Housing, Health and Life Expectancy Inequality in China*

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Abstract

We document large inequality in life expectancy at age sixty across cities and sectors of employment in China. The life expectancy is higher in larger cities and among public sector retirees, with a gap exceeding ten years between rural residents and tier-one city public sector retirees. To understand the inequality, we develop a dynamic optimization model of health investment and housing choice for retirees. We show that the inequality is largely attributable to the heterogeneity in income, in the coverage of publicly funded health insurance, and in the housing investment market. Counterfactual experiments show that equalizing publicly funded medical coverage will significantly reduce the inequality in life expectancy. A large decline in house prices will decrease life expectancy more in tier-two and tier-three cities.

Keywords: health production, medical insurance coverage, housing costs, life expectancy inequality

JEL code: E20, I14, R21

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1 Introduction

It is well documented that individuals with better socioeconomic conditions can expect to live longer, and that there is a causal effect from economic conditions to health. Rudolf Virchow's famous statement "Medicine is a social science, and politics nothing but medicine at a larger scale," still resonates today. The importance of understanding how socioeconomic conditions shape the inequality in mortality and life expectancy is self-evident. However, the quantitative contribution of various socioeconomic factors, such as wealth and medical insurance coverage, is still not clear.

This paper studies inequality in life expectancy across regions and sectors of pre-retirement employment (i.e., public vs. private sectors) in China, focusing on individuals aged 60 and older. Based on the China Health and Retirement Longitudinal Study (CHARLS), we show that life expectancy increases with city size, with a gap of about 4.4 years between residents in tier-one and tier-three cities.[1] In fact, the largest city in China, Shanghai, also boasts the highest life expectancy, both at birth and at sixty. The life expectancy of city residents is about 8.3 years higher than that of rural residents on average. In addition, the gap in life expectancy at age sixty exceeds 4.7 years between retirees from the public sector and the private sector.[2] The gap between rural residents and tier-one city public sector retirees reaches a staggering number of 11.6 years.

The inequality in China is unique in two respects. First, the fact that larger cities in China have higher life expectancy stands in contrast to findings in other middle-income countries. For instance, based on a sample of 363 cities of Latin America, Bilal et al. (2021) find that life expectancy is shorter for men living in large cities, although they find no association for women. Second, rigid barriers exist in China that limit migration across regions and hinder the mobility between the public and private sectors, therefore the large cross-region and between-sector inequality warrants a careful analysis, especially in the presence of the huge rise in life expectancy in China in recent years owing to the health insurance reforms (Gruber et al., 2023).[3] As we will show, public sector retirees enjoy a more generous publicly funded health care system, which contributes significantly to their higher life expectancy.

We focus on seven groups of individuals to capture the large inequality in China, corresponding to retirees from two sectors (private vs. public) in tier-one, tier-two, tier-three cities, as well as rural residents.[4] To understand the observed inequality, We construct a dynamic op-

[1] The lists of tier-one, tier-two, and tier-three cities are reported in Table B.1.

[2] The public sector includes governments, the military, schools, universities, and state-owned enterprises.

[3] Research based on the U.S. data find a strong link between life expectancy and ethnicity. While China is highly homogeneous in ethnicity, its inequality in life expectancy is still large, even after controlling for income.

[4] Rural residents are not further divided by the sector of employment because the majority of them are in the private sector.

timization model with endogenous health investment, paying particular attention to the roles played by the unequal medical insurance coverage and the distinctively divergent house price growth rates across cities. While the health care system in China features a large disparity as a legacy from the pre-reform era, the main theme of medical care reform has always been the equalization of coverage. This motivates us to estimate the out-of-pocket medical expenses as a fraction of total medical expenses from the data, and use the structural model to analyze the potential effects of further medical reforms on life expectancy inequality.

In the structural model, we explicitly include housing assets to capture the wealth effect of housing on health investment and life expectancy. Housing wealth accounts for 88.4% of the total wealth for old-age homeowners in China, and is the largest contributor to wealth inequality across different tiers of cities due to the highly heterogeneous growth rate of house prices. Larger-city retirees are wealthier on average, not only because of their higher income, both pre- and post-retirement, but also because of the higher growth rate of house prices which generates the housing wealth effect. Our model includes the endogenous allocation of wealth between housing and bonds over the life of retirees. Housing transactions are costly, which endogenously generates home ownership rates that evolve with age and differ across regions and sectors of employment. Our simulation results reveal a significant relationship between home ownership rates and mortality rates, as homeowners utilize their housing assets to cover health expenses.

In addition to medical insurance coverage and house price growth, we also consider the heterogeneous post-retirement incomes and housing costs in terms of explicit or implicit rents. This is inspired by the spatial equilibrium literature which postulates that larger cities offer higher incomes to compensate for the higher housing costs, which leads to equalized utility across regions in the absence of migration costs.[5] We show that retirees in larger cities in China live longer, which implies that significant migration barriers between cities still exist in China.

In the structural estimation, we estimate the set of parameters in the dynamic optimization model via the simulated method of moments. One of the key parameters is the elasticity of substitution between health and consumption. If health and consumption are substitutes, then large city residents substitute the expensive housing consumption for the relatively cheap health investment, thus higher housing costs lead to more health investment. Furthermore, largeer city residents receive higher incomes as compensation for the higher housing costs, which financially enables them to invest even more in health. We obtain a point estimate of 0.475 for the elasticity of substitution between health and consumption. Thus, health and consumption are complements in the utility function, implying that high housing costs in large cities suppress health investment. Another important parameter is the curvature of the health production

[5]See Rosen (1979) and Roback (1982) for early contributions of the spatial equilibrium literature.

function. We find a curvature of 0.64, implying that wealthy individuals cannot have much better health because of the diminishing marginal product of health investment.

Our model closely matches the between-group heterogeneity observed in the data regarding mortality rates and home ownership rates. Retirees from the public sector have significantly lower mortality rates and higher life expectancy relative to private sector retirees, and rural old-age residents have a higher mortality rate than urban retirees. The home ownership rate is the highest among rural residents and the lowest among retirees in tier-one cities. Relative to tier-three cities, tier-two cities have a slightly higher home ownership rate.

In the factor decomposition, we study the relative importance of each socioeconomic factor in driving the inequality in life expectancy based on the estimated model. Specifically, we impose the socioeconomic factors of the rural resident group on the remaining six groups, only allowing one factor to be heterogeneous across groups at a time. Simulation results from these experiments show how the heterogeneity in one socioeconomic factor leads to inequality in life expectancy, controlling for all the other factors in our model. We find that heterogeneous income is the most important driver of the inequality in life expectancy. The heterogeneity in income alone can explain about 62.4% of the rural-urban gap in life expectancy. Heterogeneity in medical insurance coverage is also a significant drive as it alone explains 57.7% of the gap in life expectancy between the public and the private sectors. Cross regional heterogeneity in the house price growth rate is also important, it generates a gap in life expectancy of 7 years between tier-three and tier-one cities, and explains 44% of the rural-urban gap in life expectancy. Heterogeneity in the wealth level at retirement explains about 26% of the rural-urban gap in life expectancy.

We conduct three counterfactual experiments to study the implications of our model. The first experiment studies the effects of a house price decline. The results show that a 30% decline in house price reduces health investment both contemporaneously and in the long run, and it slightly lowers life expectancy and increases the inequality. It is noteworthy that this experiment is relevant to the ongoing policy initiative to implement property tax in China. While a comprehensive nationwide property tax is not currently in place, the Chinese government has been experimenting with pilot programs in selected cities. The implementation of property tax is likely to cause a large decline in house prices in China (Zhu and Dale-Johnson, 2020), which will have heterogeneous impacts on life expectancy in China, as indicated by our experiment.

The second and third experiments study the impacts of better or more equalized coverage of publicly funded health insurance. This is motivated by the inequality plaguing China's health care system, which is under much pressure to be further reformed.[6] Our experiments show that

[6]In 2023, many Chinese localities, including Hubei, Sichuan, and Heilongjiang, are implementing health insurance reform for urban employees and retirees, drawing widespread attention (https://www.hsph.harvard.edu/china-health-partnership/2023/02/17/china-health-insurance-protests/). After the reform, contri-

a lower out-of-pocket cost encourages more health investment, which leads to lower mortality rates and higher life expectancy in the long run, with the most significant gain received by rural residents and private sector retirees. When we equalize the health insurance coverage by imposing the lowest out-of-pocket expenditures of retirees from the public sector in tier-one cities on other groups of retirees, the life expectancy is nearly equalized among urban retirees and the rural-urban gap in life expectancy is significantly decreased.

