Macroeconomic Implications of the Affordable Care Act in an Economy with Endogenous Health and Consumer Bankruptcy  
(Job Market Paper)  

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Abstract  
I quantitatively explore the macroeconomic and welfare consequences of the Affordable Care Act (ACA), and examine the role of consumer bankruptcy in predicting its welfare implication. I develop a life cycle general equilibrium model in which individuals invest in their health capital. They experience stochastic emergency and non-emergency medical events, the distributions of which depend on individual health capital. The asset market is incomplete, and individual bankruptcy decisions are endogenous in order to capture interactions between income and health. My model replicates various untargeted moments of data in the Medical Expenditure Panel Survey (MEPS): (i) The poor more frequently visit emergency rooms, compared to the rich, and this gap is disproportionately larger for working age individuals; (ii) The gap in medical conditions between the poor and the rich is substantially amplified over the life cycle; (iii) The poor spend more on healthcare in middle and later life, but the rich pay higher medical expenditures in early life. Using the model economy, I find that the ACA improves welfare by 0.85 percent of the average consumption. The ACA enhances average health status in the economy, which not only improves welfare directly, but also indirectly through lower earnings and consumption inequality. Despite these positive welfare gains, the model predicts that the ACA increases average bankruptcy rates. While medical bankruptcies for the old fall, non-medical bankruptcies for the young and poor rise due to an increase in the costs of borrowing in general equilibrium.  

JEL Classification: E21,H51,I13,K35.  
Keywords: Income Inequality, Health Capital, Consumer Bankruptcy, General Equilibrium, Affordable Care Act.  

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1 Introduction

Health care is an important component of the macroeconomy in the U.S.\(^1\) At the same time, medical costs are considered to be one of the largest financial burdens for people. This has led researchers to investigate the responses of consumer bankruptcy for medical bills.\(^2\) The goals of this paper are (i) to quantitatively investigate the macroeconomic and welfare consequences of the ACA, and (ii) to examine the role of bankruptcy rates in predicting its welfare implication.

I construct a life cycle general equilibrium model that builds on the standard health capital framework of Grossman (1972) as well as the consumer bankruptcy framework used in Chatterjee et al. (2007) and Livshits et al. (2007). This general equilibrium model allows me to examine the interaction between changes in relative prices and household decisions. I find that this interaction is important in studying the effects of the ACA and assessing their welfare implications, as this national policy can have significant effects on individual decisions through price channels. In addition, my model extends the standard health capital model by separating emergency medical events and non-emergency medical events. Individuals cannot adjust the amount of emergency medical expenditures, but they can choose the amount of non-emergency medical expenditures.\(^3\) These medical events, or health shocks, decrease the stock of health capital, which results in a reduction in utility and labor productivity. Moreover, the distributions of emergency and non-emergency health shocks are functions of individual health capital. Those who have better health have a lower probability of emergency medical events and severe medical conditions.

A novel feature of my model is that health capital is endogenously affected by the financial status of individuals through non-emergency medical expenditures and health insurance. In other words, individuals decide the amount of their medical spending and whether to purchase health insurance or not, in addition to standard consumption-savings decisions. Further, individuals are allowed to borrow to finance health-related expenditures and default on debt. This setting allows me to capture the interaction between income inequality and health inequality. To the best of my knowledge, mine is the first paper to analyze the effects of a health care reform in a standard incomplete markets model that incorporates both endogenous health capital and endogenous consumer

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\(^1\)In 2014, it constituted 17 percent of GDP, and accounted for the second largest component (21 percent) of government spending.

\(^2\)These studies have shown that medical expenditures are one of the major sources of consumer bankruptcy (Sullivan et al. (2001); Fay et al. (2002); Himmelstein et al. (2009); Austin (2014)), and have emphasized the positive effects of health care reforms on household bankruptcy (Gross and Notowidigdo (2011); Mazumder and Miller (2014); Dobkin et al. (2016); Hu et al. (2016)). A key feature of the recent Affordable Care Act (ACA) is that it is a health care reform at the national level, compared to the reforms that are either specific to certain income and age groups (e.g., the State Children’s Health Insurance Program) or specific to certain regions (e.g. Oregon health insurance experiment and Massachusetts health care reform), most of which are the basis of the above studies.

\(^3\)This setting is based on the fact that hospitals can check the financial ability of non-emergency patients before providing non-emergency medical treatment, but they cannot take this financial screening step before providing emergency medical treatments due to regulations in the Emergency Medical Treatment and Labor Act (EMTALA).
I calibrate the model to the U.S. economy prior to the ACA using micro and macro data. I show that my model replicates various untargeted moments on health insurance, health inequality, and bankruptcy. In particular, this model successfully reproduces differences in emergency room visits, medical conditions, and medical expenditures between low and high income individuals, as found in the Medical Expenditure Panel Survey (MEPS). The MEPS reveals two new facts and one fact that has been previously documented in the literature. The first is that although low income individuals visit emergency rooms more often than high income individuals over the life cycle, this gap is substantially larger for working-age individuals. Second, in terms of medical conditions, there is no large difference between low income individuals and high income individuals in early life, but the gap appears when individuals start working and increases thereafter. Lastly, as noted by Ozkan (2014), the data shows that the rich spend more on healthcare than the poor in early life, while the poor spend more on healthcare in middle and later life. My model replicates these patterns found in the data. The distributions of health shocks, which vary with individual health capital, are important in driving its quantitative success. Without this setting, the model cannot capture the heterogeneity in emergency room visits and medical conditions. In addition, when their health capital-dependent distributions are removed, the rich spend more on health care over their whole life cycle, which is inconsistent with data.

Using the model economy, I examine the following four components of the ACA: (i) Medicaid expansion; (ii) progressive subsidies for individual health insurance; (iii) individual health insurance market reforms; and (iv) insurance mandate with a penalty. The first main finding is that the ACA improves welfare by 0.85 percent. Two channels work behind this improvement in welfare. First, there is a direct effect of improvements in health status. Expansions in health insurance make it possible for young and poor individuals to spend more on healthcare, compared to the benchmark economy. It causes improvements in health for younger and poorer individuals. Due to the health capital dependent distributions of health shocks, the effect of spending on healthcare in early life is amplified over the life cycle. Therefore, a small increase in medical expenditures

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4The empirical facts are obtained from the main MEPS longitudinal files with two supplementary data: Emergency Room Visits and Medical Condition. By merging this data, I keep track of emergency bases room visits, medical conditions, and medical expenditures for individuals with different incomes.

5To analyze medical conditions across income groups, I construct a quantity measure for medical conditions by following the method in Prados (2012). Similarly, I use the morbidity measures of the World Health Organization (WHO) that quantify the degree of disability for each disease. With the supplement of Medical Condition in the MEPS, I construct the medical conditions measure at individual levels. An appealing feature of this strategy is that this measure can be directly mapped into health capital models, as the degree of disability can be interpreted as the depreciation of health capital from health shocks.

6This welfare gain is measured by the average of the percentage increase in consumption each household would be willing to pay in all future periods and contingencies so that the expected utility from the current period in the initial steady state equals that of the equilibrium associated with the ACA.
in early life both improves average health status and reduces inequality of health status. The other channel behind improvements in welfare come through reduced inequality of earnings and consumption. Since earnings are also partially determined by health, expansions in health insurance from the ACA raise the incomes of the poor, which, in turn, leads to improvements in earnings inequality over the life cycle. These improvements give rise to a reduction in consumption inequality.

A striking finding is that, although the ACA improves welfare, it actually increases the average bankruptcy rates. A key to understanding this result is to note that the default rate responds differently across age groups due to general equilibrium effects that lead to a reduction in precautionary savings motives and an increase in distortionary taxes required to fund the expansions in health insurance. There are two driving forces behind this result. First, low income individuals reduce precautionary savings, driven by the possibility of health shocks, as their health insurance coverage rises. Second, increases in income tax rates raise taxes on high income households and reduce their returns on capital. The reduction in the aggregate capital stock increases the risk-free interest rate, which raises the cost of borrowing through equilibrium loan rate schedules consistent with the default risk. This has a disproportionate impact on younger generations. For the young, shocks on earnings are more burdensome than health shocks. Since they have relatively lower earnings and did not have enough time to accumulate savings, the young are more likely to access financial markets to borrow against future earnings. However, they pay more in interest, resulting in higher default rates. On average, older generations suffer less from this increase in the cost of borrowing, as they have accumulated assets over time. In addition, health is relatively more important for older generations than for younger ones. The prevalence of health insurance lessens the financial burden for poor and old households and it reduces the default rate for old households. In other words, in terms of reasons for bankruptcy, although the ACA reduces medical bankruptcies, it increases bankruptcy from income shocks due to this general equilibrium effect. As these forces offset each other, the average default rates may not decline with the ACA. This result implies that the benefits younger generations enjoy, directly indirectly, through better health, are greater than the losses incurred from the rising cost of borrowing driven by an increase in the risk-free interest rate. Importantly, the bankruptcy rate alone may not be sufficient in predicting the welfare implications of the ACA.

The organization of the paper is as follows. Section 2 briefly reviews the literature related to my work. Section 3 documents stylized facts on emergency room usages, medical conditions, and medical expenditures across income groups. Section 4 and 5 explain the institutional background, economic environments, model solution, and calibration. Section 6 describes the result and section 7 concludes this paper.
2 Related Literature

My work is a part of the literature that endogenizes individual health status. The seminal work is that of Grossman (1972), which provides a theoretical framework for investment in health. His health capital framework has been widely used in various health relevant studies. Following this framework, Halliday et al. (2009) study life cycle features in health investment. Hall and Jones (2007) use the endogenous health framework to account for why medical expenditures in the U.S. have increased over time. Yogo (2016) uses the health capital model to explain key facts on asset allocation across bonds, stock, and housing. He combines the portfolio choice problems with the health capital framework, and finds that the endogenous health capital technology helps to account for the key empirical facts on asset allocation.7

My work is in line with literature that investigates the relationship between economic inequality and health. Deaton (2003) investigates the relationship of inequalities in health and income. He finds that although health directly affects income, the direct opposite channel is not clear. However, Deaton (2003) claims that income can indirectly affect health through institutional channels such as health insurance policy and education. Prados (2012) studies the relationship between the payment of medical expenditures and the inequality of earnings over the life cycle. She shows that feedback from health to income account for a large portion of earnings inequality. Ales et al. (2012) study the efficient allocation of health resources across different income groups. Ozkan (2014) studies differences in health care usage and the evolution of health between high and low income individuals. Using the data from the MEPS, he finds that the rich spend more than the poor on medical treatment early in their lives, while the poor spend more than the rich later in life. Ozkan (2014) shows that preventative health treatments can account for these stylized facts. In particular, my work is closely related to his study, in the sense that he endogenizes the distribution of health shocks and investigates its implication on welfare.

There are empirical studies that address the relationship between health insurance policies and household financial well-being. Dobkin et al. (2016) find that for uninsured working-age individuals, the unpaid medical bills have influences on their credit status and bankruptcy. Mahoney (2015) studies the effects of the financial cost of bankruptcy on health insurance choices. He shows that those who have a higher cost of bankruptcy are more likely to buy health insurance. Gross and Notowidigdo (2011) investigates the effect of the expansion of Medicaid on consumer bankruptcy, and finds that it has decreased the probability of bankruptcy. Mazumder and Miller (2014) find

7My paper is also related to the literature on household bankruptcy. In household studies, Fay et al. (2002) use the Panel Study of Income Dynamics (PSID) and show that households strategically file for bankruptcy. Chatterjee et al. (2007) conduct a policy experiment to investigate the effect of the change in the Chapter 7 bankruptcy law. Livshits et al. (2007) investigate how differences in bankruptcy law affect consumption smoothing behavior between the U.S. and European countries. Athreya (2008) investigates the relationship between social insurance and default policies over the life cycle.
that the Massachusetts health reform improved financial conditions across households. Hu et al. (2016) find that Medicaid expansions under the Affordable Care Act generally improve financial well-beings for low income households, while the expansions do not have significant impact on household bankruptcy.

My work is relevant to papers that take structural approaches to analyze the implications of the health insurance policies. Hansen et al. (2014) examine the welfare consequences of Medicare Buy-in program that allows those aged 55 - 64 to buy Medicare. Attanasio et al. (2010) examine macroeconomic and welfare implications of alternative Medicare financial schemes to treat problems in the U.S. that come from aging and the huge rise in medical expenditures. Cole et al. (2012) study a trade between short-run benefits from generous health insurance policies and long-run efforts in health investment such as smoking and exercise.

Among these studies with structural approaches, my work is closely related to literature on the Affordable Care Act (ACA). Nakajima and Tuzemen (2015) investigate labor market implications of the ACA. Pashchenko and Porapakkarm (2013) investigate welfare implications of the ACA. They focus on two key components in the ACA: a regulation of individual health insurance market and an increase in income redistribution. The authors find that a major source of welfare improvement of the ACA comes from the redistribution effect. Kuklik (2010) adds the margin of household bankruptcy to the model of Pashchenko and Porapakkarm (2013). He find that similar welfare implications as Pashchenko and Porapakkarm (2013), and that the ACA does not have large impacts on the aggregate households bankruptcy rate.

Pashchenko and Porapakkarm (2013) and Kuklik (2010) address the similar topic, but the mechanism of my model is significantly different. My allowing for endogenous health drives this difference. In Pashchenko and Porapakkarm (2013) and Kuklik (2010), expansions in health do not cause changes in aggregate variables such as capital stock, the risk-free interest rate, and output. In this work, health capital substitutes for physical capital and there are redistributive effects following an expansion in health insurance. In addition to aggregate results, the sources of improvement in welfare are different. In Pashchenko and Porapakkarm (2013) and Kuklik (2010), a major part of welfare improvement is caused by additional income from larger subsidies for low income households. Health care redistributes income from high-income to low-and middle income households through these subsidies and Medicaid. As health is exogenous in his model, consumption alone determines welfare. Expansions in health make it possible for low income households to consume more as their medical costs from health shocks are subsidized, which is the main driving force behind welfare improvements in their works. Conversely, in my model, enhancements in health for low income individuals drive welfare improvements. These welfare improvements are achieved through the following life cycle dynamics. Expanding health insurance improves health for some poor and young households. One resulting effect is that the levels of incomes in middle
age increase, as their labor productivity improves, and this raises consumption. The other effect is to improve health itself, which improves welfare in my model.

In terms of model mechanism, Jung and Tran (2016) is most related to my work. As in Pashchenko and Porapakkarm (2013), they investigate the welfare implications of the ACA with two additional model components: general equilibrium and endogenous health capital. However, they do not address household bankruptcy. In addition, in his work, the distribution of health shocks is the same within each age cohort. Thus, his framework does not capture heterogeneities in health shocks and medical expenditures across individuals with different incomes in data. Contrary to my result, Jung and Tran (2016) predict that welfare declines with a general equilibrium effect.

In contrast to the literature above, my model jointly features household bankruptcy and endogenous health. Although medical expenditures are an important cause of household bankruptcy, previous studies have usually focused on either household bankruptcy or endogenous decisions on medical expenditures, but not both. In addition, even with endogenous health, most previous studies do not address how health insurance policies endogenously form the distribution of health shocks, which is important in evaluating the efficiency of health care reforms. My work can jointly analyze the interactions among these margins.

My work is also related to the literature that examines the role of medical expenditures in increasing precautionary savings by the old. Kotlikoff (1986) shows that the precautionary savings motive arising from possible medical expenditures accounts for a large part of aggregate savings. Hubbard et al. (1995) investigate the interaction between social insurance and precautionary savings. De Nardi et al. (2010) shows that the length and cost of medical treatment explain why higher income elderly have large levels of savings. Kopecky and Koreshkova (2014) examine the impact of saving motives from medical and nursing home expenses on aggregate savings. My work also explores changes in savings incentives of the elderly following expansions in health insurance. Importantly, I explore how changes in the savings of the old affect younger generations’ behavior.

My work also contributes to the literature on the endogenous grid method, originally developed by Carroll (2006). Barillas and Fernández-Villaverde (2007) extends it to models with endogenous labor supply. Fella (2014) extends the endogenous grid method for multiple discrete choices problems with exogenous borrowing constraints. The endogenous grid method I used to solve my model extends his work by allowing for default, nonlinear loan rate schedules as well as multiple discrete choices.

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8 Ozkan (2014) exceptionally endogenizes the distribution of health shocks via preventative medical treatments. However, he solves his model with a partial equilibrium and does not endogenize default decisions.
3 Stylized Facts

In this section, I demonstrate stylized facts on differences in emergency room usages, medical conditions, and medical expenditures across individuals with different incomes. In particular, I present how these three factors vary across income groups over the life cycle. In Section 3.1, I briefly describe the data source and how to construct variables related to the stylized facts. I document the stylized facts in Section 3.2.

3.1 Data and Variables Construction

I use data from the Medical Expenditure Panel Survey (MEPS). This data is representative for non-institutionalized population in the U.S. The survey period is annual, and each survey keeps track of respondents’ records for two consecutive years. The MEPS address a wide range of individual information on education, demographic features, and medical service usages. In particular, the MEPS details individual health related information. The MEPS contains individual information on medical conditions, emergency room usages, medical expenditures, insurance status, and the offer of employer-based health insurance. I choose the sample periods between 2000 and 2011 in order to define family units based on Health Insurance Eligibility Unit (HIEU). This identification variable is not available in the samples before 2000, although the survey starts from 1996.  

To construct family income, I follow the method in Ozkan (2014). I define family units based on the variable of Health Insurance Eligibility Unit (HIEU), and calculate the total family income by summing up the income of all members in each household. Based on the constructed family income, I denote income groups for age groups: 0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79, and 80+. Thus, given a same level of family income, family members with different ages can be included in different income groups. This makes it possible for individuals to be ranked in their age group’s bin.

