18 percent of U.S. GDP. a_0 and a_1 are taken from Gouveia and Strauss (1994). As in Jeske and Kitao (2009) and Pashchenko and Porapakkarm (2013), the scale parameter of the income tax function a_2 is chosen to match the fraction of tax revenue financed by progressive income taxation of 65 percent, which is the average value of the OECD member countries. The proportional income tax τ_y is chosen to balance the government budget constraint.

Firm: TFP z is chosen to normalize output to 1. θ is chosen to reproduce the empirical finding that the share of capital income is 0.36. Annual depreciation rate δ is 8 percent.

Hospital: Following Chatterjee et al. (2007), hospital mark-up ζ is chosen to represent the zero profit condition of the hospital.

3.1 Model Performance

Before conducting a series of counterfactual experiments for the three healthcare reforms, I demonstrate the performance of the model by assessing the consistency of the untargeted results of the model with their empirical counterparts.

Life-cycle Dimensions: Figure 4 depicts the life-cycle profiles of average consumption, earnings and assets. The shape of the consumption profile is concave and relatively flatter than the other two profiles. Earnings profiles increase until the mid-40s and decline until retirement. After retirement, households receive Social Security benefits. Households save assets until their retirements and spend them afterward. The shape of the three profiles resembles that of their empirical counterparts, which are documented in Heathcote, Perri and Violante (2010) and Díaz-Giménez, Glover and Ríos-Rull (2011).

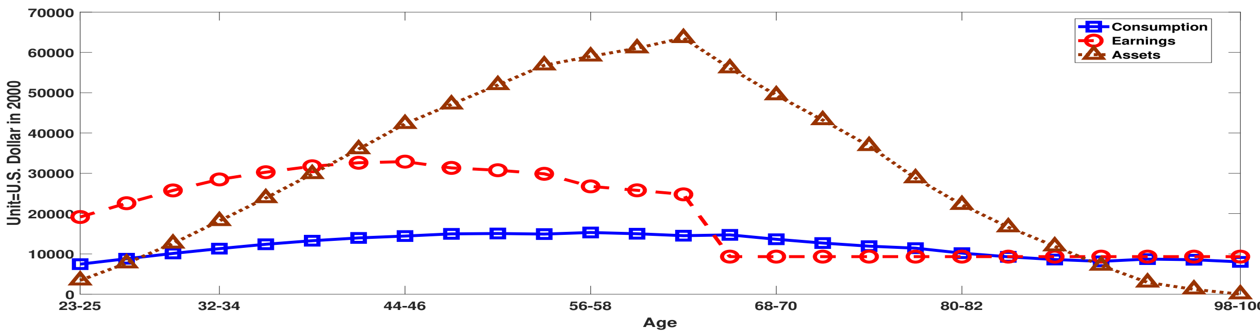

Figure 4: Age Profiles of Consumption, Earnings and Assets

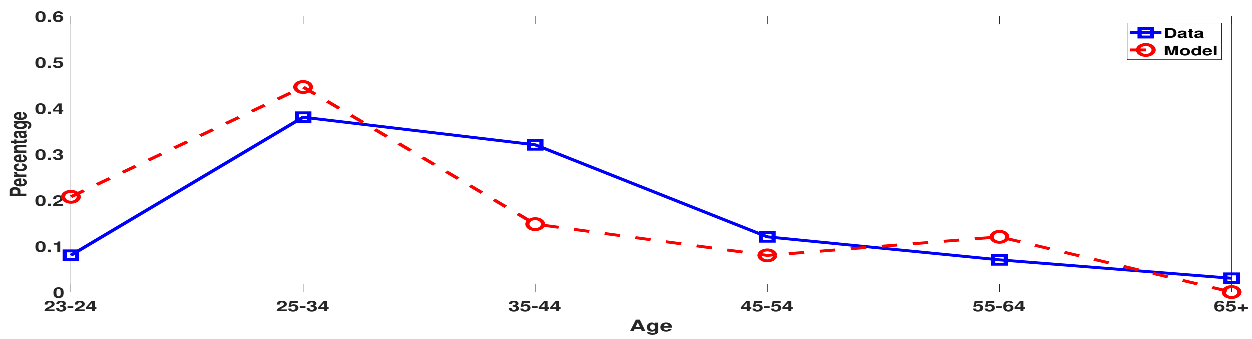

Figure 5: Age Profiles of Bankruptcy Filings (Source: Sullivan et al. (2001))

Figure 5 displays the profiles of the fraction of bankruptcy filings over the life-cycle. In the data, the life-cycle profile of bankruptcy filings is hump-shaped, and bankruptcy filers aged between 25 and 44 consist of more than half of the total bankruptcy filers. The model broadly reproduces these features well, meaning that it successfully reflects how default risks evolve over the life-cycle.

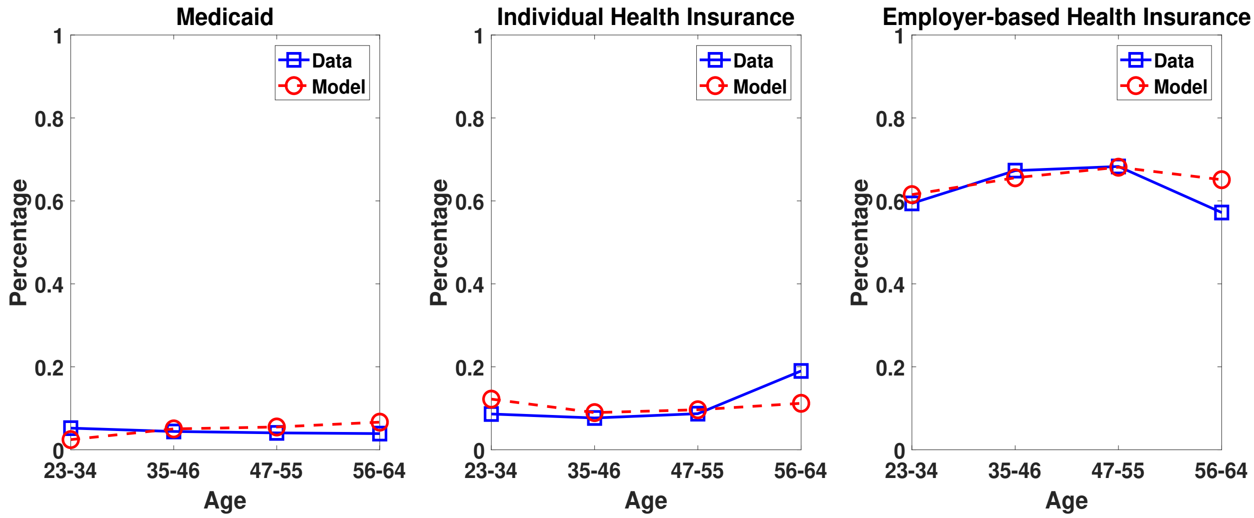

Figure 6: Age Profiles of Insurance Take-up Ratios

Figure 6 shows the age profiles of take-up ratios for health insurance. These take-up ratios in the model are broadly similar to those in the data. Before the expansion of Medicaid under the ACA, only a small portion of working-age households used Medicaid, as it was available only to low-income households. The model generates this feature well. Regarding individual health insurance, the model reproduces the life-cycle profile for those aged between 23 and 55 well. However, the model does not match the empirical rise in its take-up ratio for those aged between 56 and 64 because the model cannot capture early retirement. In the data, those who take early retirement tend to purchase individual health insurance until they reach the Medicare eligibility age. Since all households in the model are required to retire at age 65, the model fails to reproduce this. The model succeeds in generating the hump-shaped age profiles in employer-based health insurance in the data, which implies that the model, overall, reflects life-cycle features of health insurance behavior well .

Table 3: Untargeted Cross-sectional Moments

Moment	Empirical Value	Model Value
Debt - Earnings Ratio	0.084	0.099
Fraction of Uncompensated ER	0.502	0.469
Correlation b.w. Income and ER Visits	-0.09	-0.12
Correlation b.w. Income and Medical Conditions	-0.15	-0.24

The model period is triennial . I transform the triennial moments into annual moments.

Cross-sectional Dimensions: Table 3 shows cross-sectional moments that are not explicitly targeted. The empirical values of these moments are obtained from previous studies and the data. The empirical value for the debt-to-earnings ratio is from Livshits et al. (2007). The debt to earnings ratio is 0.084 in the data and 0.099 in the model. The fraction of uncompensated ER is computed by counting households whose total ER expenditure is less than 50 percent of the total charge of ER in the MEPS. The fraction is 0.502 in the data, and 0.469 in the model. The model also generates reasonable values on health-related cross-sectional moments. The empirical values of these health-related moments below are from the MEPS. The model generates negative values of the correlation between income and emergency room visits and of the correlation between income and medical conditions quantified to health shocks. Note that the negative correlation values can be reproduced owing to the model's setting for the distribution of health shocks: the likelihood of emergency and non-emergency health shocks negatively depends on health capital.

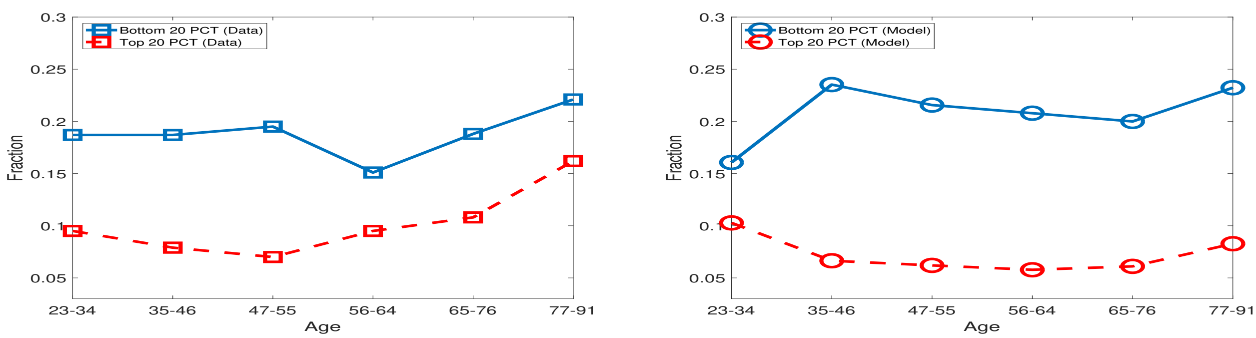

Figure 7: Bottom and Top End of the Emergency Room Usage Distribution

Figure 7 implies that the model endogenously captures the features of emergency room usage of low-income individuals and high-income individuals. The left panel of Figure 7 shows that, in the data, low-income individuals visit emergency rooms more frequently over the life-cycle, which is well-replicated in the model. Note that the fraction differs across income levels, as the distribution of emergency health shocks depends on health capital. If the distribution depended only on age, there would be no difference in visits to emergency rooms across income groups.

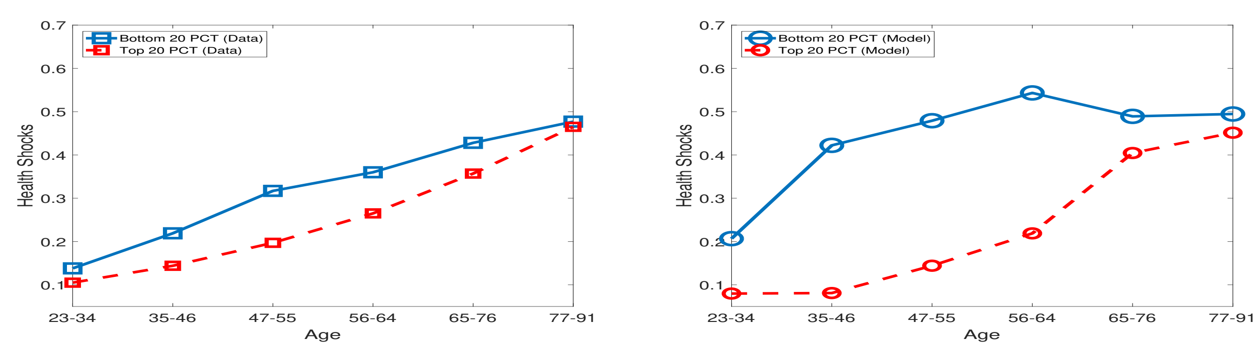

Figure 8: Bottom and Top End of the Medical Conditions Distribution

Figure 8 compares the age profiles of medical conditions between individuals in the top 20 percent of income and those in the bottom 20 percent. It implies that the model captures the distributional features of medical conditions across income groups. The left panel of Figure 8 implies that low-income individuals tend to suffer from more severe health shocks than high-income individuals, which is presented in the model's result. These successes of the model make it possible to capture asymmetric financial risks across income groups, as health risks are linked to financial risks via emergency and non-emergency medical expenses.

4 Results

In this section, I investigate the effects of the option to default on the optimal health insurance policy. To do so, I take the following steps. First, following the literature, I turn off the option to default by imposing an extremely large penalty on defaulting. Specifically, I restrict defaulting households to have no labor income and to get by with the small amount of accidental bequest until their credit history recovers to good.[25] In this setting, households default only when their budget set for non-defaulting is the empty set. Second, I compare the economy with the option to default to that without the option to default. Third, I define the function of the health insurance system and the social welfare function. Fourth, I use these functions to find both the optimal health insurance policy in the economies with and without the option to default. Finally, I compare these optimal health insurance policies. Note that in the economy without the option to default, there is no borrowing because the level of the natural borrowing limit is zero with an endogenous survival rate.

4.1 The Effect of the Option to Default on the Economy with the Baseline Health Insurance System

Figure 9 displays the life-cycle profiles of wealth accumulation over the life-cycle, according to whether the option to default is available. As can be seen in Figure 9, the option to default leads to an increase in the level of debts and a decrease in savings over the life-cycle. As noted in the top-right panel of Figure 9, households in the 10th percentile of net worth make substantial loans in the economy with the option to default during the working-age period, while those without

[25] This setting implies an annual income of approximately 1240 dollars, and this restriction lasts 10 years on average. A small income is required to maintain a positive value of life. Additionally, one might consider not allowing the option to default mechanically without any penalty. This setting is not feasible because the monotonicity of the expected value function does not hold around the default region.

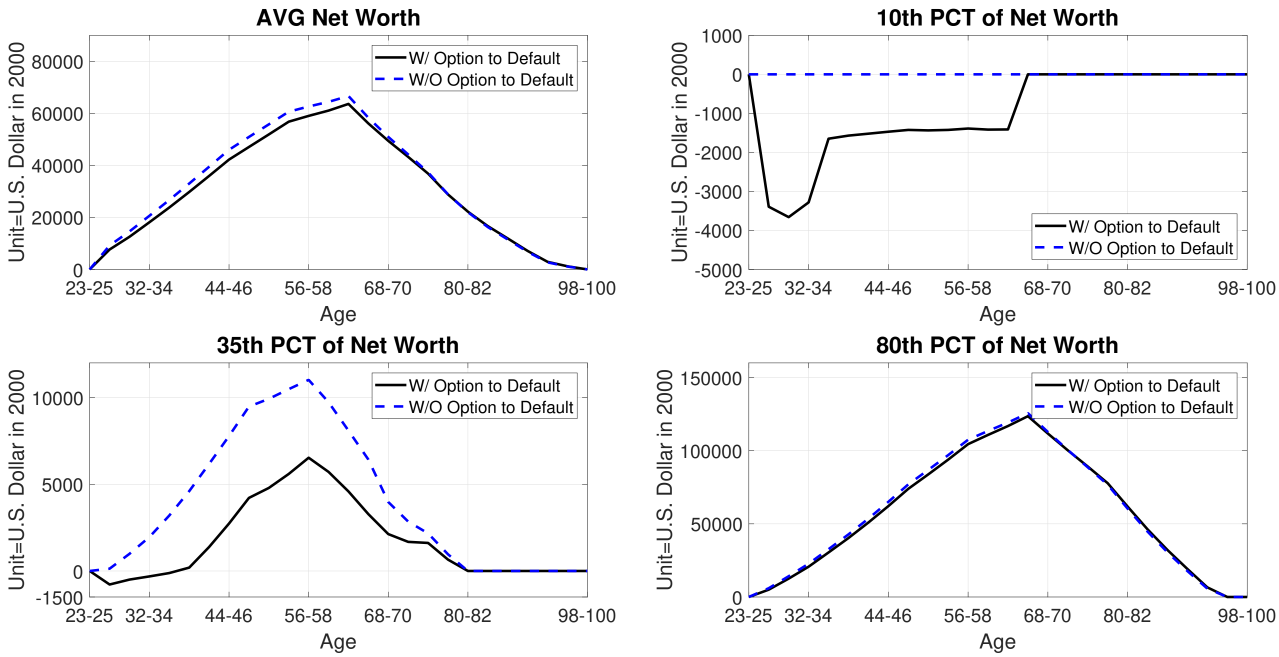

Figure 9: The Effect of the Option to Default on Net Worth

the option to default are stuck at the borrowing limit.[26] When the option to default is available, even households in the 35th percentile of net worth rely on debts in their early phase of the life-cycle. In contrast, without the option to default, households in the 35th percentile of net worth start accumulating assets from a very early phase of their life-cycle. Meanwhile, the right-bottom panel of Figure 9 implies that the option to default has little impact on the evolution of wealth for the rich because they are less likely to encounter the browning constraint. These findings imply that with the option to default, households have access to credit that reduces households' precautionary savings motives.

This difference in the extent of the precautionary motives affects the demand for health insurance, medical spending, and thereby the evolution of health. Table 4 presents these three outcomes, according to the option to default is available. 'Health Insurance' in Table 4 shows that insulating the option to default increases the demand for health insurance. When the option to default is unavailable, the total insurance take-up ratio increases by 6.5 percentage points. This increase is driven by households that demand further private health insurance. The take-up ratio of Medicaid shows little change due to its invariant rule for income eligibility, while the take-up ratios of IHI and EHI increase by 2.7 and 3.6 percentage points, respectively. Figure 10 implies that the phase of changes in health insurance differs across age groups. When the option to default is unavailable,

[26]Recall that without the option to default, households cannot borrow because the natural borrowing limit is zero with an endogenous survival rate.

Table 4: The Effect of the Option to Default on Health-related Outcomes

Moment	w/ OPT DEF	w/o OPT DEF
Health Insurance		
Total Insurance Take-up Ratio	81.9%	88.4%
Medicaid Take-up Ratio	4.4%	4.5%
IHI Take-up Ratio	10.6%	13.3%
EHI Take-up Ratio	66.9%	70.5%
AVG IHI Eff. Price*	1348	1293
AVG EHI Eff. Price*	696	697
Medical Expenditure		
AVG Medical Exp.*	6091	6228
CV of Medical Exp.	2.52	2.48
Health Measure		
AVG Health	0.707	0.700
STD of Log Health	0.769	0.797
AVG Health Shocks	0.346	0.349
AVG Prob of ER Visits	0.124	0.127
Life Expectancy	74.20	74.20

The model period is triennial . I transform the triennial moments into annual moments.
* Unit=U.S. dollar in 2000.

households in the 20s-30s tend to purchase more IHI, while households in the 40s-50s choose more EHI. This difference occurs because all working-age households increase their demand for health insurance due to the lack of the option to default, while the offer rate of EHI is relatively low for young-age groups.[27] This increase in the demand for health insurance implies that the option to default reduces households' precautionary motives and acts as implicit health insurance by leading households to be reluctant to purchase health insurance, as noted in Mahoney (2015).

'Medical Expenditure' in Table 4 presents that eliminating the option to default increases spending on healthcare services and reduces its inequality. Insulating the option to default increases the average medical expenditure by 2.2 percent and reduces the coefficient of variation for medical expenditures by 1.6 percent. The upper panels of Figure 11 indicate that the option to default results in substantial differences in medical spending behavior over the life-cycle. When the option to default is unavailable, households reduce medical spending substantially in their 20s and rapidly increase spending from their 30s onward. Eliminating the option to default leads households to spend on health more equally over the life-cycle. These findings imply that, as noted in Figure 9, with the option to default, households can reduce their precautionary savings and have access to credit, thereby facilitating smoothing out their medical spending across states and over the life-cycle.

