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The role of medical expenses in the saving decision of elderly: a life cycle model

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The role of medical expenses in the saving decision of elderly: a life cycle model

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Abstract

In this paper, 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 expenses 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.

Keywords: Income Inequality; Social Mobility; Price-to-rent ratio.

JEL Classification:

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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).

[1]Source: OECD Health Statistics

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 healthcare 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 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 lays out the theoretical framework. Section 3 shows both the benchmark's simulation results and the counterfactual results. Section 4 concludes.

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.

2.1 The Environment

Time is discrete and infinite indexed by $n = 0, 1....$ 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:

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

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:

$$y_{t+1} = (1 - \rho) * \mu_y + \rho * y_t + e_t \tag{2}$$

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:

$$a_{t+1} = (1-\tau)y_t + (1+r)a_t - m_t - c_t + b_t \tag{3}$$

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:

$$b = max \quad \{0, \underline{c} + m_t - [(1-\tau) * y_t + (1+r) * a_t]\} \tag{4}$$

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:

$$\int b^i \, \mathrm{d}i = \int \tau * y^i \, \mathrm{d}i \tag{5}$$

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:

$$\begin{aligned} V(a,m,y,t) &= \max_{c,a'} u(c) + \beta \mathbb{E}_{(y',m')}[V(a',y',m',t+1)|(a,y,m)] \\ s.t. \qquad c + a' &\leq (1-\tau)y + (1+r)a - m + b \qquad (6) \\ a' &\geq 0 \qquad (7) \end{aligned}$$

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 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 $(\psi_1, \psi_2, ..., \psi_N)$ 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:

$$\sum_t \mu_t \int_X a'(x,t) d\psi_t = \bar{s} \tag{8}$$

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

$$\psi_{t+1}(B) = \int_X T(x,t,B) d\psi_t, \forall B \in B(X) \tag{9}$$

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.

2.3 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 $\bar{\mathrm{s}}$.

In the counterfactual analysis, we successively shut down the heterogeneity of labor income (all agents have the same income $\overline{\mathrm{y}}$), shut down the heterogeneity of medical expenses (all agents have the same income $\overline{\mathrm{m}}$), and remove the medical costs for all agents ($m = 0$ for whole population). We hold the aggregate saving $\bar{\mathrm{s}}$, 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.

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.

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 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

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 1: Parameters

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.

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 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,

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: Share of the Agents with Non Medical Costs

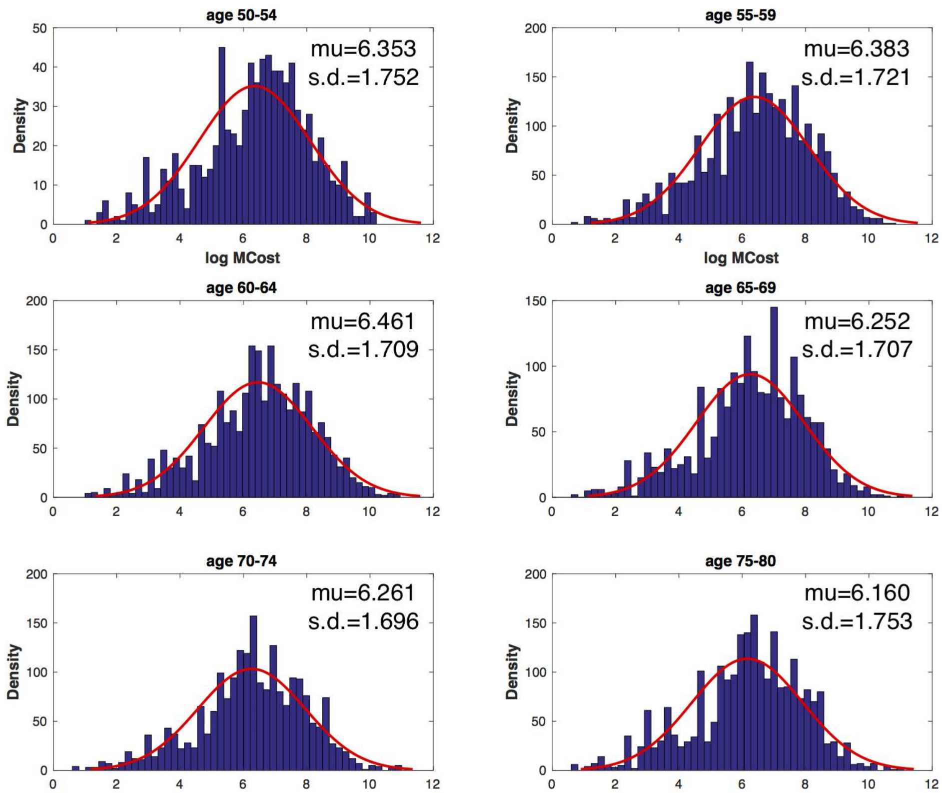

Figure 1: Medical Expenses Distribution in Age Groups

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 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 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.