The rest of this article proceeds as follows. Section 2 provides background information on the evolution of the health care system and the housing market in China, and it offers a discussion of the related literature. Section 3 describes some key facts based on the China Health and Retirement Longitudinal Study. In Section 4, we present the life-cycle model of health investment and portfolio choice in retirement. Section 5 discusses exogenous model inputs for estimation, while in Section 6, we estimate the model via the simulated method of moments based on a set of moments on heterogeneous mortality rates and home ownership rates. Section 7 uses the estimated model to evaluate the contributing factors of the inequality in life expectancy. Section 8 uses the estimated model to conduct counterfactual studies. Finally, Section 9 provides a summary of the research.

2 Background and Literature

Given the importance of the health care system and housing market in our study, we present the health care system in modern China and offer a discussion of the housing market in this section. We also present a review of related studies towards the end of the section.

2.1 Health Care in China

The health care system in China has gone through a series of reforms in the last decades in order to reduce the inequality of health care, some of which are still ongoing. Because many reform details are available in Chinese texts only, we delve into the original materials and summarize them in Appendix A, particularly in Figure A.1 which shows graphically the evolution of the health care system since the end of 1970s.

Large inequality in health care coverage still exists after these reforms. As detailed in Appendix A, the current health care system in China, for workers and retirees alike, includes two major types: the URRBMI (Urban and Rural Resident Basic Medical Insurance) and the UEBMI (Urban Employee Basic Medical Insurance). The two types offer drastically different coverage. Even within the same type, the coverage differs significantly across regions. This is

butions by employers into employees' personal accounts will be directly paid to the pooled fund to support the reimbursement of ordinary outpatient medical bills, creating a more equitable system.

Table 1: Medical Insurance Coverage in 2020

		Beijing URRBMI	Beijing UEBMI	Suzhou UEBMI
Outpatient care	Deductible (yuan)	100-500	1300	400
	Coverage ratio	50-55%	70-90%	70-90%
	Annual coverage cap (yuan)	4,500	20,000	4,800
Hospitalization	Deductible (yuan)	300-1,300	650-1,300	200-600
	Coverage ratio	75-80%	95.5-99.1%	95%
	Annual coverage cap (yuan)	250,000	500,000	350,000

Notes: This table reports the coverage of publicly funded medical insurance. The coverage for Beijing citizens is available from the Beijing Municipal Medical Insurance Bureau, and the coverage for Suzhou citizens is retrieved from the website of the Suzhou municipal government (https://www.suzhou.gov.cn/szsrmzf/zfwj/202003/9abcb56e82aa44ab9302e402ab0ee20f.shtml). The UEBMI mostly covers retirees from the public sector, and the URRBMI mostly covers farmers, migrant workers, and those retired from the private sector.

because the insurance funds are mostly pooled at the prefecture level, and prefectural governments, who are responsible for covering the deficits of pooled insurance funds, are incentivized to provide lower coverage if the prefectures are economically less developed.

The primary forms of inequality are different deductibles, coverage ratios, and annual coverage caps. The coverage ratio, defined as the fraction of medical expense paid out of the insurance funds after deductibles and before reaching the cap, is typically higher in the UEBMI than in the URRBMI, and it is usually higher in more economically advanced regions. The annual coverage limits of outpatient care and hospitalization, set by regional governments, also tend to be higher in the UEBMI and in more economically developed regions.[7]

As an illustration, Table 1 reports the deductibles, coverage ratios, and annual coverage limits in 2020 for three different groups of retirees enrolled in Beijing URRBMI, Beijing UEBMI and, Suzhou UEBMI, respectively. The coverage is more generous in Beijing than in Suzhou. Within Beijing, the coverage of the UEBMI is more generous than the URRBMI.

Another form of health care inequality is the "medicines in the list". The Ministry of Human Resources and Social Security publishes two lists of medicines that should be covered by publicly funded medical insurance: the category-A list and the category-B list. While the category-A list should be strictly implemented in each region, the category-B list can be adjusted at the discretion of the regional governments in accordance with the level of economic development. As a result, more medicines are included in the category-B list in regions where governments face smaller deficits. Health infrastructure, which differs tremendously across regions, also leads to health care inequality.

The above-mentioned factors are ultimately translated into health care inequality across

[7]By contrast, the Affordable Care Act in the US bans any annual and lifetime coverage caps on essential benefits.

city tiers and sectors of employment. Larger cities are able to support more generous health care packages because governments face laxer budget constraints. The public sector employees and retirees enjoy more generous coverage because they are enrollees of the UEBMI, and a large fraction of government employees and retirees receive additional subsidies; while a large fraction of the private sector employees and retirees are enrollees of the less generous URRBMI.

We capture the large inequality in health care coverage by calculating out-of-pocket medical expenditure as a share of the total medical expenditures, i.e., the OOP share, for individuals in different city tiers and sectors, employing the detailed information reported in CHARLS. As we will show in Table 7, the OOP share exhibits large inequality across cities and sectors.

2.2 Housing Market in China

In our analysis of life expectancy inequality, we explicitly consider housing investment. Housing assets are vitally important for individuals in China. Table 2 shows the levels and compositions of wealth for each of the seven groups we study, where "housing" is the average housing wealth of homeowners within the group. The average total wealth differs considerably across regions, with the wealth of city retirees an order of magnitude higher than those of rural residents; while the difference between the private and public sectors is relatively small. As shown in the table, the average non-housing wealth accounts for less than 10% of the average wealth in each group. It is clear that housing is the largest contributor to wealth inequality across regions in China.

Table 2: Wealth Composition of Retirees in China (10,000 Yuan)

Wealth	*Total*	*Non-housing*	*Housing* (*homeowners*)
Rural	7.54	0.59	6.95
Tier 1, private sector	239.01	5.21	252.92
Tier 2, private sector	96.48	4.33	84.20
Tier 3, private sector	63.74	1.11	51.75
Tier 1, public sector	341.13	2.87	280.96
Tier 2, public sector	112.29	3.17	105.98
Tier 3, public sector	63.95	2.11	52.80

Notes: Authors' calculation based on the CHARLS. "Housing" is the average housing wealth for homeowners within the group.

The dominance of housing in wealth and the large inequality have been shaped by the development of China's real estate market since the early 2000s when the privatization of the real estate sector started and urbanization began to accelerate. The national average house price index appreciated by a factor of 5 between 2003 and 2017 (Liu and Xiong, 2020), which has led to an extremely high share of housing in total wealth. During the same period of time,

the house price index experienced an appreciation amounting to eleven folds in Beijing, eight folds in Shenzhen and Guangzhou, and six folds in Shanghai, as reported in Liu and Xiong (2020). The unusually high growth rates of house prices in these tier-one cities are consistent with the much higher housing wealth of retirees in these cities shown in Table 2. By contrast, the house price index appreciated about three folds in tier-three cities. In other words, the large cross-region wealth inequality in China is attributable to very different house price appreciation rates across different city tiers.

The growth rates of house prices began to slow down gradually after 2018, due to factors such as imbalances between supply and demand, slowing urbanization, slowing GDP growth, and the aging population (Rogoff and Yang, 2024). The growth rates in the second and tier-three cities turned negative in 2022 (Xiong, 2023). Given the critical importance of housing assets, a decline in house prices might significantly impact health investment and life expectancy, which motivates us to conduct a quantitative analysis of the effect of a 30% decline in house prices.

The implementation of property tax in China is a potential trigger of a large decline in house prices. Thus far, property tax is absent in China except for the so-called pilot program experimented in Shanghai and Chongqing. In April 2023, the Chinese government announced that a national registration system is now in place as a preparation for nationwide property tax.[8] As demonstrated in Zhu and Dale-Johnson (2020) through simulations, the introduction of property tax will increase the cost of property holding and reduce the willingness of investors and home buyers to hold properties, especially for those who have multiple properties for investment purposes, thus creating downward pressure on house prices.