This difference in medical spending behaviors affects the evolution of health. 'Heath Measure' in Table 4 shows that insulating the option to default reduces average health status while increasing

[27] Appendix H shows the details.

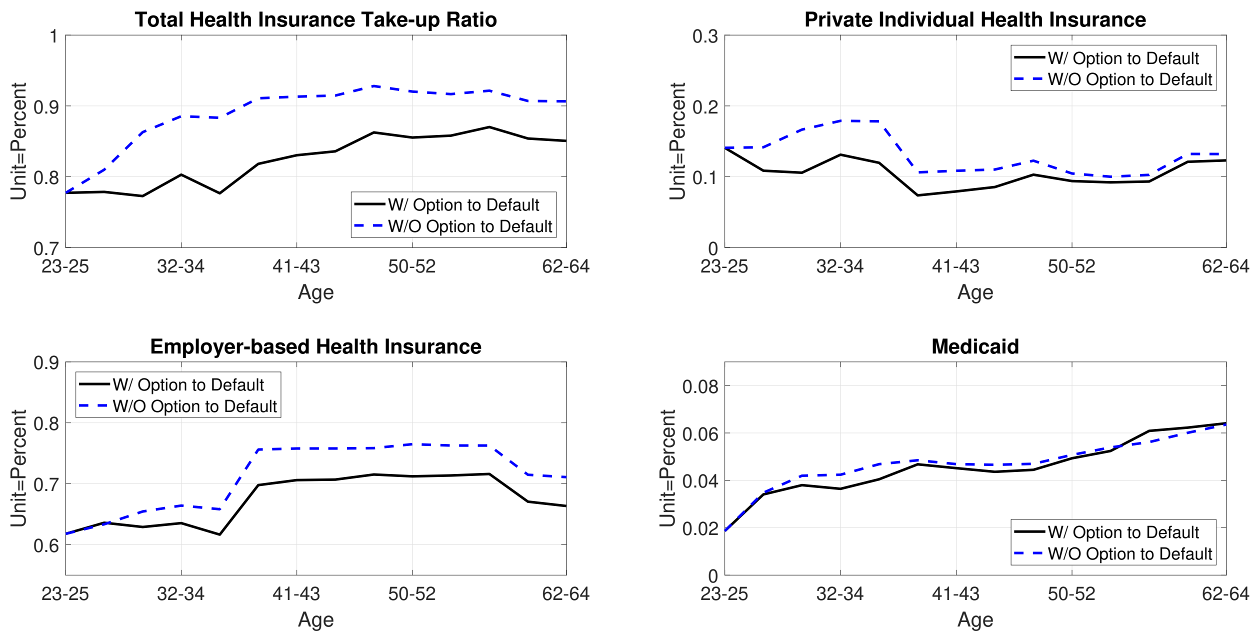

Figure 10: The Effect of the Option to Default on Health Insurance

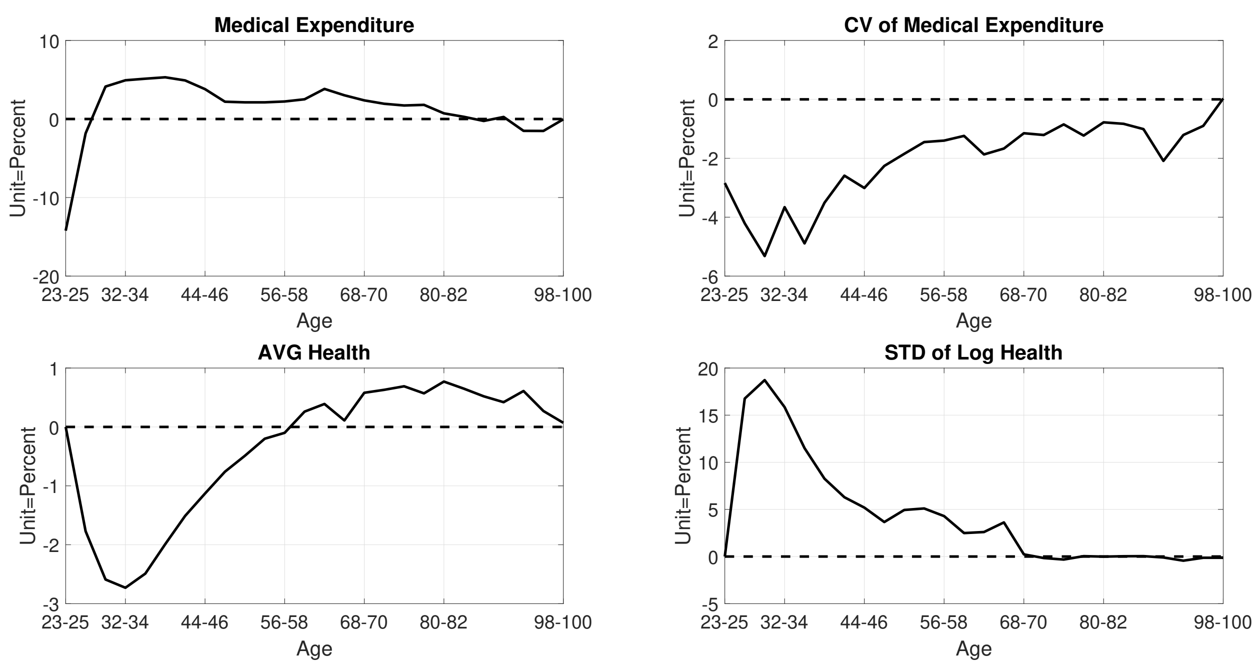

Figure 11: Changes in Medical Expenditure and Health from the Economy with the Option to Default to that without the Option to Default

inequality in health. The absence of the option to default reduces average health by 1 percent and increases the standard deviation of the log of health status by 3.6 percent. The average health shock and the average probability of ER visits are also larger in the economy without the option to default. The lower panels of Figure 11 indicate that the option to default yields considerable differences in the evolution of health over the life-cycle. When the option to default is unavailable, households in their 20s and middle 30s undergo a substantial reduction in average health because many of them cannot smooth out spending on healthcare services against health shocks due to the lack of access to credit and insufficient assets. Households recover health from the late 30s onward by increasing medical spending, of which the source is their assets. In turn, older households achieve slight improvements in health. Insulating the option to default substantially increases the standard deviation of the log of health status in the early phase of the life-cycle because a few young households face medical events but cannot spend substantially on health due to their low income and the lack of access to credit. The difference in inequality in health decreases as they age because households are more likely to smooth their medical spending by having more time to accumulate assets.

Table 5: The Effect of the Option to Default on Aggregate Variables

Moment	w/ OPT DEF	w/o OPT DEF
Y	1*	1.02
K/Y	2.96	3.11
Risk-free Int. Rate	4%	3.46%
AVG BOR. Int. Rate	18%	-
Debt/Earnings	0.099	0
AVG B.K. Rate	1.128%	0.547%
Frac of B.K. with Med. Bills	0.64	0.81
Market Wage	0.254	0.261
Unit of Eff. Labor	2.52	2.5
STD of Log Earnings	1.29	1.31
AVG Cons	0.342	0.346
STD of Log Cons	0.917	1.024
AVG Tax Rate	22.1%	21.9%

The model period is triennial . I transform the triennial moments into annual moments.

* I normalize the output value in the benchmark model with the option to default to 1.

Table 5 implies that these differences in medical spending and household finance have quantitatively substantial impacts on the quantities and prices of the aggregate economy. As noted in Figure 9, eliminating the option to default causes households to increase their life-cycle savings due to the additional precautionary motives. This increase in savings induces an increase in the capital-output ratio, thereby resulting in a decrease in the risk-free interest rate and an increase in the market wage in general equilibrium. When the option to default is unavailable, all bankruptcies are non-strategic and non-voluntary, and the rate is 0.547 percent. Recall that, as noted in Figure 11, the absence of the option to default deteriorates health and increases inequality in health for young households. These changes in health decrease the average efficient unit of labor and increase the standard deviation of the log of earnings.[28] These disparities in earnings induce different evolution of consumption. Figure 12 implies that the increase in earnings leads to an increase in consumption, and more dispersed earnings give rise to an increase in inequality in consumption. Insulating the option to default causes the consumption profile to be steeper because the lack of access to credit hinders households from smoothing consumption over the life-cycle.

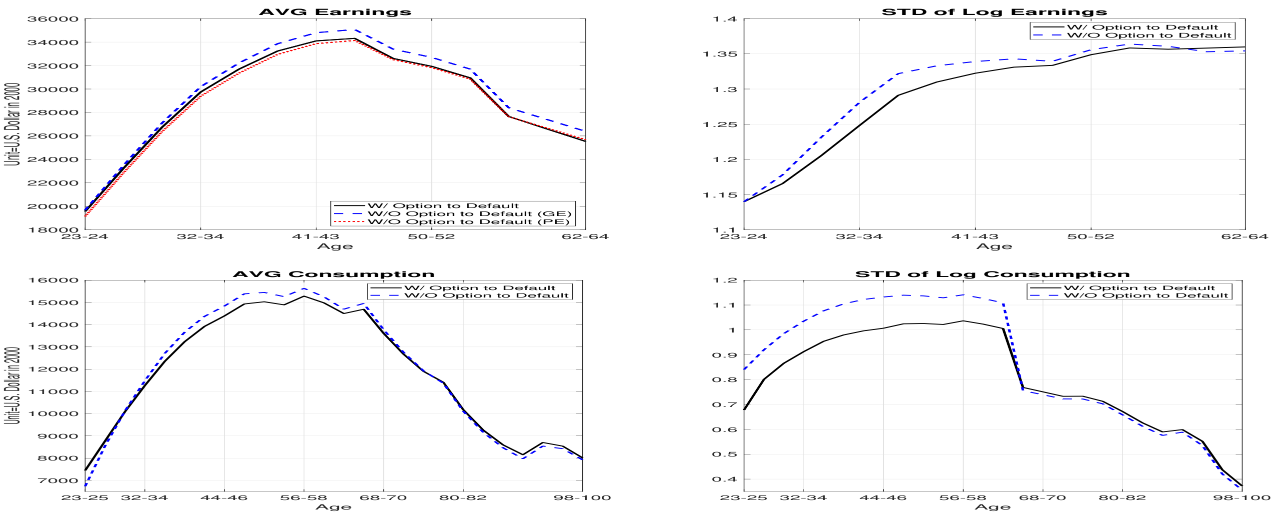

Figure 12: The Effect of the Option to Default on Earnings and Consumption

To sum up, the option to default reduces households' precautionary motives and enables households to smooth their medical spending through borrowing. This smoothing behavior for medical spending leads overall health to improve and to be more equally distributed while the reduced precautionary motives decrease savings and the demand for health insurance. These changes in savings and health are substantially significant to affect the quantities and prices of the aggregate economy.

4.2 Health Insurance Policy and Social Welfare Function

All health insurance policies in this study address the reforms of two types of health insurance for non-retirees: Medicaid (public health insurance for non-retirees) and IHI. The ideal target is to characterize a complete set of healthcare reforms that maximizes social welfare. However, healthcare reforms in the U.S. include a large number of policy components that affect a wide

[28]Figure 12 shows that the average levels of earnings are higher in the economy without the option to default, although the overall level of health is lower. This gap occurs because general equilibrium effects induce a higher level of wage in the economy without the option to default due to such a large increase in the aggregate capital.

range of agents.[29] I put my focus mainly on policy components related to households. In addition, in all policy experiments going forward, I preserve the system of employer-based health insurance in the baseline economy because healthcare reforms currently proposed in the U.S., such as the ACA and the American Health Care Act (AHCA), have mainly focused on policies for Medicaid and IHI.

Specifically, my goal is to find the optimal design of three objects: (i) the eligibility rule of Medicaid, (ii) the subsidy rule for the purchase of IHI, and (iii) the reform of the IHI market on its pricing rule, p_{IHI}, and coverage rates, (q^e_{IHI}, q^n_{IHI}). Ideally, one would impose no restrictions on the objects the government can select. Unfortunately, optimizing such unrestricted objects is computationally unfeasible. Therefore, first, I represent (i) the eligibility rule for Medicaid and (ii) the subsidy rule for the purchase of IHI in one function with a two-parameter family. The subsidy function of Medicaid and IHI is given by

$$\Phi(y, i; \bar{M}, a_p) = \begin{cases} 1 & \text{if } y \leq \bar{M} \ \&\ i = MCD \\ -\frac{1}{a_p} \cdot y + \frac{1}{a_p} \cdot \bar{M} + 1 & \text{if } \bar{M} < y \leq \bar{M} + a_p \ \&\ i = IHI \\ 0 & \text{otherwise} \end{cases} \tag{23}$$

where $\Phi(y, i; \bar{M}, a_p)$ is the proportion of subsidy on the premium of health insurance i given to households whose income is y. $\bar{M}$ is the income threshold for Medicaid eligibility, and a_p is the income threshold of the subsidy for the purchase of IHI. For example, if a household earns income lower than the income eligibility of Medicaid M, this household can use Medicaid. If a household is between $\bar{M}$ and $\bar{M} + a_p$, this household is not eligible for Medicaid, but it can receive a subsidy for the purchase of IHI as much as a fraction $-1/a_p \cdot y + 1/a_p \cdot \bar{M} + 1$ of the health insurance premium. Note that when a_p increases, the subsidy covers more households with larger benefits.

I define the IHI market reform as follows:

$$\mathbf{\Pi}(b_p) = (p_{IHI}, q^n_{IHI}, q^e_{IHI}) = \begin{cases} (p_{IHI}(h_c, j_g), 0.55, 0.7) & \text{if } b_p = 0 \\ (p_{IHI}(j_g), 0.70, 0.8) & \text{if } b_p = 1 \end{cases} \tag{24}$$

where $\mathbf{\Pi}(b_p)$ is a vector of the pricing rule for IHI p_{IHI}, the coverage rate for non-medical expenses q^n_{IHI}, and that of emergency medical expenses q^e_{IHI} conditional on a reform of b_p. $b_p = 0$ implies no reform in the IHI market. Thus, the premium of IHI depends on the current health status h_c as well as age group j_g, and its coverage rates (q^n_{IHI}, q^E_{IHI}) are lower than those of Medicaid and employer-based health insurance. $b_p = 1$ implies that the premium depends only on age group

[29] For example, policies in the Affordable Care Act reach the health insurance industry, household, firm and government sectors.

j_g and that the coverage rates, (q^e_{IHI}, q^n_{IHI}), improve to be the same as the EHI and Medicaid's coverage rate.

The above setting is sufficiently flexible that the functions enable me to replicate not only pre-existing healthcare systems around the world but also alternative healthcare reforms recently proposed in the U.S. For example, if $\bar{M}$ is larger than the income of a household whose income is the highest, this policy implies a universal healthcare system (single-payer healthcare system). Additionally, by choosing $b_p = 1$ and adjusting $\bar{M}$ and a_p properly, it is possible to mimic the Medicaid expansion and the progressive subsidies for the purchase of individual health insurance of the ACA. Furthermore, if one chooses $b_p = 0$ and establishes lower values of $\bar{M}$ and a_p than those of the ACA, he can mimic the policies of the American Health Care Act. The parameterization of healthcare reform permits us to avoid restricting the scope of this study to specific reforms. Rather, this flexibility makes it possible to explore more general features of health insurance policies, which allows the characterization of optimal health insurance policies.

Healthcare reforms can be represented by three parameters $(\bar{M}, a_p, b_p)$. An issue is that different healthcare reforms require different levels of tax revenues because the reforms are funded by taxes. I adjust a_0 of the income tax function , $a_0\{y - (y^{-a_1} + a_2)^{-1/a_1}\} + \tau_y\, y$, to balance the government budget while preserving the values of a_1, a_2 and τ_y in the baseline economy. Recall that a_0 determines the upper bound of the progressive tax as income y goes to infinity. Therefore, the higher a_0, the more progressive the tax system. As noted in Pashchenko and Porapakkarm (2013), this setting takes into account that more redistributive healthcare reforms require more progressive income taxes.

The government maximizes a social welfare function (SWF). The SWF values the ex-ante lifetime utility of an agent born into the stationary equilibrium implied by the chosen healthcare reform. The government solves

$$\max_{\bar{M}\geq 0, a_p \geq 0, b_p \in \{0,1\}} SWF(\bar{M}, a_p, b_p) \tag{25}$$

such that

$$SWF(\bar{M}, a_p, b_p) = \int V^G_{j=23}(\mathbf{s}_0; \bar{M}, a_p, b_p)\mu(d\mathbf{s}_0, j = 23; \bar{M}, a_p, b_p)$$

$$\mathbf{s}_0 = (a = 0, i = i_0, h = h_0, \epsilon_e, \epsilon_n, \eta, \zeta, \omega)$$

(23) and (24).

where $V^G_{j=23}(\cdot; \bar{M}, a_p, b_p)$ is the value of households at age 23 associated with $(\bar{M}, a_p, b_p)$, $\mu(\cdot; j = 23; \bar{M}, a_p, b_p)$ is the distribution over households at age 23 associated with $(\bar{M}, a_p, b_p)$. Recall that all newborn households start with zero assets and the maximum level of health capital stock. The initial distribution of health insurance status is obtained from the MEPS by computing the joint distribution between earnings and health insurance status at age 23. I interpret that the level of earnings in the MEPS reflects the level of labor productivity η. I assume that $(\epsilon_e, \epsilon_n, \eta, \zeta, \omega)$ are on their stationary distributions at age 23.

I quantify welfare changes from the baseline economy by computing the consumption equivalent variation **CEV** in the following way:

$$\sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,0}(\mathbf{s}, j)) u((1 + \mathbf{CEV}) c_0(\mathbf{s}, j), h_{c,0}(\mathbf{s}, j)) \mu_0(d\mathbf{s}, j) \tag{26}$$
$$= \sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,1}(\mathbf{s}, j)) u(c_1(\mathbf{s}, j), h_{c,1}(\mathbf{s}, j)) \mu_1(d\mathbf{s}, j)$$

where β is the discount rate, and $\pi_{j+1|j}(h_c)$ is the rate of surviving up to age $j+1$ conditional survival up to age j with a current health status h_c. The subscripts of these variables indicate the economy concerned. A subscript of 0 means that the variables refer to an economy with the baseline health insurance system, and a subscript of 1 implies that the variables refer to an economy with a changed health insurance system.

4.3 Optimal Health Insurance Policies

Table 6: Optimal Policies and Welfare Changes

		w/ OPT DEF	w/o OPT DEF
Health Insurance System $[M, a, b]$		[0.303, 8.3, 1]	[0.308, 0, 0]
Total Change		+11.64	+17.16
Consumption	Total	+1.68	+3.19
	Level	+2.68	+3.39
	Distribution	-1	-0.2
Health	Total	+9.96	+13.97
	Quantity	+1.30	+0.7
	Level (Flow)	+0.73	+0.57
	Distribution (Flow)	+7.93	+12.7

Unit = Percentage change from each of the baseline economies.
The health insurance system of the baseline economy is $[M, a, b] = [0.048, 0, 0]$

Table 6 shows the optimal health insurance policies and their welfare changes.[30] In the economy with the option to default, the optimal health insurance system indicates that the threshold

[30] Conesa et al. (2009) decomposed welfare changes into these four components, using a feature of the utility function in their study: the utility function is homothetic with respect to consumption. This model has two differences from theirs. First, the utility function in this study is homothetic not with respect to consumption but with respect to

of eligible income for Medicaid $\bar{M}$ is 30.3 percent (approximately \$11,039) of the average income in the Baseline economy (\$36,432.5), the subsidies for the purchase of IHI, a are given up to households whose income is between 30.3 percent (approximately \$11,039) and 830 percent (approximately \$302,390) of the average income in the baseline model (\$36,432.5). Thus,

both consumption and health. Second, the endogenous survival rate induces an additional source of welfare changes. To decompose welfare changes, I modify the procedure in Conesa et al. (2009) as follows.

