Three essays in inequality and health economics

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**NANYANG
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**THREE ESSAYS IN INEQUALITY AND
HEALTH ECONOMICS**

**XINWEN NI
SCHOOL OF SOCIAL SCIENCES**

2018

THREE ESSAYS IN INEQUALITY AND HEALTH ECONOMICS

XINWEN NI

SCHOOL OF SOCIAL SCIENCES

A thesis submitted to the Nanyang Technological University
in partial fulfilment of the requirement for the degree of
Doctor of Philosophy

2018

Statement of Originality

I certify that all work submitted for this thesis is my original work. I declare that no other person's work has been used without due acknowledgement. Except where it is clearly stated that I have used some of this material elsewhere, this work has not been presented by me for assessment in any other institution or University. I certify that the data collected for this project are authentic and the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

A handwritten signature in blue ink, appearing to read '倪新文' (Ni Xinwen), written over a horizontal line.

Xinwen Ni

August, 2018

Supervisor Declaration Statement

I certify that all work submitted for this thesis is my original work. I declare that no other person's work has been used without due acknowledgement. Except where it is clearly stated that I have used some of this material elsewhere, this work has not been presented by me for assessment in any other institution or University. I certify that the data collected for this project are authentic and the investigations were conducted in accordance with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

Dr. Yang Tang
August, 2018

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Executive Summary

This thesis consists of three self-contained essays on inequality and health economics. The first essay investigates the role played by housing in inequality and social mobility. Housing typically takes up a major proportion of households' expenditure, and thus it certainly plays a critical role in shaping the pattern of income inequality and social mobility. Whether high housing price-to-rent ratio will amplify inequality and inhibit social class upgrading is still a controversial issue in the existing literature. In this paper, we develop a partial equilibrium life-cycle framework to address these issues. Agents in our economy are divided into two social classes according to the initial human capital level inherited from their parents. Those who belong to upper class will draw their innate abilities from a distribution that first order stochastically dominates those from lower class. Throughout the entire lifecycle, agents make endogenous human capital investment and housing tenure decisions. We calibrate the model to mimic some stylized facts in the the real world counter part. Our simulation results indicate an inverse-U pattern between housing price-to-rent ratio and measures of income inequality, and as well as a U-shape pattern between price-to-rent ratio and social mobility measured by Shorrocks Index. The implication is that housing tends to amplify the inequality and slow down the social mobility when houses can only be purchased by a small group of agents in the economy. Moreover, our results also suggest that better quality of education as a result of a higher return to human capital investment tends to dampen the role of housing.

The second essay studies the role of medical expenses in the saving decision of elderly. We develop an multi period overlapping generation framework to investigate agents' consumption and saving decisions, inequality and welfare among elderly. We assume that agents are heterogeneous in the non-asset income and the medical expenditure. In order to explicitly analyze the effects of medical expenditure, we conduct three counterfactual exercises. We successively shut down the heterogeneity in labor income, in the level and in the dispersion of medical ex-

penses respectively. By comparing the benchmark with the counterfactual results, we find that in general wealth inequality decreases with age, and income uncertainty contributes the most to wealth inequality. Both average consumption and consumption inequality increase with age. Consumption inequality largely tracks income inequality. Though uncertainty in medical expenditures has little effect on consumption inequality, a higher level of medical expenditures may exacerbate consumption inequality. Meanwhile, the average saving of elderly exhibits an inverse-U shape with age. The impacts on average saving are similar both in benchmark and in counterfactual exercises. Welfare increases with age.

In the third essay, we build an overlapping generation model to examine the reason why developed countries with similar background have implemented different social health insurance systems. We propose two hypotheses to explain this phenomenon: (i) the different participation rates of the poor in the voting; (ii) the distinct attitudes towards the size of the government and the existence of a compulsory social health insurance system. Agents need to vote for one of two policies: Policy I without Social Health Insurance (SHI) but with the subsidy for the poor, and Policy II with fully covered SHI. By comparing either their current utility or the expected life time utility, households will choose one policy. We find that under Policy I, the derivative of the changes of expected utility with respect to income is not monotonic. This means that both the poorest and the richest dislike the social health insurance system. With the calibrated parameters, we solve the benchmark and find that the public's attitude towards the size of the government and the lower representation of the poor affect the election result. The changes in the minimum consumption level under Policy I affect the voting results most, followed by the attitude. Voting Participant rate plays the most insignificant role in the voting outcome. The sensitivity analysis shows that our main findings are robust to the input parameters.

Chapter 1

Understanding the Role of Housing in Inequality and Social Mobility

1.1 Introduction

The seminal work by [Piketty](#) in [2014](#) presented a "U-Shaped" pattern of inequality for the past century. In particular, the last forty years have seen a rapid rise in top income inequality in the United States ([Keister and Moller, 2000](#); [Piketty and Saez, 2006](#); [Saez, 2009](#)). Right before the Subprime Mortgage Crisis in 2007, the highest concentration of income since 1979 was observed when the top 1% of households accounted for almost 20 percent of total income ([Sherman and Stone, 2010](#)). Many studies have been done about the possible causes of the rising inequality: [Morris and Western \(1999\)](#) believed that the supply side demographic shifts can be the contributors to the changes of the income distributions. [Harrison and Bluestone \(1990\)](#) regarded the economic restructuring could be one of the reasons. Skill-biased technological change ([Bound and Johnson, 1989](#)) and institutional shifts ([Levy and Temin, 2007](#)) have also been considered.

During the same time span, housing price and housing value to rent in the U.S

climbed to the top until the financial crisis of 2007-2008 ([Campbell et al., 2009](#)). Housing typically takes up a major proportion of households' expenditure, and thus it certainly plays a critical role in shaping the pattern of income inequality. However, the role of housing in the rise of social inequality is basically ignored in the previously mentioned studies. There are three aspects of housing in the U.S. that may impact the distributions of income and have been discussed the most in the literature: housing affordability ([Chi and Laquatra, 1998](#); [Mimura, 2008](#); [Quigley and Raphael, 2004](#)), homeownership ([Chi and Laquatra, 1998](#)), and subprime lending ([Belsky et al., 2007](#); [Stegman et al., 2007](#)). Based on empirical analysis, [Rognlie \(2014\)](#) argued that indeed, there existed an upward trend of net capital share after 1984 as mentioned in [Piketty \(2014\)](#); however, when he disaggregated the capital share into the housing sector and the non-housing sector, only the housing sector was found to have contributed to the inequality increases.

It seems that we need a bridge to connect housing and inequality. [Cantó et al. \(2000\)](#) and [Andrews and Leigh \(2009\)](#) showed that there existed a strong trade-off between income inequality and social mobility. [Aaberge et al. \(2002\)](#) exhibited that the U.S., which suffered from a higher degree of inequality, had lower mobility of earnings than the Scandinavian countries. Whether high housing Price-to-Rent ratio will amplify inequality and inhibit social class upgrading is still a controversial issue in the existing literature. We infer that social mobility plays an important role. Methods of measuring social mobility have been developed with time: [Shorrocks \(1978\)](#), [Maasoumi and Zandvakili \(1986\)](#), [Jarvis and Jenkins \(1998\)](#), [Schluter and Trede \(2003\)](#), [Nichols and Favreault \(2009\)](#). However, in this paper, we still adopt the most commonly used Shorrocks Index as our measure method. [Kennickell and Starr-Mccluer \(1997\)](#), [Charles and Hurst \(2003\)](#), [Aaberge et al. \(2002\)](#), [Klevmarken et al. \(2003\)](#) reports measurement of social mobility. In our study, we try to match our simulation results with the study of [Kennickell and Starr-Mccluer \(1997\)](#).

In this chapter, we develop a partial equilibrium life-cycle framework to address

the relationships among inequality, social mobility and housing. For the basic setting of the model we follow [Benabou \(1994\)](#). Agents in our economy are divided into two social classes, the upper class and the lower class according to the initial human capital level inherited from their parents. Those who belong to the upper class will draw their innate abilities from a distribution that first order stochastically dominates those from the lower class. Throughout the entire lifecycle, agents make endogenous human capital investment and housing tenure decisions. We calibrate the model to mimic some stylized facts in the the real world counter part. Our simulation results indicate an inverted-U pattern between housing price-to-rent ratio and measures of income inequality, and as well as a U-shape pattern between price-to-rent ratio and social mobility measured by Shorrocks Index. The implication is that housing tends to amplify the inequality and slow down the social mobility when houses can only be purchased by a small group of agents in the economy. Moreover, our results also suggest that better quality of education as a result of a higher return to human capital investment tends to dampen the role of housing.

The rest of the paper is structured as follows. Section [1.2](#) lays out the theoretical framework. Section [1.3](#) illustrates both the benchmark’s simulation results and the counterfactual results. Section [1.4](#) presents our conclusions.

1.2 Model

Time is discrete and infinite indexed by $t = 0, 1, \dots$. The economy is populated by overlapping generations of individuals. The size of each cohort is normalized to be 1. Each individual lives two periods: the Youth and the Old-age. Each individual gives birth to one child at the end of her middle-age. The new born child is endowed with the same human capital as her parent through at-home learning ([Benabou, 1994](#)). We will describe the timeline in detail later. Individuals are also heterogeneous in their innate abilities, which are drawn randomly upon birth from a specific distribution function defined over $[\underline{a}, \bar{a}]$.

We let $i \in [0, 1]$ denote the individual index. Individual i born in period t is endowed with h_t^i units of human capital. Each individual will engage in human capital accumulation through her Youth. h_{t+1}^i denotes human capital level that she owns by the end of the Youth, and it also equals to the human capital level that is inherited by her child born in the time $t + 1$.

Individuals are classified into two classes according to their initial human capital levels. There exists a threshold human capital level $\bar{h}$. Individuals belong to the upper class if their initial human capital exceeds $\bar{h}$, otherwise they belong to the lower class. Individuals from two classes draw their innate abilities from two independent distributions. We denote $G(\cdot)$ as the distribution function if the individual belongs to upper class, and $F(\cdot)$ if the individual belongs to lower class. Moreover, we assume $G(\cdot)$ first-order stochastic dominates $F(\cdot)$ (FOSD). Specifically, we let $G(a)$ take the following form:

$$G(a) = \left(\frac{F(a) - \underline{a}}{\bar{a} - \underline{a}} \right)^{\frac{1}{\alpha}} \times (\bar{a} - \underline{a}) + \underline{a}, \quad \alpha > 1 \quad (1.1)$$

This captures the essence that individuals from the upper class face a "superior" distribution of talents.

Given the realization of innate ability a and initial human capital h_t^i , each individual i born in t then makes the human capital investment decision I_t^i . Specifically, the accumulation of human capital can be denoted by an increasing function as follows:

$$h_{t+1}^i = (1 - \delta)h_t^i + a_t^i (I_t^i)^\gamma \quad (1.2)$$

where $\delta \in (0, 1)$ is the human capital depreciation rate, and $\gamma \in (0, 1)$ represents the elasticity of investment to human capital accumulation. Higher abilities or investment will result in higher human capital in the next period.

Individuals receive wage income both in the Youth and in the Old-age. Wage rate is paid at per unit of human capital. We abstract away from the analysis of labor market and assume that the wage rate is exogenous. Individuals obtain utilities

from both consumption goods and housing services. We distinguish the housing tenure decision by allowing individuals to choose between renting and purchasing a house. Individuals gain higher utilities from owning a house than from renting one. We also assume individuals are altruistic and they value their children's initial human capital level. Specifically, the individual's utility function takes the following form:

$$u = \log c_t + \beta \log c_{t+1} + \nu \log h_{t+1} + e\Gamma_{\{i \in \{o,r\}\}} \quad (1.3)$$

where c_t and c_{t+1} represents the goods consumption of individuals in the Youth and the Old-age, respectively. $\beta \in (0, 1)$ is the subjective discount rate, and $\nu > 0$ captures the degree of altruism. $e > 0$ governs the utility premium from owning the house. Following literatures (such as [Ortalo-Magne and Rady, 1999](#)), we assume the utility premium is positive. $\Gamma_{\{i \in \{o,r\}\}}$ is an indicator function and equals to 1 if the agent owns a house.

If an individual decides to rent the house, she solves the following utility maximization problem ¹:

$$\begin{aligned} u^r &= \max (\log c_t^r + \beta \log c_{t+1}^r + \nu \log h_{t+1}^r) \\ \text{s.t. } c_t^r &= w_t h_t - R_t - I_t^r \\ c_{t+1}^r &= w_{t+1} h_{t+1}^r - R_{t+1} \\ h_{t+1}^r &= (1 - \delta) h_t + a_t (I_t^r)^\gamma \end{aligned}$$

where R_t and R_{t+1} denote the rental price in t and $t + 1$, respectively. We do not allow individuals to switch from renters to owners at the end of the Youth. Hence, the housing tenure decision should be made based upon the present value of life-time utilities.

If an individual decides to own the house, she solves the following utility maxi-

¹We drop individual indexes in the remainder of the paper, except in parts where such choice may jeopardize the clarity of our exposition.

mization problem:

$$\begin{aligned}
u^o &= \max (\log c_t^o + \beta \log c_{t+1}^o + \nu \log h_{t+1}^o + e) \\
s.t. \ c_t^o &= w_t h_t - P_t - I_t^o \\
c_{t+1}^o &= w_{t+1} h_{t+1}^o + P_{t+1} \\
h_{t+1}^o &= (1 - \delta) h_t + a_t (I_t^o)^\gamma
\end{aligned}$$

Individuals born in t purchase housing at price P_t by the end of their the Youth, and they sell their house at price P_{t+1} by the end of their Old-age. We do not consider the option of mortgages, and this implies individuals need to purchase the house at full price if they decide to own it.

To simplify the analysis, we also abstract away the supply side of the housing market. We let housing sales and the rental price evolve exogenously over time since examining housing price dynamics is not the major focus of the paper.

1.2.1 Equilibrium Characterization

In this subsection, we explicitly solve the individual's optimal decision over consumption, human capital investment and housing tenure.

If an individual decides to become a renter, solving the utility maximization problem gives following result:

$$\left(\frac{h_{t+1}^r - (1 - \delta) h_t}{a_t} \right)^{\frac{1}{\gamma}} \left[1 + \frac{h_{t+1}^r}{\gamma a_t} \frac{\left(\frac{h_{t+1}^r - (1 - \delta) h_t}{a_t} \right)^{1 - \gamma}}{\beta + \frac{\beta R_{t+1}}{(w h_{t+1}^r - R_{t+1})} + \nu} \right] = w_t h_t - R_t \quad (1.4)$$

It is straightforward to obtain that h_{t+1} is increasing in both abilities a_t and initial human capital h_t . Moreover, the comparative statics show that $\partial h_{t+1} / \partial R_t < 0$ and $\partial h_{t+1} / \partial R_{t+1} > 0$. Therefore, higher future (current) rents tend to induce (encourage) more human capital investment. With given ability level and initial human capital, if the current rental is higher, the investment in education I_t will

be crowded out. Lower I_t will lead to less human capital accumulation, then, $\partial h_{t+1}/\partial R_t < 0$. The reason why h_{t+1} increases with future rental R_{t+1} might not be intuitive. In our model, the information for the next period is available to agents. This means that, the agents who know that the rents are higher in the next period will save more to gain a higher total utility. In the basic model, we do not allow the individuals to save or to borrow. However, the investment in human capital accumulation could account for a kind of saving. Therefore, when rental goes up in the Old-age, agents will accumulate more human capital.

Similarly, if an individual decides to become an owner, solving the utility maximization problem gives following result:

$$\left(\frac{h_{t+1}^o - (1 - \delta)h_t}{a_t}\right)^{\frac{1}{\gamma}} \left[1 + \frac{h_{t+1}^o}{\gamma a_t} \frac{\left(\frac{h_{t+1}^o - (1 - \delta)h_t}{a_t}\right)^{1 - \gamma}}{\left[\beta + \nu - \frac{\beta P_{t+1}}{(wh_{t+1}^o + P_{t+1})}\right]} \right] = w_t h_t - P_t \quad (1.5)$$

In contrast to the case of renters, the effects of innate abilities on human capital investment become ambiguous. This is simply because housing can crowd out human capital investment by smoothing consumption between the Youth and the Old-age. Individuals do not necessarily need to invest in education in the Youth in order to enjoy higher consumption in the Old-age. Housing can play a similar role as they can be sold when individuals reach the end of the Old-age. The reason why human capital investment is not completely replaced by housing consumption is because individuals are altruistic.

In the following, we also examine a special case where innate abilities can also be passed by from parent to child over time. In other words, individuals no longer need to draw their innate abilities from given distributions. This special case forces us to keep track of the dynamics of human capital accumulation for a given innate ability. It will also give us a clearer picture about how the agents end up choosing between renting and purchasing a house. In Figure 1.1, we present the results for an

Figure 1.1: Dynamic Transition of Human Capital Given Fixed Low Ability Level

Note: Given $P/R=2.8$

individual with a relatively-low innate ability ($\underline{a}$). The left and right panels depict human capital accumulation path over 50 periods if the individual is endowed with a relatively low or high initial human capital level, respectively.

The blue line and the pink line simulate the house renters' or owners' human capital level along time without the opportunity to make the tenure choices. The star denotes the tenure decision. If the star is blue, then the agent chooses to be a house renter.