For emergency room usages, I use the supplement of “Emergency Room Visit” in the MEPS. I combine this supplement into the main panel survey by using individual ID. For medical conditions, I use the supplement of “Medical Condition” in the MEPS. I combine the supplement into the main panel survey by using individual ID. The files of “Medical Condition” provide individual disease records. I quantify individual medical conditions via the morbidity measure (years lived with disability (YLD)) from the World Health Organization (WHO). This measure indicates the degree of disability across disease categories. However, the morbidity measure alone is not enough to quantify individual medical conditions, as many individuals are exposed to multiple medical conditions at the same time. To handle these problems, I follow the method in Prados

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9The details of data selection process are in Appendix A.
For each individual, I convert multiple medical conditions into a multiplication term of disability indices. This makes it possible to handle different types of diseases and multiple medical conditions at the same time. For medical expenditures, I convert their nominal values into the value of US dollar in 2000 with the CPI. \(^\text{10}\)

### 3.2 Facts on Emergency Room Visits, Medical Conditions, and Medical Expenditures

![Figure 1: Age Profile of the Fraction of Using Emergency Rooms](image)

I start by investigating an empirical fact on emergency room usages. Figure 1 shows the fraction of visiting emergency rooms between the top 20 percent income individuals and the bottom 20 percent income individuals over the life cycle. Although low income individuals are more likely to visit emergency rooms than high income individuals over the life cycle, the gap becomes disproportionately larger for working-age individuals. The ratio of the fraction in the top 20 percent income individuals to that in the bottom 20 income individuals is below 1.5 until 10s, but this ratio rapidly rises until 40s. It slowly decreases in 50s. From retirement periods, 60s, the difference of emergency room usages is getting smaller in later life.

Figure 2 indicates the life cycle profile of medical conditions transformed by health shocks between high income individuals and low income individuals. Between age 0 and 19, there is no such a big gap between low income individuals and high income individuals. Given the confidence

\(^{10}\)The details are in Appendix A.
interval at the 95 percent level, the gap of medical conditions in early life is not significant different. However, the gap in medical conditions appears around the beginning of working age period, the difference is getting larger until 50s. From retirement periods, 60s, the difference gets diminished and keeps declining until later life.

Figure 3 is the age profile of medical expenditures between low income individuals and high income individuals. I reconfirm the finding in Ozkan (2014). The poor spend more on health cares in middle and later life, while the rich spend more on health cares in early life. Until 10s, individuals in the bottom 20 percent income spend less on health cares than those in the top 20 percent income, but the medical spending of the bottom income quintile overtakes that of the top income quintile from age 20 and the gap increases until age 49. The difference starts to decline in 50s and keep decreasing in later life.

These stylized facts commonly share a hump shape of the ratio profiles between low income individuals and high income individuals. It implies that during periods of working, individuals face very different circumstances across income groups. To sum up, during childhood, the gaps are small across income groups, become larger while individuals are working, and are diminished again from retirement period and onward.

4 The Model Economy

The benchmark model is based on the US economy before the ACA. I start with an explanation of institutional background for health care and consumer bankruptcy. Then I present the
model environments and equilibrium.

4.1 Legal Environment

The model economy is based on two institutional features: Chapter 7 bankruptcy filing and the Emergency Medical Treatment and Labor Act (EMTALA).

I model default based on Non-Business Chapter 7 bankruptcy. The modeling strategy for default hugely rests on the work of Chatterjee et al. (2007). Individuals have two types of credit status: “good credit status” and “bad credit status”. "Good credit status" means that there is no bankruptcy on the credit record. "Bad credit status" implies that a bankruptcy is recorded for this individual on the credit record. These credit statuses determine the range of feasible actions of individuals in the financial market.

**Good credit status individuals**

- Individuals with good credit status can either save or borrow through unsecured debt.

- Individuals with good credit status also can default on their debt. In the period of filing for bankruptcy, these Individuals can neither save nor dissave. They have “bad credit status” next period.

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11 Chapter 7 covers 70% of household bankruptcies. The other type of household bankruptcy is Chapter 13, which I do not address Chapter 13 here. In addition, I do not consider business bankruptcies, as this paper focuses on non-entrepreneurs.
• If individuals with good credit status either have no debt or pay back their unsecured debt, they keep their "good credit status" for next period.

**Bad credit status individuals**

• Individuals with bad credit cannot borrow, but they can save assets.

• Individuals with bad credit status pay the cost of "bad credit status" as much as $\chi$ portion of their earnings for each period.

• Individuals with bad credit can default only on non-discretionary medical expenditures (emergency room medical expenditures), as borrowing was not allowed in the previous period. In this case, they preserve their "bad credit status" for next period.

• Unless they default, with an exogenous probability $\lambda$, the bad credit status is recovered to good credit status at the beginning of next period.  

I model household bankruptcies for medical reasons based on the EMTALA. Congress enacted the EMTALA in 1986 in order to prevent hospitals from dumping out patients with emergency conditions. The EMTALA requires hospitals with emergency departments to screen and treat an emergency medical condition, regardless patients’ ability to pay or their insurance status. The EMTALA forces hospitals to provide emergency medical treatment to patients on credit. Patients can default on the debt incurred.  

In the model, there are two types of medical expenditure. The first type of medical expenditure is emergency medical expenditures that are non-discretionary. This assumption is reasonable, as according to Holmes and Madans (2013), medical doctors working in emergency rooms said that 90 percent of emergency medical conditions are needed to treat in 15 minutes. The second one is non-emergency medical expenditure that is discretionary. I assume this discretion because hospitals can monitor patients’ financial abilities before providing non-emergency medical treatments. It is important to note that the EMTALA works only for emergency medical conditions.

The model has two types of debt. The first type of debt comes through financial intermediaries. This type of debt can be used all types of spending, including consumption, health insurance, emergency medical expenditures, and non-emergency medical expenditures. The other type of debt arises from the relationship between hospitals and households, without any financial intermediary. This debt incurs only for emergency medical treatments of which costs are non-discretionary. This type of debt exists due to the EMTALA that enforces hospitals to provide emergency medical treatments without monitoring the ability to repay medical bills before the treatment. These two types

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12 The value $1/\lambda$ is the average duration of bad credit status. In the US, it is ten years.

13 Holmes and Madans (2013) show that unpaid debts in emergency departments are composed of 6% of the total cost of hospitals. In addition 55% of US emergency care is uncompensated.
of debts are unsecured and they are subject to Chapter 7 bankruptcy.

4.2 Model

The economy is populated by a continuum of individuals in J overlapping generations. It is a triennial model. They are born with age 0, and start to work at age $J_w$, retire at age $J_r$. In each period, individuals at age $j$ face an exogenous survival probability up to live $j + 1$ conditional on living up to $j$, $\psi_{j+1,j}$. The model has an exogenous population growth rate, $n$. The composition of generations is stationary, in the sense that the relative size of cohorts is always the same. In addition, there are 8 age groups, $j_g$: 0-11, 11-23, 24-35, 36-44, 45-53, 54-62, 75+.

4.2.1 Health Technology

The model has two types of medical conditions: emergency medical condition and non-emergency medical condition. In the model, I represent them by using two types of health shocks: emergency health shocks, $\varepsilon_e$ and non-emergency health shocks, $\varepsilon_n$.

Emergency health shocks, $\varepsilon_e$, evolve as follows:

$$
\varepsilon_e = \begin{cases}
\varepsilon_{de} & \text{with probability } p_{de} \text{ conditional on } X_{er} = 1 \\
\varepsilon_{ne} & \text{with probability } 1 - p_{de} \text{ conditional on } X_{er} = 1 \\
0 & \text{with probability } P(X_{er} = 0)
\end{cases}
$$

(1)

where

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

$0 \leq \varepsilon_{ne} \leq \varepsilon_{de} \leq 1$

$h_e = (1 - \varepsilon_e)h$

$m_e(\varepsilon_e)$

where $\varepsilon_{de}$ are drastic emergency health shocks, $\varepsilon_{ne}$ are non-drastic emergency health shocks, $X_{er}$ is the random variable of emergency medical events. $h$ is the stock of health capital, $\kappa_e$ is the scale parameter for the probability function of emergency medical events, $\alpha_e$ the curvature parameter for the probability function of emergency medical events, and $A_{j_g}$ is the age effect parameter for the probability of emergency medical events. $h_e$ is the stock of health capital after the realization of emergency health shocks, and $m_e(\varepsilon_e)$ are emergency medical expenditures.
Individuals experience an emergency medical event, $X_{er} = 1$, with a probability of $(1 - h + \kappa_e)^{\alpha_e}/A_{jg}$. This probability function implies that given a age group $jg$, healthier individuals are less likely to visit emergency rooms. It means that the distribution of emergency health shocks is endogenous, as individual spending on non-emergency medical treatment endogenously determines health capital. Once an emergency medical event, $X_{er} = 1$, occurs, individuals experience either drastic emergency health shocks, $\epsilon_{de}$, or non-drastic emergency health shocks, $\epsilon_{ne}$. Then, they receive medical treatment in an emergency room, and their health capital is depreciated by $\epsilon_e h$ where $\epsilon_e \in \{\epsilon_{de}, \epsilon_{ne}\}$. Note that emergency medical treatments do not fully recover the health capital $h$. This assumption is because hospitals transfer patients to non-emergency rooms when these patients need to receive time-consuming recovery treatments. Here, I assume that emergency medical expenditure, $m_e(\epsilon_e)$ is non-discretionary, as the EMTALA makes emergency medical expenditures always being paid. Since emergency medical expenditure, $m_e(\epsilon_e)$ is non-discretionary, the amount of emergency medical expenditure is determined by types of emergency health shocks, which is represented by the function of $\epsilon_e$.

To model non-emergency medical conditions and treatments, I modify the health capital model of Grossman (1972). In the spirit of his work, health capital evolves as follows:

$$h' = (1 - \epsilon_e)(1 - \epsilon_n)h + \psi_{jg} m_n^{\phi_{jg}} = (1 - \epsilon_n)h_e + \psi_{jg} m_n^{\phi_{jg}}$$

(2)

where

$$\epsilon_n \sim \text{TN} \left( \mu = 0, \sigma = \frac{(1/h) - 1 + \kappa_n)^{\alpha_n}}{B_{jg}}, \min = 0, \max = 1 \right)$$

where $h$ is the stock of health capital, $\epsilon_e$ is emergency health shock, $\epsilon_n$ is non-emergency health shock. $\psi_{jg}$ is the efficiency of non-emergency health technology at age group $jg$, $\phi_{jg}$ is the curvature of non-emergency health technology at age group $jg$, $m_n$ is non-emergency medical expenditure. $h_e$ is the stock of health capital after receiving emergency medical treatments, and $\text{TN} \left( \mu, \sigma, a, b \right)$ is a truncated normal distribution in which the lower bound of its domain is $a$, the upper bound of its domain is $b$, and its original normal follows a mean of $\mu$ and a standard deviation of $\sigma$, respectively.

For individuals at age $j$, the health capital $h$ is predetermined and an emergency health shock $\epsilon_e$ and a non-emergency health shock $\epsilon_n$ are consequently realized at the beginning of the period. These two health shocks causes a depreciation of the stock of health, and the non-depreciated part of health capital, $(1 - \epsilon_e)(1 - \epsilon_n)h$, represents individual current health status. Individuals can choose the level of health capital for next period, $h'$, by using non-emergency medical expenditure, $m_n$. The distribution of non-emergency health shocks follow a truncated normal distribution,
$TN \left( \mu = 0, \sigma = \frac{\left(1/h\right)^{\kappa_n} \alpha_n}{B_j}, min = 0, max = 1 \right)$. Truncated normal distributions are proper to represent the distribution of health shocks in data sets. For example, a majority of young individuals do not experience health shocks, which represented by a truncated normal distribution with a small of $\sigma$. For old individuals, a sizable fraction of them suffer from health shocks, which can be represented by a truncated normal distribution with a large value of $\sigma$. The average and the standard deviation of $\varepsilon_n$ increase with $\sigma$. More importantly, this scale parameter $\sigma$ is the function of the level of health capital, $h$, and age, $j$. The scale parameter $\sigma = \left(\frac{1}{h} - 1 + \kappa_n\right)^{\alpha_n} / B_j$, implies that given an age group $j_g$, those who have a higher level of health capital are less likely to face health shocks and face less serious health shocks. Since spending on non-emergency medical expenditure determines health capital, the distribution of non-emergency health shocks is endogenous.

There are three important features in this health technology. First, while the amount of emergency health expenditure is determined by the types of emergency health shocks, households can choose the amount of non-emergency medical expenditures $m_n$ that determines the level of non-emergency medical treatments. Second, the recovery after emergency medical treatments depends on non-emergency expenditure. For example, if someone is poor and face an emergency medical health shock, he will receive emergency medical treatments regardless whether he can pay for. However, this patient may not obtain enough recovery treatments due to his tighter budget constraint, as recovery treatments are included in non-emergency medical treatments. The third feature is that the timing assumption of the health capital is different from that used in other models to prevent rich individuals from always maintaining the best health levels. If health status were fully deterministic, the model would generate unrealistic health profiles that keep the implied health level highest for the very wealthy over the life cycle. The timing assumption used here avoids such unrealistic health status profiles.

### 4.2.2 Preferences

Preferences are represented by an isoelastic utility function over an aggregate that is itself a Cobb-Douglas utility function over consumption $c$ and a current health status term $h_c = (1 - \varepsilon_e)(1 - \varepsilon_n)h$,

$$u(c, h_c) = \frac{\left(c^\alpha h_c^{1-\alpha}\right)^{1-\sigma}}{1 - \sigma} \quad \text{where} \quad h_c = (1 - \varepsilon_e)(1 - \varepsilon_n)h$$

where $\alpha$ is the weight on consumption, and $\sigma$ is the coefficient of relative risk aversion.
4.2.3 Labor Income

Labor income $y_l$ is comprised to the four terms: the aggregate market wage $w$, a deterministic age term $\varpi_j$, a current health status term $h_c = (1 - \varepsilon_e)(1 - \varepsilon_n)h$ and an idiosyncratic productivity shock $\eta$. The idiosyncratic productivity shock is composed of two part, a persistent shock $e$, and a transitory shock $v$.

\[
\log(y_l) = \log(w) + \log(\varpi_j) + \log(h_c) + \log(\eta) \\
\log \eta = e + v \\
e' = \rho_e e + \varepsilon, \varepsilon \sim N(0, \sigma_e^2) \\
v \sim N(0, \sigma_v^2) \\
h_c = (1 - \varepsilon_e)(1 - \varepsilon_{h,j})h
\] (4)

Note that labor income is partially endogenous, because the level of health capital, $h$, is endogenously determined. This setting is consistent with findings in empirical studies.\(^{17}\)

4.2.4 Financial Market

There are competitive financial intermediaries and loans are defined by each individual state. It implies that with the law of large numbers, ex post realized profits of lenders are zero for each type of loans. The lenders can observe the state of each borrower and the price of loans is determined, using individual default probabilities and the risk-free interest rate. Denote $d(a', i', h'; j, e)$ as the default probability of households with a total debt, $a'$, insurance purchase status, $i'$, health capital for next period, $h'$, current age, $j$ and current earnings shock, $\eta$. Then, the loan price is

\[
q(a', i', h'; j, \eta) = \frac{\psi_{j,j+1}(1 - d(a', i', h'; j, \eta))}{1 + r_f} \\
\]
(5)

where $\psi_{j,j+1}$ is the probability of surviving up to age $j+1$ conditional on surviving up to $j$ and $r_f$ is the risk-free saving equilibrium interest rate.

\(^{15}\)I include age, the square of age and the cubic of age to control age.

\(^{16}\)I assume that health capital $h$, emergency health shock $\varepsilon_e$, non-emergency health shock $\varepsilon_n$ are not separately observable in the data, but the product of the three terms $(1 - \varepsilon_e)(1 - \varepsilon_{h,j})h$ is observed as health status in data sets.

\(^{17}\)Jones (2008) and Currie and Madrian (1999) review empirical evidence on the effect of health shocks on labor outcomes.
4.2.5 Health Insurance Plans

The health insurance plans in the benchmark model resemble the U.S. health insurance system prior to the Affordable Care Act (ACA). In terms of health insurance providers, there are two types of health insurances: public health insurances and private health insurances. The feasibility of these health insurances depends on individual states such as income and age.

Public Health Insurance

The model has two types of public health insurances: Medicaid and Medicare. Medicaid is a government insurance program for children and working age individuals in low income households. Medicaid is particularly more generous for children than adults.18 In the baseline model, both poor children and poor working age individuals can access Medicaid, while the eligibility criterion is stricter to working age individuals. Medicare is another type of government health insurance program for old individuals. In the baseline, all of the retired individuals use Medicare and do not access private insurance markets. After the realization of both emergency and non-emergency health shocks, households determine the total level of non-emergency medical expenditure, \( m_n \) and pay the total medical expenditure, \( m = m_n + m_e \). For Medicaid (Medicare) holders, insurance provides coverage \( q_d m (q_m m) \) and \((1 - q_d)m ((1 - q_d)m)\) becomes an out-of-pocket medical expenditure of an insured individual.

Private Health Insurance

The model has two types of private health insurances: employer-based health insurance and individual private health insurance. Employer-based health insurance is only available to those who have received the offer of it from their employers. The offer rate of employer-based health insurance tends to be higher in high salary jobs. Thus, I assume that the offer of employer-based health insurance is random and the probability of an offer rate increases with worker’s persistent idiosyncratic productivity, \( e \). Specifically, the probability of an offer of employer-based health insurance, \( es \), is given by \( p(es|e) \) where \( e \) is the persistent component of the idiosyncratic shock on earnings. In addition, \( p(es|e) \) increases with \( e \). Contrary to employer-based health insurance, any offer is not required to purchase Individual private health insurance. Individual private health insurance is available to any children and workers.

Employer-based health insurance has one unique premium, \( p_e \). This price is independent of any individual state, which reflects that in the U.S., the providers of employer-based health insurances cannot discriminate employees based on their preconditions due to the Health Insurance Portability and Accountability Act (HIPAA). In addition, a fraction \( \psi \in (0, 1) \) of the premium,  

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18The State Children’s Health Insurance Program (SCHIP) provides health insurance for children and pregnant women whose household income is below 133 percent of the federal poverty line. However, the SCHIP does not give benefit for working households without children. In the MEPS, from 2000 to 2010, 36 percent of individuals younger than 24 years old have benefit from Medicaid, while only 6 percent of individual between age 25 and age 64 use Medicaid.
Individual health insurance has premiums, \( p_i(h, j_g) \), where \( h \) and \( j_g \) are health capital and age group, respectively. This setting is to model that insurance health providers differentiate prices by using customers’ health record, age, and smoking.\(^{19}\) There are many private health insurance providers in both employer-based health insurance markets and individual private health insurance markets. Their premiums are competitively determined. Thus, for employer-based health insurance markets, the total revenue from all employer-based health insurance holders is the same as the total cost they pay. Similarly, in the private health insurance markets, the total revenue is equal to the cost in each group of health status, \( h_c \), age group, \( j_g \) sub-market.