First, I compute the change in the total welfare as CEV in (26). Second, I decompose CEV into welfare changes due to variation in the survival probability and the rest. I denote changes in welfare due to variation in the survival rate as CEV_q and the rest as CEV_f and compute them in the following way:

$$
\begin{aligned}
a &= \sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,1}(\mathbf{s},j)) u(c_1(\mathbf{s},j), h_{c,1}(\mathbf{s},j)) \mu_1(d\mathbf{s},j) \\
&\quad - \sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,0}(\mathbf{s},j)) u(c_0(\mathbf{s},j), h_{c,0}(\mathbf{s},j)) \mu_0(d\mathbf{s},j) \\
b &= \sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,0}(\mathbf{s},j)) u(c_1(\mathbf{s},j), h_{c,1}(\mathbf{s},j)) \mu_1(d\mathbf{s},j) \\
&\quad - \sum_{j=1}^{J} \int_{\mathbf{s}} \beta^{j-1} \pi_{j+1|j}(h_{c,0}(\mathbf{s},j)) u(c_0(\mathbf{s},j), h_{c,0}(\mathbf{s},j)) \mu_0(d\mathbf{s},j)
\end{aligned}
$$

$$
CEV_q = \frac{a-b}{a} \cdot CEV
$$

$$
CEV_f = \frac{b}{a} \cdot CEV.
$$

Third, I decompose CEV_f into changes in welfare due to variations in consumption, CEV^c, and those changes due to variations in the flow of health CEV^h. To do so, let V(c,h) be the lifetime value of households keeping the survival probability in the baseline economy. Then, let CEV_c^0 and CEV_h^0 be defined as

$$
V((1+CEV_c^0)c_0, (1+CEV_c^0)h_0) = V(c_1, h_0)
$$

$$
V((1+CEV_h^0)c_0, (1+CEV_h^0)h_0) = V(c_0, h_1).
$$

Because the utility function is not homothetic with respect to consumption, the summation of CEV_c^0 and CEV_h^0 is not equal to CEV_f. I adjust their scale by defining CEV_c and CEV_h as follows:

$$
CEV_c = \frac{CEV_c^0}{CEV_c^0 + CEV_h^0} \times CEV_f
$$

$$
CEV_h = \frac{CEV_h^0}{CEV_c^0 + CEV_h^0} \times CEV_f.
$$

I further decompose CEV_c^0 into a level effect CEV_{cl}^0 and a distributional effect CEV_{cd}^0 as follows:

$$
V((1+CEV_{cl}^0)c_0, (1+CEV_{cl}^0)h_0) = V(\hat{c}_0, h_0)
$$

$$
V((1+CEV_{cd}^0)\hat{c}_0, (1+CEV_{cd}^0)h_0) = V(c_1, h_0)
$$

where $\hat{c}_0 = \frac{C_1}{C_0} c_0$ is the consumption allocation obtained by rescaling the allocation c_0 with the change in aggregate consumption $\frac{C_1}{C_0}$. Note that $CEV_c^0 \approx CEV_{cl}^0 + CEV_{cd}^0$, but this does not hold for CEV_c. I define CEV_{cl} and CEV_{cd}

all working-age populations are eligible either for Medicaid or for the subsidy for the purchase of IHI. However, this does not mean that everyone receives the same amount of benefits. When household's income decreases by \$1,000 in the interval above $\bar{M} = 0.303$, the subsidy increases by 0.33 percent of the health insurance premium. The optimal health insurance policy implements the reform of the IHI market in (24). In the economy without the option to default, the optimal policy is to have a threshold of eligible income for Medicaid $\bar{M}$ of 30.8 percent (approximately \$11,221) of the average income in the Baseline economy while not providing a subsidy for IHI, $a = 0$, with the absence of its reform, $b = 0$.

The magnitude of these welfare changes is relatively large, compared to that in the literature. This difference occurs because the utility function implies the complementarity of consumption and health and includes a substantially large constant term, $B_u = 3004.29$. Because the complementarity means that the marginal utility of consumption increases with health, the compensation of consumption under poor health status has to be substantially large for an alternative case with better health status. Additionally, as the constant term, B_u, increases to guarantee the positive value of life with endogenous default, the impact of changes in consumption on the utility value becomes smaller, thereby increasing the size of required CEVs.[31]

The features of these optimal policies are as follow. First, while the optimal health insurance policy with the option to default provides subsidies for the purchase of IHI, $a = 8.3$, to almost all middle- and high-income households along with the reform of the IHI market, $b = 1$, that without the option to default does not change policies relevant to IHI at all, $a = b = 0$. Second, in both economies, whereas changes in health are the main driving force behind the welfare improvements of the optimal health insurance policies, changes in consumption play a relatively larger role in welfare changes in the case without the option to default. I will examine the mechanisms behind these results going forward in detail.

4.3.1 The Effect of the Option to Default on the Optimal Health Insurance

'Medical Expenditure' in Table 7 implies that the option to default results in larger responses of medical spending to healthcare reforms. Comparing 'OPT_d^d' with 'OPT_d^{nd}' indicates that the optimal policy of the economy with the option to default, $[M, a, b] = [0.303, 8.3, 1]$, increases the

as follows:

$$CEV_{cl} = \frac{CEV_{cl}^0}{CEV_c^0 + CEV_h^0} \times CEV_f$$

$$CEV_{cd} = \frac{CEV_{cd}^0}{CEV_c^0 + CEV_h^0} \times CEV_f.$$

I take the same decomposition as that for the flow of health.

[31] The value of this term is 66.27 in the baseline economy of Hall and Jones (2007). Their model does not address borrowing and default.

average medical expenditure by 4.81 percent and decreases the coefficient of variation by 2.92 percent when the option to default is available, while the same policy raises the average medical expenditure by 4.19 percent and reduces its coefficient of variation by 2.45 percent when the option to default is unavailable. Likewise, comparing 'OPT_{nd}^{d}' with 'OPT_{nd}^{nd}' shows that the optimal

Table 7: Changes of Health-related Outcomes from Each of the Baseline Economies

Moment	OPT_d^d	OPT_d^{nd}	OPT_{nd}^d	OPT_{nd}^{nd}	M_L^d	M_L^{nd}
OPT DEF	Y	N	Y	N	Y	N
Health Ins. System*						
M (MDC Elig.)	0.303	0.303	0.308	0.308	0.1	0.1
a (IHI Subsidy)	8.3	8.3	0	0	0	0
b (IHI Reform)	1	1	0	0	0	0
Medical Expenditure						
AVG Medical Exp.	$+4.81\%$	$+4.19\%$	$+3.46\%$	$+2.98\%$	$+1.13\%$	$+1.19\%$
CV of Medical Exp.	-2.92%	-2.45%	-2.81%	-2.39%	-1.02%	-0.73%
Health Measure						
AVG Health	$+4.89\%$	$+4.67\%$	$+4.62\%$	$+4.45\%$	$+2.23\%$	$+1.77\%$
STD of Log Health	-10.27%	-9.78%	-9.79%	-9.49%	-5.08%	-4.17%
Prob of ER Visits	-8.82%	-8.55%	-8.37%	-8.21%	-4.28%	-3.51%
Life Expectancy**	+0.07	+0.07	+0.07	+0.06	+0.03	+0.03
Health Insurance						
Ins. Coverage	$+18\,pp$	$+11\,pp$	$+17\,pp$	$+11\,pp$	$+10\,pp$	$+6\,pp$
MCD Take-up Ratio	$+27\,pp$	$+27\,pp$	$+32\,pp$	$+32\,pp$	$+8\,pp$	$+7\,pp$
IHI Take-up Ratio	$+36\,pp$	$+33\,pp$	$-3\,pp$	$-6\,pp$	$+1\,pp$	$+1\,pp$
EHI Take-up Ratio	$-46\,pp$	$-49\,pp$	$-12\,pp$	$-15\,pp$	$+1\,pp$	$-2\,pp$
IHI Eff. Price	-21.82%	-18.22%	$+16.95\%$	$+18.37\%$	$+19.35\%$	$+16.67\%$
EHI Eff. Price	$+11.51\%$	$+13.84\%$	$+5.38\%$	$+7.69\%$	-0.53%	$+2.69\%$
Welfare Change						
Total	$+11.64\%$	+16.68%	$+11.55\%$	$+17.16\%$	$+4.34\%$	$+6.43\%$
Consumption	$+1.68\%$	$+2.5\%$	$+2.05\%$	$+3.19\%$	$+0.78\%$	$+1.11\%$
Health	$+9.96\%$	$+14.18\%$	$+9.5\%$	$+13.97\%$	$+3.55\%$	$+5.32\%$
Health Qty	$+1.3\%$	+0.73%	$+1.24\%$	$+0.7\%$	$+0.55\%$	$+0.25\%$
Health Lvl	$+0.73\%$	$+0.59\%$	$+0.7\%$	$+0.57\%$	$+0.32\%$	$+0.22\%$
Health Dist	$+7.93\%$	$+12.86\%$	$+7.57\%$	$+12.7\%$	$+2.68\%$	$+4.85\%$

OPT_d^d represents the result of the optimal health insurance policy in the economy with the option to default. OPT_d^{nd} demonstrates results for the economy with no option to default when the optimal policy in the economy with the option to default is implemented. OPT_{nd}^d displays results for the economy with the option to default when the optimal policy in the economy with no option to default is implemented. OPT_{nd}^{nd} shows the result of the optimal health insurance policy in the economy with no option to default. M_d^L demonstrates results for the economy with the option to default when $[M, a, b] = [0.1, 0, 0]$. M_{nd}^L demonstrates results for the economy with no option to default when $[M, a, b] = [0.1, 0, 0]$.
pp = percentage point change, % = percentage change.
* The health insurance system of the baseline economies is $[M, a, b] = [0.048\,, 0,\ 0]$.
** Unit=Year.

health insurance of the economy with no option to default, $[M, a, b] = [0.308, 0, 0]$, generates a larger increase in the average medical expenditure and a greater reduction in its coefficient of variation, when the option is available, 'OPT_{nd}^{d}'. The panels of the first raw of Figure 13 indicate that the option to default (solid lines) brings an additional increase in medical spending during the working-age period, and the panels of the second raw present that the option to default further reduces inequality in medical spending mainly during the working-age period. This is because these changes in medical spending are driven by the option to default, which is available only during the working-age period.

'Health Measure' in Table 7 implies that, in the case with the option to default, the larger responses of medical spending lead to more significant changes in health. For each of the health insurance policies, the option to default generates a larger increase in average health and further reductions in the standard deviation of the log of health status and the probability of ER visits. Comparing 'OPT_d^d' with 'OPT_d^{nd}' indicates that the optimal policy of the economy with the option to default, $[M, a, b] = [0.303, 8.3, 1]$, brings a further increase in the average health by 0.22 percentage points; a greater reduction in the standard deviation of the log of health status by 0.49 percentage points; and a greater reduction in the probability of ER visits by 0.27 percentage points. Similarly, comparing 'OPT_{nd}^d' with 'OPT_{nd}^{nd}' implies that the optimal policy in the case without the option to default, $[M, a, b] = [0.308, 0, 0]$, generates greater changes in these variables when it is implemented in the economy with the option to default, 'OPT_{nd}^d'. The panels of the third raw of Figure 13 imply that the option to default (solid lines) further increases average health, and the panels of the last raw indicate that the option brings a greater reduction in inequality in health.

'Health Measure' in Table 7 also indicates that that the provision of IHI subsidies, a, and the reform of the IHI market, b, induce a larger improvement in health and a further reduction in health inequality, when the option to default is available.[32] Shifting 'OPT_{nd}^d' to 'OPT_d^d' indicates that, with the option to default, the IHI-related policies bring a further increase in average health by 0.27 percentage points and a greater reduction in the coefficient of variation of the log of health by 0.48 percentage points, whereas the same policy change in the case without the option to default, ('OPT_{nd}^{nd}' to 'OPT_d^{nd}'), further raises average health by 0.22 percentage points and further decreases its coefficient of variation by 0.29 percentage points. These differences imply that when the option to default is available, the provision of IHI subsidies and the reform of the IHI market induce low-middle income households to spend more on health by reducing the dependence on default as implicit health insurance, thereby leading them to have better and more equally distributed health.

'Welfare Change' in Table 7 implies that in the economy with the option to default, these larger changes in health in response to the IHI-related policies are a source of further improvements in welfare. Changing from $[0.308, 0, 0]$ to $[0.303, 8.3, 1]$ in the economy with the option to default, ('OPT_{nd}^d' $\rightarrow$'OPT_d^d'), leads to further improvements in welfare due to changes in health by 0.46 percentage points, while the same policy change in the economy without the option to default,

[32] Since the difference in the income threshold for Medicaid eligibility between the optimal health insurance of the economy with the option to default and that without the option to default is small (0.05), changing both from 'OPT_{nd}^d' to'OPT_d^d' and from 'OPT_{nd}^{nd}' to 'OPT_d^{nd}' can be regarded as the provision of IHI subsidies and the reform of the IHI market in addition to the similar degree of Medicaid expansion.

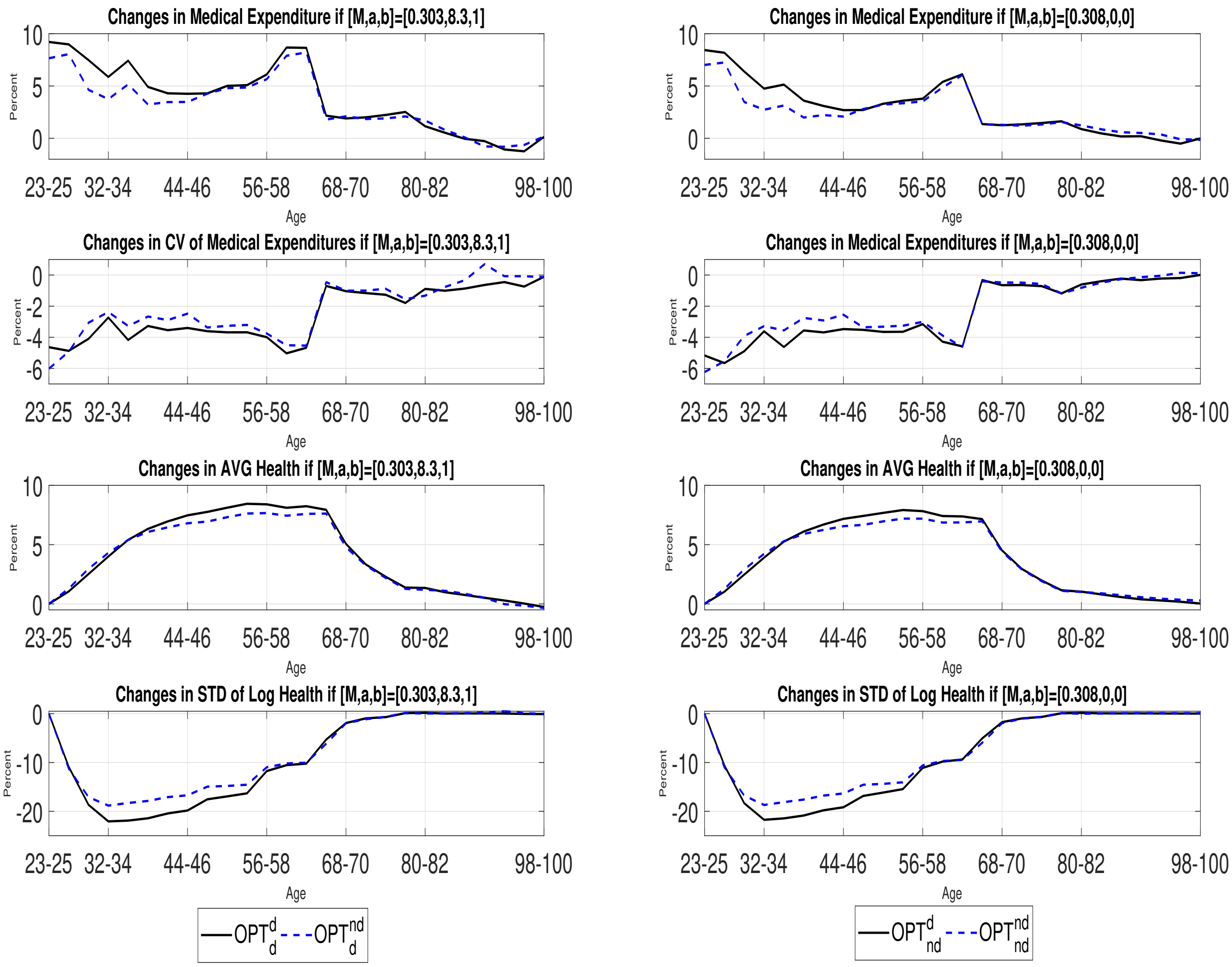

Figure 13: Changes in Health and Medical Expenditure from Each of the Baseline Economies

(‘OPT_{nd}^{nd}’ →‘OPT_{d}^{nd}’), improves welfare from changes in health by 0.21 percentage points. This gap implies that with the option to default, the provision of subsidies for IHI and the reform of the IHI market are more effective in producing better health outcomes for low-income households. Therefore, distributional changes in health are the main driving force behind this gap in welfare changes. Changing from $[0.308, 0, 0]$ to $[0.303, 8.3, 1]$ in the economy with the option to default, (‘OPT_{nd}^{d}’ →‘OPT_{d}^{d}’), leads to further improvements in welfare due to distributional changes in health by 0.36 percentage points, whereas the same change in the economy without the option to default, (‘OPT_{nd}^{nd}’ →‘OPT_{d}^{nd}’), brings a further improvement in welfare from distributional changes in health by 0.16 percentage points.

‘Welfare Change’ in Table 7, at the same time, also indicates that the additional IHI-related policies play a role in reducing welfare due to changes in consumption regardless of the option to default, but its magnitude is greater in the economy without the option to default. Changing from

$[0.308, 0, 0]$ to $[0.303, 8.3, 1]$ in the economy with the option to default, ('OPT^{d}_{nd}' →'OPT^{d}_{d}'), bring a further reduction in welfare from changes in consumption by 0.37 percentage points, whereas the same policy change without the option to default, ('OPT^{nd}_{nd}' →'OPT^{nd}_{d}'), further decreases welfare from changes in consumption by 0.69 percentage points. This difference implies that when the option to default is available, in response to the IHI-related policies, the magnitude of improvements in welfare from changes in health is greater, while the extent of welfare losses from changes in consumption is smaller. The quantitative difference in this trade-off causes the optimal health insurance policies to be very different, according to whether the option to default is available.

Table 8: Changes in Macroeconomic Variables from Each of the Baseline Economies

Moment	OPT^{d}_{d}	OPT^{nd}_{d}	OPT^{d}_{nd}	OPT^{nd}_{nd}	M^{d}_{L}	M^{nd}_{L}
OPT DEF	Y	N	Y	N	Y	N
Health Ins. System*						
M (MDC Elig.)	0.303	0.303	0.308	0.308	0.1	0.1
a (IHI Subsidy)	8.3	8.3	0	0	0	0
b (IHI Reform)	1	1	0	0	0	0
Macro Variables						
Y	+1.83%	+1.49%	+2%	+1.76%	+0.81%	+0.9%
K/Y	-0.56%	-1.24%	-0.03%	-0.58%	-0.25%	+0.13%
AVG Cons	+2.56%	+3.22%	+2.43%	+3.22%	+0.39%	+1.33%
STD of Log Cons	-4.37%	-7.37%	-4.02%	-7.27%	-1.46%	-2.74%
Market Wage	-0.31%	-0.71%	-0.02%	-0.32%	-0.14%	+0.07%
Units of Eff. Labor	+2.15%	+2.21%	+2.02%	+2.09%	+0.95%	+0.82%
AVG Earnings	+1.84%	+1.5 %	+2%	+1.77%	+0.81%	+0.89%
STD of Earnings	-3.07%	-2.88%	-2.99%	-2.84%	-1.67%	-1.33%
AVG Tax Rate	$+1.17\,pp$	$+1.08\,pp$	$+0.84\,pp$	$+0.36\,pp$	$+0.56\,pp$	$+0.01\,pp$
Risk-free Int. Rate	$+0.06\,pp$	$+0.14\,pp$	$0\,pp$	$+0.06\,pp$	$+0.03\,pp$	$-0.01\,pp$
AVG BOR. Int. Rate	$-0.04\,pp$	-	$-0.35\,pp$	-	$+0.19\,pp$	-
AVG Default Premium	$-0.1\,pp$	-	$-0.35\,pp$	-	$+0.17\,pp$	-
AVG Debt/Earnings	-14.73%	-	-12.65%	-	-4.53%	-
AVG Bankruptcy Rate	$-0.25\,pp$	$-0.2\,pp$	$-0.22\,pp$	$-0.2\,pp$	$0\,pp$	$-0.1\,pp$
Welfare Change						
Total	+11.64%	+16.68%	+11.55%	+17.16%	+4.34%	+6.43%
Cons	+1.68%	+2.5%	+2.05%	+3.19%	+0.78%	+1.11%
Cons Lvl	+2.68%	+3.37%	+2.54%	+3.39%	+0.4%	+1.35%
Cons Dist	-1%	-0.87%	-0.49%	-0.2%	+0.38%	-0.24%
Health	+9.96%	+14.18%	+9.5%	+13.97%	+3.55%	+5.32%

OPT^{d}_{d} represents the result of the optimal health insurance policy in the economy with the option to default. OPT^{nd}_{d} demonstrates results for the economy with no option to default when the optimal policy in the economy with the option to default is implemented. OPT^{d}_{nd} displays results for the economy with the option to default when the optimal policy in the economy with no option to default is implemented. OPT^{nd}_{nd} shows the result of the optimal health insurance policy in the economy with no option to default. M^{L}_{d} demonstrates results for the economy with the option to default when $[M, a, b] = [0.1, 0, 0]$. M^{L}_{nd} demonstrates results for the economy with no option to default when $[M, a, b] = [0.1, 0, 0]$.
pp = percentage point change, % = percentage change.
* The health insurance system of the baseline economies is $[M, a, b] = [0.048\,, 0,\, 0]$.
** Unit=Year.