3.2 The Wealth Distribution over the Life Cycle

Figure 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 ($m = \overline{m}$), which controls the variance and let the medical costs equal to the mean costs for their age; and the counterfactual exercise III ($y = \overline{y}$) 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 we can conclude that the average saving curves show an inverse-

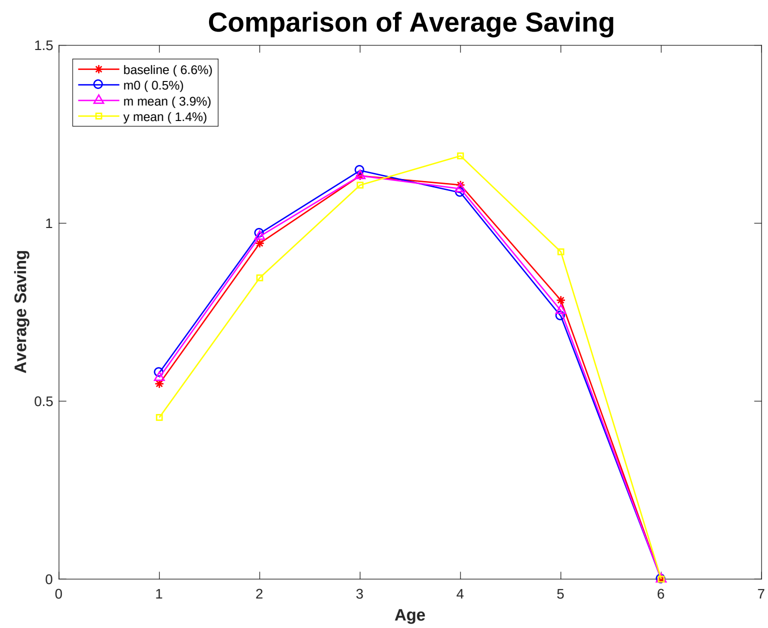

Figure 2: Average Saving in Benchmark Model and Counterfactual Exercises

U shape in all cases of the elderly. In the early periods, agents prefer saving 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 tow 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, the magnitudes of average saving are similar in the baseline model, in the counterfactual exercise I ($m = 0$) and in the counterfactual exercise II ($m = \overline{m}$). Table 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

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

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 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 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),

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

only around ten percent of the agents are qualified to take the 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 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 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 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 $m = \overline{m}$ 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., $y = \overline{y}$ model), the average saving level is slightly lower in the first 3 periods (Figure 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 5). This means that, the aggregate saving ($\overline{s}$) 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 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 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 ($m = \overline{m}$) 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 ($y = \overline{m}$) is the highest and peaks at 65%. Since the interest rate in this case is unrealistically high (28.43%), the motive is strong enough to push the ratio up to over 50%.