The results suggest that the individual will eventually switch from owner to renter. A higher initial human capital level will delay the switching period. In the long run, human capital converges to a steady-state level, regardless initial human capital level. Mathematically, We define the steady-state human capital level for a renter (h^r) as follows:

$$\left(\frac{\delta h^r}{a}\right)^{\frac{1}{\gamma}} \left[\frac{1}{(wh^r - R)} + \frac{1}{\delta\gamma} \frac{1}{(\beta + \nu) wh^r - \nu R} \right] = 1 \quad (1.6)$$

Similarly, we simulate the dynamics of a dynasty with a relatively high ability. In Figure 1.2, we present the results for an individual with a relatively high innate ability. The left and right panel depict the human capital accumulation path over 50 periods if the individual is endowed with a relatively low or high initial human

(a) High ability with low initial h

(b) High ability with high initial h

Figure 1.2: Dynamic Transition of Human Capital Given Fixed High Ability Level (Low Price-to-Rent Ratio)

Note: Given $P/R=2.8$

capital level, respectively.

The results suggest that the individual will eventually be a house owner. A lower initial human capital level will delay the switching period. In the long run, human capital converges to a steady-state level. We formally define the steady-state human capital level for a house owner (h^o) as follows:

$$\left(\frac{\delta h^o}{a}\right)^{\frac{1}{\gamma}} \left[\frac{1}{wh^o - P} + \frac{1}{\delta\gamma(\beta + \nu)} \frac{1}{wh^o - (2\beta + \nu)P} \right] = 1 \quad (1.7)$$

The following two panels in Figure 1.3 present the pattern of human capital accumulation if the dynasty is endowed with a high or low initial human capital level under the condition of a higher price-to-rent ratio (P/R). The left panel presents the result where in the beginning the individual chooses to be a renter and becomes an owner after 2 periods. The dynasty's human capital stocks at first then starts to decline as housing can already serve the purpose of smoothing consumption instead of the education investment. In period 4, the individual returns to be a renter till it is optimal for her offspring to be an owner again. Similar processes repeat. In the right panel, for a dynasty with high initial human capital and innate abilities, the individual starts to be an owner and remains to be owner over a long time. Meanwhile, for the same reason, human capital keeps declining until the

Figure 1.3: Dynamic Transition of Human Capital Given Fixed High Ability Level (High Price-to-Rent Ratio)

Note: Given $P/R=6.2$

offspring's optimal tenure choice is no longer owning the house, she switches to a renter status in a certain period. Then the processes are the same as in the left panel. Under both situations, there is no steady-state where the dynasty's housing tenure decision remains unchanged. They keep oscillating between being an owner and being a renter.

As depicted in the special case, there may not exist a steady-state at the dynasty level, if we define a steady-state as the state where human capital stock remains constant over time. This becomes more prominent when individuals within the same dynasty draw their innate abilities upon birth. In the following, we define a steady-state at the aggregate level instead. Define the set of dynasty in the upper class in t who remain in the upper class in $t + 1$ as:

$$S_{t,t+1} = \{i : h_{t+1}(i) > \bar{h} \mid h_t(i) > \bar{h}\} \quad (1.8)$$

Define the set of dynasty in lower type in t who upgrade to upper class in $t + 1$ as:

$$J_{t,t+1} = \{i : h_{t+1}(i) > \bar{h} \mid h_t(i) \leq \bar{h}\} \quad (1.9)$$

The fraction of dynasty in the upper class is:

$$Q_{t+1} = \sum_{i \in S_{t,t+1}} + \sum_{i \in J_{t,t+1}} \quad (1.10)$$

When the fraction of the upper class remains stable, we claim that this economy asymptotically converges to the steady-state.

1.3 Quantitative Analysis

In the quantitative analysis, we assume that the Price-to-Rent ratio varies. Then, we focus on the changes at the social mobility level and the shifts of inequality. In order to explain the mechanism, we also examine detailedly how the fraction of individuals of upper type, investment in education and welfare etc. respond when the economy converges to steady-state. We set the value for a group of parameters and use it as our benchmark. Then, we also do a counterfactual experiments on the different elasticity of human capital investment γ and extra utility gain as house buyers e .

1.3.1 Parameterization

Each period, the Youth or the Old-age, in our economy is set to be 20 years. Since the individual's behavior in the adolescent years would not affect our analysis, we do not take this period into account. This means that, the period of Youth starts from the age of 20 years and lasts until the age of 40 years, while agents in the Old-age are from 40 years old to 60.

The parameter space in our model contains $\{\beta, \delta, \alpha, w, v, \gamma, e, \underline{a}, \bar{a}, \bar{h}\}$ (Table 1.1). β is the subjective discount rate and we set it to be 0.6, so it corresponds to an annual discount rate of 0.97. δ is human capital depreciation rate, and we let it be 0.2 so it is equivalent to an annual depreciation rate of 1.1 percent. α is the parameter which controls the ability distribution differences between the upper

class and the lower class. It was calibrated to ensure that the upper income tail follows the Pareto's law with the tail index equal to 1.2 (Clementi and Gallegati, 2005). We normalize the wage rate w to be 1 and set it constant. Then, we let the rental equal to one third of the average income. The housing price-to-rent ratio is exogenous, and we set it to be 6.0 in the benchmark calibration, which matches the weighted house value-to-rental ratio in 1985 in the U.S. (Benabou, 2000). e is the utility premium from owning a house, and we calibrate it to match an average homeownership rate of 66 percent. γ is the elasticity of human capital investment and we solve it to match the elasticity of return to education from a standard Mincer regression commonly found in the literature. $\bar{h}$ denotes the threshold human capital level to identify upper and lower classes. It was solved by the model to match the social classes distribution in the U.S. in 1985. We also normalize the lower bound of the ability distribution ($\underline{a}$) to be 1, and calibrate the upper bound of the uniform distribution ($\bar{a}$) such that the resulting 90-10 income ratio in U.S. equals to 5.0, which is commonly documented in the literature. v captures the bequest motive and measures the relative importance of the decedent's human capital level to the individual's own consumption. We calibrate the number to match a 30-percent average expenditure share on education.

1.3.2 Social Mobility and Inequality

We follow Kennickell and Starr-Mccluer (1997) to compute the Shorrocks Index in this subsection. They calculated the six-year transition matrix ($A_{KS,6}$) from 1983 to 1986 for quantiles and top percentile ranges. The seven states were: bottom 20 %, 20-39%, 40 - 59%, 60 - 79%, 80 - 89%, 90 - 94%; 95 - 99%, top 1% percentile.

Parameter	Value	Source (Targets)
β	0.6	discount rate
δ	0.2	human capital depreciation rate
α	2	parameter to control ability distributions
v	5.0	bequest motive
γ	0.3	elasticity of human capital investment
e	1.0	extra utility gain as house owners
$\underline{a}$	1	lower bound of ability
$\bar{a}$	3	upper bound of ability
$\bar{h}$	26	threshold human capital level to identify social class
w	1	wage rate

Table 1.1: Parameters

$$A_{KS,6} = \begin{bmatrix} 0.672 & 0.246 & 0.063 & 0.018 & 0.001 & 0.000 & 0.000 \\ 0.246 & 0.495 & 0.190 & 0.042 & 0.019 & 0.007 & 0.000 \\ 0.066 & 0.192 & 0.480 & 0.208 & 0.037 & 0.016 & 0.000 \\ 0.021 & 0.082 & 0.329 & 0.418 & 0.113 & 0.036 & 0.002 \\ 0.011 & 0.071 & 0.212 & 0.301 & 0.225 & 0.177 & 0.004 \\ 0.000 & 0.028 & 0.164 & 0.104 & 0.180 & 0.430 & 0.094 \\ 0.000 & 0.031 & 0.024 & 0.061 & 0.045 & 0.247 & 0.593 \end{bmatrix}$$

In the transition matrix, the number in the i_{th} row and j_{th} column of the matrix represents the fraction of individuals who belong to income group i in the initial period and switch to income group j in the next period. Hence, the sum of each row equals to 1. With a square mobility transition matrix A of dimension m , the Shorrocks index $s(A)$ is given by:

$$s(A) = \frac{m - \sum_i a_{ii}}{m - 1}$$

where m denotes the number of income groups and a_{ii} is the diagonal element of the i_{th} row. The Shorrocks Index $S_{KS,6}$ from [Kennickell and Starr-Mccluer \(1997\)](#) was

equal to 0.61450. When the social mobility in one economy is harder, more families will be trapped in the same income group, which makes a_{ii} relatively large. It also results in a larger negative part in the Shorrocks index calculation. Therefore, the harder the changes of social class are, the smaller the Shorrocks index will be.

At the beginning of our simulation period, we divide all the individuals into 7 groups according to their life-time income. Specifically, similar to the study of [Kennickell and Starr-Mccluer \(1997\)](#), the seven income groups include bottom 20 %, 20-39%, 40 - 59%, 60 - 79%, 80 - 89%, 90 - 94%; 95 - 99%, and the top 1% percentile, respectively. We then track all the individuals throughout the entire simulation period until the economy reaches its steady-state. By comparing the state to which each individual initially belongs to with the state at the last period, we get the transition matrix for the whole period $T(A_S^T)$. By comparing the state which each individual/ family belongs at t with the state at $t+1$, we could get the transition matrix for each period $t(A_S^t)$. Therefore, for each given Price-to-Rent ratio, there exist one whole period transition matrix $T(A_S^T)$ and $(T - 1)$ each period transition matrix $t(A_S^t)$.

In [Benabou \(2000\)](#), the weighted house value-to-rental ratio in 1985 in the U.S. is close to the Price-to-Rent ratio 6 in our model. Given this ratio, the simulated transition matrix A_S^T is given as,

$$A_S^T = \begin{bmatrix} 0.764 & 0.232 & 0.004 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.212 & 0.536 & 0.240 & 0.012 & 0.000 & 0.000 & 0.000 \\ 0.024 & 0.216 & 0.552 & 0.208 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.027 & 0.313 & 0.480 & 0.153 & 0.027 & 0.000 \\ 0.000 & 0.000 & 0.020 & 0.360 & 0.320 & 0.300 & 0.000 \\ 0.000 & 0.000 & 0.050 & 0.075 & 0.250 & 0.500 & 0.125 \\ 0.000 & 0.000 & 0.100 & 0.200 & 0.100 & 0.100 & 0.500 \end{bmatrix}$$

The transition matrix of our study is similar to $A_{KS,6}$ shown previously. After calculation, the Shorrocks Index S_S^T of our benchmark equals 0.6294, which bears a close parallel to [Kennickell and Starr-Mccluer's](#) $S_{KS,6}$ as well. From the matrix

$A_{KS,6}$ we can observe that updating the social class to a level higher than 3 is almost impossible. It is also less likely for the top classes and the bottom classes to change their level. The upper middle classes (60-79% and 80-89%) have more opportunities to jump to another social class. However, it is harder to upgrade than to downgrade. These features all match the real data.

Figure 1.4: Social Mobility and Inequality

Note: negative correlation between social mobility and inequality.

Figure 1.4 displays the plot for the social mobility (Shorrocks Index S_S^T , blue) and inequality (90/10 ratio, red) with respect to the changes of Price-to-Rent ratio. Until $\frac{P}{R} = 8$, the Shorrocks Index at first descends from 0.60, hit the bottom of 0.35 at $\frac{P}{R} = 4$ and then climbs up to 0.81. In contrast, the inequality, the 90-to-10 ratio, rises from 1.24, reaches the peak of 1.8 when $\frac{P}{R} = 3.8$ and then falls to the lowest level at 1.2. While inequality demonstrates an inverted U-shape, the social mobility presents a U-shaped curve. After $\frac{P}{R}$ equals to 8, inequality increases marginally and social mobility drops quickly. A negative correlation between the social mobility and inequality can be observed from the figure.

To further test the relationship between social mobility and inequality, we di-

Price to Rent	Correlation
1.0 – 2.8	−0.4932
3.0 – 5.2	−0.7529
5.4 – 12.0	−0.4502

Table 1.2: Correlation between Inequality and Social Mobility

vide the X-Axis into three parts according to the intersection points of these two curves. Table 1.2 exhibits the correlations between social mobility and inequality corresponding to certain Price-to-Rent ratio ranges. In general, the Shorrocks Index negatively correlates with the 90/10 ratio. Before and after the intersection, the correlation is less strong than in the middle.

1.3.3 Effects of Price-to-Rent Changes

Figure 1.5: Effects of Price-to-Rent Ratio Changes

In order to have a clearer picture of the story behind the movement of housing, social mobility and inequality, in Figure 1.5 we present simulation results regard-

ing the fraction of upper class, the investment in education, the average utility, inequality and the investment-to-wealth ratio with various housing price-to-rent ratios ranged from 1.0 to 12.0. We also show the fraction of renters in the whole economy, as well as the renters' proportions among upper class and among lower class. We only report the steady-state result. We consider the economy has reached its steady-state if the percentage of change in the fraction of individuals in the upper class within several consecutive periods has been sufficiently small ($< 0.01\%$).

When owning a house becomes more expensive than renting, the fraction of renters in both classes will undoubtedly increase as shown in our results (Figure 1.5). There is also a “U-shape” pattern characterizing the relation between the fraction of individuals in upper class and the Price-to-Rent ratio. In contrast, an inverted “U-shape” pattern is observed in the 90-to-10 wage ratio against the Price-to-Rent ratio. The intuition captured in these results is illustrated as follows: when housing price is equal to or just slightly above the rental price, individuals can manage to own housing as well as invest in human capital simultaneously. This explains why there is a high fraction of individuals in the high class and low wage inequality when housing Price-to-Rent ratio is close to 1. When it becomes more expensive to own a house, individuals start to trade off human capital investment against housing purchase. When human capital gets deaccumulated, the fraction of individuals in the upper class declines and wage inequality rises. Finally, when owning a housing becomes too expensive such that the utility premium from owning a house cannot compensate for the cost, individuals will decide to become renters and invest in human capital instead. Therefore, the fraction of individuals in the upper class starts to recover and inequality declines when the price-to-rent ratio becomes too high. A similar pattern emerges if we measure inequality using a wage 99-to-01 ratio.

Figure 1.6: Fractions of Rents and the Upper Class and Inequality

1.3.4 Mechanism

There exist two key driving forces for the movement of social mobility and inequality in our study: the trade-off between owning a house and investing in education; and the difference of the ability distribution between upper and lower class agents. With fixed income, the higher the costs of the tenure choice are, the less amount of budget can be used for the education investment. Then, the human capital accumulation will descends. Meanwhile, if the agents are from the upper class, they have better chance to draw a high ability. The higher the ability is, with fixed investment in education, the more human capital accumulates.

With the help of by Figure 1.6, we illustrate the interaction between these two driving forces and the effects of them together. The left panel displays the fraction of renters and the fraction of upper type and the diagram on the right shows to which group, upper or lower, the 90th and 10th quantile, the individuals belong. When the individuals, who are ranked 90th and 10th in wealth, are both upper type or both from lower type, the scatter is blue or red respectively. When the 10th richest is from the upper group but the 90th is from the lower one, the scatter is black.

From the left panel we can see that, the main force that draws down the fraction of the upper type and pulls up the inequality level is the remaining unchanged fraction of renters. Until $\frac{P}{R}$ comes to near 4, all households own houses. The

increased housing price is a barrier to human capital accumulation. Meanwhile, inequality reaches the peak. After that, with more households give up owning houses, inequality begins to drop. Although the fraction of upper type (the blue line) keeps going down for a while then turns to increase again, but the speed of falling is slower.

The right panel of Figure 1.6 exhibits whether the representative agents (10th and 90th richest) draw the ability from the same distribution. When the Price-to-Rent ratio is relatively low, the 90th and 10th richest individuals are both from the upper type (blue stars). This means that both the poor and the rich draw the ability from the distribution $G(\cdot)$ which has a higher average. Agents have equal chances of human capital accumulation. Inequality is relatively low. When the 90th comes from the lower group but the 10th belongs to the upper type (black stars), they draw the ability from different distributions $G(\cdot)$ and $F(\cdot)$. This means that even investing same amount in the education, the accumulated human capital is lower for the poor. Inequality rises fast and reaches a peak. As the 90th and the 10th are both "poor", when they are both from the lower class (red stars), they have equal "bad luck" and inequality decreases. With the increase of the fraction of the upper class, the 90th and 10th again come from different groups and eventually both from the upper class.

In the simulation results, the point where Price-to-Rent ratio $\frac{P}{R}$ equals to 4 is the turning value for most of the curves. At that point, the fraction of renters starts to increase from 0 and part of individuals begin to rent instead of owning houses, while inequality and social mobility hit the ceiling and the floor respectively (Figure 1.4). Meanwhile, the investment in education, the utility and the investment-over-wealth ratio turn decrease into increase (Figure 1.5). However, only the fraction of the upper type keeps going down after $\frac{P}{R} = 4$. The reason is easy to be understand: the fraction of the upper type house renters remain unchanged until $\frac{P}{R} = 6$ (third diagram in the first row in Figure 1.5). The housing price is not high enough to force any household in the upper type to give up owning a house but to invest more

in education. Then the higher housing price will draw human capital accumulation down in the upper type. Some of the initial upper class agents cannot accumulate enough (higher than the threshold $\bar{h}$), and then they fall to the lower class. Because of that, the fraction of the upper type continues to drop.