Overall, housing asset is the most important asset for the majority of households in China. House prices in different cities experienced different degrees of rise, correction, and gradual stabilization over the past few decades, which led to large heterogeneity in housing assets. In addition, a large decline in house prices is likely in the coming years.

2.3 Literature

Several studies have documented life expectancy inequality by income and region in China, e.g., life expectancy between rich and poor (Baeten et al., 2013), between rural and urban areas (Van de Poel et al., 2012), or between and within provinces (Huang and Liu, 2023). Relative to these papers, our work provides new insights regarding inequality across cities and sectors of employment, and it quantitatively explores the relative importance of housing, wealth, income and medical insurance coverage.

Our modeling strategy is similar to Yogo (2016). One distinguishing feature of our model is that we study the heterogeneities in the mortality rate and life expectancy across different cities

[8] See https://global.chinadaily.com.cn/a/202304/26/WS64492319a310b6054facff65.html.

and sectors of employment, while Yogo (2016) focuses on how portfolio choices of retirees depend on health status and health investment. To better capture the heterogeneities, we construct a model that is distinctive to Yogo (2016) in the following two aspects. First, we allow shocks to house price growth to be mildly persistent rather than purely transitory. Persistent shocks are not only more realistic, but also pose much more risks to the individual's portfolio and hence have very different implications on health investment. Second, wealth is non-homogeneous in our value function due to the persistence of house price shocks. This non-homogeneity allows wealth level itself to be an essential driver of health investment, mortality, and portfolio choice.

Our paper is closely related to De Nardi et al. (2010), which estimates a life-cycle model of retirees to study the savings of older people. Similarly, we use a life-cycle model of retirees, with health and medical expenditures being a major source of uncertainty for retirees. The key difference between our paper and theirs is that our model includes endogenous health investment and portfolio choice. In addition, we focus on housing and retirees' heterogeneity, which coincides with the main finding in Cutler and Sportiche (2022) regarding older Americans, highlighting the importance of heterogeneity across multiple dimensions when examining the health impacts of house price shocks.

Our paper builds on the vast literature that documents the relationship between financial resources and health. Both income and wealth have strong independent correlations with health. Positive income shocks improve health (Frijters et al., 2005; Lindahl, 2005), and negative wealth shocks due to the stock market fluctuations impair physical and mental health and increase mortality (Schwandt, 2018). Chetty et al. (2016a) provides a comprehensive empirical study of the income gradient of life expectancy in the US and its evolution over time. Many public health researchers have attributed the health-income gradient to a causal effect from income to health (Wilkinson, 1990). This effect is even stronger for poor individuals and retirees. Moreover, the existing literature has conducted an in-depth discussion that effectively resolves the endogenous problems between assets and health. Our model builds upon the established relationship between health and financial means, and it offers additional insights by showing quantitatively how the heterogeneity in financial resources leads to inequality in life expectancy.

Our paper contributes to the literature on the health care system and the heterogeneity in individual health or life expectancy. Health care access varies geographically and could have meaningful impacts on health (Finkelstein et al., 2016, 2021; Miller et al., 2021; Goldin et al., 2021). In addition, the impacts of the healthcare system on health and life expectancy could be heterogeneous across income, wealth, and some other personal characteristics (Chetty et al., 2016b; Montez et al., 2019). All those factors can cause geographical inequality in health, even within a country. Deryugina and Molitor (2021) find that, within the U.S., the top 10 percent of counties have a life expectancy of 81.0 years or more, while the bottom 10 percent have a life expectancy of 74.4 years or less, resulting in an interdecile gap of 6.5 years. This gap is larger

than the gap between the public sector and the private sector retirees at age 60 in China, but smaller than the rural-urban gap in life expectancy that we find for retirees in China.

Our model is also related to several studies of the implications of health and medical expenditure risks on consumption and portfolio decisions. Previous literature studies how savings and portfolio choices are affected by medical expenses (Marshall et al., 2011; Cooper and Zhu, 2016) nursing home expenses (Kopecky and Koreshkova, 2014), and long-term care risks (İmrohoroğlu and Zhao, 2018). While medical expenses are exogenous in these studies, our model includes an endogenous health investment decision, enabling us to investigate the socioeconomic factors underlying the observed inequality in life expectancy.

3 Empirical Evidences

In this section, we begin by describing the data and reporting summary statistics. Next, we show empirical results regarding the mortality rate and life expectancy in China, focusing on the heterogeneity across cities and sectors of pre-retirement employment.

3.1 Data

Our empirical study is based on the China Health and Retirement Longitudinal Study (CHARLS), a panel survey designed to study the health and wealth dynamics of Chinese residents ages 45 and older. We focus on individuals aged between 60 and 100 to ensure all the observations are retirees.[9] Our sample consists of four waves of surveys conducted in 2011, 2013, 2015, and 2018 respectively. After dropping individuals aged below 60 or above 100, the sample includes 13,097 households and 22,326 individuals (63,294 observations in total) in 126 prefectures. There are 4 tier-one cities, 19 tier-two cities, 81 tier-three cities, and 96 rural areas (prefectures) in the sample.

Table 3 reports the summary statistics. As the table indicates, the average biannual mortality in our sample is 6.1%, where mortality is calculated as the fraction of survey respondents who die between the two consecutive survey waves.[10] In the sample, 20.3% of individuals are retirees from the public sector, and 51% of the individuals are female. We define homeowners as individuals who own one or more housing units, and the average home ownership rate is 83.2%. The average annual income per person is 12,079 yuan with a large standard deviation,

[9] Up until the end of 2024, the mandatory retirement age in China is 60 for men, and 55 for women as public servants or 50 for the rest of the types of workers. There are some exceptions for individuals with a certain standing in the hierarchy. We drop observations aged above 100 because the sample sizes of these oldest retirees are too small to construct reliable moments.

[10] This biannual mortality rate is understated because respondents may die within one year after the first one of the two consecutive waves of surveys.

where income is defined as the sum of individual annual labour income, retirement income, self-employment income, agricultural income, and social security income. The average wealth per person, defined as household wealth divided by household size, is 380,752 yuan in the sample, where wealth is the sum of housing assets, cash, deposits, bonds, stock, and funds.

Table 3: Summary Statistics

	Mean	Std	Min	Max
Raw age	68.790	7.101	60	99
Mortality	0.061	0.239	0	1
Public sector	0.203	0.402	0	1
Home ownership	0.832	0.374	0	1
Female	0.511	0.500	0	1
Annual income (yuan)	12,079	159,888	0	39,061,356
Wealth (yuan)	380,752	3,082,201	20	98,000,408
Housing share in wealth	0.884	0.194	0	1
OOP medical expense / income	0.462	0.881	0	4.344
Annual medical expense: OOP (yuan)	5,893	43,689	0	3,615,402
Annual medical expense: total (yuan)	8,311	82,472	0	9,637,799
Number of households	13,097			
Number of individuals	22,326			
Number of observations	63,294			

As shown in Table 3, housing share in total wealth is 88.4% for homeowners. This is calculated by dividing the reported value of housing assets by the total value of all assets of homeowners. The out-of-pocket medical expense relative to income is 46.2% on average, where the medical expense includes health insurance premiums, hospitalization costs, outpatient costs, prescription drugs, transportation costs, and self-treatment costs. The out-of-pocket medical expenses and total medical expenses are 5,893 yuan and 8,311 yuan on average, respectively.

3.2 Mortality Rates and Life Expectancy

To study the mortality rates of the seven groups of individuals in our sample, we employ the following specifications:

$$Death_{i,t+2} = \beta_1 Age_{it} + \beta_2 Age_{it}^2 + \beta_3 Region_i \times Sector_i + \beta_4 \times Health_{it} + \gamma X_{it} + \lambda_t + \epsilon_{i,t+2}, \quad (1)$$

where $Death_{i,t+2}$ is the death indicator which equals to one if the i^{th} individual dies between period t and $t+2$ (two consecutive surveys), Age_{it} is the adjusted individual's age, i.e., $(actual\ age_{it} - 60)/10$, $X_{i,t}$ is a vector of individual characteristics, and λ_t is the year fixed effect.