Individuals need to make a decision on the purchase of private health insurances before both emergency and non-emergency health shocks are realized. After the realization of these health shocks, individuals determine the total level of non-emergency medical expenditure, \( m_n \) and spend the total medical expenditure, \( m = m_n + m_e \). For employer-based health insurance (individual health insurance) holders, insurance provides coverage \( q_e m (q_i m) \) and \((1 - q_e)m ((1 - q_i)m) \) becomes an out-of-pocket medical expenditure of an insured individual. Households without any health insurances have to pay all of their medical expenditure, \( m \), as an out-of-pocket medical expenditure.

**4.2.6 Tax System and Government Budget**

Taxes are levied from two sources: payroll and income. On the one hand, Social security, \( \Psi \), and Medicare, \( q_m \), are financed from payroll tax. \( \tau_{ss} \) is the payroll tax rate for Social security, \( \tau_{med} \) is that for Medicare. On the other hand, income tax covers the government expenditure, \( G \), social welfare program, \( \zeta \), Medicaid, \( q_d \), and the subsidy of employer-based health insurance, \( \psi p_e \). I choose the progressive tax function from Gouveia and Strauss (1994), as this has been widely used in the macroeconomic policy literature. The income tax function \( T(y) \) is given by

\[
T(y) = a_0 \{ y - (y^{a_1} + a_2)^{-1/a_1} \} + \tau_{y} y 
\]

where \( y \) is taxable income. \( a_0 \) means the upper bound of the progressive tax as income \( y \) goes infinite. \( a_1 \) determines the curvature of the progressive tax function, and \( a_2 \) is a scale parameter. To use Gouveia and Strauss (1994)’s 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 is 65% (OECD Revenue Statistics 2002). \( \tau_{y} \) is chosen to balance the total government budget.

\(^{19}\)This is based on the health insurance system before ACA. The ACA prevents insurance providers from differentiating prices based on individual states. In the latter part of the paper, I will change this assumption to conduct the policy experiment of the ACA
4.2.7 Firm

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

$$\max_{K,N} F(K, N) - wN - rK$$  \hspace{1cm} (7)

where $K$ is the aggregate capital stock and $N$ is aggregate labor.

4.2.8 Overview of Household’s Decisions

Individuals experience three phases of the life cycle: childhood phase, working phase, and retirement phase. Decision making problems differ in each of the phases.

Childhood Phase

Decision problems for children are simplified. During childhood periods, individuals receive an exogenous endowment from their parents. The level of endowment is constant during childhood periods. Children use all of their endowment in each period, and saving is not allowed. At the beginning of period, emergency health shocks, $\varepsilon_e$, and non-emergency shocks, $\varepsilon_n$, are realized. If a child experiences an emergency medical condition, emergency medical treatments are conducted, and their cost $m_e$ incurs. Then, children choose consumption, $c$, health insurance for next period, $i'$, non-emergency medical expenditures, $m_n$, and the payment of out-of-pocket costs $(1 - q_i \mathbb{1}_i)(m_n + m_e)$ where $q_i$ is the coverage rate of insurance, $i$, and $\mathbb{1}_i$ is the indicator function for health insurance, $i$. The stock of health capital next period, $h'$ is determined by the law of motion, $h' = (1 - \varepsilon_e)(1 - \varepsilon_n)h + \psi_{jg} m_{n} g_{jg}$ for age group $jg$.

Working Phase

For working individuals, each period consists of two sub-periods. At the beginning of sub-period 1, working age individuals face emergency health shocks, $\varepsilon_e$, and non-emergency health shocks, $\varepsilon_n$. Then, the cost of emergency medical treatments, $m_e$ incurs. After these emergency medical treatments, idiosyncratic shocks on labor productivity, $\eta$ are realized, which determines the labor productivity with health shocks. Next, individuals choose whether to default.

In sub-period 2, the feasible choices differ with credit status and default decision in sub-period 2. I begin with problems with good credit. Non-defaulters with good credit choose consumption, $c$, savings or debt, $a'$, health insurance for next period, $i'$, non-emergency medical expenditures, $m_n$ and the payment of out-of-pocket costs $(1 q_i \mathbb{1}_i)(m_n + m_e)$ where $q_i$ is the coverage rate of insurance $i$ and $\mathbb{1}_i$ is the indicator function for health insurance $i$. They keep staying with the good credit status for next period. Defaulters with good credit can neither save nor dis-save, and they

\[^{20}\text{Note that emergency medical expenditure is non-discretionary}\]
can choose consumption, $c$, health insurance for next period, $i'$, and non-emergency medical expenditures, $m_n$. Then, they pay out-of-pocket costs $(1 - q_i \mathbb{1}_i)m_n$ where $q_i$ is the coverage rate of insurance $i$ and $\mathbb{1}_i$ is the indicator function for health insurance $i$. Note that defaulter do not pay back not only their debt $a'$ but also emergency medical expenditures, $m_e$, as both are included in unsecured debts. Their credit status changes to bad credit status for next period.

Working individuals with bad credit face the following problems. Non-defaulters with bad credit are not allowed to borrow and pay a pecuniary cost of bad credit status as much as a fraction $\chi$ of their earnings. The other decision making problems of them are the same as those of non-defaulters with good credit. They can choose consumption, $c$, savings, $a' \geq 0$, health insurance for next period, $i'$, non-emergency medical expenditures, $m_n$ and the payment of out-of-pocket costs $(q_i \mathbb{1}_i)(m_n + m_e)$ where $q_i$ is the coverage rate of insurance $i$ and $\mathbb{1}_i$ is the indicator function for health insurance $i$. With a probability of $\lambda$, non-defaulters with bad credit experience the recovery of their credit to good status. Defaulters with bad credit pay a pecuniary cost of bad credit status as much as a fraction $\chi$ of their earnings. They can neither save or dis-save, and they can choose consumption, $c$, health insurance for next period, $i'$, non-emergency medical expenditures, $m_n$ and the payment of out-of-pocket costs $(1 - q_i \mathbb{1}_i)m_n$ where $q_i$ is the coverage rate of insurance $i$ and $\mathbb{1}_i$ is the indicator function for health insurance $i$. Defaulters with bad credit also do not pay back emergency medical expenditures, $m_e$, as they are unsecured debts. They keep staying with their bad credit status for next period.

**Retirement Phase**

Retired individuals do not have any labor income but receive social security benefit, $ss$, for each period. It is not possible for them to borrow, but they can save. I abstract from their decisions on private health insurance. All retired individuals have Medicare and do not use any private health insurance. At the beginning of period, retired individuals face non-emergency health shocks, $\varepsilon_e$ and non-emergency health shocks, $\varepsilon_n$. Then, emergency medical costs, $m_e$, incur. Retired individuals make decisions on consumption, $c$, savings, $a' \geq 0$, non-emergency medical expenditures, $m_n$ and pay out-of-pocket costs $(1 - q_m)(m_n + m_e)$ where $q_m$ is the coverage rate of Medicare.

**4.2.9 Household’s Dynamic Problem**

The individual optimal decision problems can be represented recursively. I begin with the problems of children. Their state is $(\bar{y}, i, h, \varepsilon_e, \varepsilon_n, \omega)$, where $\bar{y}$ is income, $i$ health insurance, $h$ is health capital, $\varepsilon_e$ is emergency health shocks, $\varepsilon_n$ is non-emergency health shocks, and $\omega$ is the offer of employer-based health insurance. $\bar{y}$ is determined when they are born. At the beginning of each period, emergency health shocks, $\varepsilon_e$, non-emergency health shocks, $\varepsilon_n$, and the employer-based

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21 They do not have any debt, $a'$ via financial sectors, as individuals with bad credit cannot borrow regardless their default decision.
health insurance offer, \( \omega \), are realized. Let \( \psi_j^C(\bar{y}, i, h, e_e, e_n, \omega) \) denote the value function age \( j < J_w \) agent, where \( J_w \) is the starting age of working. Then, children solve

\[
\psi_j^C(\bar{y}, i, h, e_e, e_n, \omega) = \max_{\{c, i', h_c, m_n \geq 0\}} \left( \frac{c^\alpha h_c^{1-\alpha}}{1 - \sigma} \right)^{1-\sigma} + \beta \sum_{\bar{e}_n, \bar{\omega}'} \frac{c_{i', j+1} \pi_{\bar{e}_n|\bar{h}', j+1} \pi_{\bar{\omega}'|\bar{y}', j+1} \psi_{j+1}^C(\bar{y}', i', h', e_{e'}, e_{n'}, \omega')} {1 - \sigma} + \beta \sum_{\bar{e}_n, \bar{\omega}'} \frac{c_{i', j+1} \pi_{\bar{e}_n|\bar{h}', j+1} \pi_{\bar{\omega}'|\bar{y}', j+1} \psi_{j+1}^C(\bar{y}', i', h', e_{e'}, e_{n'}, \omega')} {1 - \sigma} \\
\]

\[
c = x - (1 - q_i(1 - 1_{\{i=NHI\}})) m_n - p(i', h_c, j_g)
\]

where

\[
x = \max \{c, \bar{y} + \kappa - (1 - q_i(1 - 1_{\{i=NHI\}})) m_e(e_e) - T(\bar{y}) - (\tau_{ss} + \tau_{med})\bar{y}\} \in \{NHI, MCD, IHI, EHI\}
\]

\[
h_c = (1 - e_n)(1 - e_e)h
\]

\[
h' = (1 - e_n)(1 - e_e)h + \phi_{j_g} m_n \psi_{j_g}
\]

where \( c \) is consumption, \( i' \) is health insurance for next period, \( m_n \) is non-emergency medical expenditure, and \( h_c \) is the current health status. \( \beta \) is the discount rate, \( \pi_{j, j+1} \) is the rate of surviving up to age \( j + 1 \) conditional on surviving up to age \( j \), and \( \pi_{\bar{e}_n|\bar{h}', j+1} \) is the probability of emergency health shock \( \bar{e}_n' \) for next period conditional on the stock of health capital \( h' \) at age \( j + 1 \). \( \pi_{\bar{\omega}'|\bar{y}', j+1} \) is the probability of non-emergency health shock \( \bar{\omega}' \) for next period conditional on the stock of health capital \( h' \) at age \( j + 1 \), and \( \pi_{\bar{\omega}'|\bar{y}', j+1} \) is the probability of receiving the employer-based health insurance offer for next period conditional on the income level \( \bar{y} \). \( q_i \) is the insurance coverage rate for health insurance, \( i \), and \( 1_{\{i=NHI\}} \) is the indicator function of not holding any health insurance. \( p(i', h_c, j_g) \) is the health insurance premium for \( i' \) conditional on the current health status, \( h_c \), and age group, \( j_g \), and \( x \) is cash on hand. \( c \) is the consumption floor, \( \kappa \) is accidental bequest, \( T(\cdot) \) is income tax, and \( \tau_{ss} \) and \( \tau_{med} \) are payroll taxes for Social security and Medicare, respectively. For the set of health insurance, \( i \), \( NHI \) means no health insurance, \( MCD \) is Medicaid, \( IHI \) is private individual health insurance, and \( EHI \) is employer-based health insurance. \( \phi_{j_g} \) and \( \psi_{j_g} \) are the efficiency of health technology for age group \( j_g \) individuals and the curvature of health technology for age group \( j_g \) individuals, respectively.

Individual choices are restricted by the cash on hand level, \( x \). Let denote the net income as the subtraction of out-of-pocket emergency medical costs, income tax, and payroll taxes for Social security and Medicare from the summation of income and accidental bequest, \( \bar{y} + \kappa - (1 - q_i(1 - 1_{\{i=NHI\}})) m_e(e_e) - T(\bar{y}) - (\tau_{ss} + \tau_{med})\bar{y} \). \(^{22}\) If this net income is greater than the consumption floor, \( c \), this net income becomes cash on hand. However, if the net income is lower than the consumption floor, \( c \), cash on hand, \( x \), is equal to the consumption floor, \( c \). For children, saving

\(^{22}\) Since endowment, \( \bar{y} \), is the only income for children, earnings is the same as income.
is not allowed and endowment, $\bar{y}$ is the only source of their income. Thus, given a level of cash on hand, $x$, children choose the composition among consumption, $c$, non-medical expenditure, $m_n$, and health insurance premium, $p(i', h_c, j_g)$.

$$i' \in \begin{cases} 
\{0, MCD, IHI, EHI\} & \text{if } \bar{y} \leq FPL133\% & \omega = 1 \\
\{0, MCD, IHI\} & \text{if } \bar{y} \leq FPL133\% & \omega = 0 \\
\{0, IHI, EHI\} & \text{if } \bar{y} > FPL133\% & \omega = 1 \\
\{0, IHI\} & \text{if } \bar{y} > FPL133\% & \omega = 0 
\end{cases}$$

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

(9)

The insurance coverage rate, $q_i$, is different across the types of health insurances, $i \in \{NHI, MCD, IHI, EHI\}$. If an individual has a health insurance $i \in \{MCD, IHI, EHI\}$, his health insurance company covers $q_i(m_n + m_e(\varepsilon_e))$ and the remaining cost, $(1 - q_i)(m_n + m_e(\varepsilon_e))$ becomes his out-of-pocket medical cost. If one does not have any health insurance, $i = NHI$, the whole medical cost, $m_n + m_e(\varepsilon_e)$, becomes his out-of-pocket medical cost. The feasible choice of health insurance for next period, $i'$, depends on the combination of children income level, $\bar{y}$, and the employer-based health insurance offer, $\omega$. If an individual’s income is lower than 133 percent of the Federal Poverty Line (FPL), they are eligible for Medicaid. To use employer-based health insurance, it is necessary to have the employer-based health insurance offer, $\omega$ from employers. If an individual has income more than 133 percent of the FPL and does not have any employer-based health insurance offer, individual private health insurance, $IHI$ is the only available choice. The employer-based health insurance offer and Medicaid eligibility are not exclusive one another, resulting in the above four possible combination of health insurance choice. The premiums of health insurances differ across health insurances. If an individual does not hold any health insurance, $i' = 0$, or has benefit from Medicaid, $i' = MCD$, he does not pay any premium. The price of individual private health insurance, $p_{IHI}(h_c, j_g)$ depends on a buyer’s current health status, $h_c$, and age group, $j_g$. Employer-based health insurance has a unique price, $p_{EHI}$, which means its price is independent of health insurance holders’ health status and age.

Individuals start working at age $J_w$ and continue working until age $J_r - 1$. The state of working individuals is $(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega)$ and $v \in \{G, B\}$, where $a$ is their level of asset, $i$ is health insur-

23Emergency medical expenditure, $m_e$, is not a choice variable, as it is non-discretionary.
ance, $h$ is health capital, $\epsilon_e$ is emergency health shocks, $\epsilon_n$ is non-emergency health shocks, and $\eta$ is idiosyncratic shocks on labor productivity. $v$ is credit status, where $G$ and $B$ mean good credit and bad credit, respectively. In sub-period 1, emergency health shocks, $\epsilon_e$, non-emergency health shocks, $\epsilon_n$, idiosyncratic earnings shocks, $\eta$, and the employer-based health insurance offer, $\omega$, are realized. Next, individuals decide whether to default. Let $V_j^G(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega)(V_j^B(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega))$ denote the value function of age $J_w \leq j < J_f$ agent with good (bad) credit in sub-period 1. They solve

$$V_j^G(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega) = \max \{v_j^{GN}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega), v_j^{GD}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)\}$$  \hspace{1cm} (10)

$$V_j^B(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega) = \max \{v_j^{BN}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega), v_j^{BD}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)\}$$  \hspace{1cm} (11)

where $v_j^{GN}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ and $v_j^{GD}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ are the value of non-defaulting with good credit (bad credit) and $v_j^{BN}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ and $v_j^{BD}(i, h, \epsilon_e, \epsilon_n, \eta, \omega)$ are the value of defaulting with good credit (bad credit).

In sub-period 2, non-defaulters with good credit solve

$$v_j^{GN}(a, i, h, \epsilon_e, \epsilon_n, \eta, \omega) = \max_{\{c, d', f, m_n \geq 0\}} \frac{(c^\alpha h^{1-\alpha})^{1-\sigma}}{1-\sigma} + \beta \pi_{j+1} \sum_{\epsilon_e', \epsilon_n', \eta', \omega'} \pi_{\epsilon_e|\epsilon_e'} \pi_{\epsilon_n|\epsilon_n'} \pi_{\eta|\eta'} \pi_{\omega|\omega'} V_{j+1}(a', i', h', \epsilon_e, \epsilon_n, \eta', \omega')$$

$$c + q(a', i', h'; j, \eta)a' + p(i, h, j, \gamma) = (1 - (\tau_{ss} + \tau_{med}))w \xi_j + a - (1 - q_i (1 - \mathbb{1}_{i=NHI}))(m_n + m_e(\epsilon_e)) - T(y) + \kappa$$

where

$$i \in \{NHI, MCD, IHI, EHI\}$$

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

$$h' = (1 - \epsilon_n)(1 - \epsilon_e) h + \phi_j m_n$$

$$y = w \xi_j + (\frac{1}{q^f} - 1)a \cdot 1_{a > 0}, \text{ where } \xi_j = \sigma_j h_c \eta$$

where $q(a', i', h'; j, \eta)$ is the loan price of individuals with future endogenous state, $(a', i', h')$, conditional on the current idiosyncratic labor productivity, $\eta$, and age $j$, $w$ is the market equilibrium wage, and $\xi_j$ is individuals efficient unit of labor at age $j$. A positive (negative) value of $a$ implies savings (debt). Working age individuals pay taxes based on payroll income, $w \xi_j$, and total income, $y$. $(\frac{1}{q^f} - 1)a \cdot 1_{a > 0}$ is capital income where $q^f$ is the risk-free bond price, $a$ is the level of asset at the current period, and $1_{a > 0}$ is the indicator function for savings. Individuals make decisions on whether to purchase health insurance for next period and pay a premium, $\tilde{p}(i, h, j, \gamma)$. Their
feasible choice of health insurance depends on the status of income and employer-based insurance offer. Decision making problems on health insurance for working-age individuals are very similar to those for children other than Medicaid eligibility. The criteria of Medicaid eligibility for Adults, $\bar{M}$ is much stricter than that for children. The eligibility depends on incomes and family structures. Since I abstract from family structures in the model, I calibrate to match the take-up ratio of Medicaid among working individuals in the MEPS.