The mechanism is as follows: when the housing price is low, almost every individual can afford both owning house and human capital investment. With housing price increase, at first the tenure choice among the whole population remain unchanged (pink line in the left panel in Figure 1.6). Individuals with relatively low human capital may choose owning house rather than investing in human capital. Social mobility declines, mainly because the poor remain poor. The rich, however, invest in their education, accumulate human capital, enjoy higher income along time and simultaneously can afford owning a house. They still remain in the upper class. Since the initially poor individuals partially give up the human capital accumulation but the rich ones keep increasing their income, the upgrade of social class gets harder and inequality grows. When housing prices become even higher, individuals with high initial human capital may also have to purchase a house instead of investing in human capital. The poor invest in education while the initially richer ones consume expensive housing services. The dispersion of the poor and the rich get smaller. Then, the social upgrade becomes easier and then social mobility increases. Income inequality starts to decline. Eventually, when housing prices become "unaffordable", every individual chooses to rent a house and engage in human capital accumulation, so inequality declines again.

Figure 1.7 shows the transition dynamics of inequality (red), social mobility measurement, Shorrocks Index (blue), and the fraction of upper type (black) when the Price-to-Rent ratio equals to 2, 4 and 6 respectively. It is clear that the relationship between social mobility and inequality are negative for every given $\frac{P}{R}$ on the process to the steady state. For the fraction of upper type (black), no matter how high or low the value in the equilibrium is, it quickly converges to the level close to the equilibrium state. When the black line becomes stable, the red and blue, the

Figure 1.7: Transition Dynamics of Social Mobility, Inequality and Fraction of Upper Class given Different Price-to-Rent Ratio

lines of inequality and of social mobility, come to a relatively stable situation.

There exists an uncertainty in our model, namely the ability. In order to rule out the possibility that one or few households keep drawing extremely low or high ability in a row, we do the bootstrapping (Figure 1.8). We repeat the simulation 100 times. Each time, we have the same setting for everything except a different ability draw. Then we take the average of each variables and plot the figure. We can see, the trend for every curve is the same, meaning that our simulation result is not a special case of our model.

1.3.5 Different Elasticities of Human Capital Investment

Previously, the elasticity of the human capital investment has been set to 0.3. In this subsection, we release this setting and show the movement of the key variables in the model: the fraction of upper type, the fraction of renters, social mobility and inequality. From Figure 1.9, we can see that the trend of each line remains the same: inequality (red) and social mobility (dark blue) are negatively correlated; generally, the inequality line shows an inverted U-shape; as the Price-to-Rent ratio

Figure 1.8: Bootstrapping Results

Note: 100 times.

increases, the fraction of renters rises from 0 up to 1. Meanwhile, the fraction of upper type (light blue) still presents a U-shape. They only differ in degree: the U-shape becomes shallower and the difference between peak and crest of the inverted U is smaller.

When γ is smaller, the same investment in education turns to less human capital accumulation. Then, compared to purchasing and owning a house, investment is a less attractive option for households. Since there is not enough incentive for education, only few initially rich individuals could invest enough to reach the threshold for upper type and a larger proportion of households is stuck in the cycle: less investment, lower human capital, worse ability draw. Every household suffers poverty, but it does not mean that the social mobility is low. In contrary, the Shorrocks Index climbs to the top. This could explain why there is a U-shape in the equality curve instead of an inverted U. In addition, since the average of human capital is low, the income must be low. Then, with the same increase in the housing price,

Figure 1.9: Different Elasticities of Investment to Human Capital Accumulation

individuals facing lower elasticity of investment in human capital start to give up the choice of owning a house sooner than in the benchmark. The fraction of renters hits the upper limit more quickly.

On the other hand, when the elasticity of human capital investment is high, education brings more rewards, then accumulation of human capital becomes easier, higher income follows and more investment in education will be made. The accumulation of human capital is also high. That's why no matter how much the housing price rises, the fraction of upper type is always near 1. Everyone enjoys the virtuous circle. Social mobility is high and inequality is low. One thing needs to be pointed out: when γ equals to 0.35, the inflection point of the inverted U-shaped inequality curve happens at the spot where the individuals start to rent a house.

It is interesting that the inequality curve looks more like a U-Shape rather than an inverted U shape, when $\gamma = 0.25$ (Figure 1.10, red line). The inequality curve is cut into four stages: increase, decrease, rise again and remain unchanged by

Figure 1.10: Social mobility and Inequality when $\gamma = 0.25$

the peak point ($P/R = 3.4$), the bottom point ($P/R = 5$) and the point where $P/R = 8$ (the inflection point from increasing to staying stable). It seems that in the first stage, the results shown in Figure 1.10 go against what we find before: both inequality and social mobility increase. It is necessary to analyze the transition dynamics to see how this happens.

From the Figure 1.11, we can see that in the dynamics, inequality and social mobility are still negative correlated. Indeed, if we only trace the last point, both inequality and social mobility increase. In the cases of $\frac{P}{R} < 3.4$ (1.4, 2.0, 2.6 and 3.2 respectively), for the first 4 periods, inequality directly jumps to as high as 1.5 and then declines with the increase of social mobility. But when $\frac{P}{R}$ is smaller, the inequality decreases more along the time.

Given the elasticity of human capital investment γ equals to 0.25, before P/R reaches 3.4, the fraction of renters (blue) in the dynamics remains zero, or almost zero along the whole periods (Figure 1.11). All individuals purchase houses instead of investing in education. Inequality increases. In Figure Figure 1.10, when P/R is between 3.4 to 5, the “poor” individuals invest in education and accumulate human capital, while the “rich” ones can still afford to own a house. This will eventually narrow the gap between the “poor” and the “rich”. Then the inequality level starts

Figure 1.11: Transition Dynamics when $\gamma = 0.25$

to decrease. When P/R is between 5 to 8, the fraction of renters no longer increases from 0. The differences of initial accumulation of human capital force the inequality level to increase. After $P/R = 8$, all individuals rent a house for the whole periods. The increase of Price-to-Rent no longer affects investment in education (human capital). The inequality level remains stable.

We could observe that a very small difference in γ could change the shift of social mobility and inequality dramatically. Therefore, a small improvement of the transition from education to human capital would strongly contribute to the control of the increase of inequality. This change could be reached by, for example, improving the efficiency of education, or reallocating the education resources. This finding insight gives the government a new political option to solve the social mobility and the inequality problems.

1.3.6 Different Preference of Owning a House

In the previous analysis, the preference of owning a house (the extra utility gain from owning a house, e) has been set to 1 for all cases. Here, we release this parameter to the range between 0.1 and 4 (Figure 1.12).

Figure 1.12: Different Preference of Owning a House

Similar to the results with different elasticity of investment to human capital accumulation, the trends of social mobility, inequality, the fraction of the upper class and the fraction of renters match the results when we control the parameter e . With the increase of the Price-to-Rent ratio, the Shorrocks index takes a U-shape while inequality and the fraction of upper class show an inverted U-shape.

However, when the individuals have very low preference for owning a house, the effect of housing price changes is quite weak (graphs in the first column in Figure 1.12). The fraction of renters will quickly jump from 0 to 1, while the fraction of upper type will have a minor change along the increase of the Price-to-Rent ratio. The social mobility and inequality will be affected but quickly become stable. When the preference increases, the role played by housing gets more important. The U-shape of the fraction of the upper type gets longer and deeper. The bottom level of social mobility becomes lower. This results in that the peak level of inequality hits a new height.

This suggests that when the government can “teach” individuals to be less persistent in owning their own house, the inequality problem brought by the housing

market will be automatically mitigated. In the reality, the preference of owning a house is indeed different from country to country. Some argue that the preference is related to culture, which is different to be changed. Indeed, in certain culture, people (e.g. Chinese) view owning a house as the foundation of building a family, and as a popular investment tool. They have a higher utility premium from this point. However, even among OECD countries, which have distinguished rent control level and policies to protect renters, the homeownership is significantly different. It means that the government can change the magnitude of the utility gain from owning a house. Take 2004 for example, the ratio of owning a flat or a house was 83.2% in Spain, 70.7% in the U.K., 68.7% in the U.S., 54.8% in France and 41% in Germany respectively ([Andrews and Sánchez, 2011](#)). In Germany, the homeownership is quite stable and remains around 40% after the Second World War. In [Andrews et al. \(2011\)](#), they show that Germany has the third strictest rent control in the private rental market. Besides, Germany has a good supply of high quality standard of social housing for the rental market which makes the rent could be long and stable enough for the tenants ([Voigtländer, 2009](#)). In the private rental market, the tenants' right is also well protected. For example, German law accepts only several grounds for termination from the landlords' side. However, even though house owners have valid reason and informed tenants three-month in advance, tenants still can object to the termination and require continuation of the lease if the termination causes undue hardship. With the protection, the benefit earned from owning a house becomes less, it will lower the utility premium e and will further weak the impact of housing on inequality.

1.4 Conclusion

Housing typically takes up a major proportion of household expenditure and thus it certainly plays a critical role in shaping the pattern of income inequality and social mobility. Whether a high housing relative to rental price will amplify inequality and

inhibit social class upgrading is still a controversial issue in the existing literature. In this paper, we develop a partial equilibrium lifecycle framework to address those issues.

The agents in our economy are divided into two social classes according to the initial human capital level inherited from their parents. Those who belong to upper class will draw their innate abilities from a distribution that first order stochastically dominates those from lower class. Throughout the entire lifecycle, agents make endogenous human capital investment and housing tenure decisions. We calibrate the model into mimic some steady state in the the real world counter.

Our simulation results indicate an inverted-U pattern between the housing Price-to-Rent ratio and measures of income inequality, and a U-shape pattern between the Price-to-Rent ratio and social mobility measured by the Shorrocks Index. Social mobility is negatively correlated with inequality in all the cases we analyzed in this paper.

The mechanism is clear: when the housing price is low, almost every individual can afford both owning house and human capital investment. With housing price increase, individuals with relatively low human capital may choose owning house rather rather than investing in human capital. On the other hand, the rich invest in their education, accumulate human capital, enjoy higher income along time and simultaneously can afford owning a house. Since the initially poor individuals partially give up the human capital accumulation but the rich ones keep increasing their income, the upgrade of social class gets harder and inequality grows. When housing price becomes even higher, individuals endowed with high initial human capital need to choose between purchasing a house and investing in human capital. The poor who can no longer afford owning a house, invest in education while the initially richer ones consume expensive housing services. The dispersion of the poor and the rich get smaller. Then, the social upgrade becomes easier and then social mobility increases. Income inequality starts to decline. Eventually, when housing prices become "unaffordable", every individual has to rent a house and therefore

engage in human capital accumulation. Inequality declines again.

Moreover, our results also suggest that better quality of education induced by a higher elasticity of human capital investment against added human capital tends to dampen the role of housing. Similarly, if the government can "teach" individuals to be less persistent in owning their own house, the inequality problem brought by the housing market will be automatically mitigated.

Chapter 2

The Role of Medical Expenses in the Saving Decision of Elderly

2.1 Introduction

In the past century, inequality moved from a relatively high level to the bottom in the 70's and 80's and then experienced a rapid rise in the United States and some other high income European countries(Keister and Moller, 2000; Piketty and Saez, 2006; Saez, 2009). Right before the Subprime Mortgage Crisis in 2007, the income concentration rate has reached the highest since 1979, where almost 20 percent of total income are held by the top 1% households in the U.S (Sherman and Stone, 2010). Many studies have been devoted to study the possible causes of the rising inequality: Piketty (2014) argued that the capital share is the main driven factor for the recovery of inequality. Morris and Western (1999) believed that the supply factor such as demographic shifts could contribute to the changes of the income distributions. Harrison and Bluestone (1990) regarded the economic restructure could be one of the reasons. Skill-biased technological change (Bound and Johnson, 1989) and institutional shifts (Levy and Temin, 2007) also have been considered.

During the same time span, most industrialized countries have experienced an upward trend in the medical expenses, shown as an increasing fraction of GDP

among most OECD countries ([Huber, 1999](#), [Huber and Orosz, 2003](#) and [Marino et al., 2017](#)). Taking the U.S. and Germany as examples, in 1970, the medical expenses as a share of GDP are 4% for Germany and 6% for the U.S.. In 2016, this fraction raised to 11% and 18% for these two countries respectively. Before the financial crisis, the average growth rates of the healthcare expending are from 4% to 6% annually. Even though many governments cut down the general public budget including medical costs funded by the public resources due to the financial crisis, the medical expenses of OECD have risen again at a high speed (3.4% in 2016)¹ recently. The increase will continue: the expenditure on medical costs among OECD countries will raise from 6% of GDP in 2010, up to around 9% in 2030 and further more to one seventh (around 14%) of GDP in 2060 ([De la Maisonneuve and Oliveira Martins, 2013](#)).

The growing trend of the health-related expenditures matches the increasing pattern of inequality in the U.S. and in European countries. As a big proportion of GDP, the medical costs must play an important role in the raise of inequality, and must also have effects on people to make saving and consumption decisions. Many studies tried to view the saving and consumption decision problems and the corresponding wealth inequality and consumption inequality issues from the perspective of health economics. In the study of [De Nardi et al. \(2010\)](#) and [De Nardi and Yang \(2016\)](#), they built an overlapping generation model to analyze the saving motives driven by medical expenditure. By examining the inequality in health care utilization of 10 European countries and the U.S., [Van Doorslaer et al. \(2000\)](#) pointed out that the U.S has the most serious inequality problem. In study of [Schoen et al. \(2010\)](#), they argued that for the U.S. citizens, a universal and comprehensive health-care system reform could contribute to resolving the inequality issues.

In this paper, we develop a multi-period overlapping generation framework to study consumption, saving decisions, inequality and welfare among elderly people with age above 50. In the basic setting of the model, we follow the work of [Huggett \(1996\)](#). By assuming that agents are heterogeneous in the non-asset income and the

¹Source: OECD Health Statistics

medical expenditure, we use the calibrated parameters to solve for decision rules via backward induction. Using the terminal condition, we can solve the value function at each age for each possible asset holding, health status, earning status and the corresponding invariant distribution measure. In order to explicitly analyze the effects of medical expenditure, we conduct three counterfactual exercises. We successively shut down the heterogeneity in labor income, the level and the dispersion of medical expenses. By comparing the benchmark with the counterfactual results, we can have a clear picture about how each factor affects agents among different ages, and we can study how the saving decision, inequality and welfare change.

The rest of the paper is structured as follows. Section 2.2 lays out the theoretical framework. Section 2.3 shows both the benchmark's simulation results and the counterfactual results. Section 2.4 concludes.

2.2 Model

The model can be considered as an extension of Huggett's framework, in which we include medical expenditure and only focus on elder agents.

2.2.1 The Environment

Time is discrete and infinite indexed by $n = 0, 1, \dots$. At the beginning of each period, a continuum of agents are born. The size of each cohort is normalized to be 1. We do not consider accidental death along the life cycle, so agents survive from age 0 to age N . The instantaneous utility function at each period takes the standard CRRA form:

$$u(c) = \frac{c^{1-\sigma} - 1}{1-\sigma} \quad (2.1)$$

where σ is the coefficient of relative risk aversion ($\sigma \geq 1$).

We assume that agents are heterogeneous along two dimensions: i) the non-

asset income (y_t), ii) the medical expenditure (m_t). Follow the convention in the literature, we assume each individual's labor income follows an stochastic $AR(1)$ process:

$$y_{t+1} = (1 - \rho) * \mu_y + \rho * y_t + e_t \quad (2.2)$$

where $e_t \sim N(0, \sigma_y)$ and ρ is the $AR(1)$ coefficient. The stochastic labor income can be further discretized into a finite-state Markov Chain with a finite number of possible values in the set Z according to Tauchen(1986). Moreover, the shocks are also i.i.d across agents. Therefore, there is no aggregate level uncertainty in the economy.

Medical expenditure, m_t , is defined as the out-of-pocket medical costs. Throughout the paper we treat the medical costs as exogenous shocks to the agents, since the major focus of the paper is to examine the effects of medical expenditure on the aggregate outcome and individual's decision. The shocks are also assumed to be age dependent. Each individual of age t has certain chance to be healthy and his medical cost m_t equals to zero. Those who have non-zero medical expenses draw medical costs m_t from a log-normal distribution at the beginning of each age, $\log(m_t) \sim N(\mu_{mt}, \sigma_{mt})$, where μ_{mt} and σ_{mt} are the mean and the standard deviation of the normal distribution for the agents of age t . μ_y , σ_y , μ_{mt} , and σ_{mt} are independent. We have done robustness check by allowing the covariance between income and health expenses, the results remain robust.

The timeline of the economy is as follows: agents draw idiosyncratic income and medical expense at the beginning of each period. Agents will then make the saving decision accordingly. Borrowing is not allowed in our basic model. Agents are not endowed with any initial wealth: a_0 equals to 0 for all. At age N , the last period of their lives, agents will consume everything when the bequests motive is absent. Therefore, a typical budget constraint for a representative agent at age t is:

$$a_{t+1} = (1 - \tau)y_t + (1 + r)a_t - m_t - c_t + b_t \quad (2.3)$$

where a_t is the saving (assets) held at age t , τ denotes the tax and b_t describe the government transfer.

Each agent takes the government transfer as given. But from the perspective of the government, b_t is determined such that all the agents are able to afford at least $\underline{c}$ unit of consumption as well as paying for the incurring medical expenses within the period. Specifically, b_t is given as:

$$b = \max \{0, \underline{c} + m_t - [(1 - \tau) * y_t + (1 + r) * a_t]\} \quad (2.4)$$

where $\underline{c}$ denotes the minimum consumption provided by the government transfer. The above implies that when the agents have very low income or draw very high medical expenses, while at the same time they are endowed with low assets from the last period, the government will protect those vulnerable groups, so they can maintain a minimum standard of living.