The heterogeneity in mortality rate is captured by $Region_i \times Sector_i$, dummies for the seven types of individuals where rural residents are treated as the omitted type. Here, $Region_i$

Table 4: Mortality Rate

	(1) Death		(2) Death		(3) Death	
Age	0.082***	(0.02)	0.027	(0.03)	0.018	(0.04)
Age-squared	0.127***	(0.01)	0.125***	(0.01)	0.141***	(0.02)
City: 1st tier (private)	-0.489***	(0.10)	-0.448***	(0.11)	-0.418***	(0.14)
City: 2nd tier (private)	-0.404***	(0.05)	-0.385***	(0.05)	-0.360***	(0.06)
City: 3rd tier (private)	-0.224***	(0.03)	-0.199***	(0.03)	-0.209***	(0.04)
City: 1st tier (public)	-0.722***	(0.18)	-0.744***	(0.21)	-0.786***	(0.30)
City: 2nd tier (public)	-0.695***	(0.08)	-0.693***	(0.08)	-0.658***	(0.10)
City: 3rd tier (public)	-0.561***	(0.04)	-0.552***	(0.05)	-0.502***	(0.06)
Health: 1 Very poor			0.484***	(0.04)	0.446***	(0.05)
Health: 2 Poor			0.186***	(0.03)	0.183***	(0.04)
Health: 4 Good			-0.017	(0.04)	-0.017	(0.04)
Health: 5 Very good			0.023	(0.04)	-0.029	(0.05)
Health: 1 Very poor × Age			0.018	(0.04)	0.050	(0.05)
Health: 2 Poor × Age			0.095***	(0.03)	0.093***	(0.03)
Health: 4 Good × Age			0.002	(0.03)	-0.026	(0.04)
Health: 5 Very good × Age			-0.019	(0.04)	-0.069	(0.05)
Housing owner			-0.043*	(0.03)	-0.067	(0.07)
Female			-0.195***	(0.02)	-0.188***	(0.03)
ln Income					-0.004	(0.00)
ln Wealth					-0.008	(0.01)
Housing share					0.285***	(0.08)
Med. exp.: health inv.					-0.008	(0.01)
Doctor visits					0.001	(0.00)
Constant	-1.952***	(0.02)	-1.922***	(0.04)	-2.076***	(0.13)
Observations	45643		43705		32460	

Notes: This table reports the Probit model results to show how the mortality rate depends on city tier and sector of pre-retirement employment, as well as health status, age and its interaction with health status, and other variables. Robust standard errors are in parentheses. Significance * .10, ** .05, *** .01.

represents three city tiers and the rural region, and $Sector_i$ is an indicator variable equal to one for public sector retirees.

The term $Health$ represents health dummies. CHARLS records the self-reported health status which takes the five values between 1-5, with a value of 1 corresponding to very poor health and 5 to very good health. In the regression, we treat health status 3 (i.e., "fair") as the omitted group.[11]

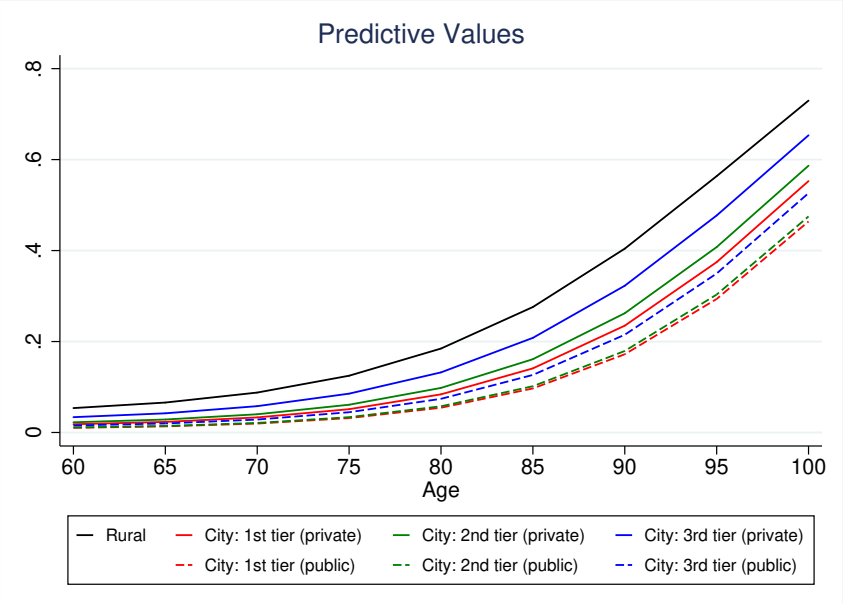
[11] As we show in Table B.2 in Appendix B.2, the self-reported health status is negatively related to various diseases and disabilities, i.e. the subjective self-assessment is in line with more objective health conditions.

We use the probit model to estimate the equation. Table 4 reports the results. The coefficients of age and age^2 are both positive. The coefficients of region-sector interaction are all negative, implying a lower mortality rate of city retirees relative to their rural counterparts. The coefficients of health dummies show that the mortality rate is decreasing in health. The mortality rate is significantly lower among the public sector retirees, and the lowest among public sector retirees from tier-one cities, as indicated by the low coefficients for the tier-one public sector dummy.

The coefficient of the female dummy is negative, which is not surprising. The coefficient of homeowner is negative but not statistically significant. As we will show, home ownership rates differ significantly across the region-sector groups, hence the role of home ownership is partly captured by the region-sector dummies. The coefficient of housing share in total wealth is significantly positive. Thus, the mortality rate is higher among individuals who have more wealth in the form of housing.

Based on the specification in column (1) of Table 4, we plot Figure 1 to show the average age profile of mortality rate for each of the seven groups. Evidently, rural residents (black solid line) have the highest mortality rate, and private sector retirees (solid lines) have higher mortality than public sector retirees (dashed lines).

Figure 1: Biannual Mortality Rates



We use the mortality rates shown in Figure 1 to calculate the life expectancy at age 60 for each of the seven groups. The first step is to divide the biannual rates by two to convert them into annual rates. Next, for a unit measure of individuals aged 60, we calculate the fraction of individuals who die between period t and $t+1$. Specifically, at the beginning of period t, the fraction of survivors is $\prod_{k=0}^{t-1}(1-death_k)$ where $death_k$ is the annual mortality rate, thus

the fraction of individuals who die between t and $t+1$ is $Life_t = \prod_{k=0}^{t-1}(1 - death_k) \times death_t$. Finally, the life expectancy at age 60 is

$$Expectancy = \sum_{t=1}^{T} Life_t \times t \tag{2}$$

As shown in Table 5, life expectancy is the lowest among rural individuals (15.54 years), and highest among the public sector retirees in tier-one cities (27.15 years). The difference in life expectancy between public sector retirees in tier-one cities and rural residents is 11.61 years, which is reported in the "*T1 pub-rural*" column. The "*rural-urban*" column shows the difference in life expectancy between the average of urban retirees and the rural residents, which amounts to 8.26 years. Finally, the "*public-private*" column shows the difference between the average of the public sector retirees and the average of the private sector retirees, which is 4.66 years in the data.

Table 5: Inequality in Life Expectancy in the CHARLS Data

Private sector				Public sector			T1 pub	urban	public
tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3	-rural	-rural	-private
23.42	21.96	19.02	15.54	27.15	26.69	24.54	11.61	8.26	4.66

Notes: This table reports life expectancy at sixty years of age for the seven groups in the data. "T1 $pub - rural$" is the difference in life expectancy between public sector retirees in tier-one cities and rural residents. "$rural - urban$" shows the difference in life expectancy between averages of urban retirees and rural residents, and the "$public - private$" shows the difference between averages of public sector retirees and private sector retirees.

4 The Model

To understand the above empirical facts, we construct an optimization model in which individuals choose consumption and health investment. We briefly introduce a simple static model to illustrate how health investment depends on income and housing costs. Then, we focus on a fully fledged dynamic model that includes bond investment and housing investment to quantitatively study socioeconomic factors that drives the heterogeneity in mortality and life expectancy..

4.1 The Simple Static Model

In the simple static model, an individual with income y allocates the income among the consumption of numeraire goods (C), housing consumption (S), and health investment (H) are

specified as follows:

$$\begin{aligned} &\max_{C,S,H} \quad \left[(1-\alpha)(C^{1-\xi}S^{\xi})^{1-1/\eta} + \alpha H^{1-1/\eta}\right]^{\frac{1}{1-1/\eta}} \\ &s.t. \qquad\qquad C + qS + H = y, \end{aligned} \tag{3}$$

where $\xi \in (0,1)$ is the utility weight on housing and $\alpha \in (0,1)$ is the utility weight on health. The parameter $\eta \in (0,\infty)$ is the elasticity of substitution between health and the composite of housing and non-housing consumption. We use q to denote the housing cost (i.e., the rental rate of housing). For simplicity, we assume that one unit of income (y) can be converted into one unit of health (H). We will specify a more realistic health production function when we lay out the dynamic model.