Table 8 contains changes in macroeconomic variables from each of the baseline economies.

As can be seen in Table 8, the absence of the option to default increases the extent of changes in the aggregate capital in response to each healthcare reform, thereby leading to large changes in consumption.[33] Comparison of 'OPT_d^d' to 'OPT_d^{nd}' implies that the optimal policy of the case with the option to default, $[M, a, b] = [0.303, 8.3, 1]$, decreases the ratio of capital to output by 0.56 percent in the economy with the option to default, while the ratio is reduced by 1.24 percent in the economy without the option. The comparison also shows that the policy, $[M, a, b] = [0.303, 8.3, 1]$, increases the average consumption 2.56 percent in the economy with the option to default, while it increases by 3.22 percent in the economy without the option to default. Likewise, comparison of 'OPT_d^{nd}' to 'OPT_{nd}^{nd}' indicates that the optimal health insurance policy in the case without the option to default, $[M, a, b] = [0.308, 0, 0]$, yields greater changes in the level and distribution of consumption to the economy without the option to default, 'OPT_{nd}^{nd}'.

This gap in the extent of changes in consumption is due to differences in the degree of precautionary motives, according to whether the option to default is available. Figure 14 indicates that, in the case without the option to default (dotted lines), changes in consumption in response to the reforms are greater, while changes in earnings are smaller. The panels of the first and second row in Figure 14 show that the economies without the option to default generate larger increases in the level of consumption and greater reductions in inequality over the life-cycle. The panels of the third row imply that both health insurance policies induce less increases in the average earnings over the life-cycle in the economy with the option to default. These results suggest that in the economy without the option to default, the stronger precautionary motives of savings are dissolved following the expansion of health insurance coverage, thereby leading to more significant changes in consumption.

These larger responses of consumption and savings bring more distortions in income taxes to the economy without the option to default. 'AVG Tax Rate' in Table 8 indicates that the economy without the option to default suffers from more distorted income taxes in response to the IHI-related policies. Changing from $[0.308, 0, 0]$ to $[0.303, 8.3, 1]$ in the economy with the option to default, ('OPT_{nd}^d' $\rightarrow$ 'OPT_d^d') brings about a further increase in the average tax rate by 0.33 percentage points, while the same policy change in the economy without the option to default, ('OPT_{nd}^{nd}' $\rightarrow$ 'OPT_d^{nd}'), causes an increase in the average tax rate by 0.72 percentage points.

This difference in the degree of distortions in income taxes affects the magnitude of welfare changes due to variations in consumption. 'Welfare Change' in Table 8 presents changes in welfare from consumption changes. The absence of the option to default leads to greater changes in welfare from consumption variations. The IHI-related policies in the economy with the option to default,

[33] Note that in all the economies, the average consumption increases, and the standard deviation of the log of consumption decreases. These changes are because of an increase in the average earnings and a decrease in its inequality due to changes in health following the reforms.

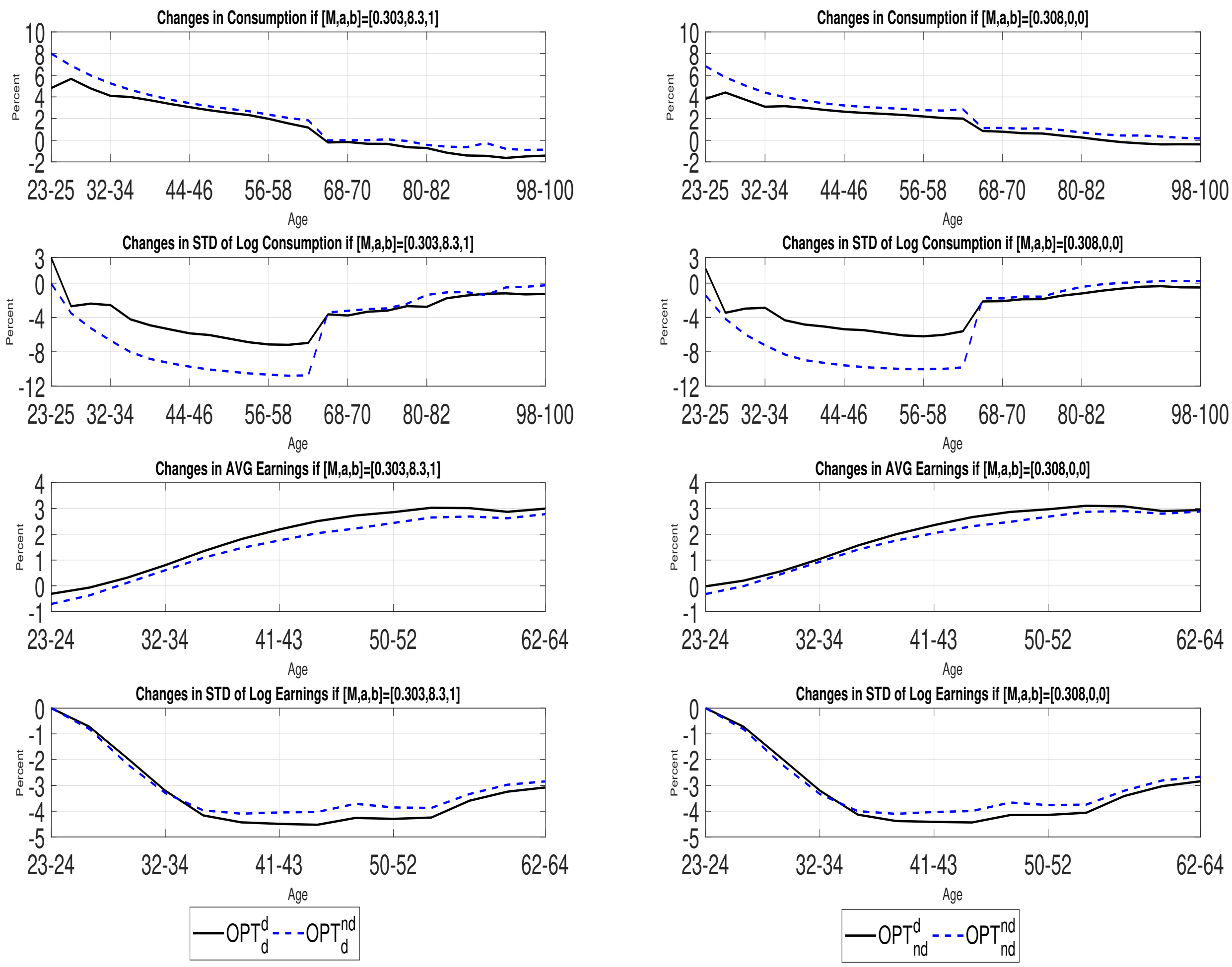

Figure 14: Changes in Consumption and Earnings from Each of the Baseline Economies

(‘OPT^d_{nd}’ $\rightarrow$ ‘OPT^d_d’), further reduce welfare due to changes in consumption by 0.37 percentage points, while the same policy change in the economy without the option to default, (OPT^{nd}_{nd}’ $\rightarrow$ ‘OPT^{nd}_d’) further decreases welfare from variations in consumption by 0.69 percentage points. This gap is driven by differences in the direction of changes in the average consumption. In the economy without the option to default (OPT^{nd}_{nd}’ $\rightarrow$ ‘OPT^{nd}_d’), more distorted income taxes due to the IHI-related policies prevent the average consumption from increasing, thereby leading to a reduction in welfare due to variations in the level of consumption by 0.02 percentage points. In contrast, in the economy with the option to default (‘OPT^d_{nd}’ $\rightarrow$ ‘OPT^d_d’), fewer distortions in income taxes following the IHI-related policies allow the average consumption to increase, thereby inducing an improvement in welfare due to changes in the level of consumption by 0.14 percentage points.

Comparison of Table 8 to Table 9 indicates that general equilibrium effects amplify the reduc-

Table 9: Changes in Macroeconomic Variables from Each of the Baseline Economies in Partial Equilibrium

Moment	OPT_d^d	OPT_d^{nd}	OPT_{nd}^d	OPT_{nd}^{nd}
OPT DEF	Y	N	Y	N
Health Ins. System*				
M (MDC Elig.)	0.303	0.303	0.308	0.308
a (IHI Subsidy)	8.3	8.3	0	0
b (IHI Reform)	1	1	0	0
Macro Variables				
Y	+1.87%	+1.63%	+2%	+1.84%
K/Y	-0.5%	-1.08%	-0.02%	-0.47%
Risk-free Int. Rate	$0\,pp$	$0\,pp$	$0\,pp$	$0\,pp$
AVG BOR. Int. Rate	$+0.08\,pp$	-	$-0.33\,pp$	-
AVG Default Premium	$+0.08\,pp$	-	$-0.33\,pp$	-
AVG Debt/Earnings	-14.26%	-	-12.66%	-
AVG Bankruptcy Rate	$-0.23\,pp$	$-0.2\,pp$	$-0.22\,pp$	$-0.2\,pp$
Market Wage	0%	0%	0%	0%
Units of Eff. Labor	+2.16%	+2.26%	+2.02%	+2.11%
AVG Earnings	+2.16%	+2.26 %	+2.02%	+2.11%
STD of Earnings	-3.08%	-2.92%	-2.99%	-2.87%
AVG Cons	+2.63%	+3.47%	+2.44%	+3.34%
STD of Log Cons	-4.43%	-7.51%	-4.04%	-7.31%
AVG Tax Rate	$+1.17\,pp$	$+1.11\,pp$	$+0.5\,pp$	$+0.35\,pp$
Welfare Change				
Total	+12.02%	+17.03%	+11.65%	+17.58%
Cons	+1.99%	+2.71%	+2.14%	+3.31%
Cons Lvl	+2.76%	+3.63%	+2.56%	+3.52%
Cons Dist	-0.77%	-0.92%	-0.42%	-0.21%
Health	+10.03%	+14.31%	+9.5%	+14.27%

OPT_d^d represents the result of the optimal health insurance policy in the economy with the option to default. OPT_d^{nd} demonstrates results for the economy with no option to default when the optimal policy in the economy with the option to default is implemented. OPT_{nd}^d displays results for the economy with the option to default when the optimal policy in the economy with no option to default is implemented. OPT_{nd}^{nd} shows the result of the optimal health insurance policy in the economy with no option to default.
pp = percentage point change, % = percentage change.
* The health insurance system of the baseline economies is $[M, a, b] = [0.048\,, 0,\ 0]$.
** Unit=Year.

tion in aggregate capital by increasing the risk-free interest rate, which plays a role in reducing welfare. The top-left panel in Figure 14 shows that the optimal health insurance of the economy with the option to default (solid line) reduces consumption for households older than age 70 compared to households in the baseline economy, which is related to tax distortions and general equilibrium effects. Note that as general equilibrium effects become stronger, their negative impact on welfare changes from variations in consumption becomes more considerable.

To sum up, both the reform of the IHI market and the subsidy for the purchase of IHI play a role in improving welfare through changes in health. At the same time, these IHI-related policies play a role in reducing welfare through consumption changes due to more distorted taxes. When the option to default is available, the IHI-reltad policies brings further improvements in welfare from changes in health and less deterioration in welfare from changes in consumption. These differences occur because households use the option to default as implicit health insurance that reduces their precautionary motives. The IHI-related policies reduce the dependence on this implicit health insurance by decreasing the effective prices of health insurance for young and low-income households, thereby leading to increases in their medical spending and improvements in their health. Meanwhile, with the option to default, households' decisions on savings and consumption are less sensitive to the IHI-related reforms, which dampens income tax distortions. These tax distortions are more significant in the economy without the option to default due to its larger responses of consumption and savings; and the distortions are amplified in general equilibrium. As a result, in the economy with the option to default, the IHI-related policies are components of the optimal health insurance, whereas these policies are not the optimal in the economy without the option to default.

These results imply that when households can easily access to defaults, more redistributive healthcare reforms might need to be considered. These policies might help young and low-income households reduce the use of default and bankruptcy as implicit health insurance, thereby leading to further improvements in welfare from better health outcomes.

5 Conclusion

This paper explores how defaults and bankruptcies affect optimal health insurance. I build a life-cycle general equilibrium model in which agents have the option to default on their emergency medical bills and financial debts. They decide to invest in health capital and occasionally face emergency room events. Using micro and macro data, I calibrate the model based on the U.S. economy and use the model for the optimal health insurance policy.

I find that the option to default causes the optimal health insurance to be more redistributive. With no option to default, the optimal health insurance policy is to expand Medicaid up to households whose income is 30 percent of the average income with no change in the market of IHI. When the option to default is available, in addition to Medicaid expansion, the optimal policy is to provide subsidies for the purchase of IHI and to implement reform of the IHI market.

This difference occurs because the option to default affects the magnitude of off-setting forces of redistributive healthcare reforms in welfare changes. When the option to default is not available, households have stronger precautionary motives for savings to take care of their health more carefully through medical spending. Otherwise, health risks would become substantial financial burdens over the life-cycle. Households with the option to default, meanwhile, may rely on defaults and bankruptcies to protect against health and financial risks, thereby having weaker precautionary motives for savings. These different behavior lead the IHI-related policies to bring the economy with the option to default to further welfare gains from better health outcomes and smaller welfare losses from tax distortions. Therefore, when defaults and bankruptcies are easily accessible, implementing more redistributive health insurance policies can improve welfare by reducing the dependence on this implicit health insurance.

Regarding future research, elaborating the insurance choice behavior of the elderly is essential. Here, health insurance policies for the elderly are simplified. Given the considerable effect of long-term care on aggregate savings, as shown in Kopecky and Koreshkova (2014), studying how long-term care interacts with financial risks is a meaningful task. Such analyses are deferred to future work.

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Online Appendix

Appendix A Charges from ER Events across Income Levels

Table 10: Charges from ER Events by Income Groups

Income	Average Charges of ER Events*
0-20 pct	2443.56
20-40 pct	2436.46
40-60 pct	2249.54
60-80 pct	2307.37
80-100 pct	2325.41

Source: author's calculation based on the MEPS 2000-2011
* Unit = U.S. Dollar in 2000

Table 11: Charges from ER Events by Age and Income Groups

	Average Charges for ER Events*					
Income	Age 23 - 34	Age 35 - 46	Age 47 - 55	Age 56 -64	Age 65 - 76	Age 77 - 91
0-20 pct	1992.87	2222.93	2549.63	3025.09	2616.33	3154.18
20-40 pct	2094.95	2066.45	2752.9	2820.07	2902.95	2657.69
40-60 pct	2030.77	2129.41	2603.14	2625.31	2112.71	2197.29
60-80 pct	2023.42	2244.27	2394.9	2582.79	2348.57	2607.37
80-100 pct	2209.8	2051.07	2577.25	2464.83	2687.7	2284.63

Source: author's calculation based on the MEPS
* Unit = U.S. Dollar in 2000

Table 12: Regression Result of the Log of ER Charges

	Only Income	Age and Income
log income	0.122 (0.144)	0.12(0.144)
age		0.005778 (0.004)

I run an OLS regression of the log of ER charges on the log of income and age.
The parentheses indicate p-values.

Table 10 shows that differences in the average charges from ER events are small across income levels. The maximum gap is smaller than 200 dollars. Table 11 also confirms that the result is still robust after controlling age groups. There is no monotonic relationship between income and the amount of charges for ER events across age groups. Lastly, Table 12 indicates that the correlation between the log of charges for the ER and the log of income is not statistically significant at the 10 percent level.

Appendix B Findings on Emergency Room Visits, Medical Conditions, and Bankruptcy

Table 13: Correlation Between Health Risks and Income

Moment	Value
Corr b.w. Medical Conditions and Income	-0.146^{*}
Corr b.w. Fraction of ER Visits and Income	-0.078^{*}

[*]: statistically significant at the 5 level.

Table 13 shows that both medical conditions quantified by health shocks and the fraction of emergency room visits are negatively correlated with income.[34] The correlation between medical conditions and income is -0.146, and the correlation of the fraction of emergency room visits and income is -0.078. This indicates that the level of health risks differs across income levels. Low-income individuals are more exposed to health shocks than high-income individuals, and the poor are more exposed to emergency medical events, which is an important channel for default on emergency medical bills through the EMTALA.

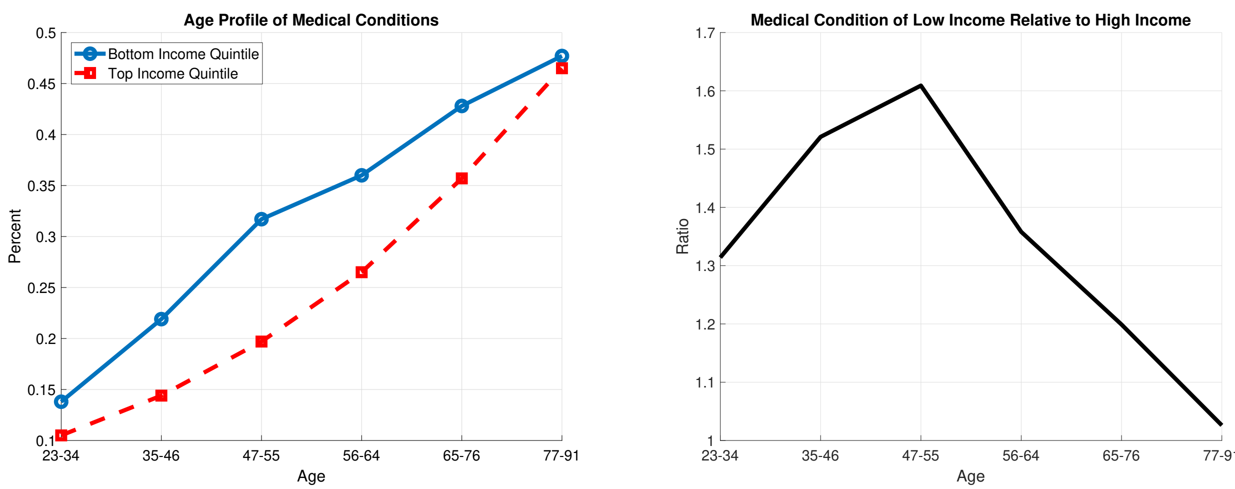


Figure 15: Age Profile of Medical Conditions

Figure 15 indicates the life cycle profile of medical conditions quantified by health shocks between high-income individuals and low-income individuals. Differences in medical conditions across income groups are shown over the whole phase of life-cycle. The gap in medical conditions increases until age 55 and declines around retirement periods and the difference gets diminished

[34] Appendix F presents how medical conditions in the Medical Expenditure and Panel Survey (MEPS) are quantified in details.

and keeps declining until later life. The gap rapidly rises until age 55, and decreases around retirement periods and getting smaller in later life. The gap is large when households within an age group are revealed by more different healthcare circumstances. For example, old households have small differences, as their healthcare circumstance might be more similar than young households due to Medicare.