The government finances its transfer through taxation. We assume balanced government budget, so government budget in each period can be written as:

$$\int b^i \, di = \int \tau * y^i \, di \quad (2.5)$$

We assume government can perfectly monitor those agents who receive transfer, and they are neither allowed to own any assets nor transfer them to the next period.

At each age, agents solve the dynamic programming problem by choosing consumption c for the current period and a risk-free asset a' for the next period. The value function for each individual is as follows:

$$\begin{aligned} V(a, m, y, t) &= \max_{c, a'} u(c) + \beta \mathbb{E}_{(y', m')} [V(a', y', m', t + 1) | (a, y, m)] \\ \text{s.t.} \quad c + a' &\leq (1 - \tau)y + (1 + r)a - m + b \end{aligned} \quad (2.6)$$

$$a' \geq 0 \quad (2.7)$$

Income y , medical costs m and assets a serve as state variables and are known at

the beginning of each period. Consumption as usual is the control variable. At final age N , agents face the terminal condition $V(N + 1) = 0$.

2.2.2 Stationary Equilibrium

The distribution of agents is defined over age, asset holdings, non-asset income status and medical expense status. Let $x = (a, m, y)$, and let $(X, B(X), \psi_t)$ be a probability space where $\psi_t(B_0)$ is the fraction of age t agents whose state x lies in set B_0 as a proportion of all age- t agents with initial distribution ψ_t . These agents make up a fraction $\psi_t(B_0)\mu_t$ of all agents in the economy, where μ_t is the share of age- t agents in t .

Definition A **stationary equilibrium** consists of $\{c(a, m, y, t), a'(a, m, y, t), r\}$ and an invariant measure of agent distribution for every age t ($\psi_1, \psi_2, \dots, \psi_N$) in the defined state space, such that

- 1 The individual agent solves its utility maximization problem by choosing the optimal rules of $c(x, t)$ and $a'(x, t)$.
- 2 The aggregate savings of all elderly in this system, $\bar{s}$ is assumed to be positive:

$$\sum_t \mu_t \int_X a'(x, t) d\psi_t = \bar{s} \quad (2.8)$$

- 3 The law of motion for the measuring of age- t agents is

$$\psi_{t+1}(B) = \int_X T(x, t, B) d\psi_t, \forall B \in B(X) \quad (2.9)$$

where $T(x, t, B)$ is a transition function. It gives the probability that the age- t agent transits from the current state (x) to state B in the next period. The transition function is determined by the optimal decision rule on asset holdings, by the exogenous transition probabilities on the labor income shock y and by the exogenous probabilities on the medical expenditure shock m_t .

4 Since we discretize both y and m , the law of motion becomes

$$\begin{aligned} \psi_{t+1}(a', m', y') \\ = \sum_{a: a' = A_t(x)} \sum_{m: m' = M_t(x)} \sum_{y: y' = Y_t(x)} \Gamma([m, y], [m', y']) \psi_t(a, m, y) \end{aligned}$$

where $\Gamma([m, y], [m', y'])$ is the transition probability matrix for the joint process of the pair, $[m, y]$.

5 For simplicity, we assume there is no population growth and population share of each t is equal, i.e., $u_t = u = 1/6$. Hence, $1 = \sum_{t=1}^N \mu_t^j$ at time j .

2.2.3 Algorithm

For the benchmark model, we solve for decision rules via backward induction. By using the terminal condition, $V(a, m, y, N + 1) = 0$, we can solve the value function at age N for each possible asset holding, health status and earning status, and subsequently the value function at age $N - 1$ and so on. Then, we solve for the invariant distribution measure. Assuming that the shocks y and m are independent, we discretize y by the Tauchen method (Tauchen, 1986) to approximate AR(1) process by Markov chain, and discretize m_t (which includes zero value and log-normal distributions for people with medical expenditures), and generate an overall transition probability matrix, $\Gamma([m, y], [m', y'])$. We calculate the distribution for age t agents using the initial condition that agents at age 1 hold zero assets, together with the initial distribution of y and m , and with the transition probability matrix. With the distribution measure and the optimal decision rules, we solve the model by aggregating all asset holdings and iterating over until the total transfer is equal to the total tax and the aggregate saving is $\bar{s}$.

In the counterfactual analysis, we successively shut down the heterogeneity of labor income (all agents have the same income $\bar{y}$), shut down the heterogeneity of medical expenses (all agents have the same income $\bar{m}$), and remove the medical

costs for all agents ($m = 0$ for whole population). We hold the aggregate saving $\bar{s}$, which is solved from the benchmark model, unchanged, and adjust the interest rate. The other processes remain the same as in the benchmark model.

To confirm our main results, we run the simulation for the benchmark model and the three counterfactual exercises. We simulate the economy with a population of 10,000 for each age cohort. At time 1, all agents at every age will be endowed with zero asset. The length of time is 100, which ensures that the influences of the initial asset setting have disappeared. At the beginning of each period, individuals realize their income y^i and medical costs m^i . Using the same method mentioned previously, we also generate the overall transition probability matrix, $\Gamma([m, y], [m', y'])$. With the given interest rate and the realization of assets, income and medical costs, we can calculate the expected value function, solve the decision about consumption and saving, and further analyze inequality and welfare.

2.3 Quantitative Analysis

In the quantitative analysis, we focus on the effects of medical expenditure and income inequality on the economy. First, we set the value for a group of parameters and use that as our benchmarks. Then, in order to analyze the effects of medical expenditure in detail, we build three counterfactual exercises: i) we directly remove the total cost of medical services for all agents; ii) we shut down the variance σ_{mt} to see whether the medical expenses uncertainty is the key driving force behind the saving motives and inequality; iii) we shut down the income uncertainty as well in order to compare the effect magnitudes between income and medical costs. By comparing the benchmark model with the counterfactual results, we can reach at a clear picture about how each factor affects agents among different ages. We can also study the respective changes in saving/wealth, consumption decisions and welfare.

Parameter	Model	Value
σ	coefficient of relative risk aversion	1.5
β	subjective discount rate	0.9
ρ_y	AR coefficient of Markov chain approximation of AR(1) process for income	0.85
σ_y	s.d. of the error term in Markov chain approximation of AR(1) process for income	$\sqrt{0.3}$
$\mu_{m,t}$	mean of lognormal distribution of the medical expense process, m_t	age group-specific
$\sigma_{m,t}$	s.d. of lognormal distribution of the medical expense process, m_t	age group-specific
N	maximum model age	6
r	interest rate per model period (5 years)	0.1
$\underline{c}$	minimum consumption level	0.125
u_t	population share of each age, t	1/6

Table 2.1: Parameters

2.3.1 Parameterization

The parameter space in our model contains $\{\sigma, \beta, \rho_y, \sigma_y, \mu_{m,t}, \sigma_{m,t}, N, r, \underline{c}, u_t\}$ (as shown in Table 2.1). σ is the coefficient of relative risk aversion and it controls the utility function. β denotes the subjective discount rate and reflects how important the future utility is for the agents. In the adoption of these two parameters we follow the literature. ρ_y and σ_y are the AR coefficient of Markov chain approximation of AR(1) process for income and its s.d. of the error term in Markov chain approximation respectively. Following [Guvenen \(2009\)](#), we abstract those two parameters using the income and pension data of 2014 HRS (Health and Retirement Study).

Following previous studies, we assume that the 5-year interest rate will be 10% in our benchmark model. $\underline{c}$ is the minimum consumption level which we borrow from [De Nardi et al. \(2010\)](#). For simplicity, we assume there is no population growth and the population share of agents at each age- t (u_t) is equal.

50-54	55-59	60-64	65-69	70-74	75-80
25.53%	24.03%	21.11%	16.34%	14.14%	13.92%

Table 2.2: Share of the Agents with Non Medical Costs

μ_m and σ_m are the mean and the standard deviation of lognormal distribution of the medical expense process respectively. We calibrate them using the 2014 HRS. HRS supplies survey data with rich details focusing on health related cores, financial and social status etc., among the retired population (50 and older) in the U.S.. Specifically, the HRS dataset contains the topics about health status, medical expenses, pension situation, social and health insurance status and so on. There is another related dataset AHEAD, a widely used nationally representative longitudinal panel surveys among American elderly as well. However, its participants are mainly 70 and above. For our analysis purpose, we choose HRS. Upon registration, the dataset HRS is free and publicly accessible. The available data starts from 1992 until 2016. Like in the case of the calibration for the income, we pick the data of year 2014. We have done robustness check by applying data of other years (2000 and 2008), the results remain robust.

In our study, we denote the out-of-pocket payments for medical services as the medical expenses. In detail, they include hospital costs, nursing home costs, outpatient surgery costs, doctor visit costs, dental costs, RX costs, in-home health care costs and other services costs. The initial size of data is 18,747. In order to fit to the model, we exclude samples with age under 50 or older than 80. Each period refers to a 5-year interval. We focus on the elderly people and the HRS data mainly covers from 50 years above, then we choose the N , the maximum model age to be 6 in order to match the survey data (age 50-80). After that we group the participants into the corresponding age groups. For the 6 groups, the sample size is 1128, 3595, 3193, 2289, 2460, and 2795 respectively. In total, the data comprises 15460 participants.

In previous studies, such as [Duan et al. \(1983\)](#), [Manning et al. \(1987\)](#) and so

Figure 2.1: Medical Expenses Distribution in Age Groups

on, the medical expenses follow a log-normal distribution. In this paper, since we define the medical costs as out-of-pocket expenditure, we found many samples whose medical costs were equal to zero in our data. In that case, for those samples reported no costs, the log expenses will be negative infinite. To deal with this, first we calculate the proportions of those endowed with zero medical cost in each age group. From Table 2.2 we can see that this ratio is strictly decreasing with age. In such case, we take the log of all the non-zero medical costs and use the results to fit the normal distribution. Figure 2.1 shows the results as fitted to the normal distribution. The six panels represent the results from 6 distinct age groups. The x-axis denotes the logged medical costs. The blue bars represent density. The red lines are the fitted normal distribution. The calibrated mean $\mu_{m,t}$ and standard deviation $\sigma_{m,t}$ are also shown in the upper right corner in each subgraph. The

fitted mean and s.d. do not seem to change much among ages. However, if we take the proportion of individuals with zero medical cost into account, we will observe a raise of mean costs with age and an increasing volatility. Then, the results will match those reported in the literature.

In our model, we assume the medical expenses for each agent are random shocks. At the beginning of each time period, the individual draws a number from the corresponding age-dependent distribution. The distribution function, which we calibrated using HRS 2014, is not a simple log normal distribution and it is a piecewise-defined function with one sub-function endowing the value equals to zero and another sub-function following the log normal distribution. Therefore, when we draw the medical shocks, there will be two steps: firstly, according to certain probability, the agents will realize whether they are “in perfect health” with no medical costs in the coming period. Following that, the “in imperfect health” ones will go for the second step drawing from the log normal distribution to determine how high their medical expenditures are.

2.3.2 The Wealth Distribution over the Life Cycle

Figure 2.2 illustrates the average saving of each age group. The x-axis is the age group which starts with one (representing the age group 50-54) in our model till six (the age group 75-80). The red, blue, magenta, and yellow lines stand for the average saving generated by the baseline model; the counterfactual exercise I ($m = 0$), which removes all medical expenses, the counterfactual exercise II ($m = \bar{m}$), which controls the variance and let the medical costs equal to the mean costs for their age; and the counterfactual exercise III ($y = \bar{y}$) in which we control the income inequality and set the labor income for each individual to be the same for everyone. In the left upper corner, the numbers in brackets stand for the labor income tax rate solved by each model.

From the Figure 2.2 we can conclude that the average saving curves show an inverse-U shape in all cases of the elderly. In the early periods, agents prefer saving

Figure 2.2: Average Saving in Benchmark Model and Counterfactual Exercises

and the saving amount accumulates with the increase of their age, while, in the last periods, they prefer consuming. After reaching the peak at age three or age four, agents decide to save less and less. At the end of age six, everyone dies. Therefore, in the last period, no matter which model it is, the average saving equals to zero.

There are two possible reasons why the average saving over the age curve increases initially and drops subsequently. First, agents need to save to deal with the potential uncertainties. In our model, these uncertainties have two sources: from labor income or from medical costs. Second, the particular form of utility function which determines agents' preference leads to a higher saving rate.

In the Figure 2.2, the magnitudes of average saving are similar in the baseline model, in the counterfactual exercise I ($m = 0$) and in the counterfactual exercise II ($m = \bar{m}$). Table 2.3 gives details of average saving in each model. We can still observe slight differences between the baseline model and these two counterfactual exercises. In the rising stage, the two counterfactual exercises (blue and magenta lines) have relative higher average saving. In the last periods, on the contrary, the average saving of these two models is lower than that of baseline model. This means that when we shut down medical costs or remove the uncertainty in the medical

Age	baseline	m=0	m= $\overline{m}$	y= $\overline{y}$
1	0.5489	0.5801	0.5664	0.4543
2	0.9436	0.9713	0.9629	0.8465
3	1.1333	1.1481	1.1335	1.1071
4	1.1074	1.0859	1.0967	1.1892
5	0.7837	0.7389	0.7547	0.9197
6	0	0	0	0

Table 2.3: Average Saving in Benchmark Model and Counterfactual Exercises (by Age)

Age	baseline	m=0	m= $\overline{m}$	y= $\overline{y}$
1	0.2327	0.1010	0.2619	0.0453
2	0.2259	0.1008	0.2534	0.0385
3	0.2239	0.0951	0.2534	0.0394
4	0.2150	0.0929	0.2411	0.0291
5	0.2141	0.0899	0.2384	0.0298
6	0.2073	0.0890	0.2344	0.0323

Table 2.4: The Fraction of Agents who Take Subsidy from the Government (by Age)

expenses, agents prefer to save more in the early periods in order to consume more later. Though the changes of counterfactual exercises I and II are similar, the mechanisms behind are different.

In our model, saving is the optimal choice for the relatively richer people. When households receive subsidies from the government, saving is not allowed. Table 2.4 shows the fraction of the "poor" agents who need help from the government and can not save at all in each of the four cases (benchmark and three counterfactual exercises). We can see that when the medical expenses are removed (the counterfactual exercise I), only around ten percent of the agents are qualified to take the

Model	baseline	m=0	m= $\overline{m}$	y= $\overline{y}$
Interest Rate	10%	6.58%	9.42%	28.43%
Tax Rate	6.6%	0.5%	3.9%	1.4%

Table 2.5: The Interest Rate and Tax Rate Solved by the Benchmark and Counterfactual Exercises

subsidies; however, for model $m = \overline{m}$, around one quarter belong to the category of "poor" people. Since for agents in counterfactual exercises I ($m = 0$), the negative part in their budget constrain is waived and the income tax rate is the lowest (0.5%, in Table 2.5), agents are generally much richer compared with the baseline model. Thus, a higher saving level of the $m = 0$ model is the result of the wealth effect. Meanwhile, the motive of saving led by the uncertainty of medical costs does not exist anymore. The average saving should descend. In this case, the two opposite forces result into a slightly shift in the model $m = 0$. In the early periods, the wealth effect reigns and causes a higher saving, whereas in the later periods, the effect of non-uncertainty of medical expenses is stronger and the average saving is relatively lower.

In the counterfactual exercise II ($m = \overline{m}$), the total labor income minus the total medical costs remains unchanged. In aggregate, there is no wealth effect because of less health-related expenses. Meanwhile, the model $m = \overline{m}$ has the largest proportion of "poor" people (Table 2.4). Taking both these aspects together with the removed uncertainty of medical expenses, the average saving should be lower than in the baseline model. However, like the blue line ($m = 0$), the magenta line ($m = \overline{m}$) is also higher than the red line (the baseline model) between age one and age three, and becomes lower later. One of the reasons why agents save more on average when they are relatively younger is still the wealth effect. Even though the fraction of households taking subsidies is higher than in the benchmark, the tax rate (3.9%) is lower for the $m = \overline{m}$ case than 6.6%, which is solved by the baseline model (Table 2.5). Another reason is that the equalized medical costs lead to fewer

extreme cases. Therefore, the proportion of agents who save is larger for the $m = \bar{m}$ case in the first few periods. As the result of all these forces, the magenta line shows a similarity with the blue line, but for different reasons.

When we remove income heterogeneity (i.e., $y = \bar{y}$ model), the average saving level is slightly lower in the first 3 periods (Figure 2.2), but higher in the later periods, compared with other three cases. The intuition behind this is quite clear: as income is initially equalized, there are fewer richer people who save more, compared with the other three models. Therefore, the average saving starts from a lower level. However, fewer people require subsidies in this case and the fraction of agents who save is higher than other three models. After three periods, agents generally have a larger saving.

Another important condition that needs to be taken into account is that in this paper, we control the aggregate saving level to solve the interest rate in the counterfactual exercises (Table 2.5). This means that, the aggregate saving ($\bar{s}$) is fixed. The same aggregate saving ensures that there are minor differences in average saving among all these models. In addition, when the interest rate is higher, for the same amount of saving, the motives caused by other factors are weaker. From Table 2.5 we know that income uncertainty is the biggest motive for saving, since it has the highest interest rate. The shocks of medical expenses should also contribute to the increase of saving. However, the effect of this factor is offset by the wealth effect.