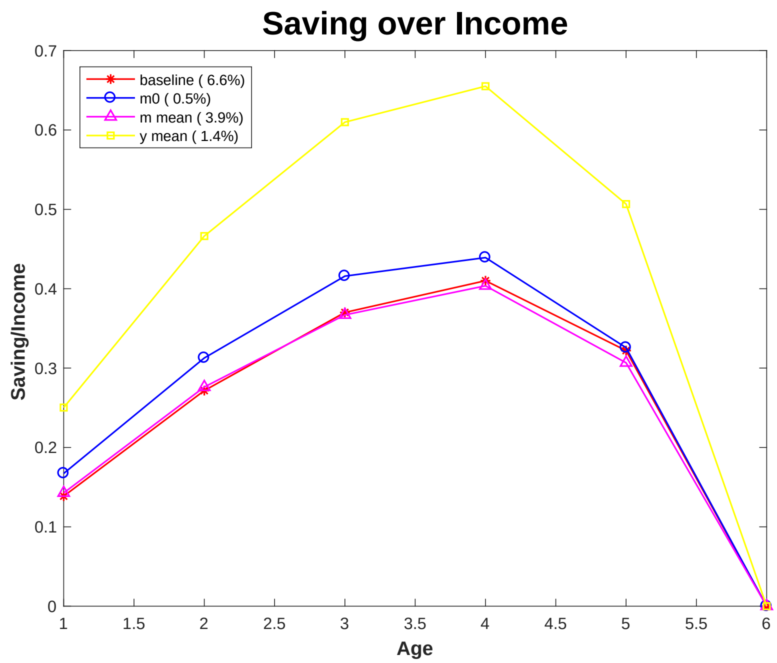

Figure 3: Average Saving over Income in Benchmark Model and Counterfactual Exercises

Saving, in our model, is the only asset. Therefore, based on the previous analysis, we believe the model with $y = \overline{y}$ (counterfactual exercise III) has the lowest inequality level. Figure 4, the Loreze curve over the whole population, confirms that. The curve generated by the $y = \overline{y}$ 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 $m = \overline{m}$ 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 $m = \overline{m}$ 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 5 we can see that the yellow line ($y = \overline{y}$ 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 three cases, wealth

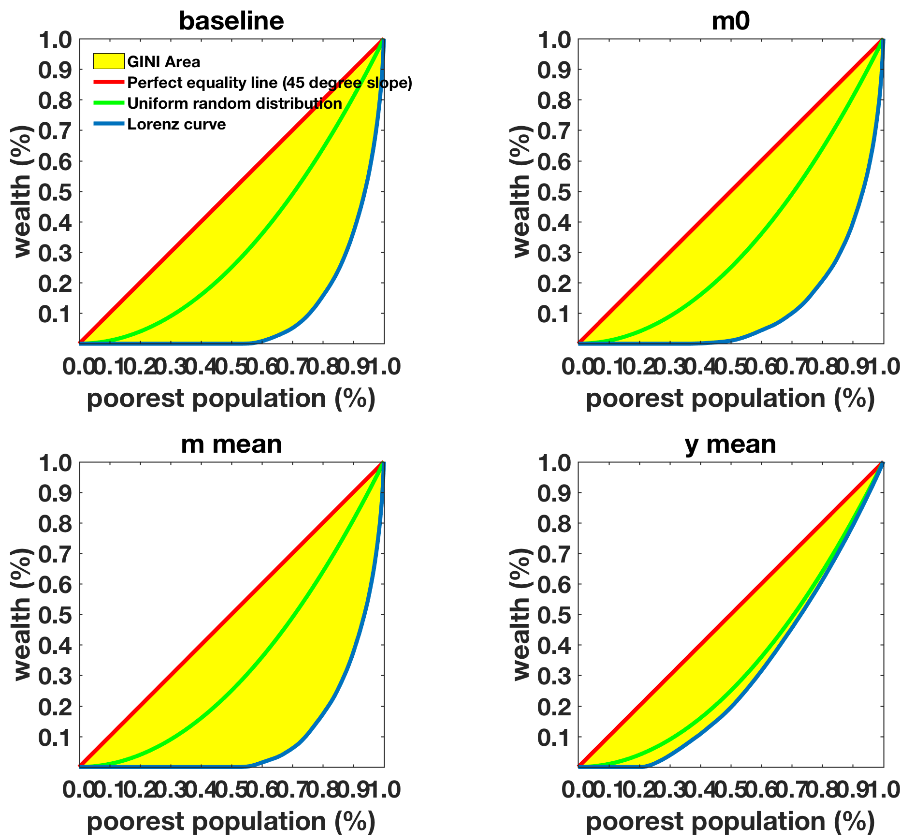

Figure 4: Inequality of Wealth: Lorenz Curve

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.