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

Working age individuals access financial intermediary to borrow at prices that reflect their default risk. Afterward, working age individuals determine their level of consumption, $c$. It is worth noting that $m_n$, is discretionary but emergency medical expenditures, $m_e(\varepsilon_e)$ are non-discretionary. Therefore, whereas non-emergency medical expenditures, $m_n$ is a choice variable, emergency medical expenditures, $m_e(\varepsilon_e)$, are not included in the decision making problem.

In sub-period 2, defaulting individuals with good credit solve the following problem,

$$v_{j}^{G.D}(i, h, \varepsilon_c, \varepsilon_n, \eta, \omega) = \max_{\{c, i', m_n \geq 0\}} \frac{(c^\alpha h_c^{1-\alpha})^{\frac{1}{1-\sigma}}}{1-\sigma} + \beta \pi_{j, i, h, \varepsilon, \eta} \sum_{\varepsilon_c, \varepsilon_n, \eta, \omega} \pi_{\varepsilon_c', \varepsilon_n', \eta, \omega'} \pi_{\varepsilon_c, \varepsilon_n, \eta, \omega} \pi_{\varepsilon_e', \varepsilon_e, \eta} \pi_{\varepsilon_e, \varepsilon_e, \eta} V_{j+1}(0, i', h', \varepsilon_c', \varepsilon_n', \eta' , \omega')$$

$$c + p(i', h_c, j_g) = (1 - (\tau_{ss} + \tau_{med})w \zeta_j - (1 - q_i(1 - 1_{\{i=NHI\}}))m_n - Tax(y) + \kappa$$

where

$$i \in \{\text{NHI, MCD, IHI, EHI}\}$$

$$h_c = (1 - \varepsilon_n)(1 - \varepsilon_e)h$$

$$h'_c = (1 - \varepsilon_n)(1 - \varepsilon_e)h + \varphi_{j,g}m_n^{\psi_{j,g}}$$

$$y = w \zeta_j, \text{ where } \zeta_j = \sigma_j h_c$$

On their budget constraint, debts from the financial intermediaries, $a$, and emergency medical expenditures, $m_e(\varepsilon_e)$ 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 next period, $i'$, and non-emergency medical expenditure, $m_n$, while they can neither save nor dissave in this period.
Non-defaulters with bad credit solve

\[
v_{j}^{B,N}(a,i,h,e_{c},e_{n},\eta,\omega) = \max_{\{c,a' \geq 0,j,m_{n} \geq 0\}} \left( \frac{(c'a'h_{c}^{1-\alpha})^{1-\sigma}}{1-\sigma} + \beta \pi_{j+1} \sum_{e_{c}',e_{n}',\eta,\omega'} \pi_{e_{c}'}^{j+1} \pi_{e_{n}'}^{j+1} \pi_{\eta}^{j+1} \pi_{\omega'}^{j+1} \left[ \lambda V_{j+1}^{G}(a',i,h',e_{c}',e_{n}',\eta',\omega') + (1-\lambda) V_{j+1}^{B}(a',i,h',e_{c}',e_{n}',\eta',\omega') \right] \right)
\]

\[c + q' a' + p(i',h_{c},j_{R}) = (1 - (\tau_{ss} + \tau_{med})) (1 - \chi) w_{j} \eta + a - (1 - q(i,1 - \mathbb{I}_{i=NHI})) (m_{n} + m_{e}(e_{c})) - T(y) + \kappa \]

where

\[i \in \{NHI, MCD, IHI, EHI\} \]
\[h_{c} = (1 - e_{c})(1 - e_{c})h \]
\[h' = (1 - e_{n})(1 - e_{c})h + \phi_{j} m_{n}^{j} \]
\[y = (1 - \chi) w_{j} \eta + (1 - \frac{1}{q} - 1 - a) \mathbb{I}_{a>0}, \text{ where } \eta_{j} = \mathbb{O}_{j} h_{c} \eta. \]

\(\lambda\) is the probability of recovering their credit status to be good, and \(\chi w_{j}\) is the pecuniary cost of staying with bad credit status. 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 cannot borrow but save. Second, they need to pay the pecuniary cost for their bad credit status as much as a fraction \(\chi\) of earnings, \(w_{j}\). The last difference is that the credit status for next period is not deterministic. With a probability of \(\lambda\), the credit status of non-defaulters with bad credit changes from bad credit to good credit, and they staying with bad credit with a probability of \(1 - \lambda\). This process reflects the exclusion penalty in Chapter 7 Bankruptcy of 10 years in the US.

Defaults with bad credit solve

\[
v_{j}^{B,D}(i,h,e_{c},e_{n},\eta,\omega) = \max_{\{c,i',m_{n} \geq 0\}} \left( \frac{(c'a'h_{c}^{1-\alpha})^{1-\sigma}}{1-\sigma} + \beta \pi_{j+1} \sum_{e_{c}',e_{n}',\eta,\omega'} \pi_{e_{c}'}^{j+1} \pi_{e_{n}'}^{j+1} \pi_{\eta}^{j+1} \pi_{\omega'}^{j+1} \left[ \lambda V_{j+1}^{G}(0,i',h',e_{c}',e_{n}',\eta',\omega') + (1-\lambda) V_{j+1}^{B}(0,i',h',e_{c}',e_{n}',\eta',\omega') \right] \right)
\]

\[c + p(i',h_{c},j_{R}) = (1 - (\tau_{ss} + \tau_{med})) (1 - \chi) w_{j} \eta + (1 - q(i,1 - \mathbb{I}_{i=NHI})) m_{n} - Tax(y) + \kappa \]

where

\[i \in \{NHI, MCD, IHI, EHI\} \]
\[h_{c} = (1 - e_{n})(1 - e_{c})h \]
\[h' = (1 - e_{n})(1 - e_{c})h + \phi_{j} m_{n}^{j} \]
\[y = w_{j} \eta, \text{ where } \eta_{j} = \mathbb{O}_{j} h_{c}. \]
The problem of defaulters with bad credit has two differences compared to those with good credit. First, defaulters with bad credit have to pay the pecuniary cost of staying bad credit as much as a fraction $\chi$ of their earnings, $w\zeta_j$. Second, they default only on emergency medical expenditures. For defaulters with bad credit, their previous status is either non-defaulter with bad credit or defaulters with bad credit. In both statuses, individuals cannot make any loan. Thus, all of the defaults are on emergency medical expenditures.

For age $j \leq J_r$, individuals solve

$$v_f^j(a, h, \varepsilon_e, \varepsilon_n) = \max_{\{c, m_n \geq 0, a' \geq 0\}} \left( \frac{c \alpha h^1}{1 - \sigma} + \beta \pi_j, j + 1 \right) \sum_{\varepsilon'_e, \varepsilon'_{n}} \pi_{\varepsilon'_e \varepsilon'_n | h', j + 1} v_{f}^j(a', h', \varepsilon'_e, \varepsilon'_n)$$

(16)

$$c + q^f a' = x - (1 - q_{med})m_n$$

where

$$x = \max\{c, a - (1 - q_{med})m_e(\varepsilon_e) + ss - Tax(y) - p_{med} + \kappa\}$$

$$h_c = (1 - \varepsilon_n)(1 - \varepsilon_e)h$$

$$h' = (1 - \varepsilon_n)(1 - \varepsilon_e)h + \phi_j m_{n,j}$$

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

where $x$ is cash on hands, $p_{med}$ is the Medicare premium, and $q_{med}$ is the Medicare coverage rate. I assume that retired workers do not access private health insurance markets. Retired households do not have labor income, but receive Social security benefit, $ss$, in each period. They can save assets, but they cannot borrow.

### 4.2.10 Hospital sector

For an individual with state $(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega)$ at age $j$, a hospital earns the following revenue.\(^{24}\)

$$m_{n,j}(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) + (1 - g_{d,j}(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega))m_e(\varepsilon_e) + g_{d,j}(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \max(a, 0)$$

(17)

where $m_{n,j}(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega)$ is the decision rule of non-emergency medical expenditure with individual state $(a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega)$ at age $j$. $m_e(\varepsilon_e)$ is emergency medical expenditures for emergency

\(^{24}\)Children and retired individuals always pay their emergency medical expenditure because of the consumption floor, $c$.\n
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health shocks $\varepsilon_e$, and $g_{d,j}(a,i,h,\varepsilon_e,\varepsilon_n,\eta,\omega)$ is the decision rule of default with individual state $(a,i,h,\varepsilon_e,\varepsilon_n,\eta,\omega)$ at age $j$. All individuals always pay non-emergency medical expenditures, $m_{n,j}$, regardless whether to default or not, as the hospital can check patients’ financial ability before providing non-emergency medical treatments. However, the payment amount for emergency medical treatments depends on individual default decisions. It is because the Emergency Medical Treatment and Labor Act (EMTALA) enforces hospitals to provide emergency medical treatments regardless whether the patients can pay back the emergency medical bills or not. 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. As Chatterjee et al. (2007) assume, the mark-up is adjusted to have zero profits in the equilibrium.\(^{25}\)

### 4.2.11 Equilibrium

I define a measure space to describe equilibrium. The state of individuals consists of assets, $a \in A$, health insurance status, $i \in I = \{NHI,MCD,HI1,EHI\}$, health capital stock, $h \in H = [0,1]$, emergency health shocks, $\varepsilon_e \in ER = [0,1]$, non-emergency health shock, $\varepsilon_n \in NER = [0,1]$, idiosyncratic shocks on earnings, $\eta \in E$, and the employer-based health insurance offer, $\omega \in O = \{0,1\}$. Denote $S = A \times I \times H \times ER \times NER \times E \times O$ as the state space of individuals. In addition, let $\mathcal{B}(S)$ denote the Borel $\sigma$-algebra on $S$. Then, for each age $j$, a probability measure $\mu_j$ is defined on the Borel $\sigma$-algebra $\mathcal{B}(S)$ such that $\mu_j : \mathcal{B}(S) \rightarrow [0,1]$. $\mu_j(B)$ represents the measure of age $j$ individuals whose state lies in $B \in \mathcal{B}(S)$ as a proportion of all age $j$. The individual distribution evolves as follows: For all $B \in \mathcal{B}(S)$,

$$\mu_{j+1}(B) = \int_{\{s|(a_{n,j}(s),g_{h,j}(s),\varepsilon_e,\varepsilon_n,\eta,\omega)\in B\}} \pi_{j+1|j}(\varepsilon_e,\varepsilon_n|g_{h,j}(s))Pr(\omega'|\eta',j+1)Pr(\eta'|\eta)\mu_j(ds)$$

(18)

, where $s = (a,i,h,\varepsilon_e,\varepsilon_n,\eta,\omega) \in S$ is the individual state, $g_{a,j}(\cdot)$ is the policy function for assets at age $j$, $g_{i,j}(\cdot)$ is the policy function for health insurance at age $j$, and $g_{h,j}(\cdot)$ is the policy function for health investment at age $j$. In addition, $\pi_{j+1|j}$ is the rate of surviving up to age $j+1$ conditional on surviving up to age $j$ and $Pr(\varepsilon_e',\varepsilon_n'|g_{h,j}(s),j+1)$ is the transition probability for $\varepsilon_e'$ and $\varepsilon_n'$ conditional on $g_{h,j}(s)$. $Pr(\omega'|\eta',j+1)$ is the probability of receiving an employer-based health insurance offer for next period conditional on $\eta'$ at age $j+1$, and $Pr(\eta'|\eta)$ is the transitional probability of idiosyncratic labor productivity for next period, $\eta'$, conditional on current idiosyncratic labor productivity, $\eta$.

---

\(^{25}\)Note that the object of default is here only emergency medical expenditures, while that in Chatterjee et al. (2007) is all the medical expenditures.
Definition 1 Given a health insurance policy, \((q_{i}, q_{\text{med}}, \Psi_{j})_{j=0}^{J-1}\), a tax policy, \((T(\cdot), \tau_{ss}, \tau_{\text{med}})\), a social security policy, \(\Psi\), and a consumption floor, \(\varepsilon\), a recursive stationary competitive equilibrium is a set of prices \(\left(w, r_{f}, r, q^{T}\right)_{j=J_{w}}^{J}, \{p(\cdot, j)\}_{j=0}^{J}, \{p_{\text{med}}\}_{j=0}^{J}\), a mark-up of the hospital \(\Theta\), a set of decision rules \(\left\{\{g_{d,j}(\cdot), g_{a,j}(\cdot), g_{i,j}(\cdot), g_{h,j}(\cdot)\}_{j=0}^{J}\right\}\), a default probability function \(\{d(\cdot, \cdot, j, \cdot)\}_{j=J_{w}}^{J}\), and values \(\left\{v_{j}^{\text{G}}(\cdot)\right\}_{j=0}^{J-1}, \left\{v_{j}^{\text{G,N}}(\cdot), v_{j}^{\text{G,D}}(\cdot), v_{j}^{\text{B,N}}(\cdot), v_{j}^{\text{B,D}}(\cdot)\right\}_{j=J_{w}}^{J}, \left\{v_{j}^{\text{f}}(\cdot)\right\}_{j=J_{w}}^{J}\) and distributions of household \(\{\mu_{j}\}_{j=1}^{J}\) such that

i. Households solve the values, and attain the decision rules.

ii. Firm is competitive pricing.

\[
w = \frac{\partial F(K^{*}, N^{*})}{\partial N^{*}}, r = \frac{\partial F(K^{*}, N^{*})}{\partial K^{*}}
\]

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 \(a^{'}.\)

\[
q(a', i', h'; j, \eta) = \frac{\pi_{j+1|j}(1 - d(a', i', h'; j, \eta) \cdot \pi_{j+1|j})}{1 + r_f}
\]

\[
d(a', i', h'; j, \eta) = \sum_{\eta', \omega', \varepsilon, \varepsilon_{n}} \pi_{\eta'} | \pi_{\omega'} | \pi_{\varepsilon'} | \pi_{\varepsilon_{n}'} | \tau_{j+1} | \tau_{j+1} + \tau_{d,j}(a', i', h', e', e_{n}', \omega')
\]

where \(g_{d,j+1}(\cdot)\) is the policy function of default at age \(j + 1\).

iv. The hospital has zero profit.

\[
\sum_{j=0}^{J} \left( \int \left( 1 - g_{d,j}(s) \right) m_{e}(e_{e}) + g_{d,j}(s) \max{\left( a, 0 \right)} + m_{n,j}(s) - \frac{m_{e}(e_{e}) + m_{n,j}(s)}{\Theta} \right) \mu_{j}(ds) \right) = 0
\]

where \(s = (a, i, h, e_{e}, e_{n}, \eta, \omega) \in S, m_{e}(e_{e})\) is emergency medical cost for \(e_{e}\), and \(m_{n,j}(s)\) is the decision rule for non-emergency medical expenditure.

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v. The bond market and the capital market are clear. This implies the following conditions.\(^{26}\)

\[
r_f = r - \delta \\
q^{rf} = \frac{1}{1 + r_f}
\]

\[
K^* = \sum_{j=J_w}^{J_e} \left( \int_s [q(g_{a,j}(s), g_{i,j}(s), g_{h,j}(s); j, \eta)g_{a,j}(s) + g_{i,j}(s)\mathbb{1}_{\{g_{i,j}(s) \in \{IHI,EHI\}\}}] \mu_j(ds) \right)
\]

, where \(s = (a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \in S\)

vi. The labor market is clear.

\[
N^* = \sum_{j=J_w}^{J_w-1} \left( \int_s [\sigma_j(1 - \varepsilon_e)(1 - \varepsilon_n)h\eta] \mu_j(ds) \right), \text{ where } s = (a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \in S
\]

vii. The good market is clear

\[
\sum_{j=J_w}^{J_w-1} \left( \int_s [c_j(s) + m_{n,j}(s) + m_e(\varepsilon_e) + p(i, h, j_g)g_{i,j}(s) + T(y)] \mu_j(ds) \right) = \sum_{j=0}^{J_w-1} \tilde{y}\mu_j
\]

\[
\sum_{j=J_w}^{J_e} \left( \int_s [c_j(s) + m_{n,j}(s) + \frac{m_e(\varepsilon_e)}{\Theta} + p(i, h, j_g)g_{i,j}(s) + T(y(s))] \mu_j(ds) \right) + \delta K^*
\]

\[
= F(K^*, N^*) - \chi w \sum_{j=J_w}^{J_w-1} \left( \int_s (1 - \varepsilon_e)(1 - \varepsilon_n)hg_{d,j}(s) \mu_j(s) \right)
\]

viii. The insurance markets are clear.

\[
\sum_{j \in J_g} \int q_{IHI} \mathbb{1}_{\{i=IHI\}}(m_{n,j}(s) + m_e(\varepsilon_e)) \mu_j(ds) = p_{IHIJ_g} \sum_{j \in J_g} \int \mathbb{1}_{\{g_{i,j}(s-1) = IHI\}} \mu_{j-1}(ds-1), \text{ for each } J_g
\]

\[
\sum_{j=0}^{J_e-1} \int q_{EHI} \mathbb{1}_{\{i=EHI\}}(m_{n,j}(s) + m_e(\varepsilon_e)) \mu_j(ds) = p_{EHI} \sum_{j=1}^{J_e} \int \mathbb{1}_{\{g_{i,j-1}(s-1) = EHI\}} \mu_{j-1}(ds-1)
\]

, where \(s = (a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \in S\).