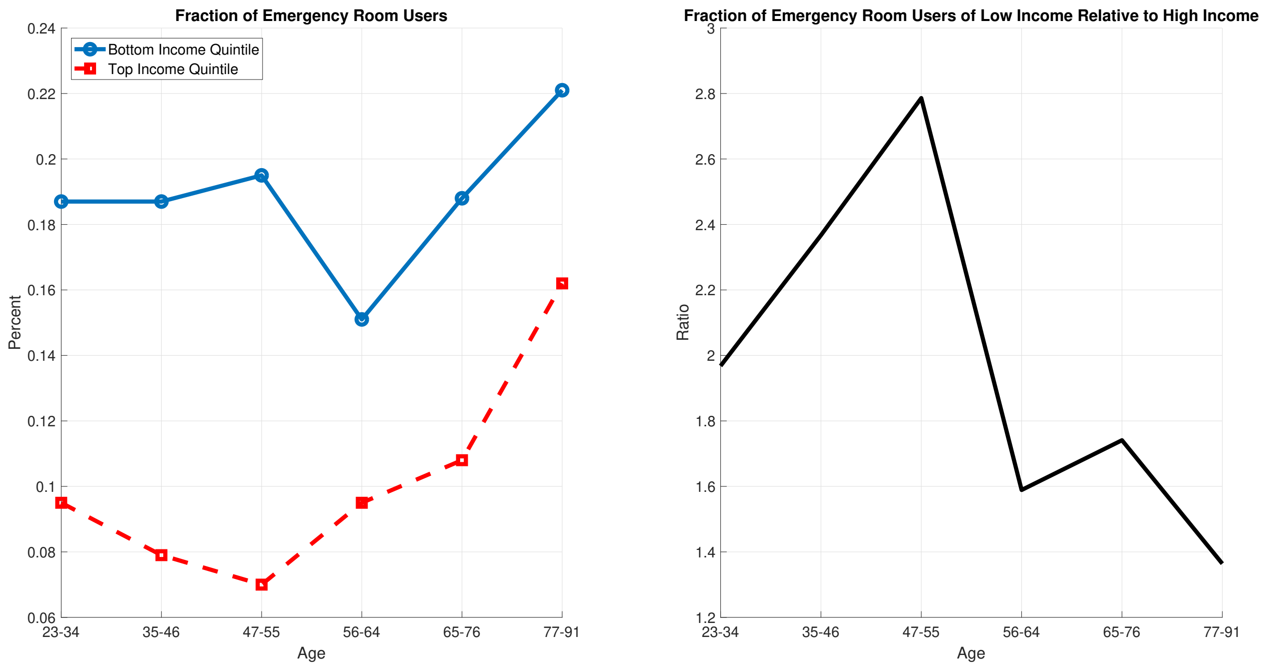


Figure 16: Age Profile of the Fraction of Emergency Room Visits

Figure 16 shows that the fraction of visiting emergency rooms between the top 20 percent income individuals and the bottom 20 percent income individuals over the life cycle. Differences in emergency room visits across income groups appear over the whole phase of life-cycle. These gaps become disproportionately larger during the working-age period. This implies that during the working-age period, low-income individuals are more substantially exposed to emergency medical events, which may lead low-income individuals medical defaults through the EMTALA. Given that old households have more similar health-related circumstances due to Medicare, the gap is larger when households within an age group have more differences in their health-related circumstances.

Appendix C Household Dynamic Problems

The households' optimal decision problems can be represented recursively. I begin with the problems of working-age households. They start working at the initial age J_0 and continue working until age $J_r - 1$. The state of working-age households is $(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$ and $\upsilon \in \{G, B\}$, where a is their level of assets, i is health insurance, h is the stock of health capital, ϵ_e is emergency health shock, ϵ_n is non-emergency health shock, ζ is non-medical expense shocks, η is idiosyncratic shock on labor productivity and ω is the current offer status for employer-based health insurance. υ is the current credit history, where G and B mean good and bad credit history, respectively.

At the beginning of sub-period 1, emergency health shocks ϵ_e, non-emergency health shocks ϵ_n, non-medical expense shocks ζ, idiosyncratic shocks on earnings η, and the employer-based health insurance offer ω are realized. Next, individuals decide whether to default. Let $V_j^G(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$ ($V_j^B(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$) denote the value function of age $j < J_r$ agent with a good (bad) credit history in sub-period 1. They solve

$$V_j^G(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega) = \max\{v_j^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega), v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)\} \quad (27)$$

$$V_j^B(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega) = \max\{v_j^{B,N}(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega), v_j^{B,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)\} \quad (28)$$

where $v_j^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$ ($v_j^{B,N}(a, i, h, \epsilon_e, \epsilon_n, \zeta, \eta, \omega)$) is the value of non-defaulting with a good credit (bad credit) history and $v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ ($v_j^{B,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$) is the value of defaulting with a good credit (bad credit) history. The values of defaulting, $v_j^{G,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ and $v_j^{B,D}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$, do not depend on the current assets a, as all assets and debts are eliminated with the default decision, $a = 0$.

Non-defaulters with a good credit history at age $j < J_r$ in age group j_g solve

$$v_j^{G,N}(a,i,h,\epsilon_e,\epsilon_n,\eta,\zeta,\omega) = \max_{\{c,\,a',\,i',\,m_n\geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u$$
$$+ \beta \pi_{j+1|j}(h_c, j_g) \underset{\epsilon_e'|h',\epsilon_n'|h',\eta'|\eta,\omega'|\eta',\zeta'}{\mathbb{E}} \left[V_{j+1}^G(a',i',h',\epsilon_e',\epsilon_n',\eta',\zeta',\omega')\right] \tag{29}$$

such that

$$c + q(a',i',h';j,\eta)a' + p_{i'}(h_c,j_g)$$
$$\leq (1-\tau_{ss}-\tau_{med}) w\bar{\omega}_j h_c^{\phi_h}\eta + a$$
$$-(1-q_i^n)\, m_n + (1-q_i^e)\, m_e(\epsilon_e) - \zeta - T(y) + \kappa$$

$$\zeta \sim U[0,\bar{\zeta}]$$
$$h_c = (1-\epsilon_n)(1-\epsilon_e)h$$
$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$
$$i \in \{NHI, MCD, IHI, EHI\}$$
$$i' \in \begin{cases} \{NHI, MCD, IHI, EHI\} & \text{if } y \leq \bar{y} \ \&\ \omega = 1 \\ \{NHI, MCD, IHI\} & \text{if } y \leq \bar{y} \ \&\ \omega = 0 \\ \{NHI, IHI, EHI\} & \text{if } y > \bar{y} \ \&\ \omega = 1 \\ \{NHI, IHI\} & \text{if } y > \bar{y} \ \&\ \omega = 0. \end{cases}$$
$$y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$$

where c is consumption, a' is asset holdings in the next period, i' is the purchase of health insurance for the next period, m_n is non-emergency medical expenditure, h_c is the current health status and β is the discount rate. $\pi_{j+1|j}(h_c, j_g)$ is the rate of surviving up to age $j+1$ condition on surviving up to age j with the current status of health h_c in age group j_g. $\mathbb{E}_{\epsilon_e'|h',\epsilon_n'|h',\eta'|\eta,\omega'|\eta',\zeta'}$ is an expectation that is taken to non-medical expense shocks ζ', (non-) emergency health shocks (ϵ_n') ϵ_e', idiosyncratic shocks on labor productivity η' and the offer probability of employer-based health insurance ω', conditional on the current idiosyncratic labor productivity η and health capital h' for the next period. $q(a',i',h';j,\eta)$ is the discount rate of loan for households with future endogenous state, (a',i',h'), conditional on the current idiosyncratic labor productivity, η and age j, and $p_{i'}(h_c, j_g)$ is the premium of health insurance i' for the next period given the current health status h_c and age group j_g. τ_{ss} and τ_{med} are payroll taxes for Social Security and Medicare, respectively. w is the market equilibrium wage, $\bar{\omega}_j$ is age-deterministic labor productivity, ϕ_c is the elasticity of earnings with respect to current health status h_c, and η is idiosyncratic shock on labor productivity. q_i^n and q_i^e are the coverage rate of health insurance i for non-emergency and emergency medical expense, respectively. $m_e(\epsilon_e)$ is emergency medical expense, $T(\cdot)$ is income tax, y is total income, and κ is accidental bequest. NHI means no health insurance, MCD is Medicaid, IHI is private individual health insurance, EHI is employer-based health insurance, $\bar{y}$ is the threshold for Medicaid eligibility, ω is the current offer status for employer-based health insurance, q^{rf} is the discount rate of the risk-free bond, and $\mathbb{1}_{a>0}$ is the indicator function for savings. Thus, $(\frac{1}{q^{rf}} - 1)a$ means capital income.

Note that the expectation is taken to emergency and non-emergency health shocks conditional on health capital $h^{'}$ for the next period, $\epsilon_e^{'}|h^{'}$ and $\epsilon_n^{'}|h^{'}$, as the distributions of these health shocks are determined by health capital $h^{'}$. In addition, the probability of the offer for employer-based health insurance is conditional on idiosyncratic shocks on earnings $\eta^{'}$ in the next period, as the offer rate $\omega^{'}$ increases with labor productivity level $\eta^{'}$.

Non-defaulters with a good credit history have an endowment from their labor income $w\bar{\omega}_j h_c^{\phi_h}\eta$, their current assets a and accidental bequest κ. Then, these households access financial intermediary to either borrow $(a^{'} < 0)$ at prices that reflect their default risk or save $(a^{'} > 0)$ at the risk-free interest rate. Afterward, they make decisions on consumption c, the purchase of health insurance $i^{'}$ and non-emergency medical expenditures m_n. In turn, non-defaulters with a good credit history pay a health insurance premium $p_{i'}(h_c, j_g)$, an out-of-pocket medical expenditures $(1 - q_i)(m_n + m_e(\epsilon_e))$, payroll taxes for Social Security and Medicaid $(\tau_{ss} + \tau_{med})w\bar{\omega}_j h_c^{\phi_h}\eta$ and income tax $T(y)$ for income $y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$. They preserve the good credit history until the next period.

Defaulting households with a good credit history at age $j < J_r$ in age group j_g solve

$$v_j^{G,D}(i,h,\epsilon_e,\epsilon_n,\eta,\omega) = \max_{\{c,\, i',\, m_n \geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u$$
$$+ \beta\pi_{j+1|j}(h_c, j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h', \epsilon_n'|h', \eta'|\eta, \omega'|\eta', \zeta'} \left[V_{j+1}^B(0, i', h', \epsilon_e', \epsilon_n', \zeta', \eta', \omega')\right] \quad (30)$$

such that

$$c + p_{i'}(h_c, j_g) = (1-\tau_{ss}-\tau_{med}) w\bar{\omega}_j h_c^{\phi_h}\eta - (1-q_i^n)m_n - T(y) + \kappa$$

$$\zeta \sim U[0,\bar{\zeta}]$$
$$h_c = (1-\epsilon_n)(1-\epsilon_e)h$$
$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$
$$i \in \{NHI, MCD, IHI, EHI\}$$
$$i' \in \begin{cases} \{NHI, MCD, IHI, EHI\} & \text{if } y \leq \bar{y} \text{ \& } \omega = 1 \\ \{NHI, MCD, IHI\} & \text{if } y \leq \bar{y} \text{ \& } \omega = 0 \\ \{NHI, IHI, EHI\} & \text{if } y > \bar{y} \text{ \& } \omega = 1 \\ \{NHI, IHI\} & \text{if } y > \bar{y} \text{ \& } \omega = 0. \end{cases}$$
$$y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}.$$

On their budget constraint, debts from the financial intermediaries a, and emergency medical expenditures $m_e(\epsilon_e)$ and non-medical expense shocks ζ do not appear, as these individuals default on these two types of unsecured debts. Defaulters can determine the level of consumption c, the purchase of health insurance for the next period i', and non-emergency medical expenditure m_n, while they can neither save nor dissave in this period. In turn, they pay a health insurance premium $p_{i'}(h_c, j_g)$, an out-of-pocket medical expenditures $(1-q_i)m_n$, payroll taxes for Social Security and Medicaid $(\tau_{ss} + \tau_{med})w\bar{\omega}_j h_c^{\phi_h}\eta$, and income tax $T(y)$ for their labor income $y = w\omega_j h_c^{\phi_h}\eta$.

Non-defaulters with a bad credit history at age $j < J_r$ in age group j_g solve

$$v_j^{B,N}(a,i,h,\epsilon_e,\epsilon_n,\eta,\zeta,\omega) = \max_{\{c,\, a'\geq 0,\, i',m_n\geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u)h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u \tag{31}$$

$$+ \beta\pi_{j+1|j}(h_c,j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h',\epsilon_n'|h',\eta'|\eta,\omega'|\eta',\zeta'} \Big[\lambda V_{j+1}^G(a',i',h',\epsilon_e',\epsilon_n',\zeta',\eta',\omega')$$

$$+ (1-\lambda)V_{j+1}^B(a',i',h',\epsilon_e',\epsilon_n',\zeta',\eta',\omega')\Big]$$

such that

$$c + q^{rf}a' + p_{i'}(h_c,j_g)$$
$$\leq (1-\tau_{ss}-\tau_{med})(1-\chi)w\bar{\omega}_j h_c^{\phi_h}\eta + a + \kappa$$
$$-(1-q_i^n)\,m_n + (1-q_i^e)\,m_e(\epsilon_e) - \zeta - T(y)$$

$$\zeta \sim U[0,\bar{\zeta}]$$
$$h_c = (1-\epsilon_n)(1-\epsilon_e)h$$
$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$
$$i \in \{NHI, MCD, IHI, EHI\}$$
$$i' \in \begin{cases} \{NHI, MCD, IHI, EHI\} & \text{if } y \leq \bar{y} \ \&\ \omega = 1 \\ \{NHI, MCD, IHI\} & \text{if } y \leq \bar{y} \ \&\ \omega = 0 \\ \{NHI, IHI, EHI\} & \text{if } y > \bar{y} \ \&\ \omega = 1 \\ \{NHI, IHI\} & \text{if } y > \bar{y} \ \&\ \omega = 0. \end{cases}$$
$$y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$$

where λ is the probability of recovering their credit history to be good, and χ is a proportion of earnings that is paid for the pecuniary cost of staying with a bad credit history. Although the problem of non-defaulters with bad credit is similar to that of non-defaulters with good credit, there are three differences between two problems. First, non-defaulters with bad credit are not allowed to borrow but they can save, $a' \geq 0$. Second, they need to pay the pecuniary cost of having a bad credit history as much as a fraction χ of earnings, $\chi w\bar{\omega}_j h_c^{\phi_h}\eta$. Lastly, the status of its credit history in the next period is not deterministic. With a probability of λ, the status of credit history for non-defaulters with a bad credit history changes to be good, and they stay with a bad credit history with a probability of $1-\lambda$. This process reflects the exclusion penalty in Chapter 7 Bankruptcy of 10 years in the U.S.

Defaulters with a bad credit history at age $j < J_r$ in age group j_g solve

$$v_j^{B,D}(i,h,\epsilon_e,\epsilon_n,\eta,\omega) = \max_{\{c,\, i',\, m_n \geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u$$
$$+ \beta\pi_{j+1|j}(h_c, j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h', \epsilon_n'|h', \eta'|\eta, \omega'|\eta', \zeta'} \left[V_{j+1}^B(0, i', h', \epsilon_e', \epsilon_n', \eta', \omega')\right] \tag{32}$$

such that

$$c + p_{i'}(h_c, j_g) = (1-\tau_{ss}-\tau_{med})(1-\chi) w\bar{\omega}_j h_c^{\phi_h}\eta - (1-q_i)m_n - T(y) + \kappa$$

$$\zeta \sim U[0,\bar{\zeta}]$$
$$h_c = (1-\epsilon_n)(1-\epsilon_e)h$$
$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$
$$i \in \{NHI, MCD, IHI, EHI\}$$
$$i' \in \begin{cases} \{NHI, MCD, IHI, EHI\} & \text{if } y \leq \bar{y} \;\&\; \omega = 1 \\ \{NHI, MCD, IHI\} & \text{if } y \leq \bar{y} \;\&\; \omega = 0 \\ \{NHI, IHI, EHI\} & \text{if } y > \bar{y} \;\&\; \omega = 1 \\ \{NHI, IHI\} & \text{if } y > \bar{y} \;\&\; \omega = 0. \end{cases}$$
$$y = w\omega_j h_c^{\phi_h}\eta + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}.$$

The problem of defaulters with a bad credit history has two differences compared to the case of households with a good credit history. First, defaulters with a bad credit history have to pay the pecuniary cost of staying bad credit as much as a fraction χ of their earnings, $\chi w\bar{\omega}_j h_c^{\phi_h}\eta$. Second, they default only on emergency medical expenses and non-medical expense shocks. For defaulters with bad credit, their previous status is either non-defaulter with bad credit or defaulters with good credit. In both statuses, individuals could not make any financial loan in the previous period.

Retired households at age $J_r \leq j \leq \bar{J}$ in age group j_g solve

$$V_j^r(a,h,\epsilon_e,\epsilon_n,\zeta) = \max_{\{c,\, a' \geq 0,\, m_n \geq 0\}} \frac{\left[\left(\lambda_u c^{\frac{v-1}{v}} + (1-\lambda_u) h_c^{\frac{v-1}{v}}\right)^{\frac{v}{v-1}}\right]^{1-\sigma}}{1-\sigma} + B_u \tag{33}$$

$$+ \beta \pi_{j+1|j}(h_c, j_g) \mathop{\mathbb{E}}_{\epsilon_e'|h', \epsilon_n'|h', \zeta'} \left[V_{j+1}^r(a', h', \epsilon_e', \epsilon_n', \zeta')\right]$$

such that

$$\zeta \sim U[0, \bar{\zeta}]$$

$$c + q^{rf} a' + p_{med} \leq ss + a + \kappa - (1 - q_{med}^n)\, m_n - (1 - q_{med}^e)\, m_e(\epsilon_e) - \zeta - T(y)$$

$$h_c = (1-\epsilon_n)(1-\epsilon_e)h$$

$$h' = h_c + \varphi_{j_g} m_n^{\psi_{j_g}} = (1-\epsilon_n)(1-\epsilon_e)h + \varphi_{j_g} m_n^{\psi_{j_g}}$$

$$y = ss + (\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$$

where ss is Social Security benefit, p_{med} is the Medicare premium, and (q_{med}^e) q_{med}^n is the coverage rate of Medicare for (non-) emergency medical expenses. For simplicity, retired households cannot borrow, but they can save. I assume that retired households do not access private health insurance markets. Retired households do not have labor income, but receive Social Security benefit, ss, in each period. Thus, they pay income tax based on Social Security benefit ss and capital income $(\frac{1}{q^{rf}} - 1)a \cdot \mathbb{1}_{a>0}$. Retired households do not pay payroll taxes, as they do have labor income.

Appendix D Proof of proposition 2.7.1

Clausen and Strub (2017) introduce an envelope theorem to prove that First Order Conditions are necessary conditions for the global solution. They show that the envelop theorem is applicable to default models where idiosyncratic shocks on earnings are iid. I extend their application to solve this model, which has persistent idiosyncratic shocks on earnings. To use their envelope theorem, it is necessary to introduce the following definition.

Definition D.0.1. I say that $F : C \to \mathbb{R}$ is **differentiably sandwiched** between the lower and upper support functions $L, U : C \to \mathbb{R}$ at $\bar{c} \in C$ if

1. L is a differentiable lower support function of F at $\bar{c}$,i.e L is differentiable, $L(c) \leq F(c)$ for all $c \in C$, and $L(\bar{c}) = F(\bar{c})$.
2. U is a differentiable upper support function of F at $\bar{c}$,i.e U is differentiable, $U(c) \geq F(c)$ for all $c \in C$, and $U(\bar{c}) = F(\bar{c})$.