Figure 2.3 illustrates the average saving over income. This shows what average proportion of income is devoted to saving. For all four cases, the curves present saddle shape. Again, the baseline model and the counterfactual exercise II ($m = \bar{m}$) are very similar. The counterfactual exercise I ($m = 0$) has a slightly higher level in general, because the negative costs are deducted from the budget constrain and this proportion of income is partially transferred to saving account. The average saving over income rate in the counterfactual exercise III ($y = \bar{m}$) is the highest and peaks at 65%. Since the interest rate in this case is unrealistically high (28.43%),

Figure 2.3: Average Saving over Income in Benchmark Model and Counterfactual Exercises

the motive is strong enough to push the ratio up to over 50%.

Saving, in our model, is the only asset. Therefore, based on the previous analysis, we believe the model with $y = \bar{y}$ (counterfactual exercise III) has the lowest inequality level. Figure 2.4, the Loreze curve over the whole population, confirms that. The curve generated by the $y = \bar{y}$ model is rather close to the uniform random distribution, which hints at a very low Gini coefficient. The rest three cases (the baseline model, $m = 0$ and $m = \bar{m}$ counterfactual analysis) have similar significantly large Gini areas (yellow). Specifically, the $m = 0$ model has about 42% agents without any assets. On the contrary, the fractions of households endowed with zero assets in the $m = \bar{m}$ model and in the baseline model are equal to 53% and 59%, respectively. The benchmark model gives the highest aggregate inequality level.

When we compare the wealth Gini coefficient of the four models with respect to age, from Figure 2.5 we can see that the yellow line ($y = \bar{y}$ model), which has no obvious trend, gives the lowest inequality level. This means that income uncertainty makes the largest contribution to wealth inequality. For the remaining

Figure 2.4: Inequality of Wealth: Lorenz Curve

Figure 2.5: Inequality of Wealth: Gini Coefficient along Age Increase

three cases, wealth inequality decreases with age. The $m = 0$ model has the lowest level among the three. Since when we waive the medical expenses, there is no precautionary saving required by medical services. Then, this saving motive, for which the rich save, weakens, while the relative poor agents are able to save more when no medical costs incur. Therefore, the decrease of saving willingness of richer agents effects together with the increasing saving among the poor. This results lower inequality. Meanwhile, the uncertainty in medical costs only has a small effect on wealth inequality. Generally speaking, since income is the main source for saving that turns to wealth, wealth inequality is mainly driven by income. The level of medical costs affects wealth inequality at a higher degree than the variance.

2.3.3 The Consumption Distribution over the Life Cycle

Figure 2.6 displays the average consumption along the age. Similar to the previous analysis, we introduce the results from the benchmark, the counterfactual exercise I ($m = 0$), which removes all medical expenses, the counterfactual exercise II ($m = \bar{m}$), which controls the variance and let the medical costs for all agents equal to the mean costs for their age, the counterfactual exercise III ($y = \bar{y}$) in which we shut down the income inequality (red, blue, magenta and yellow lines respectively).

The average consumption increases with age in all cases (Figure 2.6). The reason why consumption raises in the second half of the life cycle is easy to understand: with the decrease of average saving (Figure 2.2), both the accumulated wealth and labor income transfer to consumption. Then, average consumption rises as a result. However, in the first few periods, average saving and average consumption increase simultaneously. The explanation can be this in our study: all agents are initially endowed with zero assets. In that case, in the first period, the average consumption is the lowest, since labor income is the only source for both consumption and saving, while agents have strong motives to save for the future. From the second period, the accumulated wealth along with the non-asset income can support the raise of average saving and the increase of average consumption at the same time for age 2

Figure 2.6: Average Consumption in the Benchmark Model and the Counterfactual Exercises

and 3.

As to the comparison of average consumption among the four models (Figure 2.6), there is very little difference between the baseline and the $m = \bar{m}$ model (red star line and magnate triangle line). Compared with these two, the counterfactual exercise I ($m = 0$) and counterfactual exercise III ($y = \bar{y}$) clearly show higher rates of consumption on average. When we shut down the medical costs completely ($m = 0$, blue cycle line), the average saving doesn't change much (Figure 2.2). Therefore, the budget, used to be spent on medical services, mainly transfers to consumption rather than saving. Compared with the $m = 0$ model, the $y = \bar{y}$ model has a lower average consumption at first, then eventually reaches the highest. Combined with the saving behaviour of agents, we should notice that the fraction of agents with saving, as well as the average saving over income, are higher in the counterfactual exercise, which controls income variance ($y = \bar{y}$). The higher saving crowds out consumption in the first few periods. The higher accumulation of wealth, however, eventually pushes average consumption to the highest level.

The Figure 2.7 illustrates average consumption over income for the baseline

Figure 2.7: Average Consumption over Income

model and the other three counterfactual exercises. Like the average consumption, the average c/y also increases with age for all cases. Similarly, when we remove all medical expenses from the model (blue cycle line), the line shifts upwards. Meanwhile, after controlling the income variance, the yellow line ($y = \bar{y}$ model) starts at a very low level and eventually reaches the peak. However, compared with the benchmark model (red star line), the $m = \bar{m}$ model (magnate triangle line) generates a lower c/y . This means that when we let every agent pay the same medical costs, even though average consumption generally remained unchanged, the consumption as a share of income goes down.

Showing the overall Lorenz curve from all models together in Figure 2.8, we can easily compare inequality in consumption. For the whole population, the baseline model is the worst situation with the largest Gini area. Without any surprises, the $m = \bar{m}$ model is very similar to the benchmark. When medical costs are taken out from the model ($m = 0$), the Gini coefficient goes down a little bit. Similar to the Lorenz Curve of saving, the counterfactual exercise III ($y = \bar{y}$) generates the lowest consumption inequality.

Figure 2.8: Inequality of Consumption: Lorenz Curve (the Whole Population)

Figure 2.9: Inequality of Consumption: Gini Coefficient

When we examine the consumption inequality within each age group in detail (Figure 2.9), we can see that the consumption Gini coefficient increases with age in all cases. The mechanism is easy to understand: the poor people who receive

subsidies from the government consume at a fixed level $\underline{c}$ and save zero. Only the richer are able to save and consume simultaneously in their early ages. The different levels of wealth accumulation lead to a larger gap between the poor and the rich, as well as the increase of inequality in the later periods. This trend continues with age.

Specifically, after we remove the income shocks, the inequality level of consumption drops dramatically. Therefore, income inequality is one of the main reasons for consumption inequality. The $m = 0$ model (blue cycle line) has the lowest consumption inequality in the rest three cases. Once we set all medical costs equal to zero, there are no agents facing the situation with extreme high income and very low even zero medical expenditure. Therefore, the dispersion is smaller in this case. The $m = \bar{m}$ model has the highest Gini coefficient in consumption. From Table 2.4 we know that when the medical costs variance is shut down, more agents take subsidies and consume only $\underline{c}$. Therefore the Lorenz curve for $m = \bar{m}$ model is more convex, and the Gini coefficient is higher shown as the magnate triangle line. However, the inequality in the baseline model increases faster than in the $m = \bar{m}$ model and in the model $y = \bar{y}$. The results can also be confirmed by the 90/10 ratio.

2.3.4 The Welfare over the Life Cycle

The third important aspect we have interest in is how medical uncertainty and income variance will affect welfare. We take the average of individuals' utility as the measurement for welfare. Figure 2.10 shows that welfare increases with age. In our study, welfare is determined by the consumption level. The previous part has already shown that consumption increases with age for all four cases, therefore, the welfare's rise along age is reasonable. Specifically, the $m = 0$ model generates the lowest welfare at each age. The benchmark is slightly better than the $m = 0$ model in terms of welfare. When income inequality has been removed ($y = \bar{y}$), welfare is the highest and it increases at a faster speed.

Figure 2.10: Welfare

Model	baseline	m=0	m= $\bar{m}$	y= $\bar{y}$
Welfare	-2.4313	-2.1237	-2.4809	-1.5996
Change (%)	0	12.65	-2.04	34.21

Table 2.6: Welfare Comparison

We can see from Table 2.6 that when we waive the medical costs completely ($m = 0$) or remove the income volatility ($y = \bar{m}$), the welfare improves 12.65% and 34.21% respectively compared to the baseline model. Meanwhile, when we control the variance in the medical costs in the model, the welfare gets even worse and decreases 2.04%. This means that if the medical service costs in the economy have been equally split to every individual, it will hurt the economy by lowering the welfare. This result appears to be logical. If we want to improve the welfare, the cost of such improvement should be shouldered analogically to the wealth of each individual rather than simply force the poor and the rich pay the same.

Figure 2.11: Robustness Check: Wealth Inequality

2.3.5 Robustness Check

In our model, there is only one parameter which is neither solved by the model nor exists in the related literature, i.e. the consumption floor $\underline{c}$. Therefore, in this subsection, we change the value of $\underline{c}$ from 0.25 in the benchmark to 0.125 and 0.5 to test whether the main findings will still hold.

Here, we only show the results for wealth Gini (Figure 2.11) and consumption Gini (Figure 2.12). We can see that the general trends remain unchanged: the wealth inequality decreases with age, while the consumption Gini coefficient rises along age. When the minimum consumption level $\underline{c}$ gets higher, the wealth inequality shifts up to a much higher level. In that case, it turns out that more agents fall into vulnerable groups who need help from the government. Meanwhile, the income tax will be higher. Therefore, there are fewer fractions of agents who will be able to save. Then, the wealth will be held by even fewer proportions of people. Inequality also rises to a higher level.

As to consumption inequality, when the consumption floor $\underline{c}$ is smaller, the Gini coefficients become higher. With lower $\underline{c}$, the income tax goes down. The agents,

Figure 2.12: Robustness Check: Consumption Inequality

endowed with relatively high income or low medical costs, become even richer. Therefore, the dispersion in consumption grows. Generally, the level of inequality is pushed to a higher position.

We repeat the analysis with different minimum consumption levels $\underline{c}$ for the average saving, average saving over income, the average consumption, the average consumption over income and the welfare. The results are not much affected by $\underline{c}$. All our main findings still hold.

We have performed a robustness check, in which the initial wealth a_0 are drawn from $U(0, 1)$. The main results remain unchanged.

2.4 Conclusion

In this paper, we considered a multi-period overlapping generation framework to study the consumption, the saving decisions, and welfare among elderly people with age above 50.

We assume that agents are heterogeneous in the non-asset income, y_t and the

medical expenditure, m_t . Each individual's labor income follows a stochastic $AR(1)$ process. The stochastic labor income can be further discretised into a finite-state Markov Chain. Each individual of age t draws a medical cost m in two steps: firstly, according to certain probability, the agents will realise whether they are "in perfect health" with no medical costs in the coming period. Following that, the "in imperfect health" ones will go for the second step drawing from the log normal distribution to determine their medical expenditures. The mean and the variance of the normal distribution are age-dependent.

For the benchmark, we solve for decision rules via backward induction. Using the terminal condition, $V(a, m, y, N + 1) = 0$, we can solve the value function at age N for each possible asset holding, health status and earning status, and subsequently the value function at age $N - 1$ and so on. Then, we solve for the invariant distribution measure. With the distribution measure and the optimal decision rules, we solve the model by aggregating all asset holdings and iterating over until the total transfer equals to the total tax and the aggregate saving is $\bar{s}$.

In order to analyse the effects of medical expenditure in detail, we build three counterfactual exercises. We successively shut down the heterogeneity of labor income (all agents have the same income $\bar{y}$), the heterogeneity of medical expenses (all agents have the same income $\bar{m}$), and removed the medical costs for all agents ($m = 0$ for the whole population). By comparing the benchmark model with the counterfactual results, we can have a clear picture about how each factor affects agents among different ages and we could study how the saving decision, consumption, inequality and welfare change respectively.

Regarding wealth and saving, we found that the average saving of elderly shows an inverse-U shape with age. The level of average saving are similar in all cases. However, when we shut down medical costs or remove the uncertainty in median expense, agents prefer to save more in the early periods in order to consume more later. Meanwhile, when we remove income heterogeneity (i.e., $y = \bar{y}$ model), the average saving level is slightly lower in the first 3 periods, but higher in the later

periods.

When we compare the wealth Gini coefficient of the four models along ages, income uncertainty contributes the most to wealth inequality and there is no obvious trend with respect to age. For the other three cases, wealth inequality decreases with age. The $m = 0$ model has the lowest wealth inequality among the three. The uncertainty in medical costs has little effect on wealth inequality. Generally speaking, the level of medical costs affects wealth inequality more than the dispersion.

Both average consumption and consumption inequality increase with age. Consumption inequality largely tracks income inequality. Though uncertainty in medical expenditures has little effect on consumption inequality, a higher level of medical expenditures may exacerbate consumption inequality.

The welfare level increases with age as well. Removing income uncertainty improves the total welfare drastically by 34.21%, while removing medical costs leads to a moderate improvement of 12.65%. Shutting down medical inequality has little impact on welfare (i.e., -2.04%).

Chapter 3

Voting for Health Insurance

Policy: the U.S. versus Europe

3.1 Introduction

Over the past several decades, most industrialized countries have experienced an upward trend in the total medical expenses, reflected as an increasing share in GDP among most OECD countries. Prior to the financial crisis, the average growth rates of the healthcare expenses would range between 4% and 6% annually from 1960 onwards ([Huber, 1999](#), [Huber and Orosz, 2003](#) and [Marino et al., 2017](#)). Despite the financial crisis cause many governments to cut down the general public budget including medical costs funded by the public resources, the medical expenses of OECD have risen again at a fast speed (3.4% in 2016)¹ recently. Public expenditure on medical costs among OECD countries is expected to rise from 6% of GDP in 2010, up to around 9% in 2030 and further more to one seventh (around 14%) of GDP by 2060 ([De la Maisonneuve and Oliveira Martins, 2013](#)).

If we focus on a few most developed countries, such as the U.S., Switzerland, France, Germany, Netherlands, Japan, Belgium, Austria, Canada and the Nordic countries, the medical expenses play an even more important role than in other

¹Source: OECD Health Statistics

OECD countries. In 2014, more than 10% of GDP in the listed countries are health-related spending². The leading country is the U.S., whose health expenditure amounted to 16% of GDP in 2014.

However, the U.S. exhibits a different path in the development of health care system compared with other developed countries. It is very unique that part of the health-related costs paid by the private sector is larger than the public costs in the U.S.. In 2015, medical expenses paid by the private sector are over 52% and the out-of-pocket spending is as high as 34%, whereas, the private contribution only accounts for 15% to 20% percent of the total medical costs for the representative European countries, and the out-of-pocket medical costs for France and Germany are as low as 14% and 13%³. As to the composition of healthcare expenses, in the U.S., more than half is outpatient services and only 18% is inpatient. For Germany, these two parts are both 29%⁴. The only OECD country, with a structure similar to that of the U.S. is Czech Republic (Marino et al., 2017). Meanwhile, the growth rate of the healthcare spending in the U.S. since 1970 is higher than that in the rest of the OECD countries (Huber, 1999 and Huber and Orosz, 2003).

Schoen et al. (2010) conducted a survey among eight high-income countries and found that the residents in the U.S. had the most serious financial problems related to medical costs and were less satisfied by the health services. By examining the inequality in health care utilization among 10 European countries and the U.S., Van Doorslaer et al. (2000) pointed out that the U.S. has the most serious inequality problem. In the study of Schoen et al. (2010), they argued that for U.S. citizens, a universal and comprehensive health care system reform could contribute to resolving the inequality issues.

These differences are mainly caused by the distinct public health care systems and policies of the European countries and of the U.S. on one hand. There are three types of health care systems: National Health Care (NHC), Social Health

²Source: OECD Health Statistics 2015

³Source: OECD Health Statistics 2016

⁴Source: OECD Health Statistics 2016

U.S. System	Europe System (Germany as the representative country)
private insurance-based healthcare systems	universal healthcare
not compulsory	compulsory
partially covered	"sufficient, necessary and meaningful services"
premium depended on health condition	depended on salaried income
relative low insurance premium	high insurance premium
but high Out-of-Pocket costs	but low OOP costs
not surely includes family members	includes
from the insurance pool	"pay as you go"

Table 3.1: Main Differences between the U.S. Healthcare System and the Europe Social Health System

Insurance (SHI), and private insurance-based systems ([Blank et al., 2017](#)). The national care system, financed by taxation, is found in the U.K, Greece, Italy, Portugal, Spain and the five Nordic countries in Europe. The second healthcare model, which is based on compulsory insurance, is representative of countries such as Germany, France, Belgium, Austria, Netherlands and Switzerland ([Saltman et al., 2004](#)). Both of these types of health care systems, called the Western-type by [Marino et al. \(2017\)](#), are universal and comprehensive, and offer the residents of these countries good protection from out-of-pocket costs. The U.S. is the only industrialized country which is characterized by the private insurance based system ([Berwick and Hackbarth, 2012](#)). The main differences between the U.S. system and the Europe system could be summarised as follows (Table 3.1):

Many studies have discussed the reasons behind the adoption of specific welfare systems, and in particular on the deep differences between the social health systems in the U.S. and European countries. In their book, [Blank et al. \(2017\)](#) pointed out that social values, cultural factors, biomedical technology as well as demographic factors could cause the adoption of different healthcare systems among industrialized countries. More specifically, legal systems, political systems, social structures, public expectations and demands, interest groups, mass media, health care sector and insurance structure could all contribute to shape these differences.

[Alesina et al. \(2001\)](#) excluded income difference and deadweight loss for taxation. They believed that the low representation of minorities in the U.S, the distinct legal systems, the political structure, the behavioural differences in voting and racial discord all play significant roles.