\(^{26}\text{Chatterjee et al. (2007) show how to derive these conditions.}\)
ix. The government budget constraint satisfies

\[
\sum_{j=J_r}^{J} \int \Psi \mu_j(ds) = \sum_{j=0}^{J_r-1} \int \tau_{ss}^j \mu_j(ds) + \sum_{j=J_w}^{J-1} \int \tau_{ss} \sum_i w^j \mu_j(ds)
\]

\[
\sum_{j=J_r}^{J} \int (q_{med}(m_{n,j}(s) + m_e(\varepsilon_e)) - p_{med}) \mu_j(ds) = \sum_{j=0}^{J_r-1} \int \tau_{med} \mu_j(ds) + \sum_{j=J_w}^{J-1} \int \tau_{med} \sum_i w^j \mu_j(ds)
\]

\[
G + \sum_{j=0}^{J_r-1} \int \Xi_j(y,i) \mu_j(ds) + \sum_{j=0}^{J_w-1} \int \max \{c - x(s), 0\} \mu_j(ds) + \sum_{j=J_r}^{J-1} \int \max \{c - x(s), 0\} \mu_j(ds)
\]

\[
= \sum_{j=0}^{J} \int T(y) \mu_j(ds)
\]

\[
\Xi_j(y,i) = \begin{cases} 
    p_{MCD} & \text{if } (y \leq \text{FPL133} \text{ and } j < J_w \text{ and } i = \text{MCD}) \text{ or } (y \leq \bar{M} \text{ and } j_w \leq j < J_r \text{ and } i = \text{MCD}) \\
    \theta p_{EHI} & \text{else if } \omega = 1 \text{ and } i = \text{EHI} \\
    0 & \text{otherwise}
\end{cases}
\]

where \(x(s)\) is net worth for individual state, \(s\), \(\Xi_j(\cdot, \cdot)\) is the subsidy function of health insurances at age \(j\), and \(\theta\) is the fraction of employer-based health insurance premium covered by employers.

x. Distributions are consistent with individual behavior.

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

\[
\mu_{j+1}(B) = \int_{\{s | (g_{a,j}(s), g_{i,j}(s), g_{h,j}(s), \varepsilon_e, \varepsilon_n, \eta, \omega) \in B\}} (1 + \pi_g) \pi_{j+1} |_{j} Pr(\varepsilon_e, \varepsilon_n | g_{h,j}(s)) Pr(\omega | \eta') Pr(\eta | \eta) \mu_j(ds)
\]

, where \(s = (a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \in S\).

xi. Transfers equal to accidental bequests.

\[
\kappa = \sum_{j=J_w}^{J-1} \left(1 - \pi_{j+1 | j}\right) \int_s [(a(1 + r_f) - T(a)) \cdot 1_{\{a > 0\}}] \mu_j(ds), \text{ where } s = (a, i, h, \varepsilon_e, \varepsilon_n, \eta, \omega) \in S.
\]

5 Solution and Calibration

5.1 Numerical Solution

There are substantial computational burdens 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 41 parameters that have to be adjusted to match moments in the model with those in the data.

To solve the model, I extend the endogenous grid method. The algorithm is as follows. Let’s assume that an individual repays its debt at age \( j \). First, I apply the algorithm to the variable of assets, \( a' \), and take all of the other endogenous states as given states. Second, I numerically set up the lower bounds for the solution of asset holdings, \( a' \), which is a necessary step as there is no exogenous borrowing constraint in default models. Third, using the endogenous grid method, I calculate the First Order Condition for asset holdings (Euler equation), which is a necessary condition for an optimal choice of assets, \( a' \). Fourth, I use the Fella (2014)’s algorithm to handle non-concavities, which are caused by multiple discrete choices, and find the global solution of asset holdings, \( a' \), among the candidates provided by the FOC in the previous step.

In the first step, it is worth noting that this endogenous grid method is for solving one dimensional problem. I apply my algorithm to a continuous endogenous state variable, while discretizing the other endogenous state variables. The continuous variable I choose is assets, \( a' \); for the algorithm, and discretize the states of health capital, \( h' \), and insurance choice, \( i' \). It is because the variation in assets, \( a' \), is the largest.

In the second step, I set up the lower bound of feasible sets for the solution of asset holdings, \( a' \). This process is unnecessary in other heterogeneous household models with an exogenous borrowing constraint or a borrowing constraint depending on collateral. It is because these types of borrowing constraints are not from these models’ equilibrium conditions but from their technology. However, in my model, it is not possible to know its borrowing constraint ex-ante. It is because loan prices play a similar role in borrowing constraints, and these endogenously arise from its equilibrium. Moreover, these loan prices depend on individual state.

To set up the bounds for the solution of assets, \( a' \), I find a numerical method, motivated by the work of Clausen and Strub (2013) and Arellano (2008). They show that for every optimal debt contract, the size of the loan \( q(a')a' \) increases in \( a' \). In addition, they define the risky borrowing limit (credit limit) to be the lower bound of the set for these optimal debt contracts. I calculate the risky borrowing limits for each individual state and fix them as the lower bound of the feasible set for the solution of asset holdings, \( a' \).29

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27Here, I demonstrate the solution for the value function if debt is repaid with existing good credit. The value function of defaulting is solved by optimizing a few discrete choices. The repaying problem with bad credit is solved by Fella (2014)’s endogenous grid method.

28More details are in the appendix.

29I describe how to numerically find them in the appendix.
Definition 2 For each \((i', h'; j, \eta)\), \(a'_{rbl}(i', h'; j, \eta)\) is the risky borrowing limit if
\[
\forall a' \geq a'_{rbl}(i', h'; j, \eta), \quad \frac{\partial q(a', i', h'; j, \eta)a'}{\partial a'} = \frac{\partial q(a', i', h'; j, \eta)}{\partial a'} a' + q(a', i', h'; j, \eta) > 0
\]
The FOC is a necessary condition for an optimal choice of asset holdings, \(a'\). Let \(W_{j+1}^G(a', i', h', \eta)\) denote \(\beta \pi_{j+1} \sum \epsilon_i \epsilon_n \eta \omega + \pi_{j+1} \sum \epsilon_i \epsilon_n \eta \omega \eta_{j+1} \pi_{j+1} \eta \pi_{j+1} \eta \omega G_{j+1}(a', i', h', \epsilon_i, \epsilon_n, \eta, \omega)\). Moreover, for each state \((i', h', j, \eta)\), let \(a'_{rbl}(i', h', j, \eta)\) denote the risky borrowing limit. I formally describe the FOC.

Proposition 1

Given a pair of \((\epsilon_i, \epsilon_n)\), for any \((i', h', j, \eta)\) and for any \(a' \geq a'_{rbl}(i', h', j, \eta)\),
\[
D_1 u(c, (1 - \epsilon_i)(1 - \epsilon_n)h) = \frac{1}{D_1 q(a', i', h'; j, \eta)a' + q(a', i', h'; j, \eta)} D_1 W_{j+1}^G(a', i', h', \eta)
\]
is a necessary condition for an optimal choice of asset holdings, \(a'\).

Proof. See the appendix. ■

In the third step, I apply the endogenous grid method to obtain the above FOC for asset holdings (Euler equation), and save this necessary condition for an optimal choices, \(a'\), for each individual state.

It is worth noting that the FOC is not sufficient but necessary. I find the global optimum for asset holdings, \(a'\), by using information provided by the FOC. To do this, I use the algorithm of Fella (2014). He suggests a numerical algorithm dividing the set of solutions into two regions: a concave region and a non-concave region. In the concave region, the FOC is both necessary and sufficient condition, so the FOC directly provides a solution of an optimal choice of assets, \(a'\). In the non-concave region, the FOC gives good candidates for a global solution of assets holdings, \(a'\). Fella (2014) checks whether a candidate from the FOC is the global solution in non-concave region. Although this requires searching grid points for the solution, it is less computationally burdensome. One reason is that it does not search over the whole feasible space of solution sets. The range of grid search is restricted to the non-concave set. The other reason is that, even on the non-concave region, the processes of searching can stop once it faces a point generating a

\[30\]I show that the FOC for asset holdings exists, and it is a necessary condition for an optimal choice for asset holding, \(a'\). Clausen and Strub (2013) proves that the FOC exists and is a necessary condition for an optimal choice for assets, \(a'\) in the case with iid idiosyncratic shocks on earnings. I extend their proposition to default models with persistent shocks on earnings.
higher value than the value provided by the FOC. \textsuperscript{31} I follow his algorithm to find a global solution for asset holdings, $a'$. Using the implied decision rule for assets, $a'$, from these step, I retrieve individual value functions given other discretized endogenous state variables: health capital, $h'$, and insurance, $i'$.

Note that the endogenous grid method is used only for the asset state variable, $a'$. After the above step, I find the optimal choices for other discrete endogenous states of health capital, $h'$, and insurance, $i'$, by searching over their choice grid. This procedure is not computationally burdensome due to a small numbers of grid points on the discrete choice state variables: 4 grid points for health insurance and 20 grid points for health. By solving the value functions at age $j$ with this method, I update the loan prices of household at age $j-1$. These steps are repeated until the initial age.

\textsuperscript{31}Fella (2014) introduces a way to decrease grid searching times by using the monotonicity of cash on hands. He checks a few points closest to the candidate of the solutions. Despite efficiency gains from this step, I do not use it, because it can miss the solution if too few points are searched. Rather, I use the monotonicity of the global solution on the non-concave region for the precision.
5.2 Calibration

Table 1: Benchmark Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Calibration Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Parameters Determined Ex-Ante</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| $\theta$           | 0.36  | Curvature of production function                 | Capital share is 0.36.
| $\delta$           | 0.24  | Depreciation rate                                | Annual depreciation rate is 8%. |
| $\sigma$           | 3     | Curvature of utility function                    | Coefficient of RRA is 3 in De Nardi et al. (2010). |
| $\lambda$          | 0.33  | Probability of recovering credit status          | Average duration of exclusion is 10 years. |
| $\eta_{MCD}$       | 0.70  | Medicaid coverage rate                           |                      |
| $\eta_{H}$         | 0.55  | IHI coverage rate                                |                      |
| $\eta_{EHI}$       | 0.70  | EHI coverage rate                                |                      |
| $\eta_{MED}$       | 0.87  | Medicare coverage rate                           |                      |
| $\rho_{med}$       | 0.0211| Medicare premium                                 |                      |
| $\alpha_0$         | 0.258 | $T(y) = \alpha_0 \{ y - (y^{-\alpha_0}+\alpha_2)^{-1/\alpha_0} \} + \tau_y$ |                      |
| $\alpha_1$         | 0.768 | $T(y) = \alpha_1 \{ y - (y^{-\alpha_1}+\alpha_2)^{-1/\alpha_1} \} + \tau_y$ |                      |
| $\pi_0$            | 0.0364| Population growth rate                           |                      |
| $(\rho/N)_{j=1}$   |       | Rate of EHI offers                               |                      |
| $(\pi_{j+1})_{j=0}$|       | Survival rate                                    |                      |
| $\gamma$           |       | Incomes for children                             |                      |
| $\delta$           | (0, 0.009, 0.078) | Emergency medical expenses (0, bottom 90%, top 10%) | 0.9% and 7.8% per capita GDP. |
| $\delta$           | (0.194, 0.233)  | Emergency health shocks (0, bottom 90%, top 10%) | $2.663 in 1998 U.S. dollar, De Nardi et al. (2010). |
| $\zeta$            | 0.08  | Consumption floor                                |                      |
| B. Parameters that Require Solving the Model |       |                                                  |                      |
| $\beta$            | 0.955 | Discount factor                                  | Capital-output ratio is 3 |
| $\chi$             | 0.062 | Cost of filing for bankruptcy                    | Non-business Chapter 7 filing rate =0.302% |
| $\alpha$           | 0.544 | $1 - \alpha$ is the weight on health in utility | Take-up ratio of IHI for working adults in the MEPS. |
| $\mu$              | 1.034 | Medicaid Eligibility for adults                  | Take-up ratio of working adults= 4.4% in the MEPS. |
| $\sigma_0$         | 0.987 | Persistence of productivity shock                | 0.957 in Storesletten et al. (2004) |
| $\sigma_1$         | 0.362 | Standard deviation of persistent shock           | Gini coefficient is 0.61 |
| $\sigma_\kappa$    | 0.497 | Standard deviation of transitory shock           | Standard deviation at age 24 is 0.633 |
| $\alpha_0$         | 0.866 | $Pr(X_\kappa = 1) = \{ \frac{1}{1+k\kappa} \}^{\kappa}$ | Standard deviation of $\kappa$ is 0.076. |
| $(\delta/N)_{j=2}$ |       | $Pr(X_\delta = 1) = \{ \frac{1}{1+k\delta} \}^{\delta}$ | Fraction of emergency room users by age group. |
| $\kappa$           | 0.255 | $Pr(X_\kappa = 1) = \{ \frac{1}{1+k\kappa} \}^{\kappa}$ | Average Fraction of emergency room users is 0.128 |
| $\alpha_0$         | 0.449 | $e_\alpha \sim TN(\mu = 0, \sigma^2 = \frac{\{(1/\delta) - 2k\kappa\}^{\delta}}{n\mu})$, min = 0, max = 1 | Standard deviation of $e_\alpha$ is 0.208. |
| $(\beta/N)_{j=2}$  |       | $e_\beta \sim TN(\mu = 0, \sigma^2 = \frac{\{(1/\delta) - 2k\kappa\}^{\delta}}{n\mu})$, min = 0, max = 1 | Average of $e_\alpha$ by age group. |
| $\kappa_0$         | 0.016 | $e_\kappa \sim TN(\mu = 0, \sigma^2 = \frac{\{(1/\delta) - 2k\kappa\}^{\delta}}{n\mu})$, min = 0, max = 1 | Average non-emergency health shocks is 0.184 |
| $(\psi/N)_{j=1}$   |       | Efficiency of health technology                   | Medical expenditures by age group. |
| $(\psi/N)_{j=1}$   |       | Efficiency of health technology                   | Standard deviations by age group. |
| $\tau_{med}$       | 0.048 | Social security payroll tax rate                  | Replacement ratio is 40% |
| $\tau_{med}$       | 0.049 | Medicare payroll tax                             | Medicare premium is 2.11% |
| $\delta$           | 0.481 | $T(y) = \delta_1 \{ y - (y^{-\alpha_1}+\alpha_2)^{-1/\alpha_1} \} + \tau_y$ | Progressive tax revenue = 0.65(OECD) |
| $\tau_1$           | 0.078 | $T(y) = \delta_2 \{ y - (y^{-\alpha_2}+\alpha_2)^{-1/\alpha_2} \} + \tau_y$ | Government budget is balanced. |
| $Z$                | 1.468 | Total factor productivity                         | Total output is normalized to 1. |

My calibration strategy induces separating parameters into two groups. The first set of parameters is determined outside the model. The other set of parameters requires solving the model to match moments generated by model to their empirical counterparts.

For the first type of parameters, I choose the values of these parameters from macroeconomic literature and policies. The capital share $\theta$ is chosen to reproduce that the share of capital income
is 0.36. The depreciate rate $\delta$ is 8 percent in annual. The coefficient of relative risk aversion is fixed at 3. The probability of recovering credit status $\lambda$ is chosen to match the average duration of exclusion that is 10 years on Chapter 7 bankruptcy filing. For the insurance coverage rates, their values are chosen to match the ratios of out-of-pocket medical costs to total medical costs for each type of health insurances. The Medicaid coverage rate, $q_{MCD}$, is 70%, the coverage rate of individual private health insurance, $q_{IHI}$ is 55 percent, the coverage rate of employer-based health insurance, $q_{EHI}$, is 70 percent, and the Medicare coverage rate, $q_{MED}$ is 87 percent. The Medicare premium, $p_{med}$ is 2.11 percent of GDP per capita that is from Jeske and Kitao (2009). The values of two progressive parameters are taken from Gouveia and Strauss (1994). The upper bound parameter $a_0$ is 0.258, and the curvature parameter $a_1$ is 0.768. The offer rate of employer-based health insurances, $pr_{jg}(\omega|\eta)$, is calculated with the data from the MEPS. For each age group, $jg$, I calculate the conditional offer rates given a level of earnings in the data. Then, I draw a map the offer rate in the data into the stationary distribution of earnings shocks in the model, and calculate the conditional offer rate, $pr_{jg}(\omega|\eta)$. In this way, the offer rate is affected by persistent earnings shocks, and transitory shocks and health do not affect the offer rate. It is for reflecting the fact that working places with higher salaries are more likely to offer employer-based health insurances. To capture this characteristic, I assume that the persistent part of earnings shocks is linked to occupations.

The survival rate, $\pi_{j+1|j}$ is taken from Bell and Miller (2005). For children’ income, Lino (2001) shows that around 30 percent of households’ income is used for their children. Using the distribution of household income in Elwell (2014), I assume that the distribution of children in the model is consistent with the distribution of households in the data, and that children spend 30 percent of these households’ income. To calculate the parameter values related to emergency rooms, I use the files of “Emergency Room Visits” in the MEPS. Emergency medical expenditures, $m_e(\cdot)$, are discretized as three states that represent non-emergency medical expenditure, the average of the bottom 90 percent of emergency medical expenditures, and the average of the top 10 percent of emergency medical expenditures. These three types of emergency medical expenses correspond to three types of health shocks: no emergency health shocks, medium emergency health shocks, and extreme emergency health shocks. Medium emergency health shocks and extreme health shocks depreciate health by 19.4 percent and 23.3 percent, respectively.

46 parameters require solving the model for the calibration. Since the model is based on the setting of incomplete markets, parameters are jointly determined. The 41 parameters—including the discount rate $\beta$, the cost of filing for bankruptcy $\chi$, the weight on consumption relative to health $\alpha$, the cutoff of Medicaid eligibility for adults $\bar{M}$, the persistence of earnings shocks $\rho_e$, the standard deviation of persistent earnings shocks $\sigma_e$, the standard deviation of transitory earnings shock $\sigma_v$, the curvature of the probability function of visiting emergency rooms $\alpha_e$, eight scale
parameters for the probability function of visiting emergency rooms \( \{ E_{jk} \}_{jk=1}^8 \), the curvature of the standard deviation function of non-emergency health shocks \( \alpha_n \), eight scale parameters for the standard deviation function of non-emergency health shocks \( \{ N_{jk} \}_{jk=1}^8 \), eight parameters for the efficiency of health technology \( \{ \psi_{jk} \}_{jk=1}^8 \), and eight parameters of the curvature of health technology \( \{ \phi_{jk} \}_{jk=1}^8 \) are determined jointly by minimizing the square of the log differences between moments from data, and those generated by the model.