Let us begin with the FOC (17): For any $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$

$$\frac{\partial q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) a^{'}}{\partial a^{'}} \frac{\partial u(c, (1-\epsilon_e)(1-\epsilon_n)\bar{h})}{\partial c} = \frac{\partial W^G(a^{'}, \bar{i}^{'}, \bar{h}^{'}, \eta, j+1)}{\partial a^{'}}.$$

Lemma 2 (Maximum Lemma) and Lemma 3 (Reverse Calculus) in Clausen and Strub (2017) tell me that if each constituent function (q, u, W^G) of the FOC (17) has a differential lower support function at a point $a^{'}$, $q \times u$ and W^G are differentiable at $a^{'}$ and the FOC (17) is a necessary condition for the global solution.

Formally, **the proof of proposition 2.7.1** is as follows:

Proof. $u(\cdot, (1-\epsilon_e)(1-\epsilon_n)\bar{h})$ has trivially a differentiable lower support function, as itself is differentiable by the assumption. By lemma D.1 and lemma D.2, the discount rate of loan $q(\cdot, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$ and the expected value function $W^G(\cdot, \bar{i}^{'}, \bar{h}^{'}, \eta, j+1)$ have a differentiable lower support function, respectively. That implies that each $u(\cdot, (1-\epsilon_e)(1-\epsilon_n)\bar{h})$, $q(\cdot, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$ and $W^G(\cdot, \bar{i}^{'}, \bar{h}^{'}, \eta, j+1)$ has a differentiable lower support function. Lemma 3 (Reverse Calculus) in Clausen and Strub (2017) implies that the FOC (17) exists and holds. □

Lemma D.1. *Let a state $(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ be given. Let $a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ be the risk borrowing limit (credit limit) of $q(\cdot, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$. For all $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$, the discount rate of loan $q(\cdot, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$ has a differentiable lower support function.*

Proof. Case1: For any $a \geq 0$, $q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) = \frac{1}{1+r^{rf}}$, and there by $\frac{\partial q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) a^{'}}{\partial a^{'}} = 0$. Thus, $q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$ itself is a differentiable lower support function.

Case2: For any $a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta) < a^{'} < 0$, $q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) = \frac{1-d(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta)}{1+r^{rf}}$. It implies that finding a lower differentiable support function of $q(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$ is equivalent to doing a upper differentiable support function of

$d(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) = \sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \pi_{\eta^{'}|\eta} \pi_{\omega^{'}|\eta^{'}} \mathbb{1}_{\{v^{G,N}(a^{'}, \mathbf{s_1^{'}}, \eta^{'}, j+1) \leq v^{G,D}(\mathbf{s_1^{'}}, \eta^{'}, j+1)\}}$

, where $\mathbf{s}_1^{'} = (\bar{i}^{'}, \bar{h}^{'}, \epsilon_e^{'}, \epsilon_n^{'}, \omega^{'})$. Let us transform $\pi_{\eta^{'}|\eta}$ to a continuous PDF $f(\eta^{'}|\eta)$. Given state $\mathbf{s}_1^{'}$, let us denote $\delta(a^{'}, \eta; \mathbf{s_1^{'}}) = \pi_{\epsilon_e^{'}|\mathbf{h}^{'}} \pi_{\epsilon_n^{'}|\mathbf{h}^{'}} \int \mathbb{1}_{\{\mathbf{v^{G,N}}(\mathbf{a}^{'}, \mathbf{s_1^{'}}, \eta^{'}, \mathbf{j+1}) \leq \mathbf{v^{G,D}}(\mathbf{s_1^{'}}, \eta^{'}, \mathbf{j+1})\}} \pi_{\omega^{'}|\eta^{'}} \mathbf{f}(\eta^{'}|\eta) \mathbf{d}\eta^{'}$. Since $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$, $\{\eta^{'} : v^{G,N}(a^{'}, \mathbf{s_1^{'}}, \eta^{'}, j+1) \leq v^{G,D}(\mathbf{s_1^{'}}, \eta^{'}, j+1)\}$ is non-empty. Theorem 3 (The Maximal Default Set Is a Closed Interval) and Theorem 4 (Maximal Default Set Expands with Indebtedness) in Chatterjee et al. (2007) imply that for any $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ and for each state $(\mathbf{s}_1^{'}, \eta^{'}, j+1)$, there are two points $\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$ and $\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$ such that (i) $\{\eta^{'} : v^{G,N}(a^{'}, \mathbf{s_1^{'}}, \eta^{'}, j+1) \leq v^{G,D}(\mathbf{s_1^{'}}, \eta^{'}, j+1)\} = [\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)]$ and (ii) for any $a^{'} < a^{''}$, $[\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)] \subset [\eta_1^{'}(a^{''}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(a^{''}; \mathbf{s}_1^{'}, j+1)]$. The first property means

$\int_{\{\eta^{'} : v^{G,N}(a^{'}, \mathbf{s_1^{'}}, \eta^{'}, j+1) \leq v^{G,D}(\mathbf{s_1^{'}}, \eta^{'}, j+1)\}} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'} = \int_{\eta^{'} \in [\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)]} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$

, and the second property implies that $\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$ increases with $a^{'}$ and $\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$ decreases with $a^{'}$.

Since $\int_{\eta^{'} \in [\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)]} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$

$= \int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'} - \int_{-\infty}^{\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$, if there is an upper differentiable support of $\int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$ and an lower differentiable support of

$\int_{-\infty}^{\eta_1^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$, $\delta(a^{'}, \eta; \mathbf{s_1^{'}}) = \int_{\eta^{'} \in [\eta_1^{'}(\mathbf{a}^{'}; \mathbf{s}_1^{'}, \mathbf{j+1}), \eta_2^{'}(\mathbf{a}^{'}; \mathbf{s}_1^{'}, \mathbf{j+1})]} \pi_{\omega^{'}|\eta^{'}} \mathbf{f}(\eta^{'}|\eta) \mathbf{d}\eta^{'}$ has a differentiable lower support. Without loss of generality, I will prove the existence of a differentiable upper support of

$\int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$.

Claim: $\int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$ has an upper differentiable support.

Proof of the claim: Finding an upper support function of $\int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$ is equivalent to searching for an upper support function of $\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$. I am going to use the implicit function theorem to find an upper differentiable support. Take any $\hat{a}^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ and $\eta^{'} \in (\eta_1^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1), \eta_2^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1))$. Pick any $\epsilon_1 < \eta_2^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1) - \eta_1^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1)$. Consider a case that for a realized value $(a^{'}, \eta^{'}) \in B((\hat{a}^{'}, \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)), \epsilon)$, a household anticipates state $(a^{'}, \eta^{'}) = (a^{'}, \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1))$. In other words, the household correctly recognizes $a^{'}$ but incorrectly acknowledges $\eta^{'}$. Then, in the period after the next period, the decision rule for asset holdings is $a^{''} = g_a(a^{'}, \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$. Define this borrower's net value function $L(a^{'}, \eta^{'}; \hat{a}^{'})$ on

$B((a^{'}, \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)), \epsilon)$ in the following way:

$$L(a^{'}, \eta^{'}; \hat{a}^{'}) = u\Big(w\bar{\omega}_j h_c \eta^{'} + a^{'} - (1-q_i)(m_n^{'} + m_e(\epsilon_e^{'})) \tag{34}$$
$$-T(y^{'}) + \kappa^{'} - q(g_a(a^{'}, \eta_2^{'}(a^{'}i^{''}, h^{''}; \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), j+1) g_a(a^{'}i^{''}, h^{''}, \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1), j+1) - p_{i^{''}}, h_c^{'}\Big)$$
$$-u\Big(w\bar{\omega}_j h_c \eta^{'} - (1-q_i)m_n^{'} - T(y^{'}) + \kappa^{'} - p_{i^{''}}, h_c^{'}\Big)$$
$$+\beta\pi_{j+2|j+1}(h_c^{'}, j_g) \underset{\epsilon_e^{''}|h^{''}, \epsilon_n^{''}|h^{''}, \eta^{''}|\eta_2^{'}(a^{'}i^{''}, h^{''}), \omega^{''}|\eta^{''}}{\mathbb{E}} \Bigg[\Big[V^G(g_a(a^{'}, \eta_2^{'}(a^{'}i^{''}, h^{''}), \eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)), i^{''}, h^{''}, \epsilon_e^{''}, \epsilon_n^{''}, \eta^{''}, \omega^{''}, j+2)\Big]$$
$$-\Big[V^B(0, \eta_2^{'}(a^{'}; \mathbf{s}_1, j+1)), i^{''}, h^{''}, \epsilon_e^{''}, \epsilon_n^{''}, \eta^{''}, \omega^{''}, j+2)\Big]\Bigg]$$

Note that the value function is continuous and differentiable on $B\left((\hat{a}^{'}, \eta_2^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1)), \epsilon\right)$, as the utility function u is differentiable. Also, this value function is an implicit function for $a^{'}$ and $\eta^{'}$, and $L(\hat{a}^{'}, \eta_2^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1)); \hat{a}^{'}) = 0$. The value function is differentiable with respect to $\eta^{'}$ and its value is non-zero (positive). Thus, the implicit function theorem implies that there is an open neighborhood U of $\hat{a}^{'}$ and an open neighborhood V of $\eta_2^{'}(\hat{a}^{'}; \mathbf{s}_1^{'}, j+1))$ such that $\bar{\eta}^{'} = \bar{\eta}^{'}(a^{'}, \hat{a}^{'})$ satisfies

$$L(a^{'}, \bar{\eta}^{'}(a^{'}, \hat{a}^{'}); \hat{a}^{'}) = 0$$

, where $\bar{\eta}^{'} \in V$ and $a^{'} \in U$. Since this household overvalues repaying debt, $\bar{\eta}^{'}(\cdot, \hat{a}^{'})$ is an upper support of $\eta_2^{'}(\cdot; \mathbf{s}_1^{'}, j+1)$ at $\hat{a}^{'}$. Furthermore, the implicit function theorem implies that $\bar{\eta}^{'}(\cdot, \hat{a}^{'})$ is differentiable on U. Thus, $\bar{\eta}^{'}(\cdot, \hat{a}^{'})$ is an upper differentiable support function of $\eta_2^{'}(\cdot; \mathbf{s}_1^{'}, j+1)$ at $\hat{a}^{'}$. Since the statement holds for all $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$, $\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)$ has an upper differentiable upper support for all $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$. Therefore, the claim is proven. Q.E.D.

Since $\int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$ has an upper differentiable support function, $d(a^{'}, \bar{i}^{'}, \bar{h}^{'}; j, \eta) = \sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \int_{-\infty}^{\eta_2^{'}(a^{'}; \mathbf{s}_1^{'}, j+1)} \pi_{\omega^{'}|\eta^{'}} f(\eta^{'}|\eta) d\eta^{'}$ has an upper differentiable support function. □

Lemma D.2. *Let a state $(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ be given. Let $a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$ be the risk borrowing limit (credit limit) of $q(\cdot, \bar{i}^{'}, \bar{h}^{'}; j, \eta)$. For all $a^{'} > a_{rbl}(\bar{i}^{'}, \bar{h}^{'}; j, \eta)$, the expected value function $W^G(\cdot, \bar{i}^{'}, \bar{h}^{'}; \eta, j+1)$ has a differentiable lower support function.*

Proof. To ease notation, let us denote $\mathbf{s}_1^{'} = (\bar{i}^{'}, \bar{h}^{'}, \epsilon_e, \epsilon_n, \eta^{'}, \omega^{'})$
(i) Case 1: $\bar{a}^{'} > 0$.
In this case, the discount rate of loan becomes q^{rf}. I can use the standard technique of Benveniste and Scheinkman's theorem. Consider a case that for a realized value $(a^{'}, \eta^{'})$, a household takes $a^{''} = g_a(\bar{a}^{'}, \mathbf{s}_1^{'}, j+1)$ for all $a^{'}$ and $\eta^{'}$. Let us define this agent's net value function $L(a^{'}, \eta^{'}; \bar{a}^{'})$ in

the following way:

$$L^0(a', \eta'; \bar{a}', \mathbf{s}_1') = u\Big(w\bar{\omega}_j h_c \eta' + a' - (1-q_i)(m_n' + m_e(\epsilon_e')) - T(y') + \kappa' - q^{rf} g_a(\bar{a}', \mathbf{s}_1', j+1) - p_{i''}, h_c'\Big) \tag{35}$$

$$+\beta \pi_{j+2|j+1}(h_c', j_g) \mathop{\mathbb{E}}_{\epsilon_e''|h'', \epsilon_n''|h'', \eta''|\eta', \omega''|\eta''} \Big[V^G(g_a(\bar{a}', \mathbf{s}_1', j+1), i'', h'', \epsilon_e'', \epsilon_n'', \eta'', \omega'', j+2)\Big]$$

Since there is no debt, the agent does not default. Thus, $L^0(\bar{a}', \eta'; \bar{a}') = V^G(\bar{a}', \mathbf{s}_1') = v^{G,N}(\bar{a}', \mathbf{s}_1')$ and $L(a', \eta'; \bar{a}') \leq V^G(a', \mathbf{s}_1')$ for all $a' \geq 0$. Moreover, $L(a', \eta'; \bar{a}')$ is differentiable at $\bar{a}'$. Therefore, $L(\cdot, \eta'; \bar{a}')$ is a lower differentiable support function of $V^G(\bar{a}', \mathbf{s}_1')$.
(ii) Case2: $a_{rbl}(\bar{i}', \bar{h}'; j, \eta) < \bar{a}' < 0$.
Let us consider a case for realized value (a', η'), a household takes $a'' = g_a(\bar{a}', \mathbf{s}_1', j+1)$ for all a' and η'. Let us define this agent's net value function $L^1(a', \eta'; \bar{a}')$ in the following way:

$$L^1(a', \eta'; \bar{a}', \mathbf{s}_1') = \max\Bigg\{u\Big(w\bar{\omega}_j h_c \eta' + a' - (1-q_i)(m_n' + m_e(\epsilon_e')) \tag{36}$$

$$-T(y') + \kappa' - q - q(g_a(a', \mathbf{s}_1', j+1), i'', h''; \eta', j+1) g_a(a', \mathbf{s}_1', j+1) - p_{i''}, h_c'\Big)$$

$$+\beta \pi_{j+2|j+1}(h_c', j_g) \mathop{\mathbb{E}}_{\epsilon_e''|h'', \epsilon_n''|h'', \eta''|\eta', \omega''|\eta''} \Big[V^G(g_a(\bar{a}', \mathbf{s}_1', j+1), i'', h'', \epsilon_e'', \epsilon_n'', \eta'', \omega'', j+2)\Big],$$

$$u\Big(w\bar{\omega}_j h_c \eta' - (1-q_i) m_n' - T(y') + \kappa' - p_{i''}, h_c'\Big)$$

$$+\beta \pi_{j+2|j+1}(h_c', j_g) \mathop{\mathbb{E}}_{\epsilon_e''|h'', \epsilon_n''|h'', \eta''|\eta', \omega''|\eta''} \Big[V^B(0, i'', h'', \epsilon_e'', \epsilon_n'', \eta'', \omega'', j+2)\Big]\Bigg\}$$

$L^1(\bar{a}', \eta'; \bar{a}') = V^G(\bar{a}', \mathbf{s}_1')$ and $L^1(a', \eta'; \bar{a}') \leq V^G(a', \mathbf{s}_1')$ for all $a' \geq 0$. Moreover, $L(a', \eta'; \bar{a}')$ is differentiable with respect to a'. Therefore, $L^1(\cdot, \eta'; \bar{a}')$ is a lower differentiable support function of $V^G(\bar{a}', \mathbf{s}_1')$.

□

Appendix E Recursive Equilibrium

I define a measure space to describe equilibrium. To ease notation, I denote $\mathbf{S} = \mathbf{A} \times \mathbf{I} \times \mathbf{H} \times \mathbf{ER} \times \mathbf{NER} \times \mathbf{E} \times \mathbf{O} \times \Upsilon$ as the state space of households, where $\mathbf{A}$ is the space of households' assets a, $\mathbf{I}$ is the space of households' health insurance i, $\mathbf{H}$ is the space of households' health capital h, $\mathbf{ER}$ is the space of emergency health shocks ϵ_e, $\mathbf{NER}$ is the space of non-emergency health shocks ϵ_n, $\mathbf{O}$ is the space of the offer of employer-based health insurance ω and Υ is the space of credit history $\upsilon \in \{G, B\}$. In addition, let $\mathbb{B}(\mathbf{S})$ denote the Borel σ-algebra on $\mathbf{S}$. In addition, I denote $\mathbf{J} = \{J_0, \cdots, J_r, \cdots, \bar{J}\}$ as the space of households' age. Then, for each age j, a probability measure $\mu(\cdot, j)$ is defined on the Borel σ-algebra $\mathbb{B}(\mathbf{S})$ such that $\mu(\cdot, j) : \mathbb{B}(\mathbf{S}) \longrightarrow [0, 1]$. $\mu(B, j)$ represents the measure of age j households whose state lies in $B \in \mathbb{B}(\mathbf{S})$ as a proportion of all age j. The households' distribution at age j in age group j_g evolves as follows: For all $B \in \mathbb{B}(\mathbf{S})$,

$$\mu(B, j+1) = \int_{\left\{\mathbf{s} | \left(g_a(\mathbf{s},j), g_i(\mathbf{s},j), g_h(\mathbf{s},j), \epsilon_e', \epsilon_n', \eta', \omega', \upsilon'\right) \in B\right\}} \left[\Gamma_{\upsilon}^{\upsilon'} \ \pi_{j+1|j}(h_c, j_g) \ \pi_{\epsilon_e' | g_h(\mathbf{s},j)} \ \pi_{\epsilon_n' | g_h(\mathbf{s},j)} \ \pi_{\eta'|\eta} \ \pi_{\omega'|\eta'}\right] \ \mu(d\mathbf{s}, j) \tag{37}$$

where $\mathbf{s} = (a, i, h, \epsilon_e, \epsilon_n, \eta, \omega, \upsilon) \in \mathbf{S}$ is the individual state. $g_a(\cdot, j)$ is the policy function for assets at age j, $g_i(\cdot, j)$ is the policy function for health insurance at age j, and $g_h(\cdot, j)$ is the policy function for health investment at age j. In addition, $\Gamma_{\upsilon}^{\upsilon'}$ is the transitional probability of credit history υ' in the next period conditional on the current status of credit history υ, $\pi_{j+1|j}(h_c, j_g)$ is the rate of surviving up to age $j+1$ conditional on surviving up to age j with the current health status h_c in age group j_g and $\pi_{\epsilon_e'|g_h(\mathbf{s},j)}$ ($\pi_{\epsilon_n'|g_h(\mathbf{s},j)}$) is the transition probability for ϵ_e' (ϵ_n') conditional on $g_h(\mathbf{s}, j)$. $\pi_{\eta'|\eta}$ is the transitional probability of idiosyncratic labor productivity for the next period η' conditional on η and $\pi_{\omega'|\eta'}$ is the probability of receiving an employer-based health insurance offer ω' for the next period conditional on η'.