Given the Cobb-Douglas preference over housing and non-housing consumption, the optimal allocation satisfies

$$\frac{qS}{C} = \frac{\xi}{1-\xi}. \tag{4}$$

Substituting this optimal allocation rule into the optimization problem above, the problem is simplified into:

$$\begin{aligned} &\max_{C,H} \quad u(C,H) \\ &s.t. \quad \tfrac{C}{1-\xi} + H = y, \end{aligned} \tag{5}$$

where

$$u(C,H) = \left[(1-\alpha)\left(\frac{\xi}{q(1-\xi)}\right)^{\xi(1-1/\eta)} C^{1-1/\eta} + \alpha H^{1-1/\eta}\right]^{\frac{1}{1-1/\eta}}. \tag{6}$$

Solving the above optimization problem, we obtain the following expression for the optimal amount of health investment. Details are provided in Appendix C.

$$H = \frac{y}{\left(\frac{1-\alpha}{\alpha}\right)^{\eta}\left(\frac{1}{\xi^{\xi}(1-\xi)^{1-\xi}}\right)^{1-\eta} q^{\xi(1-\eta)} + 1}. \tag{7}$$

Equation (7) shows that investment in health increases in income and also increases in the cost of housing q if and only if $\eta > 1$, that is, if consumption and health are highly substitutable. This equation implies that larger city residents, whose income and housing costs are higher, invest more in health if $\eta > 1$. This result is intuitive: If $\eta > 1$, then health is a substitute for consumption, and larger city residents invest more in health to substitute for the more expensive housing consumption.

For the special case where the elasticity of substitution between consumption and health is unity ($\eta = 1$), we have the following expressions for health investment derived from Equation (7):

$$H \;=\; \alpha y \qquad\qquad \text{, if } \eta = 1. \tag{8}$$

Thus, health investment does not depend on housing costs when $\eta = 1$, which is because the income effect and substitution effect of a higher housing cost cancel each other. In this case, residents in larger cities invest more in health because of their higher income

For the special case where the substitution elasticity between consumption and health is zero (the Leontief preference), Equation (7) gives rise to the following health investment.

$$H = \frac{y}{\frac{q^{\xi}}{\xi^{\xi}(1-\xi)^{1-\xi}} + 1} \quad , \text{if } \eta = 0 \ . \tag{9}$$

Thus, health investment increases with income but decreases with housing costs. In Appendix C we show that when $\eta = 0$, the optimized utility of individuals, denoted $u^{\star}$, has the same expression as H, i.e.,

$$u^{\star} = H \qquad , \text{if } \eta = 0 \ . \tag{10}$$

Imposing the spatial equilibrium condition that individuals living in different cities should have the same level of utilities, equation (10) indicates that health investment is the same across cities when health and consumption have zero substitutability, implying the same life expectancy for individuals living in different cities.

We summarize the above results in the following proposition.

Proposition 1 *In the static model specified in optimization problem (3), health investment is*

(i) increasing in both income and housing cost if $\eta > 1$;

(ii) increasing in income and independent of housing cost if $\eta = 1$;

(iii) increasing in income but decreasing in housing cost if $\eta < 1$;

(iv) independent of income and housing cost if $\eta = 0$ and if the spatial equilibrium condition holds.

The proposition implies that larger city residents should have a higher life expectancy if health and consumption have a high degree of substitutability, and they should have a similar life expectancy as residents in smaller cities or rural areas if the substitutability is near zero. In the data, we observe a lower life expectancy among rural residents and a mild increase of life expectancy in city size, indicating a low degree of substitutability between consumption and health.

4.2 The Dynamic Optimization Model

In this subsection, we extended the simple static model to a dynamic model. One period in our model represents one year. We use t to denote the number of years into retirement, with t ranging between 1 and T, representing age 61-100, respectively. Individuals in the model fall into one of the seven groups described earlier, depending on their city of residence and sector

of pre-retirement employment. Because the dynamic optimization model applies to each group, we do not include the type as a state variable. We will describe the heterogeneity across groups in detail in the subsequent section.

4.2.1 Health Production and Health Shocks

Denote $h_t = log(H_t)$ where H_t is the stock of health for an individual at the beginning of the period t. The law of motion of h_t is

$$h'_t = h_t + m_t, \tag{11}$$
$$m_t = \psi \times i_t, \tag{12}$$
$$h_{t+1} = f(h'_t, age), \tag{13}$$

where m_t is the additional health as a result of the endogenous health investment, and h'_t is the total amount of health after the health investment.

Equation (12) is the health production function, where $i_t = log(I_t)$ is the logarithm of total health investment in terms of the numeraire, and the parameter $\psi \in (0, 1]$ determines the curvature of the health production function.[12]

The function $h_{t+1} = f(h'_t, age)$ captures the exogenous transition of health between period t and period $t+1$, which we estimate directly from the data. Death is defined as the state in which h_{t+1} is below a threshold level of $\underline{h}$, i.e., $h_{t+1} < \underline{h}$. In this case, the individual dies between period t and $t+1$.

In terms of timing, the individual observes her health stock h_t at the beginning of period t. If $h_t \geq \underline{h}$, then she chooses to produce m_t amount of additional health, resulting in a total health of h'_t at the beginning of period t, which enters her utility function. Next, between t and $t+1$, the health depreciates with age and receives random shocks as captured by $f(h'_t, age)$, which results in a health stock of h_{t+1} at the beginning of period $t+1$. If the individual survives (i.e $h_{t+1} \geq \underline{h}$), then she moves on to choose m_{t+1}.

Combining Equations (11)- (12) leads to the health that enters the utility function in period t as a function of the existing health at the beginning of period t and the health investment:

$$H'_t = H_t \times I_t^{\psi}.$$

It should be noted that only a fraction of the total health investment is out of pocket, and the remaining is covered by the publicly funded health care system. That is, $I_t^{oop} = OOP \times I_t$, where I_t^{oop} is the amount of out-of-pocket health investment, and OOP is the OOP share. The

[12] Theoretically, we can model health production as $m_t = log(Q) + \psi \times i_t$, i.e., $M_t = QI^{\psi}$ where Q is a scaling parameter. However, we can not separately identify Q from α in the utility function as shown in equation (6). Therefore, we choose not to include Q in the health production function.

OOP share differs by region and sector of employment. Therefore, individuals choose different levels of health investment I_t^{oop} not only because of the difference in income and wealth, but also because of the difference in the OOP share.

4.2.2 Financial Market

Housing and bonds are the two types of financial assets available in the model.[13] Bonds are risk-free and perfectly liquid. No mortgage or other borrowing is allowed in the model, because the majority of retirees in China have neither mortgage debt nor unsecured debt.

The value of housing at the beginning of period t is $D_t P_t$ where D_t and P_t denote the size and per-unit price of housing, respectively. The growth rate of house prices follows an AR(1) process with a deterministic trend. Thus, housing investment is risky. The return on housing investment comprises rental return and house price appreciation. The rental rate of houses is denoted q_t, which is the housing cost from the renter's perspective.

We separate housing consumption from housing investment in the model, and allow individuals to own housing as an asset on the one hand and obtain housing service through renting on the other hand.[14] Thus, the amount of housing service is generally different from the housing investment for individuals. An individual is defined as a homeowner if she has a positive housing investment.

We consider three types of friction in the housing market. First, there is an adjustment cost of housing transaction – a home owner needs to pay a λ fraction of the house value.[15] Second, there is a minimum housing size that differs by city tiers. Third, there is a utility gain for homeowners, i.e., homeowners derive more utility than renters for the same unit of housing, which captures the prestige associated with owning housing assets. As we will show, these frictions generate heterogeneous home ownership rates and have a significant impact on mortality rates.

4.2.3 Optimization Problem

Let $\Omega_t = (D, B, P, q, H)$ represent the current state of an individual at the beginning of a period, where D and B are the stocks of housing assets and risk-free bonds respectively, P is the price of housing asset, q is the housing cost (rental rate of housing), H is the health stock.