The targets for the above parameters are the capital-output ratio, the average of non-business Chapter 7 filing rates between 2000 and 2010,\(^{32}\) the take up ratio of individual health insurance, the percent of adults who use Medicaid, the persistence of earnings including health, the Gini coefficient of earnings, the standard deviation of the earnings shock including health at the initial working age, the standard deviation of emergency health shocks, the fraction of individuals who visit emergency rooms for each age group, the average fraction of emergency room visits, the standard deviation of non-emergency health shocks, the average of non-emergency health shocks for each age group, the average of non-emergency shocks, the average of medical expenditures for each age group, and the standard deviation of medical expenditures for each age group.

The other 5 parameters – social security tax \( \tau_{ss} \), Medicare tax \( \tau_{med} \), the scale parameter of the income tax function \( a_2 \), the proportional income tax parameter \( \tau_y \), and total factor productivity \( Z \) – are targeted to match 40 percent of the replacement ratio, 2.11 percent of GDP for Medicare premium, the fraction of tax revenue financed by progressive income tax, balanced government budget constraints, and the normalization of output as 1, respectively.

6 Result

In this section, first I check whether the benchmark matches the features of US data. I take two steps for this task. The first step is to examine how targeted moments generated by the model are close to those in the data. In the second step, I test the validation of the model by examining the performance in fitting the untargeted moments. After checking the model performance, I conduct the policy experiment of the Affordable Care Act.

\(^{32}\)The effect of The Bankruptcy Abuse Prevention and Consumer Protection Act of 2005 (BAPCPA) on non-business chapter 7 bankruptcy is not clear. It rapidly increased in 2005 and hugely decreased in 2006, but it returned to its trend afterward. The average non-business Chapter 7 filing rates between 2000 and 2004 are similar to that between 2000 and 2010.
6.1 Model Performance

6.1.1 Targeted Moments

I check how well the model performs in matching targeted moments to their empirical counterparts. The model aims to match 42 moments. They can be divided into two types of moments: aggregate moments and life cycle moments. The aggregate moments consist of key values in inequality, and health care, and macroeconomic conditions.

Table 2 shows the results in target moments at the aggregate level. The model closely matches key features of the data. Regarding the moments related to savings and debt, moments generated by the model is very close to those in the data. Regarding moments related to earnings, the gap is not large between the results from data and those in the data. The autocorrelation of earnings shock in the model is 0.935, which is close to the value in data, 0.952. The standard deviation of the log earnings shocks between age 24 and 26 is 0.338, which is not so different from the value in data, 0.365. For the Gini coefficient of earnings, the model shows 0.602, this is close to the empirical Gini coefficient of earnings, 0.61. For moments linked to health, the model results are similar to their counterpart in data. The standard deviation of emergency health shocks is 0.044, which is close to the value in data, 0.053. The standard deviation of non-emergency health shocks from the model is similar to that in the data. The model performs well in fitting the take-up ratio of individual health insurance and the fraction of Medicaid takers well.

The model has 32 life cycle moments, which are related to health variables. The model performs well in fitting these life cycle moments to their empirical counterpart. The model has 32 life cycle moments, which are related to health variables. The model performs well in fitting these life cycle

<table>
<thead>
<tr>
<th>Table 2: Targeted Aggregate Moments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>(Period= Annual</em>)</em>*</td>
</tr>
<tr>
<td>Capital-Output ratio</td>
</tr>
<tr>
<td>Average Default Rate (percent)</td>
</tr>
<tr>
<td>Auto-Correlation of Earnings Shock</td>
</tr>
<tr>
<td>Initial STD of Log Earnings</td>
</tr>
<tr>
<td>Gini Coefficient of Earnings</td>
</tr>
<tr>
<td>Average Non-Emergency Health Shocks</td>
</tr>
<tr>
<td>Average Fraction of Emergency Room Visits</td>
</tr>
<tr>
<td>Std of Emergency Health Shocks</td>
</tr>
<tr>
<td>STD of Non-Emergency Health Shocks</td>
</tr>
<tr>
<td>Individual Health Insurance Take-Up Ratio</td>
</tr>
<tr>
<td>Percent of Working-Age Medicaid Takers</td>
</tr>
</tbody>
</table>

* The model period is triennial. To compare moments from the model with those in the data, I transform these triennial moments into the annual moments.
moments to their empirical counterpart. In figure 4, the upper graph compares the life cycle profile of emergency room usages from the model with that in data. This figure shows that the model generate similar age profile of emergency room usages to their empirical counterpart. Figure 4 compares the life cycle profile of medical conditions in the model with that in data. The model replicates the monotonic profile, and the values of the model moments are close to the data moments.

Figure 5 compares medical expenditure moments in the model with those in data. The upper figure shows the age profile of the average total medical expenditure over the life cycle. The model
generates the monotonic increasing age profile of the average medical expenditures. In addition, the values for the average medical expenditure moments in the model are close to those in data over the life cycle. Similarly, in the below figure, the standard deviations for medical expenditures in the model are close to those in data over the life cycle.

6.1.2 Model Validation

In the previous section, I have shown that the performance of model in fitting targeted 42 moments. In this section, I check the validation of the model by checking how well untargeted moments generated by the model are matched to their empirical counterparts.

It is important to note that for moments relevant to emergency room usages and medical conditions; I target only their aggregate standard deviations and average age profiles. I do not target any income level specific moments within cohorts. Figure 6 implies that the model endogenously captures the features in emergency room usages between low income individuals and high income individuals. The model replicates the life cycle features in emergency room usages. Before starting working, the gaps are smaller, but this becomes larger when individuals are working. The disparity gets amplified during working phase, and starts to mitigate from retirement age.

Figure 7 shows the age profiles of medical conditions between the top 20 percent income individuals and the bottom 20 percent individuals. It implies that the model succeeds in replicating the distributional features in medical conditions across income groups. The model shows that during childhood periods, the gap is smaller. This gap is getting increasing from the starting age of working, and it becomes largest in 50s. From retirement age, the gap gets decreasing until their
later life.

Figure 8 shows the result for medical expenditures. The model shows that in early life (age 0-23); the top 20 percent income individuals pay more medical expenditures than the bottom 20 percent income individuals. Although the model fails to match the higher medical spending in low income individuals before the retirement, from age 24, medical spending for low income individuals is generally higher than that for high income individuals. The model performs well in replicating the pattern in medical expenditures between low income individuals and high income individuals.
Note that the endogenous distribution of health shocks is a key to generating the above three

Figure 9: Effect of the Endogenous Distribution of Health Shocks on Medical Expenditures

age profiles. As other models with the health capital framework follow, consider a model in which the distribution of health shocks depends only on age. Then, the model based on the exogenous distribution cannot capture disparities in medical conditions and emergency room usages across individuals with different incomes. Furthermore, the model cannot generate a life cycle profile of medical expenditures that is consistent with data. Figure 9 implies that when the distribution of health shocks are exogenous, high income individuals spend more on health care than low income individuals during their working periods, which is inconsistent with data. It means that the model with the endogenous distribution of health shocks performs better in accounting for cross-sectional differences in emergency room usages, medical conditions, and medical expenditures. Given the importance of these variables and their heterogeneity, the endogenous distribution of health shocks is crucial in investigating implications of health insurance policies.

Table 3 shows aggregate moments related to debt and bankruptcy. The values of data mo-

<table>
<thead>
<tr>
<th>Table 3: Results in Debt and Bankruptcy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Period= Annual)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Fraction of Debt Holders</td>
</tr>
<tr>
<td>Average Debt/Average Income</td>
</tr>
<tr>
<td>Fraction of Medical Bankruptcy**</td>
</tr>
</tbody>
</table>

** I calculate the fraction of emergency room users out of the total bankruptcy filers.

ments are from previous studies and data. The target for the fraction of debt holders is from
Athreya et al. (2009) and the ratio of average debts to average income is from Nakajima and Ríos-Rull (2014). I take the values for the fraction of medical bankruptcy from Himmelstein et al. (2009) and Austin (2014). The benchmark model performs well in fitting moments related to debt and bankruptcy. The fraction of debt holders is 16.7% in the model, which is larger than that in data, 12.5%. Debt-to-income ratio in the model is 22.7%, which is similar to that in data, 20%. The model generates 39.4% of medical bankruptcies, which is in the range of the fraction reported in previous studies, 16%-62.1%.

The benchmark generates interesting patterns in life-cycle implications. Figure 10 shows that the pattern of default in the benchmark broadly matches with US data.\(^{33}\) The model illustrates qualitatively similar bankruptcy filing patterns over the life cycle: younger households suffer more bankruptcy, and the default rate decreases with age. However, the benchmark generates a default profile that is quantitatively different from that in US data. The model shows an overshooting of the default rate for young households compared to the data, while the rate of old households in the model is lower than that in the data.

Figure 11 shows the age profile of take-up ratios for health insurances. These take-up ratios in the model are overall similar to those in data. Note that these life cycle moments are not targeted, while aggregate moments related to the take-up ratios are pinned down in the calibration. Those whose age between 0 and 23 are more likely to use Medicaid than other age groups, as its eligibility

\(^{33}\)The data source is from Sullivan et al. (2001).
criteria are more generous for them. The model generates this feature well. In addition, the model reflects features on individual health insurance. In particular, the model succeeds in generating the hump-shaped age profile in employer-based health insurance in data. These imply that the model is successful in reflecting life cycle features on health insurance choice behaviors.

6.2 Policy Analysis

The benchmark model well replicates targeted moments in earnings inequality, macroeconomy, and health care by the calibration. In addition, the model performs well in fitting the untargeted moments relevant to medical conditions, emergency room usage, medical expenditure, health insurance, debt, and bankruptcy. This suggests that this model is useful framework for investigating the effects of health insurance policies on health care, household bankruptcy, macroeconomy, and welfare.

I conduct a policy experiment with the Affordable Care Act (ACA). The ACA has been the largest health care reform since the creation of Medicaid and Medicare. However, note that I do not cover the whole components in the ACA due to its complexity. This health reform includes a number of policy components that affect a wide range of agents in the U.S. economy. Policies in the ACA reach health insurance industry, households, firms, and government sector. Here, I focus on policy components related to households in the ACA.

6.2.1 Key Features of the Affordable Care Act

I examine the effects of the following four components in the ACA:
1. Medicaid Expansion

- Expanding its eligibility up to all working-age individuals whose income is below 138 percent of Federal Poverty Level (FPL).\(^{34}\)

2. Subsidy Policy for Individual Health Insurance

- Providing progressive subsidies for the purchase of individual health insurances.

<table>
<thead>
<tr>
<th>Income Level % of FPL</th>
<th>Maximum Premium % of Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>133-150</td>
<td>3-4</td>
</tr>
<tr>
<td>150-200</td>
<td>4-6.3</td>
</tr>
<tr>
<td>200-250</td>
<td>6.3-8.05</td>
</tr>
<tr>
<td>250-300</td>
<td>8.05-9.5</td>
</tr>
<tr>
<td>300-400</td>
<td>9.5</td>
</tr>
</tbody>
</table>

3. Individual Health Insurance Market Reforms

- Preventing health insurance suppliers from discriminating customers based on their health status and disease record.
- Standardizing the coverage rates for individual health insurances.

4. Insurance Mandate with Penalty

- Enforcing those without coverage to pay a tax penalty of 2.5 percent of income with a minimum of $695 in 2016

The ACA is composed of two types of policy components: redistributional policies and regulatory policies. The redistributional policies aim to reallocate health care resources by providing public health insurances or giving subsidy for the purchase of private health insurance to low-income individuals. The regulatory policies are to make economic agents follow the reforms by either imposing pecuniary penalty or enforcing laws. The Medicaid expansions and the subsidy policy for individual health insurance are redistributional, and health insurance reforms for individual health insurances and insurance mandate with penalty are regulatory.

Among the redistributional policies, the Medicaid expansion is about a public health insurance reform for low income individuals. Before the ACA, the eligibility of Medicaid for working-age individuals whose income was below 138 percent of FPL was expanded.

\(^{34}\)FPL is a measure of income level issued annually by the Department of Health and Human Services.
individuals hugely depends on income and family structure. In addition, the criteria for the eligibility are so strict for adults. According to the MEPS between 2000 and 2010, only 4 percent of working adults use Medicaid. The ACA expands the eligibility of Medicaid up to all working-age individuals whose income is lower than 138 percent of Federal Poverty Level (FPL).  

The subsidy policy for individual health insurance is a redistributional policy for middle-income individuals. This policy provides those whose income is between 133 percent of FPL and 400 percent of FPL with progressive subsidies for the purchase of private health insurance. Table 4 shows the schedule for the subsidy policy by income levels. For example, if an individual whose income is between 150 percent of FPL and 200 percent wants to buy an individual health insurance, all he needs to pay is 6.3 percent to 8.05 percent of his income. The rest of the cost is covered by subsidy. As a result, individuals with different incomes face different effective prices for health insurance. Poorer households face lower prices for health insurance.

The reform of individual health insurance reform is a regulatory policy for the quality of private individual health insurances. This policy is (i) to prevent insurance companies from discriminating the insurance premium based on users’ information on health and disease, and (ii) to providing higher coverage of health insurances that are standardized in four types: Platinum health plan (90% of coverage rate), Gold health plan (coverage rate 80%), Silver health plan (70% of coverage rate) and Bronze health plan (60% of coverage rate). The first regulation implies that in my policy experiment, his premium of individual health insurances is independent of health status under the ACA, while it depends on health before the ACA. Under the ACA, Information on sex, age, and smoking can only be available for charging the price of individual health insurances. The second regulation implies that the ACA improves the coverage rate of individual health insurances by laws. Before the ACA, the average ratio of out-of-pocket medical expenditures to total medical expenditures is 55% in the MEPS. This regulation enforces this ratio to be at least 40%. For the policy experiment, I choose the most popular health plan: Silver health plan (70% of coverage rate).

The insurance mandate with penalty implies that in 2016, those who do not have any health insurance have to pay the maximum amount between 2.5 percent of income and 695 dollars for tax penalty. This policy targets to mitigate adverse selection problems in individual health insurance markets by making individuals participate the insurance markets more.

### 6.2.2 Results for the Policy Experiment with the Affordable Care Act

Table 5 shows the result of policy analysis for the benchmark and the ACA at the aggregate level. Firstly, aggregate variables such as consumption, capital, and average tax rate react to change

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35 Although originally intended to apply to all states, in 2002 the U.S. Supreme Court decision made the Medicaid expansions optional for states. As a result, in 2016, 32 states out of 51 states adopt the Medicaid Expansion in the U.S.
Table 5: Aggregate Policy Analysis

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>ACA</th>
<th>Change from the Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Macroeconomic and Tax Variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>1*</td>
<td>0.992</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.474</td>
<td>0.475</td>
<td>0.2%</td>
</tr>
<tr>
<td>Savings</td>
<td>3</td>
<td>2.931</td>
<td>-2.3%</td>
</tr>
<tr>
<td>Capital to output ratio</td>
<td>3</td>
<td>2.956</td>
<td>-1.5%</td>
</tr>
<tr>
<td>Risk-free interest rate</td>
<td>3.84%</td>
<td>4%</td>
<td>+4.2%</td>
</tr>
<tr>
<td>Average tax rate</td>
<td>22.32%</td>
<td>23.10%</td>
<td>+3.5%</td>
</tr>
<tr>
<td>B. Default Rate and Debt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Default rate (percent)</td>
<td>0.294</td>
<td>0.328</td>
<td>+11.6%</td>
</tr>
<tr>
<td>Fraction of medical Bankruptcy</td>
<td>43.02%</td>
<td>41.43%</td>
<td>-3.7%</td>
</tr>
<tr>
<td>Fraction of borrowers</td>
<td>16.7%</td>
<td>15.9%</td>
<td>-4.8%</td>
</tr>
<tr>
<td>Average debt/GDP</td>
<td>22.7%</td>
<td>21.3%</td>
<td>-6.2%</td>
</tr>
<tr>
<td>Average borrowing interest rate</td>
<td>4.97%</td>
<td>5.27%</td>
<td>+6%</td>
</tr>
<tr>
<td>C. Health Related Variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Insurance take-up ratio (working-age)</td>
<td>80.39%</td>
<td>97.6%</td>
<td>+21.4%</td>
</tr>
<tr>
<td>Medicaid take-up ratio (working-age)</td>
<td>4.48%</td>
<td>22.88%</td>
<td>+410%</td>
</tr>
<tr>
<td>IHI take-up ratio (working-age)</td>
<td>7.33%</td>
<td>17.4%</td>
<td>+137%</td>
</tr>
<tr>
<td>EHI take-up ratio (working-age)</td>
<td>68.57%</td>
<td>57.35%</td>
<td>-19.6%</td>
</tr>
<tr>
<td>Medical expenditure to output ratio</td>
<td>13.42%</td>
<td>13.65%</td>
<td>+1.71%</td>
</tr>
<tr>
<td>Average health status**</td>
<td>0.634</td>
<td>0.640</td>
<td>+1%</td>
</tr>
<tr>
<td>Average Medical Condition (health shock)</td>
<td>0.292</td>
<td>0.290</td>
<td>-0.6%</td>
</tr>
<tr>
<td>D. Welfare</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welfare Change</td>
<td></td>
<td></td>
<td>+0.85%</td>
</tr>
</tbody>
</table>

* I normalize the output value in the benchmark model as 1.
** Health is measured by the normalized PCS in the section 4. I divide the PCS of all the individuals by the PCS of the healthiest. Thus, the normalized PCS is between 0 and 1.

its health insurance policy to the ACA. The level of output decreases as health insurance expands from 80.39 percent to 97.6 percent. The fall in output is driven by a decrease in the aggregate capital level. There are two reasons why expanding health insurance causes a decrease in capital. The first reason is that greater insurance coverage reduces the precautionary saving motive of poor households over different ages. Health shocks are one of the important reasons of accumulating assets over age in the absence of health insurance. For this reason, poor households have lower consumption and higher savings. However, an expansion in health insurance that extends coverage to such households curtails this precautionary saving motive. As a result, poor households increase consumption and decrease their savings. The second reason for a reduction in capital is the distortion from increase in income tax rate that decrease the return on savings. To provide more health
insurance, income taxes need to rise. An increase in income tax incurs the lower return on saving for rich households. This brings about a reduction of saving. Since the aggregate level of capital is largely determined by wealthy households, the distortion of tax caused by higher taxes is more important in reducing the aggregate capital stock.