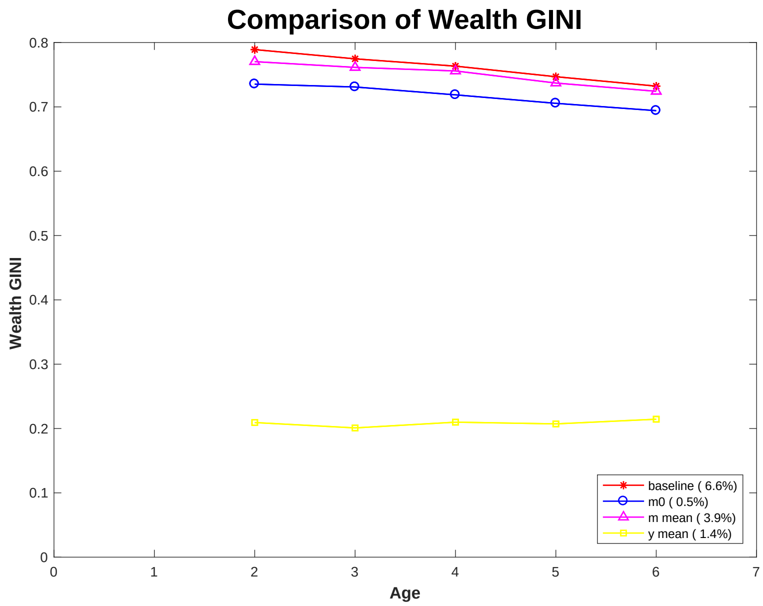

Figure 5: Inequality of Wealth: Gini Coefficient along Age Increase

3.3 The Consumption Distribution over the Life Cycle

Figure 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 ($m = \overline{m}$), which controls the variance and let the medical costs for all agents equal to the mean costs for their age, the counterfactual exercise III ($y = \overline{y}$) 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 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), 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

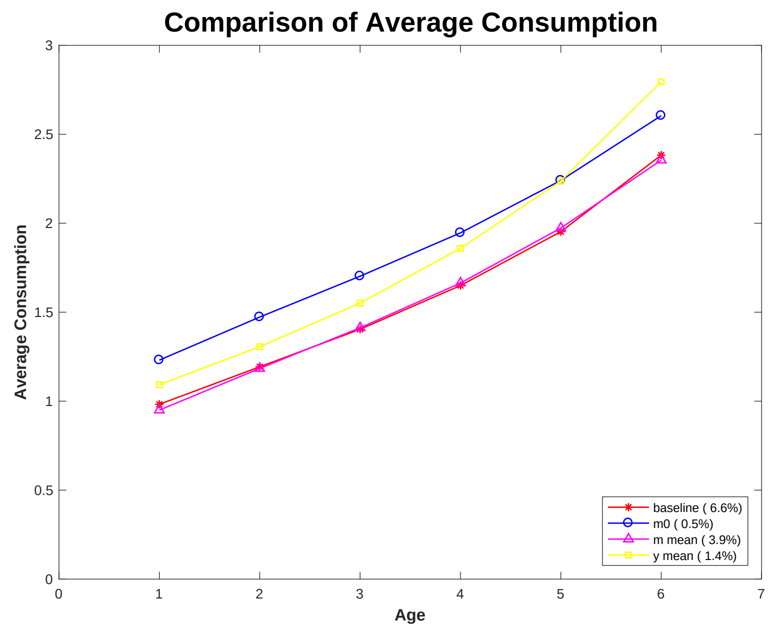

Figure 6: Average Consumption in the Benchmark Model and the Counterfactual Exercises

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 and 3.

As to the comparison of average consumption among the four models (Figure 6), there is very little difference between the baseline and the $m = \overline{m}$ model (red star line and magnate triangle line). Compared with these two, the counterfactual exercise I ($m = 0$) and counterfactual exercise III ($y = \overline{y}$) 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). Therefore, the budget, used to be spent on medical services, mainly transfers to consumption rather than saving. Compared with the $m = 0$ model, the $y = \overline{y}$ 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 ($y = \overline{y}$). 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.