[13] Bonds correspond to the following assets in the data: cash, bank deposit, wealth management product, government bonds, and housing funds. Bonds and housing account for 99.8% of the total wealth of retirees in our pooled CHARLS sample.

[14] In our CHARLS sample, 15% of individuals are renters, and about 3% of individuals have multiple condominiums.

[15] While we assume housing investment involves this selling cost, we assume the rental market involves no transaction cost, i.e., it is cost-free for individuals to adjust the amount of housing consumption.

We omit the time (age) subscript, and use D', B' and I' to denote the choice of housing asset, risk-free bond, and health investment, respectively.

We use ϕ to denote the homeowner's utility gain, and modify the utility function in equation (3) into $\left[(1-\alpha)(C^{1-\xi}((1+\phi)S)^{\xi})^{1-1/\eta}+\alpha H^{1-1/\eta}\right]^{\frac{1}{1-1/\eta}}$. The inclusion of ϕ does not affect the optimal allocation between housing and non-housing consumption shown by equation (4) because of the Cobb-Douglas preference. After some algebra, we obtain the following current utility as a function of consumption C and health H:

$$u = \left[(1-\alpha)\left(\frac{\xi}{q(1-\xi)}\right)^{\xi(1-1/\eta)}(1+\phi)^{\xi(1-1/\eta)}C^{1-1/\eta}+\alpha H^{1-1/\eta}\right]^{\frac{1}{1-1/\eta}}, \tag{14}$$

$$where \quad \phi = 0 \quad for \quad renters.$$

Homeowners Due to the presence of housing transaction costs, an individual may not be a homeowner. If an individual is a homeowner, she chooses between three alternatives: (i) housing adjustment, (ii) no housing adjustment, and (iii) exiting the housing market. This choice is given by:

$$V_t(\Omega) = \max\{V_t^a(\Omega), V_t^n(\Omega), V_t^x(\Omega)\} \tag{15}$$

for all Ω.

In the case of housing adjustment, the value function is:

$$V_t^a(\Omega) = \max_{I',D',B'}\left\{(1-\beta)u^{1-1/\theta}+\beta\left[\left(E_t(1-\nu(\Omega'))V_{t+1}(\Omega')^{1-\gamma}\right)^{\frac{1}{1-\gamma}}+\left(E_t\nu(\Omega')V_b^{1-\gamma}\right)^{\frac{1}{1-\gamma}}\right]^{1-1/\theta}\right\}^{\frac{1}{1-1/\theta}}$$

$$\begin{aligned} s.t. \frac{C}{1-\xi} &= Y - OOP\times I' + (1+r_b)B - B' + (1-\lambda+q)P_tD - P_tD', && (16)\\ H' &= H\times(I')^{\psi}, && (17)\\ P_tD' &\geq \underline{PD}, && (18) \end{aligned}$$

where u is defined by equation (14). Because we assume that housing consumption is derived from renting even for home owners and it is cost-free to adjust housing consumption, the optimal allocation over housing and non-housing consumption given by equation (4) still holds true in the dynamic model, and we omit housing consumption S from the choice set for simplicity of notation.

The term $\frac{C}{1-\xi}$ in the budget constraint is the total consumption expenditure, including both non-housing and housing consumption, which is clear from equation (4). r_b is the bond return, $\underline{PD}$ is the minimum house value, λ is the selling cost of the house, and q is the rental rate of the owned house, which generates streams of rental income for home owners. I' is the health investment.

The mortality rate $\nu(\Omega')$ is a function of the next period's state space Ω' because the mortality rate depends on H' which is the health stock the individual chooses based on Ω'. The parameter γ is the coefficient of relative risk aversion, and θ is the elasticity of inter-temporal substitution (EIS). The expectation, denoted E_t, is taken with respect to future health shocks and housing return shocks.

The bequest value V_b is a function of bequeathed wealth $F = (1-\lambda)P_{t+1}D' + (1+r_b)B'$. It has the following functional form:

$$V_b(F) = L^{\frac{1}{1-1/\theta}} \times F, \tag{19}$$

where L determines the strength of bequest motives. This bequest value is stochastic because house price P_{t+1} is uncertain. The effect of risk aversion on bequest value appears in the parameter γ in the functional equation of $V_t^a(\Omega)$.

In the case where the homeowner chooses not to adjust his or her housing wealth, he or she needs to decide on the health investment and bond purchases for the next period. The value is:

$$V_t^n(\Omega) = \max_{I',B'} \left\{ (1-\beta)u^{1-1/\theta} + \beta \left[\left(E_t(1-\nu(\Omega'))V_{t+1}(\Omega')^{1-\gamma} \right)^{\frac{1}{1-\gamma}} + \left(E_t\nu(\Omega')V_b^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \right]^{1-1/\theta} \right\}^{\frac{1}{1-1/\theta}}$$

$$\begin{aligned} s.t. \qquad \frac{C}{1-\xi} &= Y - OOP \times I' + (1+r_b)B - B' + qP_tD, \\ H' &= H \times (I')^{\psi}, \\ D' &= D. \end{aligned}$$

In the case where the homeowner chooses to exit the housing market, the value is given by

$$V_t^x(\Omega) = \max_{I',B'} \left\{ (1-\beta)u^{1-1/\theta} + \beta \left[\left(E_t(1-\nu(\Omega'))W_{t+1}(\Omega')^{1-\gamma} \right)^{\frac{1}{1-\gamma}} + \left(E_t\nu(\Omega')V_b^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \right]^{1-1/\theta} \right\}^{\frac{1}{1-1/\theta}}$$

$$\begin{aligned} s.t. \qquad \frac{C}{1-\xi} &= Y - OOP \times I' + (1+r_b)B - B' + (1-\lambda+q)P_tD, \\ H' &= H \times (I')^{\psi}, \\ D' &= 0, \end{aligned}$$

where $W_{t+1}(\Omega')$ is the value function for non-homeowners to be specified below.

Non-homeowners An individual currently not investing in the housing market can choose to become a homeowner or remain a non-homeowner. The value for this entry decision is:

$$W_t(\Omega) = \max\{W_t^n(\Omega), W_t^e(\Omega)\}, \tag{20}$$

where $W_t^n(\Omega)$, the value of remaining a non-homeowner, is given by

$$W_t^n(\Omega) = \max_{I',B'} \left\{ (1-\beta)u^{1-1/\theta} + \beta \left[\left(E_t(1-\nu(\Omega'))W_{t+1}(\Omega')^{1-\gamma} \right)^{\frac{1}{1-\gamma}} + \left(E_t \nu(\Omega') V_b^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \right]^{1-1/\theta} \right\}^{\frac{1}{1-1/\theta}}$$

$$\begin{aligned} s.t. \qquad \frac{C}{1-\xi} &= Y - OOP \times I' + (1+r_b)B - B', \\ H' &= H \times (I')^{\psi}, \\ D' &= 0. \end{aligned}$$

Again, we omit housing consumption S from the choice set for simplicity of notation. As discussed earlier, the optimal allocation over housing and non-housing consumption is given by equation (4), which still holds true in the dynamic model because we assume it is cost-free to adjust housing consumption.

The value of a non-homeowner who chooses to enter the housing investment market is given by:

$$W_t^e(\Omega) = \max_{I',D',B'} \left\{ (1-\beta)u^{1-1/\theta} + \beta \left[\left(E_t(1-\nu(\Omega'))V_{t+1}(\Omega')^{1-\gamma} \right)^{\frac{1}{1-\gamma}} + \left(E_t \nu(\Omega') V_b^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \right]^{1-1/\theta} \right\}^{\frac{1}{1-1/\theta}}$$

$$\begin{aligned} s.t. \frac{C}{1-\xi} &= Y - OOP \times I' + (1+r_b)B - B' - P_t D', \\ H' &= H \times (I')^{\psi}, \\ P_t D' &\geq \underline{PD}, \end{aligned}$$

where the continuation value $V_{t+1}(\Omega')$ is the value function of homeowners.

5 Exogenous Model Inputs

The model has a number of exogenous inputs, including the homogeneous stochastic health process, and the heterogeneous out-of-pocket medical expenditure, housing market, income, and the initial distribution of health and wealth.