The ACA increases the average default rate, but its magnitude is not sizable. This is related to the reduction in capital. In the model, the default probability is determined by the risk-free interest rate as well as an individual state. Since expanding health insurance decreases the aggregate capital level, it increases the risk-free interest rate, and this raises the overall cost of borrowing driven by equilibrium loan rate schedules consistent with default risk. On the other hands, greater health insurance coverage reduces the probability of default for sick and old people overall. Since these two effects offset each other, the effect of health insurance on the average bankruptcy rate is small. As a result, although the fraction of medical bankruptcy under the ACA is smaller than that in the benchmark, the average bankruptcy rate is higher under the ACA. In addition, the quantity and price of debt shows clear changes. As the total health insurance take-up ratio rises, the debt to output ratio falls and the average borrowing interest rate rise. These changes are the result of the rising cost of borrowing driven by equilibrium loan rate schedules consistent with default risk.

The take-up rate for health insurance increases with the ACA. Since the Medicaid expansion and the subsidy policy for individual health insurance increase the total insurance take-up ratio with a decline in the take-up ratio of employer-based health insurance. In addition, medical expenditures and average health rise, and medical conditions improve. The ratio of medical expenditures to output increases by 1.71 percent from the benchmark economy to the economy with the ACA. Compared to the benchmark economy, the average health increases 1 percent in the economy with the ACA and the average medical conditions (health shocks) improve 0.6 percent under the ACA. Here, the welfare is measured by the percentage increase in consumption in all dates and states that leaves a newborn household indifferent between the benchmark economy and the economy under the ACA. Compared to the benchmark, welfare improves by 0.85 percent under the ACA.

Figure 12 illustrates the log difference of the default rates between the economy with the ACA and the benchmark economy. It shows that the effect of broader health insurance differs over generations. The default rate rises for younger generations, while that falls for older generations. The default rate in economies with the ACA is higher than that in the benchmark up to age 44, while older households suffer from less default rate. This change takes place for the following reason. Expanding health insurance tends to decrease the aggregate capital stock, because the required increase in income tax reduces the return on savings, and low income households reduce the precautionary savings motive of. The reduced aggregate capital stock implies the rising cost of borrowing driven by equilibrium loan rate schedules consistent with default risk, and this has a larger impact on younger generations more, while older households suffer less from these. As a
result, default rate rises for young, who pay higher interest rates and suffer earnings shocks. It falls for the old who are more sensitive to health shocks.

To explore the reasons for changes in default rate over age further, note that expanding health insurance mitigates the burden of medical spending for older households. There are two sources of idiosyncratic shocks: earnings and health. For young generations, on average, idiosyncratic shocks on earnings are more important than health. To smooth their consumption, some young households need access to financial markets. However, with the rising cost of borrowing driven by equilibrium loan rate schedules consistent with default risk, under a more expansion in health insurance, the young needs to pay higher interest rates, and it is harder for them to repay their debts. This change increases the default rate of young households. In contrast, idiosyncratic shocks on health are more important for old households. When health insurance expands, health shocks have a less impact on medical spending. This decreases the default rate of older generations. As a result, default rate rises for young who pay higher interest rates and suffer earnings shocks, while it falls for the old who are more sensitive to health shocks.

Table 6 shows the policy analysis of the ACA with a partial equilibrium and that with a general equilibrium. It implies that an increase in default rates comes from general equilibrium effects. In the partial equilibrium economy, the default rate declines, which results from a decrease in medical bankruptcies. In the partial equilibrium model, savings decline due to a reduction in precautionary savings motives and a rise in income taxes to subsidize health insurances. However, since this reduction in savings does not increase the return on capital under the partial equilibrium setting, a reduction in capital is not as large as that under the general equilibrium. Moreover, under the partial equilibrium, expansions in health insurance have little impact on young generations’ costs of borrowing. The costs of borrowing, which are driven by loan rate schedules, are determined by two factors: the risk-free interest rate and default risk. Since the partial equilibrium pins down the risk-free rate, default risk is the only variable affecting the borrowing costs. For young generations,
health shocks are not a main reason for borrowing. Rather, income shocks are more important in determining their borrowing behaviors. Since expansions in health insurance has little impact on young generations with the partial equilibrium, the ACA with the partial equilibrium shows a decline in the default rate, which is majorly driven by a reduction in medical bankruptcies.

Table 6: General Equilibrium Effect vs Partial Equilibrium Effect on Default Rate

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>ACA (GE)†</th>
<th>ACA (PE)‡</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Macroeconomic and Tax Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>1*</td>
<td>0.992</td>
<td>0.992</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.474</td>
<td>0.475</td>
<td>0.475</td>
</tr>
<tr>
<td>Savings</td>
<td>3</td>
<td>2.931</td>
<td>2.933</td>
</tr>
<tr>
<td>Capital to output ratio</td>
<td>3</td>
<td>2.956</td>
<td>2.956</td>
</tr>
<tr>
<td>Risk-free interest rate</td>
<td>3.84%</td>
<td>4%</td>
<td>3.84%</td>
</tr>
<tr>
<td>Average tax rate</td>
<td>22.32%</td>
<td>23.10%</td>
<td>23.13%</td>
</tr>
<tr>
<td><strong>B. Default Rate and Debt</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Default rate (percent)</td>
<td>0.294</td>
<td>0.328</td>
<td>0.258</td>
</tr>
<tr>
<td>Fraction of medical Bankruptcy</td>
<td>43.02%</td>
<td>41.41%</td>
<td>39%</td>
</tr>
<tr>
<td>Fraction of borrowers</td>
<td>16.7%</td>
<td>15.9%</td>
<td>16.6%</td>
</tr>
<tr>
<td>Average Debt / Average Income</td>
<td>22.7%</td>
<td>21.3%</td>
<td>23.6%</td>
</tr>
<tr>
<td>Average borrowing interest rate</td>
<td>4.97%</td>
<td>5.27%</td>
<td>5.26%</td>
</tr>
<tr>
<td><strong>C. Health Related Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Insurance take-up ratio (working-age)</td>
<td>80.39%</td>
<td>97.6%</td>
<td>97.8%</td>
</tr>
<tr>
<td>Medicaid take-up ratio (working-age)</td>
<td>4.48%</td>
<td>22.88%</td>
<td>23.01%</td>
</tr>
<tr>
<td>IHI take-up ratio (working-age)</td>
<td>7.33%</td>
<td>17.4%</td>
<td>17.3%</td>
</tr>
<tr>
<td>EHI take-up ratio (working-age)</td>
<td>68.57%</td>
<td>57.35%</td>
<td>57.4%</td>
</tr>
<tr>
<td>Medical expenditure to output ratio</td>
<td>13.42%</td>
<td>13.65%</td>
<td>13.6%</td>
</tr>
<tr>
<td>Average health**</td>
<td>0.634</td>
<td>0.640</td>
<td>0.641</td>
</tr>
<tr>
<td>Average Medical Condition (health shock)</td>
<td>0.292</td>
<td>0.290</td>
<td>0.290</td>
</tr>
<tr>
<td><strong>D. Welfare</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Welfare Change</td>
<td></td>
<td>+0.85%</td>
<td>+0.809%</td>
</tr>
</tbody>
</table>

* I normalize the output value in the benchmark model as 1.
** Health is measured by the normalized PCS in the section 4. I divide the PCS of all the individuals by the PCS of the healthiest. Thus, the normalized PCS is between 0 and 1.
† GE means a general equilibrium economy that clear all market prices and the government budget are balanced.
‡ PE means a partial equilibrium economy that does not clear the risk-free interest rate and wage. Health insurance prices are cleared and the government budget is balanced.

Table 5 and table 6 show that welfare improves under the economy with ACA by 0.85 per-
cent, compared to the benchmark economy. This welfare improvement is achieved via two types of channels: direct channel via health and indirect channel via income (earnings) and consumption.

The direct effect is shown in the tables for the aggregate policy analysis. Table 5 shows that

<table>
<thead>
<tr>
<th>Age</th>
<th>Baseline Average Medical Expenditures</th>
<th>ACA Average Medical Expenditures</th>
<th>Baseline SD of Medical Expenditures</th>
<th>ACA SD of Medical Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-11</td>
<td>2698.203</td>
<td>2717.339</td>
<td>305.699</td>
<td>314.226</td>
</tr>
<tr>
<td>12-23</td>
<td>2332.595</td>
<td>2375.89</td>
<td>304.288</td>
<td>311.698</td>
</tr>
<tr>
<td>24-35</td>
<td>2874.77</td>
<td>2884.629</td>
<td>393.296</td>
<td>367.842</td>
</tr>
<tr>
<td>36-44</td>
<td>5039.536</td>
<td>5136.884</td>
<td>990.796</td>
<td>989.592</td>
</tr>
<tr>
<td>45-53</td>
<td>7043.582</td>
<td>7229.817</td>
<td>1530.183</td>
<td>1511.114</td>
</tr>
<tr>
<td>54-62</td>
<td>10743.861</td>
<td>10862.278</td>
<td>2806.015</td>
<td>2699.833</td>
</tr>
<tr>
<td>63-75</td>
<td>11691.062</td>
<td>11439.55</td>
<td>3437.825</td>
<td>3475.308</td>
</tr>
<tr>
<td>76+</td>
<td>13709.524</td>
<td>10394.026</td>
<td>3829.21</td>
<td>3863.794</td>
</tr>
</tbody>
</table>

the ACA increases the total medical expenditures, and thereby improves the average level of health. These changes at the aggregate level originate from variations in medical expenditures over generations. Table 7 compare the average and standard deviation of the benchmark economy with those of the economy with the ACA. It shows that working-age individuals spend more on health care under the ACA. In addition, the ACA decreases the standard deviations of medical expenditures within cohorts. An increase in medical expenditures is driven by expansions in health insurance through the Medicaid expansion and the subsidy policy for individual health insurance. These reforms provide health insurances to low income working-age individuals, which brings about an overall increase in medical expenditures. Declines in the standard deviations in medical expenditures come from a reduction in the variation of health shocks within a cohort. Expansions in health insurance under the ACA allow young and poor individuals spend on health care, which mitigate the level their health risk over the life cycle. It decreases the variation of health shocks across cohorts, leads to a reduction in the standard deviation of medical expenditures for working-age individuals.

These changes in medical expenditures directly affect health. Table 8 illustrates the mean and the variance of log health status. Between age 24 and 35, differences in the average health status and the variance of health status are not large. However, as agents get older, the gap in the average health status becomes larger before retirement. In addition, under the economy with the ACA, inequalities in health status are enhanced across cohorts. Since welfare is determined by consumption and health, these improvements in the level and the inequality of health status directly increase the welfare level under the ACA.

The ACA indirectly affects earnings and consumption through health, which is another chan-
Table 8: Changes in Health Status

<table>
<thead>
<tr>
<th>Age</th>
<th>Average Log Health Status</th>
<th>Variance of Log Health Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>ACA</td>
</tr>
<tr>
<td>0-11</td>
<td>-0.19</td>
<td>-0.19</td>
</tr>
<tr>
<td>12-23</td>
<td>-0.224</td>
<td>-0.215</td>
</tr>
<tr>
<td>24-35</td>
<td>-0.294</td>
<td>-0.301</td>
</tr>
<tr>
<td>36-44</td>
<td>-0.388</td>
<td>-0.380</td>
</tr>
<tr>
<td>45-53</td>
<td>-0.573</td>
<td>-0.548</td>
</tr>
<tr>
<td>54-62</td>
<td>-0.727</td>
<td>-0.667</td>
</tr>
<tr>
<td>63-75</td>
<td>-0.775</td>
<td>-0.753</td>
</tr>
<tr>
<td>76+</td>
<td>-0.888</td>
<td>0.886</td>
</tr>
</tbody>
</table>

Figure 13: Percentage Changes in the Variance of Log Earnings from the Benchmark

The Improvements in earnings inequality have influences on consumption dynamics. Figure 14 shows that the ACA reduces consumption inequality for working-age cohorts. For children, whereas consumption inequality is less severe in the economy with the ACA, the gap is not large, which is less than 1 percent. However, working-age individuals experience larger improvements.
in consumption inequality than children. This reduction in consumption inequality is an indirect channel for the welfare improvements under the ACA, which comes from improvements in earnings inequality.

In summary, a direct channel through health and an indirect channel through consumption play an important role in improvements welfare under the ACA. The direct channel comes through improvements in health status levels and health status inequality that directly follow expansions in health insurance under the ACA. The indirect channel starts from improvements in health status levels and its inequality. Since health is an endogenous factor that determines labor productivity, it improves earnings inequality, which leads to a reduction in consumption inequality. Through these two mechanisms, welfare improves under the ACA.

7 Conclusion

I study the implication of the average bankruptcy rate in evaluating the ACA and the macroeconomic and welfare consequences of the ACA. To do these, by using data from the MEPS, I investigate individual behaviors on emergency room visits, medical conditions, medical expenditures that are closely related to reforms in the ACA. I build an overlapping generations general equilibrium model that succeeds in replicating many individual features that are related to income inequality, debt, bankruptcy, medical expenditure, and health insurance. I find that the endogenous distribution of health shocks is a key model component to replicate these individual features in data.

I have found that the economy’s average default rate does not exhibit the large changes produced by the previous empirical work, and welfare can improve with a higher level of default rate, following an expansion in health insurance coverage. Moreover, I find that the ACA declines
household bankruptcies from medical reasons, but increases bankruptcies from income shocks due to general equilibrium effects. This is also reflected in a compositional change in default rate over age. Expanding health insurance increases the default rate of younger generations, while that of older generations falls. I show that these are driven by an interaction between the distortion from taxes and general equilibrium effects of a falling capital stock.

Another issue this paper addresses is the macroeconomic and welfare consequences of the Affordable Care Act. I find that increases in health insurance coverage improve health for low and middle income households at the cost of decreases in aggregate output and capital. In addition, the improvements in health reduce earnings inequality, leading to improvements in consumption inequality. These are the key channels for improvements in welfare under the ACA.

In terms of future research, endogenizing labor supply decisions seems important. Reforms in health insurance are closely related to the demand or supply behavior of labor. While I abstracted from labor supply decisions, endogenizing labor supply decisions will generate other interesting predictions from health insurance reform. Such an analysis is deferred to future work.
References


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Appendices

A Data Details

A.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 US dollar in 2000 with the CPI. The number of observations in each panel is as follows.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<td>7484</td>
<td>7577</td>
<td>7548</td>
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<td>7721</td>
<td>5835</td>
<td>8611</td>
<td>7988</td>
<td>7020</td>
<td></td>
</tr>
</tbody>
</table>

Table 9: MEPS Panel Sample Size

A.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 behaviors 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 keeps 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 (2012). Table A.2 is the morbidity measures in Prados (2012). For calculating health shocks from medical conditions, I follow
Table 10: Disability Weights (Source: Prados (2012))

The method in Prados (2012). Let's assume that a household has $D$ medical conditions. Denote $d_i$ as the WHO index for medical condition $i$, where $i = 1, \ldots, D$. For this household, its health shock $\varepsilon_h$ is represented by

$$ (1 - \varepsilon_h) = \prod_{i=1}^{D} (1 - d_i). $$

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 Expenditures (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 they pay for emergency medical treatments (ERXP00X).
B Applying Clausen and Strub (2013)’s Envelope Theorem to the model

Clausen and Strub (2013) 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 with iid idiosyncratic shocks. I extend this to solve my model with persistent idiosyncratic shock. To use their envelope theorem, it is necessary to introduce the following definition.

**Definition 3** We say that \( F : C \rightarrow \mathbb{R} \) is **differentiably sandwiched** between the lower and upper support functions \( L, U : C \rightarrow \mathbb{R} \) at \( \bar{c} \in C \) if

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

Let’s begin with the First Order Condition. Given a state \((\bar{i}, \bar{h}; j, \eta)\), let \( a'_{rbl}(\bar{i}, \bar{h}; j, \eta) \) denote the risky borrowing constraints (credit limits). Then, given a pair of \((\varepsilon_e, \varepsilon_n)\), for any \((\bar{i}, \bar{h}; j, \eta)\) and for any \( a' \geq a'_{rbl}(\bar{i}, \bar{h}; j, \eta) \), the First Order Condition (FOC) is:

\[
D_1 u(c, (1 - \varepsilon_e)(1 - \varepsilon_n)\bar{h}) = \frac{1}{D_1 q(a', \bar{i}, \bar{h}; j, \eta) a' + q(a', \bar{i}, \bar{h}; j, \eta) D_1 W^G_{j+1}(a', \bar{i}, \bar{h}, \eta)}
\]

where \( W^G_{j+1}(a', \bar{i}, \bar{h}, \eta) \) denote \( \beta \pi_{j+1} \sum \varepsilon_c \varepsilon_p \varepsilon_{\bar{i}} \varepsilon_{\bar{h}} \pi_{\bar{i}} \pi_{\bar{h}} \pi_j \pi_{\eta} V_{j+1}(a', \bar{i}, \bar{h}, \varepsilon_c, \varepsilon_p, \varepsilon_{\bar{i}}, \varepsilon_{\bar{h}}, \eta).\)

Clausen and Strub (2013) prove that if each constituent function of the FOC has a differentiable lower support function at a point, the constituent function are differentiable and the First Order Condition is a necessary condition for the global solution. For example, given a state \((\bar{i}, \bar{h}; j, \eta)\) and \((1 - \varepsilon_n)(1 - \varepsilon_c)\bar{h} \), if there are differentiable lower support function of the utility function \( u(\cdot, (1 - \varepsilon_n)(1 - \varepsilon_c)h) \), price function \( q(\cdot, \bar{i}, \bar{h}; j, \eta) \), and value function \( D_1 W^G_{j+1}(\cdot, \bar{i}, \bar{h}, \eta) \) with respect to \( a' \), the FOC holds and is a necessary condition for the global solution. Formally,

**Corollary 0.1**

\[
given a pair of (\varepsilon_e, \varepsilon_n), for any (\bar{i}, \bar{h}; j, \eta) \ and \forall a' \geq a'_{rbl}(\bar{i}, \bar{h}; j, \eta),
\]

\[
D_1 u(c, (1 - \varepsilon_e)(1 - \varepsilon_n)\bar{h}) = \frac{1}{D_1 q(a', \bar{i}, \bar{h}; j, \eta) a' + q(a', \bar{i}, \bar{h}; j, \eta) D_1 W^G_{j+1}(a', \bar{i}, \bar{h}, \eta)}
\]

holds and this is a necessary condition for the global solution.
Proof.
Claim: $u(\cdot, (1 - \varepsilon_n)(1 - \varepsilon_e)h)$, price function $q(\cdot, i', \bar{h}', j, \eta')$, and value function $W_{j+1}^G(\cdot, i', \bar{h}', \eta')$ have differentiable lower support functions.