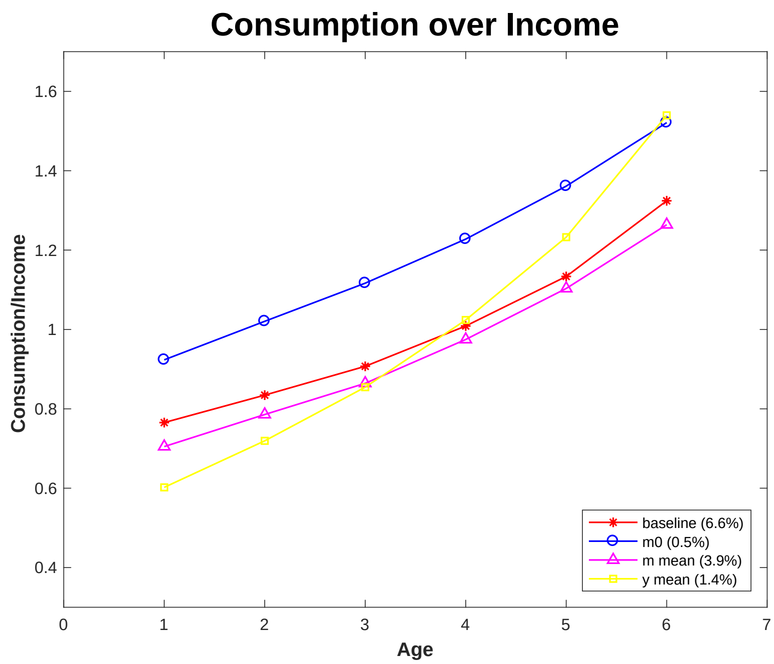

Figure 7: Average Consumption over Income

The Figure 7 illustrates average consumption over income for the baseline 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 ($y = \overline{y}$ model) starts at a very low level and eventually reaches the peak. However, compared with the benchmark model (red star line), the $m = \overline{m}$ 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 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 $m = \overline{m}$ model is very similar to the benchmark. When medical costs are taken out from the

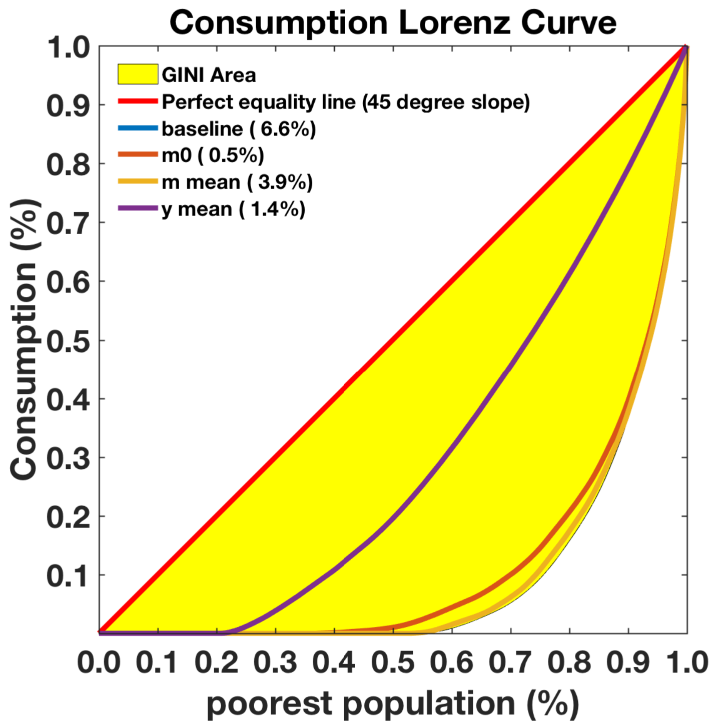

Figure 8: Inequality of Consumption: Lorenz Curve (the Whole Population)

model ($m = 0$), the Gini coefficient goes down a little bit. Similar to the Lorenz Curve of saving, the counterfactual exercise III ($y = \overline{y}$) generates the lowest consumption inequality.

When we examine the consumption inequality within each age group in detail (Figure 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