Based on previous studies in literatures and the general review of the different development in the history of the U.S. and Europe ([Appendix A](#)), we put forward two hypotheses to explain the existence of the entirely different social healthcare systems in the U.S. and in European countries. Firstly, we believe that in the U.S., the voice of the poor is less important than the rich, because poor voters are less willing to participate in the elections. In [Hill and Leighley \(1992\)](#) and in [Hill et al. \(1995\)](#), the relevant empirical evidence is illustrated. [Riker and Ordeshook \(1968\)](#) argued that because of the costs of attending the election, the poor have less chance to vote. [Blakely et al. \(2001\)](#) found that political inequality in voting was associated with poor self-health conditions. [Kingdon and Thurber \(1984\)](#) highlighted the effects of political organisations, such as labor unions. In Europe, the power of labor unions is much bigger and has helped the poor to be better represented.

The second hypothesis is that the different attitudes towards the size of the government and the existence of a compulsory social health insurance affect the voting outcomes. [Blank et al. \(2017\)](#) pointed out that residents trended to be communitarian in the health political culture, while people are individualistic in the U.S.. [Jacoby \(1994\)](#) analyzed public attitudes towards government spending. [Blais et al. \(1993\)](#) and [Risse-Kappen \(1991\)](#) emphasized the spirit of freedom, liberalization and democracy in the U.S. which led to a naturally negative attitude towards growing power of the government.

In this paper, we build a multi-period overlapping generation model to test these two hypotheses and further quantify the importance of each of the proposed factors. The rest of the paper is structured as follows. [Section 3.2](#) lays out the theoretical framework. [Sections 3.3](#) and [3.4](#) show the benchmark’s simulation results and the counterfactual results. Our concluding remarks are found in [section 3.5](#).

3.2 Model

In this section, we describe the theoretical framework. We develop an overlapping generation model, which is mainly an extension of [Huggett \(1996\)](#). In addition, we also introduce idiosyncratic shock in medical expenses, as well as the role of government.

3.2.1 The Environment

Time is discrete and infinite indexed by $n = 0, 1, \dots$. At the beginning of each period, a continuum of agents are born. The size of each cohort is normalized to be 1. We do not consider accidental death along the life-cycle, so agents survive from age 0 to age N . The instantaneous utility function at each period takes the standard CRRA form:

$$u(c) = \frac{c^{1-\sigma} - 1}{1-\sigma}$$

where σ is the coefficient of relative risk aversion ($\sigma \geq 1$).

We assume that agents are heterogeneous along two dimensions: i) the non-asset income (y_t), ii) the medical expenditure (m_t). Following the convention in the literature, we assume each individual's labor income follows an stochastic $AR(1)$ process:

$$y_{t+1} = (1 - \rho) * \mu_y + \rho * y_t + e_t$$

where $e_t \sim N(0, \sigma_y)$ and ρ is the $AR(1)$ coefficient. The stochastic labor income can be further discretized into a finite-state Markov Chain with a finite number of possible values in the set Z according to Tauchen(1986). Moreover, the shocks are also i.i.d across agents. Therefore, there is no aggregate level uncertainty in the economy.

Medical expenditure, m_t , is defined as out-of-pocket medical costs. Throughout the paper we treat the medical costs as exogenous shocks to the agents, since the

major focus of the paper is to examine the effects of medical expenditure on the aggregate outcome and individual's decision. The shocks are also assumed to be age dependent. Each individual of age t draws a medical cost m_t from a log-normal distribution at the beginning of each age, $\log(m_t) \sim N(\mu_{mt}, \sigma_{mt})$, where μ_{mt} and σ_{mt} are the mean and the standard deviation of the normal distribution for the agents of age t . μ_y , σ_y , μ_{mt} , and σ_{mt} are independent. We have done robustness check by allowing the covariance between income and health expenses, the quantitative results remain robust.

The timeline of the economy is as follows: agents draw idiosyncratic income and medical expense at the beginning of each period. Agents will then make the saving decision accordingly. Borrowing is not allowed in our basic model. Agents are not endowed with any initial wealth: a_0 equals to 0 for all. At age N , the last period of their lives, agents will consume everything when the bequests motive is absent.

3.2.2 Two Different Policies

In the model, we have two different policies for all agents to vote: policy I (without fully covered social health insurance) and policy II (with a compulsory social health insurance). For policy I, agents should take charge of their medical expenditures themselves. Government subsidies will support the poorest agents who are endowed with low income or draw high medical costs. Under policy II with fully covered social health insurance, agents pay a premium (or tax) which is a proportion of their income to join the insurance pool. Then the government will take full responsibility of everyone's medical services. Since the medical expense is waived from budget constraints, the government will no longer supply the subsidy. Once more than half of the households support one policy in the election, then the policy will become permanent.

Under Policy I, every agent needs to pay income tax to the government. Meanwhile, the government will supply a subsidy to the poor. A typical budget constraint

for a representative agent at age t is:

$$a_{t+1} = (1 - \tau)y_t + (1 + r)a_t - c_t - m_t + b_t$$

where a_t is the saving (assets) at age t , τ denotes the income tax and b_t describes the government transfer.

Each agent takes the government transfer as given. But from the perspective of the government, b_t is determined such that all the agents are able to afford at least $\underline{c}$ unit of consumption as well as paying for the incurring medical expenses within the period. Specially, b_t is given as:

$$b_t = \max \{0, \underline{c} + m_t - [(1 - \tau) * y_t + (1 + r) * a_t]\}$$

where $\underline{c}$ denotes the minimum consumption provided by the government transfer. The above implies that when the agents have very low income or draw very high medical expenses, while at the same time they are endowed with low assets from the last period, the government will protect those vulnerable groups, so they can maintain a minimum standard of living.

In this paper, $\underline{c}$ is endogenous. The government would decide the minimum consumption level based on the poverty fraction p^p . The government finances its transfer through taxation. We assume balanced government budget, so government budget in each period can be written as:

$$\int_{i \in \Omega^p} b^i \, di = \int_{\Phi} (\tau * y^i) \, di$$

where Φ denotes the entire population set, and Ω^p is the set for agents who receive subsidy from the government. Therefore, the poverty fraction is:

$$p^p = \frac{|\Omega^p|}{|\Phi|}$$

We assume government can perfectly monitor those agents who receive transfer, and they are not allowed to own any assets and transfer it to the next period.

At each age, agents solve the dynamic programming problem by choosing consumption c for this period and a risk-free asset a' for the next period. The value function for each individual is as follows:

$$\begin{aligned} V(a, m, y, t) &= \max_{c, a'} u(c) + \beta \mathbb{E}_{(y', m')} [V(a', y', m', t+1) | (a, y, m)] \\ s.t. \quad c + a' &\leq (1 - \tau)y + (1 + r)a - m + b \\ a' &\geq 0 \end{aligned}$$

From these equations, we can see that the agents must pay the medical costs m themselves and also need to factor in the expectation for the future medical expenses m' .

Under Policy II, agents need to “donate” a fee as the cost of purchasing a health insurance, afterwards the government or the government-owned health insurance company will pay for all the medical services for the entire population. Therefore, a typical budget constraint for a representative agent at age t under Policy II is:

$$a_{t+1} = (1 - \tau_{SHI})y_t + (1 + r)a_t - c_t$$

where τ_{SHI} denotes the social health insurance premium. It may also be treated as a tax since it is compulsory. We assume balanced government budget, and thus the government decides τ_{SHI} according to its budget constraint:

$$\int_i m^i \, di = \int_i [\tau_{SHI} * y^i] \, di$$

Since it is a compulsory social health insurance, agents may hold different attitudes towards Policy II. An exogenous fraction p^A of agents prefer a small government rather than a powerful one who holds huge funds and controls everyone's lives. We assume a utility loss for those agents, $\bar{A}$, under the policy with SHI. Specifically,

the utility becomes:

$$u^i(c) = \begin{cases} \frac{c^{1-\sigma}}{1-\sigma} - \bar{A} & i \in \Phi_1 \\ \frac{c^{1-\sigma}}{1-\sigma} & \text{otherwise} \end{cases}$$

where $\Phi_1 \subset \Phi$ is the set of agents who initially dislike the policy with fully covered SHI.

Similar to the situation under Policy I, at each age, every household solves the dynamic programming problem by choosing consumption c for this period and a risk-free asset a' for the next period. Then, the value function for each individual is as follows:

$$\begin{aligned} V(a, y, t) &= \max_{c, a'} u(c) + \beta \mathbb{E}_{(y')} [V(a', y', t+1) | (a, y)] \\ \text{s.t.} \quad c + a' &\leq (1 - \tau_{SHI})y + (1 + r)a \\ a' &\geq 0 \end{aligned}$$

3.2.3 Decision Rules, Participant Rate and Voting Results

Agents could be **Myopic** or have **Perfect Foresight**. If the agents are **Myopic**, they place more emphasis on the situation at present and compare the current utility between U_{no} under the Policy I without any social health insurance with U_{SHI} under Policy II. Otherwise, if the agents have **Perfect Foresight**, they compare the life time expectations between V_{no} and V_{SHI} under the two different policies.

After comparing their current utilities or their life time utility expectations, agents will form their preference of the policies.

$$\Gamma_{m,pf}^i = \begin{cases} 1 & \text{if } U_{no}^i < U_{SHI}^i \text{ for Myopic or } V_{no}^i < V_{SHI}^i \text{ for Perfect Foresight} \\ 0 & \text{otherwise} \end{cases}$$

If $\Gamma_{m,pf}^i = 1$, then agent i is a supporter of Policy II with the social health insurance,

$i \in \Psi_{m,pf}$. The m, pf denotes whether the agent is **Myopic** (m) or have **Perfect Foresight** (pf).

If all agents participate in the elections, the voting outcome equals to $\frac{|\Psi_{m,pf}|}{|\Phi|}$. However, in reality, not all agents will attend the election. Voting results depend not only on each agent's preference, but also on their participation rate w_y in the elections. w_y is income dependent. Then,

$$\text{voting results} = \frac{\int w(y) |\Psi_{m,pf}(y)| dy}{\int w(y) |\Phi(y)| dy}$$

3.2.4 Stationary Equilibrium

Income y , medical costs m and assets a are given and known at the beginning of each period. At the age N , agents face the value function $V(t+1) = 0$. Then, in our basic model, there are three state variables: m_t , y_t and a_t , and one control variable: c_t .

The distribution of agents is defined over age, asset holdings, non-asset income status and medical expense status. Let $x = (a, m, y)$, and let $(X, B(X), \psi_t)$ be a probability space where $\psi_t(B_0)$ is the fraction of age t agents whose state x lies in set B_0 as a proportion of all age- t agents with initial distribution ψ_t . These agents make up a fraction $\psi_t(B_0)\mu_t$ of all agents in the economy, where μ_t is the share of age- t agents in t .

A **stationary equilibrium** consists of $\{c(a, m, y, t), a'(a, m, y, t), r\}$ and an invariant measure of agent distribution for every age t ($\psi_1, \psi_2, \dots, \psi_N$) in the defined state space, such that

- 1 The individual agent solves its utility maximization problem by choosing the optimal rules of $c(x, t)$ and $a'(x, t)$.
- 2 The aggregate savings of all elderly in this system, $\bar{s}$ is assumed to be positive:

$$\sum_t \mu_t \int_X a'(x, t) d\psi_t = \bar{s}$$

3 The law of motion for the measuring of age- t agents is

$$\psi_{t+1}(B) = \int_X T(x, t, B) d\psi_t, \forall B \in B(X)$$

where $T(x, t, B)$ is a transition function. It gives the probability that the age- t agent transits from the current state (x) to state B in the next period. The transition function is determined by the optimal decision rule on asset holdings, by the exogenous transition probabilities on the labor income shock y and by the exogenous probabilities on the medical expenditure shock m_t .

4 Since we discretize both y and m , the law of motion becomes

$$\begin{aligned} \psi_{t+1}(a', m', y') \\ = \sum_{a: a' = A_t(x)} \sum_{m: m' = M_t(x)} \sum_{y: y' = Y_t(x)} \Gamma([m, y], [m', y']) \psi_t(a, m, y) \end{aligned}$$

where $\Gamma([m, y], [m', y'])$ is the transition probability matrix for the joint process of the pair, $[m, y]$.

5 For simplicity, we assume there is no population growth and population share of each t is equal, i.e., $u_t = u = 1/6$. Hence, $1 = \sum_{t=1}^N \mu_t^j$ at time j .

3.3 Quantitative Analysis

In the quantitative analysis, we focus on the analysis of the principle factors for the agents' voting decisions. We firstly calibrate the parameters for the benchmark model. Then, we build two counter models to test our two hypotheses: i) the voice of the poor is less important than the rich, because poor voters are less willing to participate in the elections.; ii) the distinct attitudes towards the size of the government and its power, which can be augmented with a compulsory social health

Parameter	Model	Value
N	Maximum model age	6
σ	coefficient of relative risk aversion	1.5
β	subjective discount rate	0.9
μ_y	mean income, normalized	1
ρ_y	AR coefficient of Markov chain approximation of AR(1) process for income	0.85
σ_y	s.d. of the error term in Markov chain approximation of AR(1) process for income	$\sqrt{0.3}$
$\mu_{m,t}$	mean of lognormal distribution of the medical expense process, m_t	age group-specific
$\sigma_{m,t}$	s.d. of lognormal distribution of the medical expense process, m_t	age group-specific
r	interest rate per model period (5 years)	10%
u_t	population share of each age, t	1/6
p^A	fraction who prefers smaller government, PEW	53%
p^p	poverty level, U.S. Census 2013,2014	14.8%
w_y	election participant rate, CPS 2014	income dependent

Table 3.2: Parameters from Data or Existing Literature

insurance system, affect the voting outcomes.

3.3.1 Parameterization

We have three kinds of parameters based on their different sources: the parameters which are directly calibrated from data or borrowed from literature, the calibrated parameters, and the parameters predicted from the model. The parameter space in our model contains $\{N, \sigma, \beta, \mu_y, \rho_y, \sigma_y, \mu_{m,t}, \sigma_{m,t}, r, u_t, p^A, p^p, w_y, \bar{A}, \underline{c}, \tau, \tau_{SHI}\}$ (seen in Tables 3.2, 3.3 and 3.4).

N denotes the maximum age in the model. In this paper, we assume that each age represents a period of 5 years. σ is the coefficient of relative risk aversion and

Parameter	method
$\bar{A}$	calibrated by given ACA voting results, PEW
$\underline{c}$	calibrated by given poverty level

Table 3.3: Calibrated Parameters

Parameter	method
τ	solved for given minimum consumption level
τ_{SHI}	solved by given the health services cost

Table 3.4: Model Predicted Parameters

controls the utility function. β denotes the subjective discount rate and will reflect how important the future utility is for the agents. We assume that the annual interest rate equals to 2%, therefore, the 5 years interest rate, r , will be 10% in our benchmark model. These three parameters σ, β and r are borrowed from literatures. For simplicity, we assume there is no population growth and the population share of agents at each age t (u_t) is equal.

In this paper, we use 2014 HRS (the Health and Retirement Study) data to calibrate the income and medical cost related parameters. HRS supplies survey data with rich details focusing on health related costs, financial and social status, etc., among the retired population (50 and older) in the U.S.. Specifically, the HRS dataset includes data falling under the topics of health status, medical expenses, pension situation, social and health insurance status and so on. For the purpose of our analysis, we chose the HRS. After registration, the HRS dataset is free and publicly accessible. The available data starts from 1992 and the most recently published data is from 2016.

ρ_y and σ_y are the AR coefficient of the Markov chain approximation of the AR(1) process for income and its s.d. of the error term in Markov chain approximation respectively. Following [Guvenen \(2009\)](#), we extract those two parameters using the HRS 2014. Note that there are other available data sources which we can adopt to estimate an income process from a group of more representative individuals.

50-54	55-59	60-64	65-69	70-74	75-80
25.53%	24.03%	21.11%	16.34%	14.14%	13.92%

Table 3.5: Share of the Agents with Non Medical Costs

HRS only focuses on agents whose age are between 50 and 80. However, we stick to HRS dataset because of its detailed documentation on medical expenditure, which is the major focus of the paper. In addition, if income process is indeed a stationary process, then estimation using a truncated series will still deliver the unbiased results.

We denote the out-of-pocket payments for medical services as the medical expenses. In more detail, these include hospital costs, nursing home costs, outpatient surgery costs, doctor visit costs, dental costs, RX costs, in-home health care costs and other services costs. The original data size is 18,747. In order to fit the model, we excluded samples with age under 50 or older than 80. Then, we group the participants into the corresponding age groups. For the 6 groups, the sample size is respectively 1128, 3595, 3193, 2289, 2460, and 2795. The total number of participants is 15460 in the data.

In the literature, e.g. [Duan et al. \(1983\)](#), [Manning et al. \(1987\)](#) and others, medical expenses follows a log-normal distribution. In this paper, we define the medical costs as out-of-pocket expenditure. Therefore, in the data, we found many samples with medical costs equal to zero. In such cases, the log expenses will be minus infinity. To deal with this, we first calculate the proportions of those endowed with zero medical costs in each age group. From Table 3.5 we can see that this ratio is strictly decreasing with age. Then, we take the log of all the non-zero medical costs and use the results to fit the normal distribution. Figure 3.1 shows the fitted results. The six panels represent the results from six distinct age groups. The x-axis denotes the logged medical costs. The blue bars represent the density. The red lines are the fitted normal distribution. The calibrated mean $\mu_{m,t}$ and the standard deviation $\sigma_{m,t}$ are also shown in the upper right corner in each subgraph. The fitted

Figure 3.1: Medical Expenses Distribution in Age Groups

mean and the s.d. do not seem to change much among ages groups. However, if we take the proportion of individuals with zero medical cost into account, we will observe a rise of mean costs with age and an increasing volatility. Then, the results will match those reported in the literature.