Since the utility function is differentiable, it the utility function itself is the differentiable lower support function.
By Lemma 0.1 and Lemma 0.2, price function $q(\cdot, i', \bar{h}', j, \eta')$, and value function $W_{j+1}^G(\cdot, i', \bar{h}', \eta')$ have differentiable lower support functions.
By theorem 1 (Envelope theorem) in Clausen and Strub (2013), the FOC holds and it is a necessary condition for the global solution.

Lemma 0.1 Let a state $(i', \bar{h}', j, \eta')$ be given. Let $a_{rbl}(\tilde{i}', \bar{h}', j, \eta')$ be the risky borrowing limit (risk-free credit limit) of $q(\cdot, i', \bar{h}', j, \eta')$. For all $a' > a_{rbl}(\tilde{i}', \bar{h}', j, \eta')$, the bond price function, $q(a', \tilde{i}', \bar{h}', j, \eta')$ has a differentiable lower support function.

Proof. For any $a' \geq 0$, $q(a', \tilde{i}', \bar{h}', j, \eta') = \frac{1}{1 + r_f}$ and $D_1 q(a', \tilde{i}', \bar{h}', j, \eta') = 0$. Thus, $q(a', \tilde{i}', \bar{h}', j, \eta')$ itself is a differentiable lower support if $a' > 0$.

Take any $a' \in (a_{rbl}(\tilde{i}', \bar{h}', j, \eta'), 0)$. Note that $q(a', \tilde{i}', \bar{h}', j, \eta') = \frac{1 - d(a', \tilde{i}', \bar{h}', j, \eta')}{1 + r_f}$. It implies that finding a lower differential support function of $q(a', \tilde{i}', \bar{h}', j, \eta')$ is equivalent to doing a upper differential support function of $d(a', \tilde{i}', \bar{h}', j, \eta')$.

Lemma 0.2 Let a state $(i', \bar{h}', j, \eta')$ be given. Let $a_{rbl}(\tilde{i}', \bar{h}', j, \eta')$ be the risky borrowing limit (risk-free credit limit) of $q(\cdot, i', \bar{h}', j, \eta')$. For all $a' > a_{rbl}(\tilde{i}', \bar{h}', j, \eta')$, there is a differentiable lower support function of $D_1 W_{j+1}^G(\cdot, i', \bar{h}', \eta') = \beta \pi_j \sum \varepsilon_{j+1} \pi_{j+1} \varepsilon_{j+1} \eta' \omega' \pi_{j+1} \varepsilon'_{j+1} \eta' \omega' V_{j+1}^G(a', \tilde{i}', \bar{h}', j, \eta')$. 


C Computation Method

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, and progressive subsidy or tax policies.

To solve the model with these complexities, I develop an endogenous grid method for default models with discrete choices. This method is an extended version of Fella (2014)’s endogenous grid method. Fella 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 a few types of value functions in the model, the computational issues are mainly related to two types of value functions: the value function of repaying debt $v_{j}^{G,R}(a, i, h, \varepsilon, e_n \eta, \omega)$, and the value function with bad credit status $v_{j}^{B,R}(a, i, h, \varepsilon, e_n \eta, \omega)$. The value function with bad credit status is solved with the algorithm of Fella (2014), because in this case the economy has an exogenous borrowing constrain with discrete choice, consistent with the setting of Fella (2014). My computation method is for solving the value function of repaying debts $v_{j}^{G,R}(a, i, h, \varepsilon, e_n, \eta)$ in which borrowing constraints differ across individuals states.

Before introducing details of the solution method, I briefly repeat the value function of repaying debts in sub period 2 and describe the whole picture of the solution method. Those who decide to repay their debts with good credit solve

$$v_{j}^{G,N}(a, i, h, \varepsilon, e_n, \eta, \omega) = \max_{\{c, a', i', h, m_n \geq 0\}} \left( \frac{(c \alpha h^{1-\alpha})^{1-\sigma}}{1-\sigma} + W_{j+1}^{G}(a', i', h', \eta) \right) \right.$$  

$$c + q(a', i', h', j, \eta) a' + \rho(i', h_c, j_g) = 

(1 - (\tau_{ss} + \tau_{med})) w \xi_j + a - (1 - q_i(1 - \mathbb{1}_{i=NHI})) (m_n + m_e) - T(y) + \kappa$$

where

$$i \in \{NHI, MCD, IHI, EHI\}$$

$$h_c = (1 - \varepsilon_n)(1 - \varepsilon_e) h$$

$$h' = (1 - \varepsilon_n)(1 - \varepsilon_e) h + \varphi_{fs} m_n$$

$$y = w \xi_j + \left( \frac{1}{q^f} - 1 \right) a - \mathbb{1}_{a > 0}, \text{ where } \xi_j = \bar{\sigma}_j h_c \eta$$

36 The value function of filing for default is not involved with any continuous choice variable. Also, the other value functions are restricted to a few discrete choices.
where $W_{j+1}^{G}(a',i',h',\eta)$ is $\beta \pi_{j+1} \sum \varepsilon'_e,\varepsilon'_n,\eta'\pi_{h',i',j+1} \pi_{\varepsilon'_e,\varepsilon'_n,\eta'} \pi_{\varepsilon'_e,\varepsilon'_n,\eta'} V_{j+1}^{G}(a',i',h',\varepsilon',\varepsilon',\eta').$

The whole picture of computation is the following.

1. Except for the asset variable for the next period, take all the other states as given states, which means the discretization of the other states.

2. For each individual state, calculate the risky borrowing limit by using the price function.

3. Obtain the FOC, retrieve the value function, and store the cash on hands.

4. With Fella (2014)os algorithm, divide the domain of the expected future value function into concave area and non-concave area.

5. Find the global solution and obtain the value function on the exogenous grid.

6. Optimize the discrete choices that are given from the first step.

7. Update the price.

In the following sub sections, the details of each step in the above are covered.

### C.1 Discretization of states

In the model, households need to make choices on three individual state variables: asset, health insurance, and health status (health expenditure). I discretize the state of health insurance and health status as well as other exogenous state variables. It is to use the endogenous grid method with respect to the state of asset. This way is efficient because the range of asset in the equilibrium is wide and the heterogeneity of asset is the largest comparing to the state of health insurance and health. By doing this, the problem becomes a one dimensional optimization problem given the other states. In the equation 20, the endogenous individual state variable is only $a'$ in this state.

### C.2 Calculating risky borrowing limits (credit limits)

In order to solve default models with the endogenous grid method, it is necessary to set up feasible sets for the solution. Finding the feasible set is not a trivial work because of two reasons. The first reason is that, in default models, borrowing limits are not given, as they are endogenously determined in the equilibrium. Therefore, this step is not required for other types of models in which the borrowing constraint are given before solving the models. The second reason is that the range of the feasible sets depends on the state of individuals, because the borrowing limits are affected by individual default risks that are the functions of individual state.
I set up the feasible sets of the solution based on the work in Arellano (2008); Clausen and Strub (2013). They investigate the property of the risky borrowing limits (credit limits) in their work. Arellano (2008); Clausen and Strub (2013) show that the size of loan $q(a^n)a^n$ is increases in $a'$ under every optimal debt contract. If the size of loan $q(a^n)a^n$ decreases in $a^n$, households can increase their consumption by increasing debts, which is unstable debt contracts. Arellano (2008) (Clausen and Strub (2013)) defines the risky borrowing limit (credit limit) to be the lower bound of the set for optimal contract. Figure C.2 illustrate the risky borrowing limit.

![Risky borrowing limit](image)

**Figure 15: Risky borrowing limit, Arellano(2007)**

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

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

(21)

and save them. I use the risky borrowing limits as the lower bound of feasible sets. These sets include every global solution and differ across the state of individuals. To obtain the value of derivative, $\frac{\partial q(a', \bar{i}', \bar{h}'; \bar{j}, \bar{\eta})}{\partial a'}$, I use the slope of the price function $q(a', \bar{i}', \bar{h}'; \bar{j}, \bar{\eta})$ between $a'$ and its nearest right point on the grid.

### C.3 Obtaining the FOC as the candidate of the global solution

By corollary 0.1, the FOC is a necessary condition for the global solution and exists. With the risky borrowing limits in the previous step, the FOC is defined as follows.

For each state $(\bar{i}', \bar{h}', \bar{j}, \bar{\eta})$ and $a' \geq a_{rbl}'(\bar{i}', \bar{h}', \bar{j}, \bar{\eta})$, $D_1u(c, (1 - \varepsilon_c)(1 - \varepsilon_n)\bar{h}) = \frac{1}{D_1q(a', \bar{i}', \bar{h}'; \bar{j}, \bar{\eta})a' + q(a', \bar{i}', \bar{h}'; \bar{j}, \bar{\eta})}D_1W_{j+1}^G(a', \bar{i}', \bar{h}', \bar{j}, \bar{\eta})$

(22)
On the grid $G_{a'}$ of $a'$, calculate the FOC (22). For the derivative, I use the slope of the functions between $a'$ and its nearest right point on the grid.

Using the FOC, compute the endogenously-determined level of consumption $c(a', i, h', e, e_n; j, \eta)$. Next, substitute the consumption $c(a', i, h', e, e_n; j, \eta)$ into the utility function, and retrieve the value function of repaying debts:

$$\tilde{v}^G_j (a', i, h', e, e_n, \eta, \hat{\omega}) = \frac{c(a', i, h', e, e_n; \eta, j)^\alpha ((1 - \varepsilon_e) (1 - \varepsilon_n) h)^{1-\sigma}}{1 - \sigma} + W_{j+1}^G (a', i, h', \eta)$$

(23)

In addition, for each state $(i', h', i, h, e, e_n, \eta)$ and $a'$ on the grid $G_{a'}$, store cash on hands, $coh_j (a', i, h', e, \eta)$:

$$coh_j (a', i, h', e, e_n; \eta, j) = c(a', i, h', e, e_n; \eta, j) - q(a', i, h'; j, \eta) a'$$

(24)

### C.4 Identifying the concave and non-concave regions

It is worth noting that the FOC is a necessary condition because of the non-concavities on the expected value function $W_{j+1}^G (a', i, h', \eta)$ with respect to $a'$. If the concave regions can be identified, the FOC is a sufficient and necessary condition on the concave region, which decrease the burden of computations. I use Fella (2014)’s algorithm to divide the domain of the expected value functions $W_{j+1}^G (a', i, h', \eta)$ into the concave and non-concave regions.

With the cash on hands, the FOC (22) can be represented in the following way.

For each state $(i', h', e, e_n, j, \eta)$ and $\forall a' \geq a_{rbl}' (i', h'; j, \eta)$,

$$D_1 u (coh_j (a', i, h', e, e_n, \eta)) + q(a', i, h'; j, \eta) a' (1 - \varepsilon_e) (1 - \varepsilon_n) h) =
\frac{D_1 W_{j+1}^G (a', i, h', \eta)}{D_1 q(a', i, h'; j, \eta) a_1 + q(a', i, h'; j, \eta)}$$

(25)

where $\tilde{a'}$ in $coh_j (\tilde{a'}, i, h', e, e_n, \eta)$ is constant. The LHS of (25) is monotone increasing in $a'$, because the value of $a'$ is larger than the risky borrowing limit, $a_{rbl}' (i', h'; j, \eta)$, and the utility function is strictly concave.

The issues of non-concavities are involved with the RHS. If the expected value function is concave, the RHS is monotonic decreasing. Therefore, an algorithm of identifying the non-concave regions needs to be used on the RHS. I take Fella (2014)’s algorithm that is as follows.

\[37\] Note that under every optimal contract, $q(a_1', i, h'; j, \eta) a_1'$ is weakly increasing in $a_1'$. 

10
1. For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), calculate the value of derivative on the RHS of (25) at each grid point on \(G^e_{a'}\).

2. Find grid points in which the value of derivative jumps in \(a'\), and save the jumped points with logical clause. (ex. jumping points=1, the others=0)
   - To find the jumped points, check the derivative values at two adjunct grid points, \(a'_i < a'_{i+1}\) on the grid \(G^e_{a'}\). If the value of the derivative at the greater point, \(a'_{i+1}\) is greater than the value of the derivative at the lower point \(a'_i\), \(a'_i\) is one of the jumped points.

3. For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), find the maximum value of the derivative \(v_{max}(\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), and minimum value of the derivative \(v_{min}(\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\) among the jumped grid points on the grid \(G^e_{a'}\).

4. For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), search for \(a'_i(a'_j)\) such that for all \(a' < a'_i(a' > a'_j)\), the value of derivative on the RHS of (25) is greater (smaller) than \(v_{max}(v_{min})\).\(^{38}\)

5. For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), the non-concave region is \(G^{nc}_{a'} = \{a'_i = a_{min}, \ldots, a'_i = a_{max}\}\), while the rest, \(G^{cc}_{a'} = G^e_{a'} \setminus G^{nc}_{a'}\) constitutes the concave region.

### C.5 Collecting the global solutions and updating the value function

Since the concave regions are identified by the previous procedures, the FOCs are sufficient and necessary conditions for the global solutions on the concave regions \(G^{cc}_{a'}\). For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), save the pair of cash on hands and asset grids, \(\{coh_j(a'_i, \tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta}), a'_i\}\) if \(a' \in G^{cc}_{a'}\).

If \(a' \in G^{nc}_{a'}\), the FOCs are not sufficient but necessary. However, the FOCs provide good candidates of the global solutions. For each state \((\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\), it is required to check whether \(a' \in G^{nc}_{a'}\) is a global solution by searching grids on the non-concave region, \(G^{nc}_{a'}\). If the grid \(a' \in G^{nc}_{a'}\) is consistent with the solution from the grid search, save the pair \(\{coh_j(\tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta}), a'_i\}\). With the saved pairs, retrieve the value functions, \(v_j^{Gr}(a'_i, \tilde{i}, \tilde{h}, \bar{e}_e, \bar{e}_n, \bar{j}, \bar{\eta})\). It is important to note that these value function is on endogenously determined grids in \(a\). Since the value functions preserve the monotonicity, it is possible to retrieve the value functions on the exogenous grid I set up by using linear interpolations.

The above steps are summarized in the following.

\(^{38}\)For example, in FORTRAN, to find \(a'_j\), we can use \texttt{minloc} function for the derivative values, conditional on these values are greater than \(v_{max}\).
1. If $a' \in G^{cc}_{a}$, save $\{coh_j(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}), a'\}$

2. If $a' \in G^{nc}_{a}$, solve the following problem

$$
\begin{align*}
\hat{a}^{'}_{soll} = \arg\max_{a'' \in G^{nc}_{a}(i, h', \bar{\epsilon}_e, \bar{\epsilon}_n; j, \bar{\eta})} & \; u(coh_j(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}) + q(a''(i, h'; j, \bar{\eta}))a''(1 - \bar{\epsilon}_e)(1 - \bar{\epsilon}_n)\bar{h}) \\
& + W_{j+1}^{G}(a'', i, h', \bar{\eta})
\end{align*}
$$

- If $\hat{a}^{'}_{soll} = a'$, save the pair $\{coh_j(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}), a'\}$.
- If $\hat{a}^{'}_{soll} \neq a'$, discard the pair $\{coh_j(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}), a'\}$.

3. With the saved pairs $\{coh_j(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}), a'\}$, obtain the value functions $v^{G,R}_{j}(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta})$ that are on the endogenously determined grids of $a$ in the current period.

4. Use linear interpolations to $v^{G,R}_{j}(a', i, h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta})$ and calculate the values on the exogenous grid of $a \in G_{a}$.

**C.6 Optimize the discrete choices**

Until this step, the choice of health insurance $i'$ and the status of invested health (medical expenditure) $h'$ 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:

$$
v^{G,R}_{j}(a, i, h, \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta}) = \max_{\{i', h'\}} v^{G,R}_{j}(a, i', h', \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta})
$$

**C.7 Updating the prices**

I have explained how to obtain $v^{G,R}_{j}(a, i, h, \bar{\epsilon}_e, \bar{\epsilon}_n, \bar{\eta})$. The other value functions, $v^{G,D}$ and $v^{B}$, are solved by simple grid search for a few discrete choices and using the algorithm of Fella (2014). Then, given a state $(a', i', h'; j - 1, \eta_{-1})$, the default probability is

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39 The value function of defaulter is solved by optimize the discrete choice on health insurance. In addition, the value function with bad credit is solved by the algorithm of Fella (2014), because it has the discrete choices with an exogenous borrowing constraint, consistent with the circumstance of his algorithm.
\[
d p(a', i', h'; j - 1, \eta_{-1}) = \sum_{e_e} \pi_{e_e|h', j_g} \sum_{e_n'} \pi_{e_n'|h', j_g} \sum_{\pi} \pi_{\eta|\eta_{-1}, g_{df}, j}(a', i', h', e_e', e_n', \eta)
\]
\[
g_{df, j}(a', i', h', e_e', e_n', \eta) = \begin{cases} 
0 & \text{if } v_{G,R}^j(a', i', h', e_e', e_n', \eta) > v_{G,D}^j(i', h', e_e, e_n, \eta) \\
1 & \text{if } v_{G,R}^j(a', i', h', e_e', e_n, \eta) \leq v_{G,D}^j(i', h', e_e, e_n, \eta)
\end{cases}
\]

With the default probability \(d p(a', i', h'; j - 1, \eta_{-1})\), the loan prices at age \(j - 1\) is
\[
q(a', i', h'; j - 1, \eta_{-1}) = \frac{\pi_{j|j-1} (1 - d p(a', i', h'; j - 1, \eta_{-1}))}{1 + r_{rf}}
\]
(26)

where \(r_{rf}\) is the equilibrium risk-free interest rate. Repeat the procedures until the beginning age.