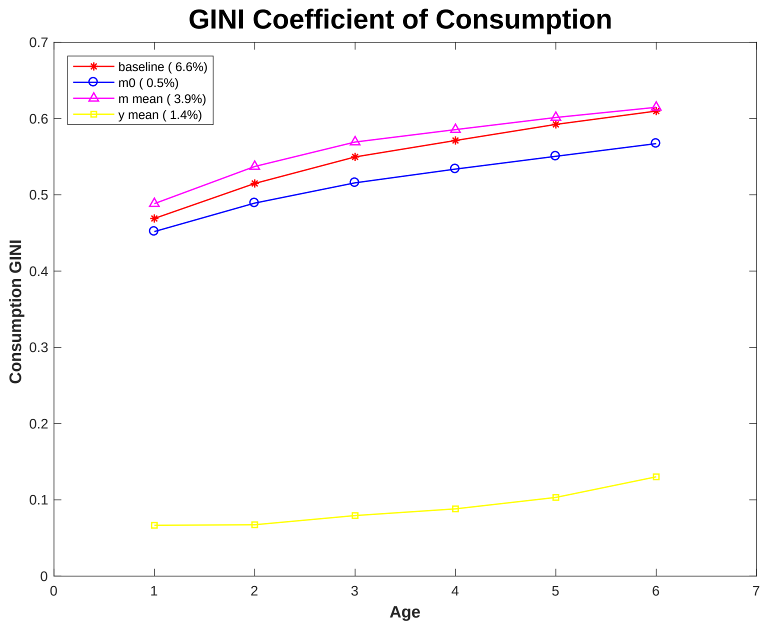

Figure 9: Inequality of Consumption: Gini Coefficient

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 $m = \overline{m}$ model has the highest Gini coefficient in consumption. From Table 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 $m = \overline{m}$ 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 $m = \overline{m}$ model and in the model $y = \overline{y}$. The results can also be confirmed by the 90/10 ratio.

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 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

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

Table 6: Welfare Comparison

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 ($y = \overline{y}$), welfare is the highest and it increases at a faster speed.

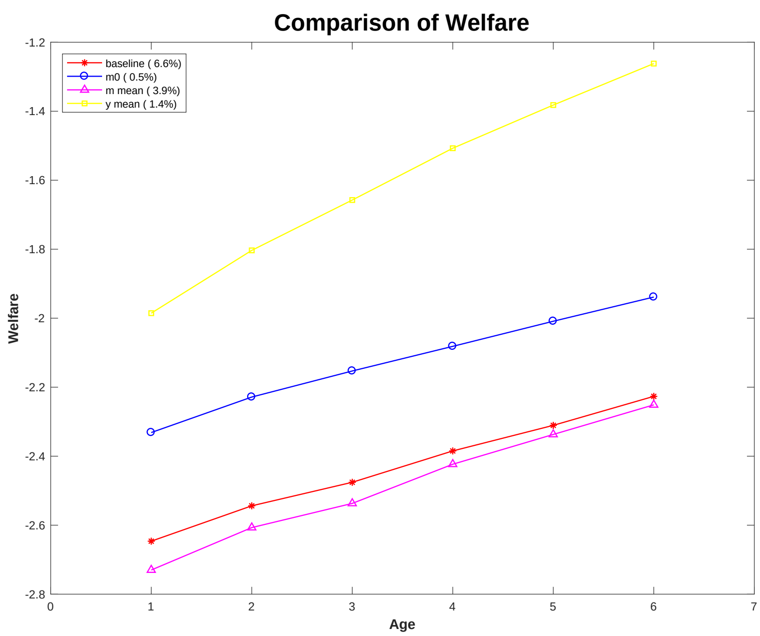

Figure 10: Welfare

We can see from Table 6 that when we waive the medical costs completely ($m = 0$) or remove the income volatility ($y = \overline{m}$), 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.

3.5 Robustness Check

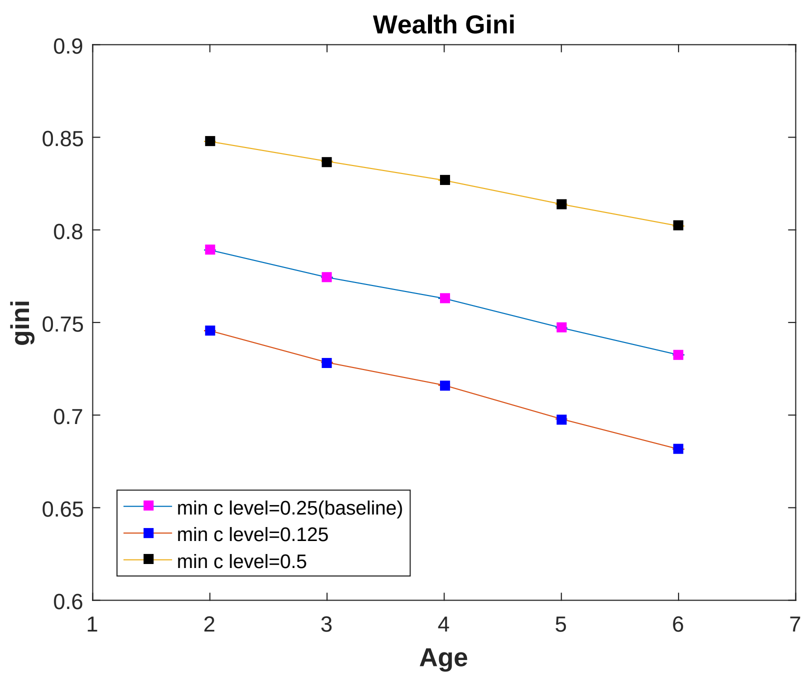

Figure 11: Robustness Check: Wealth Inequality

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 11) and consumption Gini (Figure 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 hold by even fewer proportions of people. Inequality also rises to a higher level.