Definition E.0.1 (***Recursive Competitive Equilibrium***)**.** Given an distribution of newborn agents $B_0 \in \mathbf{S}$, a social Security benefit ss, a Medicare coverage rate q_{med}, a Medicare premium p_{med}, a subsidy rule for employer-based health insurance ψ_{EHI}, mark-ups of health private insurances ν_{IHI} and ν_{EHI}, an income threshold for Medicaid eligibility $\bar{y}$, health insurance coverage rates $\{q_{MDC}, q_{IHI}, q_{EHI}\}$, private individual health insurance pricing rules $\{p_{IHI}(\cdot, j_g)\}_{j_g=1}^{4}$, subsidies for private individual health insurances $\psi_{EHI}(\cdot, \cdot)$, a tax policy, $\{T(\cdot), \tau_{ss}, \tau_{med}\}$,
a recursive competitive equilibrium is
a set of prices $\left\{w, r^{rf}, r, q^{rf}, \{q(\cdot, \cdot, \cdot, j, \cdot)\}_{j=J_0}^{J_r-1}, \{p(\cdot, j_g)\}_{j_g=1}^{4}, p_{med}\right\}$
, a set of the mark-up of hospital $\{\zeta\}$
, a set of decision rules for households $\left\{\{g_d(\cdot, j), g_a(\cdot, j), g_i(\cdot, j), g_h(\cdot, j)\}_{j=J_0}^{\bar{J}}\right\}$
, a set of default probability function $\left\{d(\cdot, \cdot, \cdot; j, \cdot)\}_{j=J_0}^{\bar{J}}\right\}$

, a set of values $\Bigg\{ \left\{V^G(\cdot,j), v^{G,N}(\cdot,j), v^{G,D}(\cdot,j), V^B(\cdot,j), v^{B,N}(\cdot,j), v^{B,D}(\cdot,j)\right\}_{j=J_0}^{J_r-1}$,
$\left\{v^{G,r}(\cdot,j), v^{B,r}(\cdot,j)\right\}_{j=J_r}^{\bar{J}} \Bigg\}$
and distributions of households $\{\mu(\cdot,j)\}_{j=J_0}^{\bar{J}}$ such that

(i) Given prices, the policies above, the decision rules $g_d(\mathbf{s},j), g_a(\mathbf{s},j), g_i(\mathbf{s},j)$ and $g_h(\mathbf{s},j)$ solve the household problems in Appendix C and $V^G(\cdot,j), v^{G,N}(\cdot,j), v^{G,D}(\cdot,j), V^B(\cdot,j)$, $v^{B,N}(\cdot,j), v^{B,D}(\cdot,j), v^{G,r}(\cdot,j)$ and $v^{B,r}(\cdot,j)$ are the associated value functions.

(ii) Firm is competitive pricing:

$$w = \frac{\partial zF(K,N)}{\partial N}, \quad r = \frac{\partial zF(K,N)}{\partial K}$$

, where K is the quantity of aggregate capital, and $N$is the quantity of aggregate labor.

(iii) Loan prices and default probabilities are consistent, whereby lenders earn zero expected profits on each loan of size $a^{'}$ for households with age j that have health insurance $i^{'}$ for the next period, health capital $h^{'}$ for the next period and the current idiosyncratic shock on earnings η:

$$\begin{aligned} q(a^{'},i^{'},h^{'};j,\eta) &= \frac{(1-d(a^{'},i^{'},h^{'};j,\eta))}{1+r^{rf}} \\ d(a^{'},i^{'},h^{'};j,\eta) &= \sum_{\epsilon_n^{'},\epsilon_e^{'},\eta^{'},\omega^{'}} \pi_{\epsilon_e^{'}|h^{'}}\pi_{\epsilon_n^{'}|h^{'}}\pi_{\eta^{'}|\eta}\pi_{\omega^{'}|\eta^{'}}\mathbb{1}_{\{v^{G,N}(\mathbf{s}_n^{'},j+1)\,\leq\, v^{G,D}(\mathbf{s}_d^{'},j+1)\}} \end{aligned}$$

, where $s_n^{'} = (a^{'},i^{'},h^{'},\epsilon_e^{'},\epsilon_n^{'},\eta^{'},\omega^{'},j+1)$ and $s_d^{'} = (i^{'},h^{'},\epsilon_e^{'},\epsilon_n^{'},\eta^{'},\omega^{'},j+1)$.

(iv) The hospital has zero profit:

$$\sum_{j=J_0}^{\bar{J}} \int \Bigg\{ [m_n(\mathbf{s},j) + (1-g_d(\mathbf{s},j))m_e(\epsilon_e) + g_d(\mathbf{s},j)\max(a,0)] - \frac{(m_n(\mathbf{s},j)+m_e(\epsilon_e))}{\zeta} \Bigg\} \mu(d\mathbf{s},j) = 0.$$

(v) The bond market and the capital market are clear:

$$
\begin{aligned}
r^{rf} &= r - \delta \\
q^{rf} &= \frac{1}{1 + r^{rf}} \\
K &= \sum_{j=J_0}^{\bar{J}} \left[\int \Big(q(g_a(\mathbf{s}, j), g_i(\mathbf{s}, j), g_h(\mathbf{s}, j); j, \eta) g_a(\mathbf{s}, j) \right. \\
&\quad \left. + \left(p(g_i, h_c, j_g) \cdot \mathbb{1}_{\{g_i(\mathbf{s},j) \in \{IHI, EHI\}}\right) \mu(d\mathbf{s}, j) \right].
\end{aligned}
$$

(vi) The labor market is clear:

$$
N = \sum_{j=J_0}^{J_r - 1} \left[\bar{\omega}_j \int \left((1 - \epsilon_e)(1 - \epsilon_n) h \eta \right) \mu(d\mathbf{s}, j) \right].
$$

(vii) The goods market is clear:

$$
\begin{aligned}
&\underbrace{\sum_{j=J_0}^{\bar{J}} \left[\int \left(c(\mathbf{s}, j) + \frac{m_n(\mathbf{s}, j) + m_e(\epsilon_e)}{\zeta} \right) \mu(d\mathbf{s}, j) \right]}_{\text{Aggregate Non-medical Consumption + Aggregate Medical Expenditures}} + \underbrace{K - (1 - \delta)K}_{\text{Aggregate Investment}} + \underbrace{G}_{\text{Government Spending}} \\
&\quad + \sum_{j=J_0}^{J_{r-1}} \left[\int \Big\{ \underbrace{\left(\psi_{IHI}(p_{IHI}(h_c, j_g), y(\mathbf{s}, j)) \cdot \mathbb{1}_{\{g_i(\mathbf{s},j) = IHI\}} \right)}_{\text{Government Subsidy for Private Individual Health Insurance IHI}} \right. \\
&\quad \left. + \underbrace{\left(\psi_{EHI} \cdot p_{EHI} \cdot \mathbb{1}_{\{g_i(\mathbf{s},j) = EHI\}} \right) \Big\}}_{\text{Government Subsidy for Employer-Based Health Insurance EHI}} \mu(d\mathbf{s}, j) \right] \\
&= \underbrace{zF(K, N)}_{\text{Total Output}} \\
&\quad \underbrace{- \chi w \sum_{j=J_0}^{J_r - 1} \left[\bar{\omega}_j \int \left((1 - \epsilon_e)(1 - \epsilon_n) h_c g_d(\mathbf{s}, j) \right) \mu(d\mathbf{s}, j) \right]}_{\text{Deadweight Loss from Default}} \\
&\quad \underbrace{- \sum_{j=J_0}^{J_r - 1} \left[\int \left(\nu_{g_i} p_{g_i}(h_c, j_g) \mathbb{1}_{\{g_i(\mathbf{s},j) \in \{IHI, EHI\}} \right) \mu(d\mathbf{s}, j) \right]}_{\text{Deadweight Loss due to the Mark-up of Private Health Insurance Markets}}.
\end{aligned}
$$

(viii) The insurance markets are clear:

For each age group j_g and each health group h_g, the premium of the private individual health insurance $p_{IHI}(h_g, j_g)$ satisfies

$$\underbrace{(1+\nu_{IHI})}_{\text{Mark-up of IHI}} \underbrace{\sum_{j\in J_g} \int q_{IHI} \cdot \mathbb{1}_{\{\{i=IHI\}\cap\{h\in h_g\}\}} \cdot (m_n(\mathbf{s},j)+m_e(\epsilon_{e,t}))\mu(d\mathbf{s},j)}_{\text{Total Medical Expenditure Covered by IHI}}$$
$$= (1+r^{rf})\, p_{IHI}(h_g, j_g) \underbrace{\sum_{j\in J_g} \int \mathbb{1}_{\{\{g_i(\mathbf{s},j)=IHI\}\cap\{h\in h_g\}\}}\mu(d\mathbf{s},j)}_{\text{Total Demand for IHI}}.$$

The premium of the employer-based health Insurance p_{EHI} satisfies

$$\underbrace{(1+\nu_{EHI})}_{\text{Mark-up of EHI}} \underbrace{\sum_{j=J_0}^{J_r-1} \int q_{EHI} \cdot \mathbb{1}_{\{i=EHI\}}(m_n(\mathbf{s},j)+m_e(\epsilon_e))\mu(d\mathbf{s},j)}_{\text{Total Medical Expenditure Covered by EHI}}$$
$$= (1+r^{rf}) \cdot p_{EHI} \cdot \underbrace{\sum_{j=J_0}^{J_r-1} \int \mathbb{1}_{\{g_i(\mathbf{s},j)=EHI\}}\mu(d\mathbf{s},j)}_{\text{Total Demand for EHI}}.$$

(ix) Social Security (ss) and Medicare are financed by their own objective payroll taxes τ_{ss} and τ_{med}. The government budget constraint is balanced:

$$\underbrace{\sum_{j=J_r}^{\bar{J}} \int (ss)\mu(d\mathbf{s},j)}_{\text{Total Social Security Benefit}} = \underbrace{\sum_{j=J_0}^{J_r-1} \int \tau_{ss}\, w\bar{\omega}_j h_c \eta \mu(d\mathbf{s},j)}_{\text{Revenue from Social Security Tax}}$$

$$\sum_{j=J_r}^{\bar{J}} \int \left(\underbrace{q_{med}(m_n(\mathbf{s},j)+m_e(\epsilon_{e,t}))}_{\text{Medical Expenses Covered by Medicare}} - \underbrace{p_{med}}_{\text{Medicare Premium}} \right)\mu(d\mathbf{s},j) = \underbrace{\sum_{j=J_0}^{J_r-1} \int \tau_{med}\, w\bar{\omega}_j h_c \eta \mu(d\mathbf{s},j)}_{\text{Revenue from Medicare Tax}}$$

$$\underbrace{G}_{\text{Government Spending}} + \sum_{j=J_0}^{J_{r-1}} \Bigg[\int \Big\{ \underbrace{\big(\psi_{IHI}(p_{IHI}(h_c, j_g), y(\mathbf{s},j)) \cdot \mathbb{1}_{\{g_i(\mathbf{s},j)=IHI\}}\big)}_{\text{Subsidy for IHI}}$$
$$+ \underbrace{\big(\psi_{EHI} \cdot p_{EHI} \cdot \mathbb{1}_{\{g_i(\mathbf{s},j)=EHI\}}\big)}_{\text{Subsidy for EHI}} \Big\}\mu(d\mathbf{s},j) \Bigg] = \underbrace{\sum_{j=0}^{J} \int T(y)\mu(d\mathbf{s},j)}_{\text{Revenue from Income Tax}}.$$

(x) Distributions are consistent with individual behavior.

For all $j \leq \bar{J}-1$ and for all $B \in \mathbb{B}(\mathbf{S})$,

$$\mu(B, j+1) = \int_{\left\{\mathbf{s} \mid \left(g_a(\mathbf{s},j), g_i(\mathbf{s},j), g_h(\mathbf{s},j), \epsilon_e', \epsilon_n', \eta', \omega', \upsilon'\right) \in B\right\}} \left[\Gamma_{\upsilon}^{\upsilon'} \; \pi_{j+1|j}(h_c, j_g) \; \pi_{\epsilon_e'|g_h(\mathbf{s},j)} \; \pi_{\epsilon_n'|g_h(\mathbf{s},j)} \; \pi_{\eta'|\eta} \; \pi_{\omega'|\eta'}\right] \; \mu(d\mathbf{s}, j)$$

, where $\mathbf{s} = (a, i, h, \epsilon_e, \epsilon_n, \eta, \omega, \upsilon) \in \mathbf{S}$ is the individual state.

(xi) Accidental bequests κ are evenly distributed to all of the households:

$$\kappa = \sum_{j=J_0}^{\bar{J}-1} \left(\int [(1 - \pi_{j+1|j}(h_c, j_g))(a(1 + r^{rf})) \cdot \mathbb{1}_{\{a>0\}}] \mu(d\mathbf{s}, j) \right).$$

Appendix F Data Details

F.1 Data Cleansing

I choose the MEPS waves from 2000 to 2011. Among various data files in MEPS, by using individual id (DUPERSID), I merger three types of data files: MEPS Panel Longitudinal files, Medical Condition files, and Emergency Room visits files. To clean this data set, I take the following steps. First, I identify household units with the Health Insurance Eligibility Unit (HIEU). Second, I define household heads who have the highest labor income within a HIEU. I eliminate households in which the heads are non-respondents for key variables such as demographic features, educational information, medical expenditures, health insurance, health status, and medical conditions. Second, among working age (23-64) head households, I drop families that have no labor income. Third, I use the MEPS longitudinal weight in MEPS Panel Longitudinal file for each individual. Since each survey of MEPS Panel Longitudinal files covers 2 consequent years, I stack individuals in the 10 different panels into one data set. To use the longitudinal weight with my stacked data set, I follow the way in Jeske and Kitao (2009). As they did, I rescale the longitudinal weight in each survey to make the sum of the weight equal to the number of HIEUs. In this way, I address the issues of different size of samples across surveys and reflect the longitudinal weight in each survey. Lastly, I convert all nominal values into the value of U.S. dollar in 2000 with the CPI. The number of observations in each panel is as follows.

Year	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006
Numbers	5218	10187	7484	7577	7548	7294
Year	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	
Numbers	7721	5835	8611	7988	7020	

Table 14: MEPS Panel Sample Size

F.2 Variable Definitions

Household Unit(MEPS Panel Longitudinal files, Medical Condition files, and Emergency Room visits files): To define households, I use the Health Insurance Eligibility Units (HIEU) in the MEPS. To capture behavior related to health insurance, the HIEU is a more proper id than dwelling unit. Since the HIEU is different from dwelling unit, even within a dwelling unit, multiple HIEUs can exist. A HIEU includes spouses, unmarried natural or adoptive children of age 18 or under and children under 24 who are full-time students.

Head(MEPS Panel Longitudinal files): The MEPS does not formally define heads in households. I define head by choosing the highest earner within a HIEU.

Household Income (MEPS Panel Longitudinal files): The MEPS records individual total income (TTLPY1X and TTPLY2X). Household income is the summation of all house members' total income.

Medical Expenditures (MEPS Panel Longitudinal files): The MEPS provides information on individual total medical expenditures (TOTEXPY1 and TOTEXPY2). However, this variable includes medical expenditures paid for by Veteran's Affairs (TOTVAY1 and TOTVAY2), Workman's Compensation (TOTWCPY1 and TOTWCPY2) and other sources (TOTOSRY1 and TOTOSRY2) that are not covered in this study, I redefine the total medical expenditure variable by subtracting these three variables from the original total medical expenditure variable.

Insurance Status(MEPS Panel Longitudinal files): For working age head households, I categorize four type of health insurance status: uninsured, Medicaid, individual health insurance, and employer-based health insurance. The MEPS records whether each respondent has a health insurance, whether the insurance is provided by the government or private sectors (INSCOVY1 and ISCOVY2), and whether to use Medicaid (MCDEVY1 and MCDEVY2). Using this variable, I define the uninsured and Medicaid users. The MEPS also records employer-based health insurance holders (HELD1X, HELD2X, HELD3X, HELD4X, HELD5X) for five subsequent survey periods. I define employer-based health insurance holders who have experience in holding employer-based health insurance within a year. I define individual health insurance holders as those who do not have employer-based health insurance (HELD1X, HELD2X, HELD3X, HELD4X, HELD5X) but have a private health insurance (INSCOVY1 and INSCOVY2).

Employer-Based Health Insurance Offer rate (MEPS Panel Longitudinal files): The MEPS provides information as to whether respondents' employer offers health insurance (OFFER1X, OFFER2X, OFFER3X, OFFER4X, OFFER5X).

Medical Conditions (Medical Condition files): The Medical Condition Files in the MEPS keep track of individual medical condition records with various measures. I choose Clinical Classification Code for identifying individual medical conditions (CCCODEX).

Health Shocks (Medical Condition files and morbidity measures from the WHO): In order to quantify these individual medical conditions, I use a measure from the World Health Organization (WHO). The WHO provides two types of measures to quantify the burden of diseases: mortality measures (years of life lost to illness (YLL) and morbidity measures (years lived with disability (YLD)). I use the adjusted morbidity measure in the study of Prados (2017). Table 15 is the morbidity measures in Prados (2017).

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		

Table 15: Disability Weights (Source:Prados (2017))

For calculating health shocks from medical conditions, I follow the method in Prados (2017). Let's assume that a household has D kinds of medical conditions. Denote d_i as the WHO index for medical condition i, where $i = 1, \ldots, D$. For this household, its health shock ϵ_h is represented by

$$(1 - \epsilon_h) = \prod_{i=1}^{D}(1 - d_i). \tag{38}$$

This measure well represents the features of medical condition in the sense that it reflects not only multiple medical conditions but also differences in their severity.

Emergency Room Usages and Charges (Emergency Room Visits files): Emergency Room Visits files in the MEPS record respondents who visit emergency rooms. These files records the Clinical Classification Code as to why respondents visit emergency rooms (ERCCC1X, ERCCC2X, ERCCC3x) and as to how much hospitals charge from emergency medical events to patients (ERTC00X).

Appendix G Computation Details

There are computational burdens in this problem, because not only the dimension of individual state is large, but also the value functions of the model are involved with many non-concave and non-smooth factors: the choice of default, health insurance, medical cost, progressive subsidy and tax policies.

To solve the model with these complexities, I extend the endogenous grid method of Fella (2014). He provides an algorithm to handle non-concavities on the value functions with an exogenous borrowing constraint. I generalize the method for default problems in which borrowing constraints differ across individuals.

Whereas there are several types of value functions in the model, the computational issues are mainly related to four types of value functions: the value function of non-defaulting households with a good (bad) credit history $v^{G,N}$ ($v^{B,N}$), the value function of retired households with a good (bad) credit history $v^{G,r}$ ($v^{B,r}$).[35] The value function with a bad credit history and two retired households' value functions are solved with the algorithm of Fella (2014), because these problems have an exogenous borrowing constrain with discrete choice, which is consistent with the setting of Fella (2014). My endogenous grid method is for solving the value function of non-defaulting with a good credit history $v^{G,N}$ in which loan prices differ across individuals states.[36]

In the following subsections, first, I demonstrate how to solve the value of non-defaulting households with a good credit history $v^{G,N}$ with my endogenous grid method.[37] Then, I show how to solve the other value functions with the endogenous grid method of Fella (2014).

G.1 Notation and Discretization of States

Before getting into details, let us begin with notations to explain the algorithm. To ease notation, I denote $\mathrm{s}_{-a} = (i, h, \epsilon_e, \epsilon_n, \eta, \omega, j)$ and $\mathrm{s}_p^{'} = (i^{'}, h^{'}, \eta, j)$. Then, $V^G(a, \mathrm{s}_{-a}) = V^G(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega, j)$ and $q(a^{'}, \mathrm{s}_p^{'}) = q(a^{'}, i^{'}, h^{'}; j, \eta)$. I also denote $W^G(a^{'}, s_p^{'}, h_c) = W^G(a^{'}, i^{'}, h^{'}, \eta, j, h_c)$ as the expected value function of working households with good credit conditional on η, h_c, age j and age group j_g, $\pi_{j+1|j}(h_c, j_g)\,\mathbb{E}_{\epsilon_e^{'}|h^{'},\epsilon_n^{'}|h^{'},\eta^{'}|\eta,\omega^{'}|\eta^{'}}\left[V^G(a^{'}, \mathrm{s}_{-a}^{'})\right]$. $G_{a^{'}} = \{a_1^{'}, \cdots, a_{N_{a^{'}}}^{'}\}$ and $G_O = \{O_1, \cdots, O_{N_O}\}$ are the grid of asset holdings $a^{'}$ and cash on hand O, respectively.

In the model, households need to make choices on three individual state variables: assets a, health insurance i, and health capital h. I discretize two endogenous states: health insurance i and

[35] The value function of filing for default is not involved with any continuous choice variable.

[36] Jang and Lee (2019) extend this endogenous grid method to solve infinite horizon models with default risk and aggregate uncertainty.