In our model, we assume the medical expenses for each agent is a random shock. At the beginning of each time period, the individual draws a number from a certain distribution. The distribution function which we calibrated using HRS 2014 is not a simple log normal distribution and it is a piecewise-defined function with one sub-function assigning the value equal to zero and another sub-function following log normal distribution. Therefore, when we draw the medical shocks, there will be two steps: firstly, according to a given probability, the agents will be assigned one of two conditions: i) “in perfect health” with no medical costs in the coming period,

or ii) “in not perfect health”, who will arrive at the second step drawing from the log normal distribution to determine how high the medical expenditures are.

There are three additional important parameters related to the two policies. p^p is the fraction of poverty in the economy. We use the poverty ratio from the U.S. Census 2013 and 2014. In both years, it equals to 14.8%. p^A denotes the probability of agents who prefer a smaller government and therefore have a negative attitude towards Policy II which comprises the compulsory social health insurance. The PEW (Pew Research Center), a non-advocacy American fact tank, has conducted surveys and provided information on the citizens’ views about the size of government since April 1976 (Figure 3.2). Since the fraction of citizens who support a smaller government with fewer services is dynamic, we take the average from 1990 (after the Cold War) until 2014. w_y is the rate of participation in elections. w_y is income different. The data we used to calibrate is CPS 2014 (U.S. Census Bureau, Current Population Survey, November 2014). The corresponding election participation rates of the ten income groups ranked from the lowest to the highest are 27.35%, 33.68%, 34.32%, 38.35%, 44.93%, 46.71%, 52.75%, 58.01%, 60.93% and 63.37% respectively. We can see that the poorer the agents are, the less they get involved in elections.

Figure 3.2: Views about Size of Government of Americans from 1976 to 2015

Note: survey data from PEW

Under Policy I, there is no social insurance system, so all agents must take full responsibility of their own medical expenses. There is a certain chance that the agent is endowed with low income or with extreme high medical costs. In such cases, the relevant agents will face severe financial problems. Under these circumstances, the government will supply a subsidy for the poorest agents. The government first decides on the fraction of people who need help and then the minimum consumption level (consumption floor) can be solved to match the poverty rate. In order to calibrate the consumption floor, we repeatedly throw different levels of $\underline{c}$ into the model and the model will generate results about the fraction of the population in need of subsidies. From Figure 3.3 we can see that with the increase of consumption floor (x-axis), the fraction of agents who take subsidies raises (left y-axis). The horizontal light blue line is the fraction of the determined poverty level (14.8%). The blue line intersects the light blue line where the consumption floor is located between 0.11 and 0.12. Eventually, the $\underline{c}$ solved in the baseline model equals to 0.113250122.

Figure 3.3: Calibrate the Minimum Consumption Level

The minimum consumption level is guaranteed by government transfers, which are supplied by the income tax collected at certain tax rate for each period. Given

$\underline{c}$ equals to 0.113250122, the τ solved by the model is 4.88% (the orange line in Figure 3.3).

Since Policy II is based on a compulsory social health insurance model, for those agents who prefer smaller government with fewer services, there will be a negative effect $\bar{A}$ as part of their utility. This parameter is hard to be calibrated directly from the data. However, if the voting result is available, we can arrive at the solution of $\bar{A}$ via backward induction in the benchmark. Then, the problem becomes a matter of estimating the election results.

Figure 3.4: Public's Overall View of Obama Care since 2009

Sources: PEW research center, <http://www.people-press.org/datasets/2016/>

On March 23, 2010, president Barack Obama signed the Patient Protection and Affordable Care Act (in short the Affordable Care Act (ACA) or Obamacare). The PEW research centre kept track of the public support level since 2009 (Figure 3.4). On average, the approval rate was 48.14%, while disapproval was measured at 43.04%. In our model, we only allow agents to approve or to disapprove Policy II in the election. Abstention is not considered as an option. Therefore, we need to transfer the approval fraction over the whole population in the survey to the approval fraction over the voters in the election. Therefore, we take $52.80\% = \frac{48.14\%}{48.14\% + 43.04\%}$ as the election result to solve the attitude parameter $\bar{A}$.

As mentioned in our model outline, agents can be either **Perfectly-Foresighted**

Figure 3.5: Fraction of Supporters for SHI Policy given Different Attitude towards Government Size (**Perfectly Foresighted** Agents)

or **Myopic**. Figures 3.5 and 3.6 show the changes in citizens' views about Policy II with SHI with respect to the increase of $\bar{A}$ in the both cases. We can see that the rise of the attitude value leads to a smaller fraction of people who prefer the SHI policy.

Figure 3.5 shows the fraction of supporters (**Perfect Foresight**) for Policy II with universal medical insurance given different attitudes towards government size. The green points denote the voting results corresponding to distinct attitude levels. The brown horizontal line is the benchmark model result (52.80%). Then, via backward induction, the solved attitude $\bar{A}^{pf}$ (**Perfect Foresight**) equals to 0.308175 when the agents make their decisions based on the expected value function of the rest of their lives.

In a similar way, Figure 3.6 exhibits the voting results for the given attitude magnitude when the agents are **Myopic**. The solved attitude level $\bar{A}^m$ equals to 0.054620 when agents make their decisions based on current utility. When we compare $\bar{A}^{pf}$ and $\bar{A}^m$, we can find that the **Myopic** agents are less tolerant of Policy II. In this paper, we discuss the "**Perfectly Foresighted**" and "**Myopic**" situations separately. In the real word, the **Perfectly Foresighted** and **Myopic**

Figure 3.6: Fraction of Supporters for SHI Policy given Different Attitude towards Government Size (**Myopic Agents**)

agents coexist in the population. Then, the real $\bar{A}$ should be located within the range $[0.054620, 0.308175]$.

Under Policy II, agents need to pay a premium τ_{SHI} to join the insurance pool. This premium can also be treated as a tax because it is compulsory. Then the government or the state-owned health insurance company will cover the expenses of all medical services for the whole population. In Figure 3.7, the orange line represents the government revenue along the horizontal axis τ_{SHI} . Ideally, the government plans to have zero revenue. Therefore, τ_{SHI} solved by our model is equal to 16.4%. In reality, the social health insurance premium applied in Germany is 15.9%, which is very close to what we calibrated.

The blue line in Figure 3.7 shows the movement of the public views on the SHI policy with the increase of τ_{SHI} . Logically, the higher the insurance premium is, the less attractive the policy is.

3.3.2 The Effects of Key Factors

In the introductory section we proposed two hypotheses as the possible key factors in explaining the reasons for the existence of different health insurance systems among

Figure 3.7: Fraction of Supporters for Policy II with SHI and Government Revenue to Different SHI Premiums

similarly developed countries: i) in the elections, the enthusiasm for participating and the voting proportion among the poorer groups are much lower than among the rich ones; ii) The role of different attitudes towards the size of the government is another proposed explanation. Based on our analysis, we point to a third possible factor: the minimum consumption level $\underline{c}$.

First, we believe that the different attitudes towards the government's size and towards the compulsory policies will also strongly affect the households' view in the elections. Agents, who have a negative image about the government, suffer a utility loss under Policy II with SHI. The more intense their negative attitudes are, the lower the current utility or expected life-long utility the agents gain; therefore, they are less willing to vote for the policy with fully covered social health insurance.

For both **Perfect Foresight** (Figure 3.5) and **Myopic** individuals (Figure 3.6), the proportion of supporters of Policy II decreases with the rise of negative attitude. In other words, when the public shows lower levels of trust in their government, it will be harder for the politicians to promote the reform of the health insurance system. In Figure 3.8, we obtain the same results under all weight (participation rate) levels.

Figure 3.8: Fraction of Supporters for Policy II with SHI given Different Attitudes and Different Voting Participation Rate

Then, we examine the general effects of the participation rate on the final voting outcomes. The participation rate can be treated as the weight to which an income class influences the election outcomes. The lower the participation rate is, the less their voices can be heard, therefore, the less their voting outcomes weigh in the final results. In order to show the effects, we simulated ten sets of participant rates corresponding to ten distinct income groups. The lowest weight level is the participation rate we used in the benchmark model: 27.35%, 33.68%, 34.32%, 38.35%, 44.93%, 46.71%, 52.75%, 58.01%, 60.93% and 63.37% respectively from the lowest income group to the highest. The highest weight group comprises 100%, representing a scenario where all agents participate. Then, for a given wealth class, we set the simulated weights increase by the same amount each time. For example, for the poorest group, the 10 different weights applied in the simulations are 27.35%, 35.42%, 43.49%, 51.57%, 59.64%, 67.71%, 75.78%, 83.86%, 91.93% and 100% respectively.

The simulated voting results are shown in Figure 3.8. Each line represents the voting results (fraction of supporters) against the negative public attitudes level

given the simulated weights for the 10 income groups. For a fixed attitude level, we can compare the election results under the different weights. We can see from the figure that with the increase of the weights, the fraction of supporters of Policy II curve moves upwards. Therefore, with the increase of the participation rate overall (especially in the poor and in the middle class), the SHI policy has a better chance to be approved.

For the public, making decisions in the election is boils down to comparing the benefits (or losses) under different policies. Therefore, the factor which can affect Policy I (without any social health insurance), will also exercise influence on voting behaviour. In this paper, the minimum consumption level $\underline{c}$ plays a significant role under Policy I. Therefore, we also take $\underline{c}$ as a key factor into account.

Figure 3.9: The Expected Utility of Age 1 Agents with Different Minimum Consumption Levels

Figure 3.9 illustrates the simulation results for the age-one agents' life time expected utility against the log income with distinct consumption floor levels $\underline{c}$ under Policy I. The third lowest $\underline{c}$ is the parameter we solved in our benchmark model. Based on that, we generate the remaining nine values with the same growth rate (5%).

We can see from the figure that the increases in the minimum consumption level $\underline{c}$ push up the value of expected utility for the agents endowed with relatively lower income. When the government raises the poverty line, the fraction of agents who take subsidies increases. Meanwhile, the minimum consumption level and the subsidized amount will increase as well. In other words, higher $\underline{c}$ will result in a better situation for the poor. However, there are no obvious differences for the agents with the highest income.

With the higher expected utility level under Policy I without SHI, Policy II, which aims at co-exposure and provides protection for the vulnerable groups from miserable living conditions, becomes a less attractive option for the poor. Therefore, when the minimum consumption level increases, the fraction of supporters for Policy II with SHI goes down, resulting a less favourable voting behaviour.

3.3.3 Multiple Cut-off Point

In the previous analysis about the minimum consumption level $\underline{c}$ in Figure 3.9 we can observe an interesting phenomenon: the value function curve is firstly convex and after a certain point, changes to concave for Policy I. However, in the literature, with an increasing income, the expected value function should monotonically increase with a decreasing rate (concave) globally. The left panel of Figure 3.10 illustrates the value function curves for the agents from every age group (age 1 to age 6). All these lines exhibit the same pattern. Our finding, while contradictory at first glance, can be explained if we consider the differences between log wage income and log total income of the poor.

In our benchmark model, under Policy I, the poorest 14.8% of the agents will receive subsidies from the government. In order to make sure everyone can consume at least at the minimum consumption level $\underline{c}$, based on the optimal choice of poor agents, the government will transfer certain amount and top up the consumption to $\underline{c}$. In that case, the total inflow for the poorest 14.8% agents is not only their labor income but also the subsidies received from government.

Figure 3.10: The Shape of Value Function Changes from Convex to Concave along the Wage Income.

Figure 3.11: Comparison of Value Functions along Wage Income and along Average Total Log Income

Seen from the right panel of Figure 3.10, even though the log wage income keeps increasing, the average log total income (total inflows) for the poorest groups does not change much. After which, the slope of the red line turns to 45 degrees. This means that the log wage income matches the average log total income.

Then, we suspect that the difference between the log wage income and the log total income for the poorest proportions is the reason for the changes of the value function curve from convex to concave (the left panels in Figure 3.10 and in Figure 3.11). In the right subfigure of Figure 3.11, we draw the expected value function curves against the average log total income instead of the log wage income. Consequently, we obtain the concave curves (monotonically increase with a decreasing rate) for all age groups. This means that, if we treat the total inflow as the income for agents, the expected value function remains concave. This matches the previous findings reported in the literature.

Figure 3.12: Multiple Cut-Off Point for Policies with and without SHI

As the expected utility under Policy I does not have a single concavity, there exists a chance that the two value function curves under the two policies might have two cut-off points. In Figure 3.12, the blue line and the red line are the value function curves under policies without or with SHI respectively. Since there is no

subsidy under Policy II to only support the poor (there is no restriction of the minimum consumption level $\underline{c}$), the red line is concave. These two lines cut at two points where the log income equals to -1.9358 and 0.9450 . The first intersection locates at the 3rd quantile and the second one is at the 73rd quantile.

The agents make their voting decisions only based on the comparison of the current utility or the life-time expected utility level. Therefore, when a certain value function curve is above another one, the curve denotes a policy that is more appreciated by that income class. Specifically, in Figure 3.12, at first the curve for Policy I is higher (blue line), then the red line (Policy II) surpasses it, and eventually Policy I ends up higher than Policy II again. In other words, in the benchmark model, in the case of the **Perfectly Foresighted** agents, who have incomes below the 3rd quantile or above the 73rd quantile, will vote for Policy I with subsidies rather than Policy II with the fully covered compulsory social health insurance system. Both the poorest and the richest agents prefer the American style and only the middle class wants a the European-style health insurance policy to be applied.

These two cut-off points divide the households into three groups: the poorest 3% of the agents, the richest 27% and the rest in between. Unlike normal commercial insurances which provide risk management to units of similar exposure, the social health insurance supply the cover to the whole population. Its premium is not based on the risk level, but on a proportion of the income. It means that the more capable ones will take more responsibilities in the system.

Based on that, the mechanism which drives the voting choices made by the poorest and the richest agents can be inferred. The poorest have very low income. Although under Policy II they only need to pay a very low premium compared to the medical costs they need to pay under Policy I, the subsidy from the government in Policy I is high enough to turn out a higher utility level. Therefore, they will disapprove the SHI policy. As for the richest, since they obtain high wage income, given the same premium rate τ_{SHI} , the amount contributed by them to the insurance

0.412	0.439	0.138	0.010	0	0	0	0	0	0
0.097	0.390	0.404	0.102	0.006	0	0	0	0	0
0.009	0.125	0.429	0.360	0.074	0.004	0	0	0	0
0	0.014	0.165	0.457	0.311	0.051	0	0	0	0
0	0.001	0.023	0.210	0.471	0.260	0.035	0.001	0	0
0	0	0.001	0.035	0.260	0.471	0.210	0.023	0.001	0
0	0	0	0.002	0.051	0.311	0.457	0.165	0.014	0
0	0	0	0	0.004	0.074	0.360	0.429	0.125	0.009
0	0	0	0	0	0.006	0.102	0.404	0.390	0.097
0	0	0	0	0	0	0.010	0.138	0.439	0.412

Table 3.6: The Income Transition Matrix

pool is much more than the average. If they only take the current utility or value function into account, they prefer to take the risk of medical expenses shocks under Policy I since the estimated medical costs will be lower than the premium that they must pay under Policy II.

However, there exists a group of agents who are recipients of benefits under Policy I as well but still vote for Policy II. Under Policy I, 14.8% of households will receive subsidies but only around 20% of those households supports this policy option. We can infer the reason behind this from the income transition matrix (Table 3.6).

The table shows the income dynamics. There are 10 income groups (10×10 matrix). The rows represent the current income classes to which the agents belong and the columns denote the agents' situation in the next period. All numbers located in the diagonal imply the proportions of agents with unchanged income classes. For example, the number 0.412 in the square of the first column and the first row denotes the probability of the group 1 income agents at present remaining in group 1. Similarly, the chance for an agent who originally takes the lowest income to jump to the second lowest income class is 43.9% (first row, second column).

For the low income households (group 1-4), they will have a good chance to

receive a higher payment in the next period. Under the case of Policy I, the increased amount will be cancelled out by the decrease of subsidies. However, under Policy II, even though they need to pay a higher premium, they do not need to worry about their medical cost shocks. The increased premium is proportional, but the decreased subsidy is a full amount. With the expectation of higher income, the relatively poor agents will vote for the social health insurance policy.

On the contrary, the relatively rich agents have a high probability to face an income drop in the next period but not to the point that they would fall into the poorest subsidized groups. They can not enjoy the benefits from Policy I, but can expect a lower premium in the future. Therefore, they are the ones who also strongly support Policy II.

3.4 Counterfactual and Sensitivity Analysis

In this subsection, we try to analyse the importance magnitude of the three proposed key factors: the minimum consumption level $\underline{c}$; the negative attitude towards bigger government and the compulsory insurance policy $A^{m,pf}$; and the lower representations of poorer voters w_y . We shut down each factor in turn to test how the final voting results would change.

We also did the sensitivity analysis for two parameters: the poverty fraction and the voting results, which were used to solve the key factors $\underline{c}$ and $A^{m,pf}$.