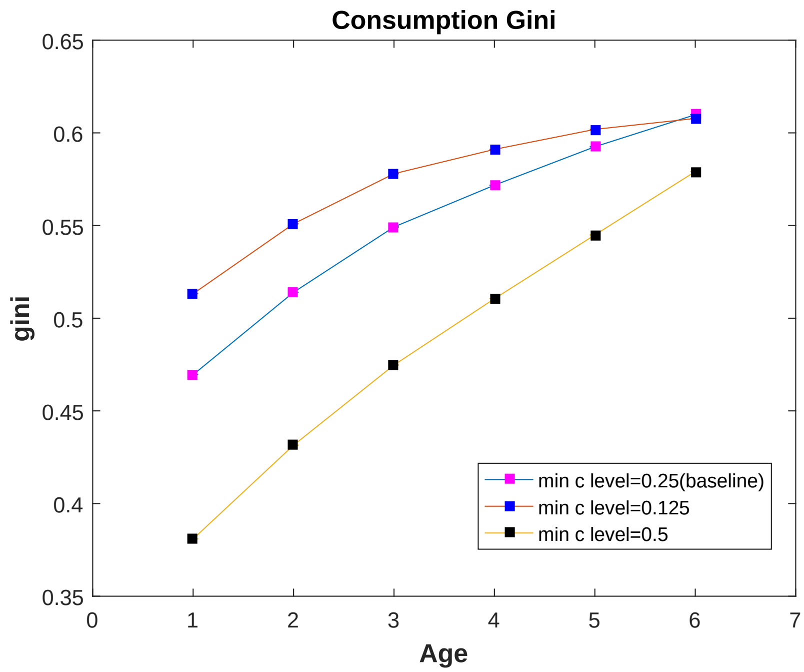

Figure 12: Robustness Check: Consumption Inequality

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, 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.

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 $\overline{\mathrm{s}}$.

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 $\overline{\mathrm{y}}$), the heterogeneity of medical expenses (all agents have the same income $\overline{\mathrm{m}}$), 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., $y = \overline{y}$ 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%).

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Appendix

A Appendix

A.1 Consumption Inequality: 90/10 Ratio

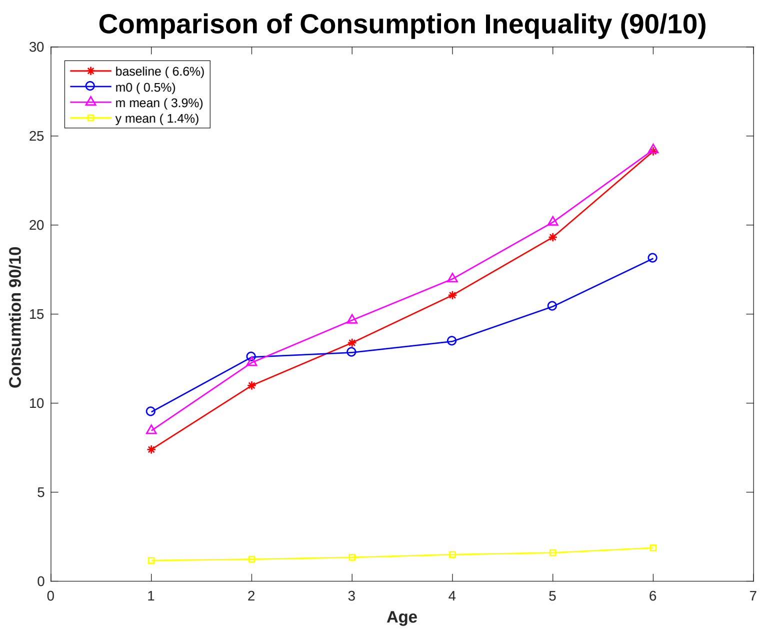

Figure 13: Inequality of Consumption: Gini Coefficient

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