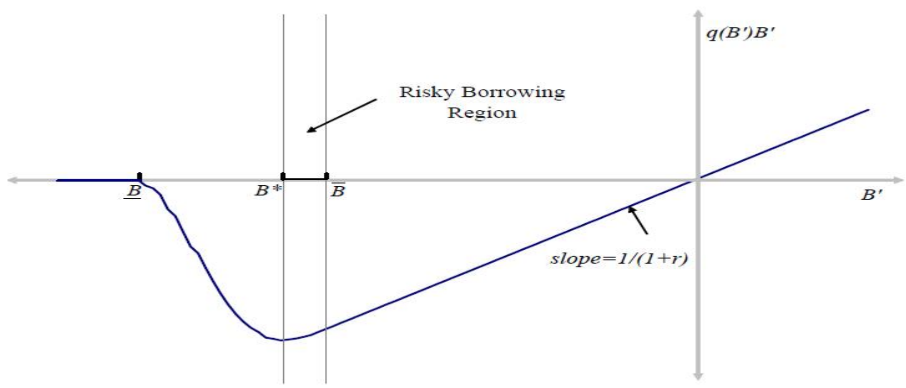
[37] The steps I use here are also described in Jang and Lee (2019). They extend this endogenous grid method to solve an infinite horizon model with default risk and aggregate uncertainty.

health capital h. I apply the endogenous grid method to assets a by taking this variable as continuous. This way is efficient because the variation of assets is the largest among the endogenous state variables. When solving the problems, I regard the choice of health insurance $\bar{i}'$ and health capital for the next period $\bar{h}'$ as given states, and apply the endogenous grid method to asset holdings a' in the next period.

G.2 Calculating the Risky Borrowing Limit (Credit Limit) $(v^{G,N})$

I set up the feasible sets of the solution based on the work in Arellano (2008) and Clausen and Strub (2017). They investigate the property of the risky borrowing limits (credit limits). They show that the size of loan $q(a')a'$ increases with a' for any optimal debt contract. If the size of loan $q(a')a'$ decreases in a', households can increase their consumption by increasing debts, which is not an optimal debt contract. Arellano (2008) (Clausen and Strub (2017)) defines the risky borrowing limit (credit limit) to be the lower bound of the set for optimal contract. For example, in Figure 17, B^* is the risky borrowing limit.

Figure 17: Risky Borrowing Limit (Arellano (2008))



For each state $s_p' = (\bar{i}', \bar{h}', j, \eta)$, I calculate the risky borrowing limit $a_{rbl}'(s_p')$ such that

$$\forall a' \geq a_{rbl}(s_p'), \frac{\partial q(a', s_p')a'}{\partial a'} = \frac{\partial q(a', s_p')}{\partial a'}a' + q(a', s_p') > 0. \tag{39}$$

I compute the numerical derivative of the discount rate of loan prices $q(a', s_p')$ over the grid of asset holdings $G_{a'}$ in the following way:

$$D_{a'}q(a_k', s_p') = \begin{cases} \frac{q(a_{k+1}', s_p') - q(a_k', s_p')}{a_{k+1}' - a_k'}, & \text{for } k < N_{a'} \\ \frac{q(a_k', s_p') - q(a_{k-1}', s_p')}{a_k' - a_{k-1}'}, & \text{for } k = N_{a'}. \end{cases} \tag{40}$$

I calculate the risky borrowing limit $a_{rbl}(\cdot)$ for each state $s_p^{'}$ and fix them as the lower bound of the feasible set for the solution of asset holdings $a^{'}$. For each state $s_p^{'}$, I denote $G_{a^{'}}^{rbl(s_p^{'})}$ as the collection of all of the grid points for asset holdings $a_k^{'}$ above the risky borrowing limit $a_{rbl}(s_p^{'})$, which means for all $a_k^{'} \in G_{a^{'}}^{rbl(s_p^{'})}$, $a_k^{'} > a_{rbl}(s_p^{'})$.

G.3 Identifying (Non-) Concave Regions

Note that the FOC (17) is not sufficient but necessary, because of non-concavities on the expected value function $W^G(a^{'}, s_p^{'})$ with respect to $a^{'}$. If the concave regions can be identified, the FOC (17) is a sufficient and necessary condition for an optimal choice of asset holdings $a^{'}$ on the concave region. I use the algorithm of Fella (2014) to divide the domain of the expected value functions $G_{a^{'}}^{rbl(s_p^{'})}$ into the concave and non-concave regions.

For each state $s_p^{'}$, the concave region is identified by two threshold grid points $\bar{a}^{'}(s_p^{'})$ and $\underline{a}^{'}(s_p^{'})$ that satisfy the following condition: for any $a_i^{'} \in G_{a^{'}}^{rbl(s_p^{'})}$ and $a_j^{'} \in G_{a^{'}}^{rbl(s_p^{'})}$ with $\bar{a}^{'}(s_p^{'}) < a_i^{'} < a_j^{'}$ ($a_i^{'} < a_j^{'} < \underline{a}^{'}(s_p^{'})$), $D_{a^{'}} W^G(a_i^{'}, s_p^{'}, h_c) > D_{a^{'}} W^G(a_j^{'}, s_p^{'}, h_c)$.[38] This condition implies that for all grid points of which values are greater than $\bar{a}^{'}(s_p^{'})$ (less than $\underline{a}^{'}(s_p^{'})$), the derivative of the expected value function $D_{a^{'}}(\cdot, s_p^{'})$ strictly decreases with asset holdings $a^{'}$.

For each state $s_p^{'}$, I take the following steps to find the thresholds $\bar{a}^{'}(s_p^{'})$ and $\underline{a}^{'}(s_p^{'})$. First, I check the discontinuous points of the derivative of the expected value function $D_{a^{'}} W^G(a^{'}, s_p^{'}, h_c)$. I compute the derivative of the expected value function $D_{a^{'}} W^G(a^{'}, s_p^{'}, h_c)$ in the same way as the derivative of the discount rate of loan price (40). Second, among the discontinuous points, I find the minimum value, which is $v_{max}(s_p^{'})$. Third, I search for the maximum $a_i^{'} \in G_{a^{'}}^{rbl(\mathbf{s}_p^{'})}$ satisfying $D_{a^{'}} W^G(a^{'}, s_p^{'}, h_c) \leq v_{max}(s_p^{'})$. The maximum is defined as $\bar{a}^{'}(s_p^{'})$. Fourth, among the discontinuous points, I find the maximum value, which is $v_{min}(s_p^{'})$. Then, I search for the minimum $a_i^{'} \in G_{a^{'}}^{rbl(\mathbf{s}_p^{'})}$ satisfying $D_{a^{'}} W^G(a^{'}, s_p^{'}, h_c) \geq v_{min}(s_p^{'})$.The minimum is defined as $\underline{a}^{'}(s_p^{'})$.

G.4 Computing the Endogenous Grid for the Cash on Hand

$$\frac{\partial q(a_k^{'}, \mathbf{s_p^{'}})\mathbf{a_k^{'}}}{\partial a^{'}} \frac{\partial u(c, h_c)}{\partial c} = \frac{\partial W^G(a_k^{'}, \mathbf{s_p^{'}}, \mathbf{h_c})}{\partial a^{'}}. \tag{41}$$

First, for each state $\mathrm{s}_p^{'}$ and h_c, and for each grid point $a_k^{'} \in G_{a^{'}}^{rbl(s_p^{'})}$, I retrieve the endogenously-driven consumption $c(a_k^{'}, \mathrm{s}_p^{'}, h_c)$ from the FOC (41). Since the utility function has a CES aggregator, the endogenously-driven consumption $c(a_k^{'}, \mathrm{s}_p^{'}, h_c)$ cannot be computed analytically. I use

[38] For each $s_p^{'}$, the thresholds are the same across h_c because the survival rate $\pi_{j+1|j}(h_c, j_g)$ is a constant number.

the bisection method to compute the endogenously-driven consumption $c(a_k^{'}, \mathrm{s}_p^{'}, h_c)$. Second, I compute the endogenously-determined cash on hand $O(a_k^{'}, \mathrm{s}_p^{'}, h_c) = c(a_k^{'}, \mathrm{s}_p^{'}, h_c) + q(a_k^{'}, \mathbf{s_p^{'}})\mathbf{a_k^{'}}$. Lastly, I store the pairs of $((a_k^{'}, \mathrm{s}_p^{'}, h_c), O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$.

G.5 Storing the Value Function over the Endogenous Grid for Cash on Hand

For each state $\mathrm{s}_p^{'}$ and h_c, and for each grid point $a_k \in G_{a^{'}}^{rbl(s_p^{'})}$, I compute the value function of non-defaulters with good credit $v^{G,N}$ over the endogenous grid for cash on hand $O(a_k^{'}, \mathrm{s}_p^{'}, h_c)$ in the following way:

$$\tilde{v}^{G,N}(O(a_k^{'}, \mathrm{s}_p^{'}, h_c), \mathrm{s}_p^{'}, h_c) = u(O(a_k^{'}, \mathrm{s}_p^{'}, h_c) - q(a_k^{'}, \mathbf{s_p^{'}})\mathbf{a_k^{'}}, \mathbf{h_c}) + \mathbf{B_u} + \mathbf{W^G}(\mathbf{a_k^{'}}, \mathbf{s_p^{'}}, \mathbf{h_c}). \quad (42)$$

Note that (i) (42) is irrelevant to any max operator and (ii) the value function $v^{G,N}(O(a_k^{'}, \mathrm{s}_p^{'}), \mathrm{s}_p^{'})$ is valued on the endogenous grid, not on the exogenous grid. I store the computed value $v^{G,N}$ over the endogenous grid for cash on hand $O(a_k^{'}, \mathrm{s}_p^{'})$.

G.6 Identifying the Global Solution on the Endogenous Grid for Cash on Hand

Using information about the identification of (non-) concave regions on asset holdings $a^{'}$ in G.3, I identify the global solutions on the pair of $(a_k^{'}, O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$.

Specifically, I take the following steps. First, for each state $(\mathrm{s}_p^{'}, h_c)$, I identify $(a_k^{'}, O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$ as the pairs of the global solution if $a_k^{'} \geq \bar{a}^{'}(\mathrm{s}_p^{'})$ or $a_k^{'} \in [a_{rbl}(\mathrm{s}_p^{'}), \underline{a}^{'}(\mathrm{s}_p^{'})]$. Note that the FOC (17) is sufficient and necessary here, as these pairs are on the concave region of the global solution. I save these pairs.

Second, for each state $(\mathrm{s}_p^{'}, h_c)$ and each $a_k^{'} \in (\underline{a}^{'}(\mathrm{s}_p^{'}), \bar{a}^{'}(\mathrm{s}_p^{'}))$, I check whether the pair of $(a_k^{'}, O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$ implies the global solution in the following way:

$$a_g^{'} = \underset{\{a_j^{'} \in (\underline{a}^{'}(\mathrm{s}_p^{'}), \bar{a}^{'}(\mathrm{s}_p^{'}))\}}{\operatorname{argmax}} u(O(a_k^{'}, \mathrm{s}_p^{'}, h_c) - q(a_j^{'}, \mathrm{s}_p^{'})a_j^{'}, h_c) + B_u + W^G(a_j^{'}, \mathrm{s}_p^{'}, h_c). \quad (43)$$

If $a_g^{'} = a_k^{'}$, then I identify the pair of $(a_k^{'}, O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$ as an global solution. Otherwise, I discard the pair of $(a_k^{'}, O(a_k^{'}, \mathrm{s}_p^{'}, h_c))$.

G.7 Interpolating the Value Function on the Endogenous Grid for Assets

Given the saved pairs of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ and $(i, h, \epsilon_e, \epsilon_n)$, I compute the corresponding current assets a. Due to the non-linear progressive tax and insurance subsidies, for each pair of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ and for each $(i, h, \epsilon_e, \epsilon_n)$, I find the corresponding assets a by using the Newton-Raphson method. Then I obtain the pairs of $(a(a_k^{'}\mathbf{s}^{'}, \mathbf{h_c}, \mathbf{i}, \mathbf{h}, \epsilon_{\mathbf{e}}, \epsilon_{\mathbf{n}}), \mathbf{a^k})$. Note that these pairs correspond to global solutions, as the saved pairs of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ implies the global solutions.

G.8 Interpolating the Value Function on the Endogenous Grid for Assets

Given the saved pairs of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ and $(i, h, \epsilon_e, \epsilon_n)$, I compute the corresponding current assets a. Due to the non-linear progressive tax and insurance subsidies, for each pair of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ and for each $(i, h, \epsilon_e, \epsilon_n)$, I find the corresponding assets a by using the Newton-Raphson method. Then, for each state, $(\mathbf{s}_p^{'}, i, h, \epsilon_e, \epsilon_n)$, I obtain the pairs of $(a(a_k^{'}, \mathbf{s}_p^{'}, i, h, \epsilon_e, \epsilon_n), a^{'})$. Note that these pairs correspond to global solutions, as the saved pairs of $(a_k^{'}, O(a_k^{'}, \mathbf{s}_p^{'}, h_c))$ implies the global solutions.

G.9 Evaluating the Value Function over the Exogenous Grid for the Current Assets

Since the value function $\tilde{v}^{G,N}$ and decision rule $g^{G,N}$ preserve the monotonicity with the current asset a, it is possible to interpolate the value on the exogenous grid for assets G_a. For each state $(\mathbf{s}_p^{'}, i, h, \epsilon_e, \epsilon_n)$, using a linear interpolation, I find a_0 such that $a_0 = a(a^{'} = 0, \mathbf{s}_p^{'}, i, h, \epsilon_e, \epsilon_n)$.

If the value of grid $a_i \in G_a$ is above a_0, I use a linear interpolation to compute the value function of $\tilde{v}^{G,N}$ and $g^{G,N}$ on the exogenous grid of the current assets G_a. If $a_i \in G_a$ is lower than a_0, I use the grid search method.

G.10 Optimize the discrete choices

Until this step, the choice of health insurance $i^{'}$ and health capital $h^{'}$ are given statuses. Optimize these two choices by searching the grid for each variable. The number of grid points for these variables is relatively smaller than that of grid points on asset a. Therefore, the computation is not so costly in this procedure. Formally, solve the following problems:

$$v^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega, j) = \max_{\{i^{'}, h^{'}\}} \tilde{v}^{G,N}(a, i^{'}, h^{'}, i, h, \epsilon_e, \epsilon_n, \eta, \omega, j)$$

G.11 Interpolating the Value Function on the Grid for Assets

Given a state $\mathrm{s}_p^{'}$ and $(i, h, \epsilon_e, \epsilon_n)$, since the level of assets a has a monotonic relation with cash on hand O, it is possible to interpolate the value function $\tilde{v}^{G,N}$ and decision rule $g^{G,N}$ over the exogenous grid of cash on hand G_O into the grid for assets G_a. Due to the non-linear progressive tax and insurance subsidies, for each state $\mathrm{s}_p^{'}$ and $(i, h, \epsilon_e, \epsilon_n)$, and for each grid point of the cash on hand $O_k \in G_O$, I find the corresponding assets a by using the Newton-Raphson method.

Next, using a linear interpolation, for each state $\mathrm{s}_p^{'}$ and $(i, h, \epsilon_e, \epsilon_n)$, I evaluate the value function $\tilde{v}^{G,N}$ and decision rule $g^{G,N}$ on the grid for the current assets G_a.

G.12 Optimize the discrete choices

Until this step, the choice of health insurance $i^{'}$ and health capital $h^{'}$ are given statuses. Optimize these two choices by searching the grid for each variable. The number of grid points for these variables is relatively smaller than that of grid points on asset a. Therefore, the computation is not so costly in this procedure. Formally, solve the following problems:

$$v^{G,N}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega, j) = \max_{\{i^{'}, h^{'}\}} \tilde{v}^{G,N}(a, i^{'}, h^{'}, i, h, \epsilon_e, \epsilon_n, \eta, \omega, j)$$

G.13 Solving the Other Values

I use the grid search method to solve defaulting values $v^{G,D}$ and $v^{B,D}$, because they do not an intertemporal choice on assets and the number of grid points over health insurance i and health status h is relatively small.

For values of retired households $v^{G,r}$ and $v^{B,r}$ and values of non-defaulting households with a bad credit history $v^{B,N}$, I apply the endogenous grid method of Fella (2014). It is almost the same as the previous steps other than G.2, as there is no unsecured debt in these problems. The lower bounds of feasible solution set are given by zero assets ($v^{B,N}$, $v^{B,r}$) or the natural borrowing limit ($v^{G,r}$). Precisely, with the predetermined borrowing limits, I take the steps of Section G.1 and Section G.3- Section G.11.

G.14 Updating the Expected Value Functions and Loan Price Schedules for age $j-1$

First, I update the value functions $V^G(\mathbf{s})$ and $V^B(\mathbf{s})$.

$$\begin{aligned} V^G(\mathbf{s}) &= \max\{v^{G,N}(\mathbf{s}), v^{G,D}(\mathbf{s_{-a}})\} \\ V^B(\mathbf{s}) &= \max\{v^{G,N}(\mathbf{s}), v^{G,D}(\mathbf{s_{-a}})\} \end{aligned} \tag{44}$$

Second, I update the expected value functions $W^G(\mathbf{s}_p^{'}, h_c)$ and $W^B(\mathbf{s}_p^{'}, h_c)$ for age $j-1$ and age group j_g.

$$\begin{aligned} W^G(a^{'}, i^{'}, h^{'}, \eta, j, h_c) &= \pi_{j|j-1}(h_c, j_g) \sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \pi_{\eta^{'}|\eta} \pi_{\omega^{'}|\eta^{'}} V^G(a^{'}, i^{'}, h^{'}, \eta_e^{'}, \eta_n^{'}, \eta^{'}, \omega^{'}, j) \\ W^B(a^{'}, i^{'}, h^{'}, \eta, j, h_c) &= \pi_{j|j-1}(h_c, j_g) \sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \pi_{\eta^{'}|\eta} \pi_{\omega^{'}|\eta^{'}} V^B(a^{'}, i^{'}, h^{'}, \eta_e^{'}, \eta_n^{'}, \eta^{'}, \omega^{'}, j) \end{aligned} \tag{45}$$

Lastly, the loan price function $q(a^{'}, i^{'}, h^{'};, j-1, \eta)$ is updated in the following way:

$$d(a^{'}, i^{'}, h^{'}; j-1, \eta) = \sum_{\epsilon_n^{'}, \epsilon_e^{'}, \eta^{'}, \omega^{'}} \pi_{\epsilon_e^{'}|h^{'}} \pi_{\epsilon_n^{'}|h^{'}} \pi_{\eta^{'}|\eta} \pi_{\omega^{'}|\eta^{'}} \mathbb{1}_{\{v^{G,N}(a^{'}, i^{'}, h^{'}, \epsilon_e^{'}, \epsilon_n^{'}, \eta^{'}, \omega^{'}, j) \leq v^{G,D}(i^{'}, h^{'}, \epsilon_e^{'}, \epsilon_n^{'}, \eta^{'}, \omega^{'}, j)\}}$$

$$q(a^{'}, i^{'}, h^{'}; j-1, \eta) = \frac{1 - d(a^{'}, i^{'}, h^{'}; j, \eta)}{1 + r^{rf}}$$

where $d(a^{'}, i^{'}, h^{'}; j-1, \eta)$ is the expected default probability with state $(a^{'}, i^{'}, h^{'}; j-1, \eta)$.

I repeatedly take these steps (G.1 - G.10) until the initial age.

Appendix H Offer Rate of Employer-Based Health Insurance

Table 16: Offer Rate of Employer-Based Health Insurance

	Age			
Earnings PCT	23-34	35-46	47-55	56-64
0-2.9	0.413	0.365	0.368	0.399
2.9-6.6	0.449	0.487	0.428	0.43
6.6-12.3	0.322	0.386	0.4	0.376
12.3-20.5	0.352	0.437	0.514	0.494
20.5-31.1	0.376	0.597	0.669	0.633
31.1-43.5	0.511	0.744	0.793	0.747
43.5-56.5	0.673	0.834	0.845	0.789
56.5-68.9	0.791	0.89	0.878	0.82
68.9-79.5	0.846	0.91	0.899	0.847
79.5-87.7	0.884	0.912	0.902	0.855
87.7-93.4	0.916	0.918	0.9	0.859
93.4-97.1	0.912	0.887	0.876	0.813
97.1-100	0.884	0.912	0.913	0.854

Source: author's calculation based on the MEPS 2000-2011

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