5.1 Health Process

The exogenous component of health is a function of age and lagged health, as shown in equation (13). To estimate this exogenous process, we augment the five self-reported health statuses in CHARLS with "death" as an additional status. Specifically, we use the following vector to denote health categories,

$$h^\star = \{h_0^\star, h_1^\star, h_2^\star, h_3^\star, h_4^\star, h_5^\star\}, \tag{21}$$

where $h_5^\star$ denotes the best health status, and $h_0^\star$ denotes the worst which is death.[16]

Given the six statuses, we estimate an ordered probit model, regressing the current health status on age, age-squared, and dummies for the lagged health status, controlling for income, wealth, and year effects. It is important to note that the transition of health status observed in the panel data of CHARLS includes both the exogenous changes and the endogenous health investment. By controlling for income and wealth in the ordered probit regression, the coefficients on lagged health and age effectively capture the exogenous changes in health.

Table 6 reports the estimation results. We find significant coefficients for lagged health dummies where the "fair" status is the omitted group. The negative coefficients for poor and very poor health and the positive coefficients for good and very good health imply a strong serial correlation of health status. The coefficients of age and age-squared are both negative, implying the deterioration of health as one ages. The positive coefficients of income and wealth are consistent with our theoretical prediction that richer individuals invest more in health.

Table 6: Health Transition

		lagged Health				lagged Health × Age					
Age	Age^2	Very poor	Poor	Good	Very good	Very poor	Poor	Good	Very good	ln(Income)	ln(Wealth)
-0.050	-0.053	-1.000	-0.656	0.492	0.916	0.0023	-0.0005	-0.067	-0.049	0.009	0.035
(0.021)	(0.014)	(0.029)	(0.016)	(0.020)	(0.029)	(0.036)	(0.020)	(0.026)	(0.037)	(0.002)	(0.004)

This table reports the ordered probit regression results. The dependent variable is health status. Robust standard errors are in parentheses. Age is defined as (actual age - 60)/10.

We use the coefficients on age, age-squared, lagged health status and its interaction with age in Table 6 to estimate the exogenous process of shocks. The positive effects of income and wealth on health are captured by the endogenous health investment in our model, which occurs after the realization of exogenous health shocks.

5.2 Out-of-pocket Medical Expenditure

As discussed in Section 2.1, the out-of-pocket share of total health expenditures (the *OOP* share) features a large disparity between sectors and across regions. To capture the disparity, we regress the *OOP* share on dummies of the seven groups of individuals, as well as age, age-squared, health dummies, and interaction of health dummies with age, controlling for the year fixed effect.[17]

Table 7 reports the OLS estimation results. Coefficients of region-sector dummies are all negative, indicating a lower *OOP* share for urban retirees than rural residents, who are the

[16]The state of death is assigned to individuals who die between two waves of surveys.

[17]It is noteworthy that, during our sample period of 2011-2018, the average *OOP* share in China fell from 40.27% to 35.75% (https://data.worldbank.org/indicator/SH.XPD.OOPC.CH.ZS?locations=CN&view=chart).

omitted group. Retirees from the public sector enjoy a much lower OOP share than private sector retirees. In addition, the OOP share is lower in larger cities.[18]

Table 7: Heterogeneous Out-of-pocket Expenditure Share

			Private sector			Public sector		
Const.	Age	Age^2	tier 1	tier 2	tier 3	tier 1	tier 2	tier 3
0.653	-0.006	-0.025	-0.16	-0.133	-0.098	-0.288	-0.186	-0.173
(0.008)	(0.009)	(0.005)	(0.022)	(0.012)	(0.008)	(-0.024)	(0.014)	(0.011)

	lagged Health				lagged Health ×Age			
	Very poor	Poor	Good	Very good	Very poor	Poor	Good	Very good
	0.13	0.143	-0.181	-0.263	-0.006	-0.023	0.049	0.046
	(0.012)	(0.008)	(0.011)	(0.012)	(0.013)	(0.008)	(0.011)	(0.012)

This table reports the OLS regression results. The dependent variable is out-of-pocket medical expenditure as a share of the total medical expenditure. Robust standard errors are in parentheses. Age is defined as (actual age - 60)/10.

5.3 Housing Market

We assume house price growth is the sum of the deterministic and stochastic components, i.e., the growth rate at time in tier j cities is

$$r^P_{j,t} = \mu_j + \tilde{p}_t,$$

where μ_j is the deterministic component. The stochastic component $\tilde{p}_t$ follows an AR(1) process, i.e., $\tilde{p}_t = \rho\tilde{p}_{t-1} + \epsilon_t$, with the random shock follows $\epsilon_t \sim N(-\frac{\sigma^2}{2}, \sigma^2)$. We set $\rho = 0.15$ and $\sigma = 0.08$ for all cities and the rural area to capture the weak serial correlation and low volatility of house price growth in China.

We use $\mu_j = 6\%$, 4%, 2%, and 1% for tier-one, tier-two, tier-three cities, and the rural region, respectively.[19] Fang et al. (2016) find that the average growth rates of real house prices are 13.1%, 10.5%, and 7.9% between 2003-2013 in tier-one, tier-two, and tier-three cities, respectively. However, housing prices in most cities in China have been declining since 2019.

The rental return of houses is calculated based on the rent-to-price ratio. The ratio is generally close to or even below two percent in different regions. Thus, we set the rent-to-price ratio of houses to 2%.

The housing cost, represented by q in equation (14), differs tremendously across regions. In our CHARLS sample, the average monthly rent per square meter is 28.1 Yuan, 14.2 Yuan, and 8.7 Yuan for tier-one, tier-two, and tier-three cities, respectively. The rental rate in rural

[18] For robustness, we re-run regressions using the Tobit model, and we find similar patterns. See Table B.3.

[19] The underlying assumption is that individuals invest only in housing markets of their own cities or cities of the same tier. In reality a small fraction of wealthy individuals may invest in different tiers of cities.

areas is only about a quarter or one-fifth of the rent in tier-three cities.[20] We normalize the housing cost of rural regions to one, i.e., one unit of housing service for one unit of non-housing consumption, and we set the housing cost of tier-one, tier-two, and tier-three cities to 13, 6.5, and 4, respectively.

We set the minimum house value to 10 times the average income in cities, and set it to the level of average income in the rural regions, to capture the fact that rural residents in China are allotted residential land free of charge, but city residents pay a high house price which mainly is land cost.

5.4 Income

Income is exogenous and deterministic in the structural model, which is a realistic assumption because we focus on the economic decisions of retirees. We regress log income on region-sector dummies and age to capture income inequality of the old-age individuals in our CHARLS sample. Table 8 reports the results. As the table shows, income is lower among rural residents (the omitted group in region-sector dummies). Income is significantly higher in larger cities. Within each city tier, income is significantly higher among public sector retirees.

Table 8: Heterogeneous Income

			Private sector			Public sector		
Const.	Age	Age2	tier 1	tier 2	tier 3	tier 1	tier 2	tier 3
7.639	-0.068	-0.04	0.94	0.554	0.43	1.111	0.637	0.498
(0.01)	(0.02)	(0.01)	(0.05)	(0.02)	(0.02)	(0.18)	(0.07)	(0.04)

This table reports the OLS regression results. The dependent variable is log income. Robust standard errors are in parentheses. Age is defined as (actual age - 60)/10.

5.5 Initial Health and Wealth

For each type of individual, we calculate the joint distribution of health, financial wealth, and housing wealth based on the observations aged 55-65 in our CHARLS sample, and use the distribution as the starting point in the simulations.

Table 9 illustrates the composition of initial wealth per person for the seven groups. The cross-sectional heterogeneity is similar to the patterns observed in Table 2 which reports wealth compositions for all retirees, including those aged above 65. Namely, wealth is higher among larger city residents, and among public sector retirees. The wealth of rural residents is strikingly lower than that of city residents. For each group, housing assets are dominantly important, and home ownership rates are high.

[20] See https://research.ke.com/ResearchResults.