3.4.1 Counterfactual Analysis

The first counterfactual exercise we do is to control the consumption floor $\underline{c}$ and set it equal to zero under Policy I. Next, we shut down the public attitude towards the size of the government. Then we waive the influence of the lower representation of the poor.

When we remove the protection for agents to consume at a survival level, some agents who draw an extremely low income and high medical expenses will suffer

	<u>C</u>	Attitude	Weight
Myopic	77.36%	66.25%	53.09%
vs Baseline (52.8%)	+46.50%	+25.47%	+0.56%
Perfect Foresight	94.63%	78.61%	55.98%
vs Baseline (52.8%)	+79.23%	+48.89%	+6.02%

Table 3.7: The Counterfactual Analysis Results

negative consumption. In the case of these agents, we set them to consume at a very low positive level which is close to zero. Then their utility, which follows a CAAR form, will converge to negative infinity.

Table 3.7 shows that these three factors, $\underline{c}$, Attitude $A^{m,pf}$ and the weight w_y indeed affect the election results. For the **Myopic** agents, when we shut down these factors separately, the fractions of the agents who approve the social health insurance policy rises to 77.36%, 66.25% and 53.09% respectively. Compared to the voting result (52.8%) we used in the benchmark model, the three counterfactual exercises raise the results by +46.50%, +25.47% and +0.56%. Similarly, for the **Perfect Foresight** case, the increases caused by the three factors are +79.23% ($\underline{c}$), +48.89% (A^{pf}) and +6.02% (w_y) and further push the supporters among the population up to 94.63%, 78.61% and 55.98% respectively.

The change in minimum consumption level affects the voting results the most and it is followed by the attitude towards bigger governments. The voting participation rate plays the most insignificant role in influencing the voting outcomes. Compared to the **Myopic** agents, the **Perfectly Foresighted** agents would be affected to a higher degree by all three factors.

There exists a surprisingly high value of 94.63% in the results. If the agents have **Perfect Foresight**, and when we remove the restriction of minimum consumption, almost the whole population prefer to have fully covered social health insurance. We can infer from Figure 3.13 that when we shut down the consumption floor, the expected utility curve no longer changes from convex to concave but remains

Figure 3.13: Comparison of Value Functions under the Two Policies in the Counterfactual Analysis (Control $\underline{c}$)

concave all along. Without protection from the government, the poor households have to face the extreme conditions themselves and gain negative utility converging to negative infinity. Furthermore, no matter which income level the agents belong to, they make their decisions based on expectations. The risk of falling into the miserable state makes Policy I less attractive for almost all agents.

3.4.2 Sensitivity Analysis

In the baseline model, the poverty fraction is used to calibrate the minimum consumption level $\underline{c}$. With a lower (higher) poverty level, the model generates a smaller (larger) minimum consumption constrain $\underline{c}$. We change the poverty fraction p^p to 10% and 20% instead of 14.8% to test the sensitivity. This is followed by another sensitivity analysis about the voting result, which was applied to solve the attitude level $A^{m,pf}$. We change the voting results to 60% and to 40% instead of 52.8% to examine whether our main findings hold.

When p^p drops to 10%, $\underline{c}$ decreases to 0.036140 and the income tax goes down to 3.97% (seen in Table 3.8). But in order to match the voting outcome of 52.8%, attitudes solved by the model for both **Myopic** and **Perfectly Foresighted** agents

Poverty	$\underline{c}$	Income Tax	A^m	A^{pf}
10.0%	0.036140	3.97%	0.213008	0.618295
14.8%	0.113250	4.88%	0.054620	0.309995
20.0%	0.205310	5.99%	-8.9418e-04	0.137045

Table 3.8: Sensitivity Analysis I: Parameters Solved at Different Poverty Rates

$p^p = 10\%$	$\underline{c}$	Attitude	Weight
Myopic	80.01%	75.83%	54.00%
vs Baseline (52.8%)	+51.53%	+43.63%	+2.27%
Perfect Foresight	92.86%	81.24%	56.74%
vs Baseline (52.8%)	+75.86%	+53.87%	+7.46%

Table 3.9: Results with Controlled Key Factors given Poverty Rate 10%

become higher (0.213008 for A^m and 0.618295 for A^{pf}).

In contrast, a higher poverty fraction (20%) leads to an increase both in the consumption floor (to 0.205310) and in the income tax (to 5.99%). Meanwhile, the negative attitude must be lower than the results solved in the benchmark model to maintain the same voting result (52.8%). Especially for the **Myopic** agents, A^m becomes as low as almost zero (-8.9418e-04).

Table 3.9 and Table 3.10 show the effects of those three key factors given poverty rate equal to 10% and 20% respectively. Similar to the counterfactual analysis, we shut down the minimum consumption $\underline{c}$, the negative attitude $A^{m,pf}$ and the participant rate w_y correspondingly for both the **Myopic** and **Perfectly Foresighted** agents.

Although the poverty rates are different, the ranking of the effects among those key factors remain unchanged. Shutting down the consumption restriction under Policy I causes the largest change in the final voting result. The negative attitude towards government size and the compulsory social health insurance also plays an important role, especially for the **Perfectly Foresighted** agents. The participation rates of low income households have the minimal effect. For the **Myopic** agents

$p^p = 20\%$	$\underline{c}$	Attitude	Weight
Myopic	78.67%	52.54%	52.21%
vs Baseline (52.8%)	+49.00%	-0.48%	-1.30%
Perfect Foresight	96.60%	72.56%	53.89%
vs Baseline (52.8%)	+82.96%	+37.41%	+2.07%

Table 3.10: Results with Controlled Key Factors given Poverty Rate 20%

Figure 3.14: Comparison of Value Functions along Wage Income under Poverty Fractions of 20% and 14.8% (Benchmark Model)

case, given $p^p = 20$, there even exists a decrease in the voting result.

From Figure 3.14, we can illustrate reason why there is a negative effect of the poverty rate to the **Myopic** agents. These two panels exhibit the expected utility curves under the poverty fraction of 20% (left panel) and 14.8% (right panel). Compared to the benchmark, a larger proportion of poor agents prefer Policy I with subsidies from the government. Therefore, when the voting weight of all agents increases up to 100%, the voices scaled up the most are from those income groups, as the poor agents are underrepresented in benchmark model. Therefore, the ratio of supporters for Policy I increases and agents who approve the social health insurance policy decreases.

In the baseline model, the average result of the ACA voting survey (52.8%) is used to calibrate the agents' attitudes towards the policy with fully covered social health insurance $A^{m,pf}$ for both the cases of Myopic and Perfect Foresight agents.

Voting Results	A^m	A^{pf}
45.0%	0.086660	0.431935
52.8%	0.031823	0.194727
60.0%	0.026376	0.149101

Table 3.11: Sensitivity Analysis II: Parameters Solved with Different Voting Results

Voting=45%	$\underline{C}$	Attitude	Weight
Myopic	75.37%	66.25%	45.58%
vs 45%	+67.49%	+47.22%	+1.28%
Perfect Foresight	93.81%	78.61%	47.57%
vs 45%	+108.46%	+74.69%	+5.72%

Table 3.12: Results with Controlled Key Factors given the Voting Results 45%

We change the voting results to 60% and to 40% instead of 52.8% to test the sensitivity.

Table 3.11 shows the negative attitude $A^{m,pf}$ solved by the model given different voting results. From the table we observe that when the voting result is lower (higher), the $A^{m,pf}$ for both the **Myopic** and **Perfectly Foresighted** conditions becomes higher (lower). The mechanism is as follows: given the other situations unchanged, when the $A^{m,pf}$ increases, the agents have worse views on government services and power abuse problems. They are in turn less willing to leave a huge budget of the total health costs in the hands of the government. The reverse is also a reasonable phenomena, where agents put more trust in the government to handle a big budget as $A^{m,pf}$ decreases.

The repeated counterfactual analysis shows similar results (Table 3.12 and Table 3.13): the influences of the three factors are ranked as follows: the minimum consumption level, $\underline{C}$; the attitude, $A^{m,pf}$; and the voting participation rate, w_y . In other words, even though the changed voting results give different values of attitude calibrated by the model, the main findings remain the same.

Voting=60%	$\underline{C}$	Attitude	Weight
Myopic	77.23%	66.25%	59.88%
vs 60%	+28.72%	+10.41%	-0.19%
Perfect Foresight	95.89%	78.61%	62.73%
vs 60%	+59.82%	+31.02%	+4.55%

Table 3.13: Results with Controlled Key Factors given the Voting Results 60%

3.5 Conclusion

In this paper, we build an overlapping generation model to examine the reason why developed countries with similar background have implemented different social health insurance systems. Based on findings reported in the literature, we propose two hypotheses to explain this phenomenon: i) the voice of the poor is less important than the rich, because poor voters are less willing to participate in the elections.; ii) the distinct attitudes towards the size of the government and its power, which can be augmented with a compulsory social health insurance system, affect the voting outcomes.

Agents, who face income shocks and medical cost shocks simultaneously, need to vote for one of the two policies: Policy I without Social Health Insurance (SHI) but with the subsidy for the poor and Policy II with fully covered SHI. By comparing their current utility or their expected life time utility, households will choose one policy.

We find that under the Policy I, the derivative of the changes of expected utility with respect to income is not monotonic. This means that both the poorest and the richest do not favour the social health insurance system. It was an unexpected result at first: since under Policy II, the insurance premium (tax) is a proportion of income but the protection (health-related services) is the same for everyone, those agents who have low income should prefer this policy. However, in our model, there exist the minimum consumption level $\underline{c}$. In the reality, Supplemental Security Income (SSI) is a United States government means-tested welfare program that

provides cash assistance and health care coverage (i.e., Medicaid) to people with low-income and limited assets who are either aged 65 or older, blind, or disabled (children included). It is the minimum consumption which doesn't exist in Germany social system. German social security system includes Unemployment Insurance, Health Insurance, Old age pension insurance, Invalidity insurance, Child support, and Social care. With this subsidy, the optimal choice of the poorest has been changed.

With the calibrated parameters, we solve the benchmark and find that the public's attitude towards the size of the government and the lower representation of the poor motivate the election results. The changes in the minimum consumption level under Policy I affect the voting results most, followed by the attitude. Voting Participant rate plays the most insignificant role in the voting outcome.

The sensitivity analysis about the poverty rate and the voting result shows that our main finding are robust to the input parameters.

From the results, we can tell that in order to propel the social health insurance reform, governments should encourage citizens who have relatively low income to participant the election. Meanwhile, governments could also monitor the public attitude and try to change their image among population. Moreover, when governments advance the reform of the social healthcare system, they should also take the subsidy system into account.

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Appendix A

Healthcare System in the U.S. and Europe

A.1 Development History of the Social Healthcare System in Europe

The roots of the modern SHI can be traced back to the history of German people in the late Middle Ages when coverage of health-related costs started becoming connected to the occupation of the subjects covered (([Abel-Smith, 1988](#))). It first appeared as voluntary worker cooperatives, then became mutual assistance associations under the support of certain craft guild ([Veraghtert and Widdershoven, 2002](#)). The modern phase of SHI systems was launched by a series of legislative acts promulgated by Bismarck in the 1880s which were a reaction to what Bismarck saw as the growing influence of Marxist ideas on labor unions. Moreover, the creation of a SHI supported Bismarck's idea of a powerful and productive German state. Nevertheless, in spite of the strong influence the idea of a powerful German state played in Bismarck's conceptualization of the German SHI system, the final outcome retained the traditional part of health funds based on occupation, but the state would play an active role in supervising and supporting the system (([Saltman et al., 2004](#))).

The SHI that emerged as the result of Bismarck’s initiatives not only laid the foundations of the SHI in Germany, but it also served as a model for most of western European states.

Even as early as the late 19th century, just few years after Bismarck’s social legislation, a growing number of states started following the German example. The first among them was Austria (part of the Austrian-Hungarian Empire) in 1887-1888 ([Hofmarcher et al., 2001](#)), while Denmark promulgated a system that would subsidize existing voluntary funds ([Vallgård, 2001](#)). Similar legislative acts were introduced in Belgium in 1894 ([Veraghtert and Widdershoven, 2002](#)). Following its unique tradition of popular sovereignty, in 1899, Switzerland held a referendum on whether the country should adopt a SHI system modelled after the German one. Although the negative response prevailed in the referendum, in 1911, the Swiss government passed legislation that allowed for state subsidies to existing voluntary funds ([Minder et al., 2000](#)). This trend continued with the French insurance law of 1920, whose implementation had to wait for another decade, while the Netherlands created its own SHI system during the WWII German occupation, in 1941 ([Sandier et al., 2004](#)). The decades following WWII, a significant number of states in western Europe shifted from a SHI system to one based fully on taxation ([Den Exter and den Exter, 2002](#)).

A.2 Healthcare Reform Debate in the United States

The history of welfare state in general and of healthcare in the United States (U.S.) followed a different path due to the country’s strong tradition of federalism, suspicion of strong central governments, importance of civil liberties and individual rights ([Steinmo and Watts, 1995](#)). Therefore, since the founding of their country, a large part of American society has seen efforts that would increase the power of central government with suspicion and would consider such policies as going against fundamental American values. Attempts towards reforming the health care system

in the U.S. would rarely result in substantial policy changes in sharp contrast with the wave of such reforms occurring in western Europe in the first decades of the 20th century ([Rushefsky and Patel, 2006](#))

In the decades that followed the Civil War and Reconstruction, the so-called Gilded Age, American presidents adopted an extreme laissez-faire and pro-business attitude and took few actions to protect labor rights ([Gordon and SABIN, 2005](#)). Nevertheless, in the last decade of the 19th century and at the beginning of the 20th century, in the Progressive Era, presidents like Theodore Roosevelt, William H. Taft and Woodrow Wilson assumed a more interventionist attitude and introduced a number of reforms that would address a growing number of social problems in the American society ([Patel, 1995](#)). The decade of the "roaring twenties" show a slowing down of the pace of social reforms.

During the Great Depression, a growing number of people found themselves in a position where they could not afford the cost of medical services. In contrast to the non-interventionist attitude of his predecessors, President Franklin D. Roosevelt was inspired by the Keynesian theory of economics and introduced a number of reforms, as part of his New Deal, that would result in a much great role of the government in the American economy ([Patel, 1995](#)). As part of the New Deal policies, Roosevelt fought to get publicly funded health care programs included in the suggested Social Security legislation ([Gordon and SABIN, 2005](#)). However, as with other aspects of the New Deal, this initiative was met with resistance by the American Medical Association who saw it as a form of "compulsory health insurance" ([Steinmo and Watts, 1995](#)). Eventually, after a long struggle the parts of the bill related to health care provisions were removed in 1935 ([Eyestone, 1978](#)). Wary of similar backlashes, in the 1930s and the 1940s, the Congress made attempts towards passing legislation to support health care provisions without angering the official medical associations and other parts of American society ([Gordon and SABIN, 2005](#)). During WWII, wage and price controls were introduced by the federal government in order to fight inflationary pressures. The U.S.'s participation in WWII meant that the government

was eager to attract employees so as to keep productivity at high levels. In order to sidestep the wage controls, schemes were introduced where employers would offer health insurance as a complement to the wages of the employees (Patel, 1995). After WWII, the attempts by President Harry Truman to introduce universal health care policies in the context of his Fair Deal met fierce opposition and were eventually frustrated (Gordon and SABIN, 2005).

The next milestone in the history of health care policies in the U.S. took place in the era of the Civil Rights Movement of the 1960s. Growing concerns about the elderly who needed support created a more favorable environment for health care reforms (Eyestone, 1978). In the context of President Lyndon B. Johnson's "Great Society" programs aiming at fighting poverty and inequality, initiatives were launched to provide health care services to more U.S. citizens (Gordon and SABIN, 2005). Such initiatives resulted in programs such as Medicare, Medicaid and the Old Americans Act in spite of opposition who argued that such programs went against fundamental American values and that in essence they would reduce the quality of health services (Oliver and Paul-Shaheen, 1997).

The administrations that followed Johnson, in the 1970s, continued to address this contentious issue. In 1971, Ted Kennedy who had been appointed as Head of Subcommittee on Health and Scientific Research of the Senate Labor and Public Welfare Committee, put forward a proposal about a universal national health insurance (the Kennedy-Griffiths bill) (Patel, 1995). Later proposals by Kennedy and Mills were met with negative reactions by workers and the elderly because they postulated that the insured would be burdened with a significant portion of the cost of the health insurance (Eyestone, 1978). In Jimmy Carter's administration consideration about the federal budget led the U.S. government to suggest modification to the bill introduced by Kennedy so as to include a larger role of the private sector and limit the costs for the government. Eventually, in 1979, a limited health insurance reform was proposed by the Carter administration at a time where the U.S. faced an economic crisis (Navarro, 1994).

More recent administrations made attempts to tackle the same issue, as were the cases of Bill Clinton and George W. Bush's presidencies ([Gordon and SABIN, 2005](#)). Before the presidential election of 2008, poll results showed that supporters of the Democratic candidate Barack Obama ranked the issue of health care reform as second, whereas supporters of the Republican candidate John McCain ranked it as fourth in importance. Such results pointed to a partisan divide where the voters of the Democratic Party believed that the government should assume a more active role in covering the cost of health care ([Skocpol and Williamson, 2010](#)). In the first year of Obama's presidency, the Affordable Health Care for America Act was voted by the House of Representatives receiving 220 votes (to 215 who voted against) and was forwarded to the Senate for passage.