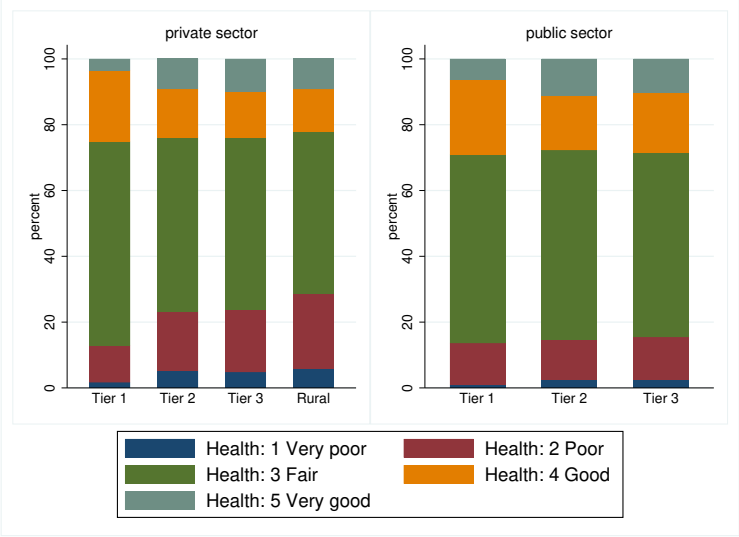
Table 9: Initial Wealth Distribution

	Wealth (10,000 yuan)				Home ownership rate
	$Non-housing$		$Housing$ $_{homeowners}$		
	mean	std.	mean	std.	mean
Rural	0.60	(4.30)	6.56	(15.36)	0.955
Tier 1, private sector	2.57	(9.56)	371.29	(1,083.89)	0.685
Tier 2, private sector	1.62	(6.47)	70.75	(378.47)	0.792
Tier 3, private sector	1.07	(4.01)	47.42	(343.72)	0.771
Tier 1, public sector	6.86	(17.40)	410.82	(1,070.73)	0.678
Tier 2, public sector	3.07	(7.43)	115.10	(639.90)	0.855
Tier 3, public sector	1.90	(9.31)	56.48	(341.83)	0.830

Wealth distribution for retirees aged 55 to 65. The author's calculation is based on the CHARLS. Housing wealth is the average for homeowners within the group.

Figure 2 displays the initial distribution of health. As the figure indicates, a larger fraction of retirees in the private sector report very poor health, and a smaller fraction of them report good or very good health. The initial health condition is better among tier-one city residents, irrespective of their pre-retirement sector of employment. Compared to city residents, a significantly large fraction of rural residents report poor or very poor health. Presumably, the inequality in life expectancy is partially driven by the different initial health conditions.

Figure 2: Initial Health Distribution



Distribution of health status for retirees aged 55 to 65. Author's calculation based on CHARLS data.

6 Structural Estimation

The model has a set of parameters that we estimate via the simulated method of moments. The set includes 9 parameters, denoted $\Theta = (\beta, \gamma, \theta, L, \alpha, \eta, \psi, \phi, \lambda)$. These parameters are identified by minimizing the distance between the moments obtained from the model and their counterparts in the data. We use 18 moments to identify 9 parameters, which leads to an overidentifying restriction of $18 - 9 = 9$.

6.1 Data Moments

To estimate the parameters of our structural model, we choose two sets of moments that summarize the heterogeneous mortality rates and home ownership rates in the data, respectively, each containing 9 moments.

The first set of moments are regression coefficients of the mortality rate on age, age-squared, and six dummies representing retirees from different sectors and city tiers (see column (1) in Table 10). By matching the six dummies, our model generates the heterogeneous mortality rates, the focal point of our study. We transform the actual age in the data into $\frac{age-60}{10}$, and the corresponding squared term is $\left(\frac{age-60}{10}\right)^2$. The transformation increases coefficients on age and age-squared to a scale similar to other coefficients.

The second set of moments is regression coefficients of the home ownership rate, using the same regressors as in the regression of the mortality rate. We choose these moments because we aim to understand the roles of housing investment and housing market frictions in determining life expectancy. In addition, we will examine how a large decline in house prices impacts life expectancy in different regions and sectors.

Table 10 reports the data moments and their standard errors. The coefficients on dummies are all relative to the base group, i.e., old-age rural residents.

While we have discussed the heterogeneity in the mortality rate in Section 3, here we briefly discuss the heterogeneity in the home ownership rate. As the table shows, home ownership rate is higher among retirees in tier-two cities than in tier-three cities. Rural residents enjoy the highest home ownership rate, while retirees in tier-one cities from the private sector have the lowest rate. Within each city tier, public sector retirees enjoy significantly higher home ownership rates. For each group, the home ownership rate declines with age for each group. Our model generates similar heterogeneity in the home ownership rate due to the frictions in the housing market, including the housing adjustment cost, the minimum housing requirement, and the additional utility gained by thehomeowners.

Table 10: Data Moments

	(1) Death		(2) Home ownership	
Age	-0.016***	(0.00)	-0.040***	(0.00)
Age-squared	0.036***	(0.00)	-0.009***	(0.00)
City: 1st tier (private)	-0.048***	(0.01)	-0.204***	(0.02)
City: 2nd tier (private)	-0.041***	(0.00)	-0.129***	(0.01)
City: 3rd tier (private)	-0.026***	(0.00)	-0.152***	(0.00)
City: 1st tier (public)	-0.063***	(0.01)	-0.166***	(0.02)
City: 2nd tier (public)	-0.055***	(0.00)	-0.050***	(0.01)
City: 3rd tier (public)	-0.050***	(0.00)	-0.060***	(0.01)
Constant	0.029***	(0.00)	0.945***	(0.00)
Observations	45643		60261	
R^2	0.052		0.056	

Notes: Data moments used in the Simulated Method of Moments estimation. *Age* is defined as (actual age - 60)/10. Robust standard errors are in parentheses. Significance * .10, ** .05, *** .01.

6.2 Parameter Estimates

The definitions and estimated values of these parameters are reported in Table 11. The last column of the table reports the standard errors of these estimates. The small standard errors indicate that each parameter is estimated with good precision. Appendix D provides details on the estimation procedure.

Table 11: Model Parameters

Symbol	Definition	Estimate	Std Err
β	discount factor	0.925	0.004
γ	relative risk aversion	3.162	0.096
θ	inter-temporal elasticity of substitution	0.813	0.023
L	bequest motive	1.202	0.052
α	health share in utility	0.468	0.026
η	substitution between health and consumption	0.475	0.013
ψ	curvature in health production	0.640	0.016
ϕ	homeowner's utility gain	0.089	0.003
λ	housing adjustment cost	0.054	0.001

Notes: The estimates of parameters in the structural model and their standard errors.

Our estimate of the elasticity of substitution between health and consumption is $\eta = 0.475$.[21] To match the key facts about asset allocation and health expenditure among American retirees in the Health and Retirement Study, Yogo (2016) chooses an elasticity between health and consumption of 0.7. Thus, both studies find that health and consumption are complements rather than substitutes. As a result, the high housing costs in large cities squeeze out health investments. This housing cost effect has been illustrated in the simple model and summarized in Proposition 1.

The curvature of the health production function is $\psi = 0.64$, implying a positive but mild income and wealth gradient of health investment. Because residents of larger cities receive higher incomes and accumulate more wealth, especially through housing investment, they tend to invest more in health. However, this income and wealth channel is partially counteracted by the housing cost channel. With two channels combined, health investment is increasing in city size in the data as well as in our model.[22]

The estimated utility weight on health (i.e., "health share") is $\alpha = 0.468$. In simulation exercises, we find that a larger α increases health investment and lowers mortality rates, and increases the inequality in life expectancy.

Our estimates for the discount factor, the risk aversion, and the EIS all fall in the conventional ranges. It is informative to compare our estimates to those in Calvet et al. (2023) based on structural estimations using a panel of Swedish households. Our discount factor of 0.925 is equivalent to a time preference rate of $-log(0.925) = 7.8\%$, which is larger than the mean time preference rate of 5.21% reported in Calvet et al. (2023). Our estimated risk aversion and EIS are 3.163 and 0.813, lower than the estimated mean values of 7.57 and 0.96 reported in Calvet et al. (2023).

The estimated housing transaction cost is $\lambda = 0.054$, i.e., 5.4% of the house value. The cost is interpreted as a combination of monetary costs and psychological costs. This cost makes housing adjustment lumpy, which is consistent with the empirical findings that retirees rarely downsize their houses even in older age (Venti and Wise, 2004). As we will show in the counterfactual simulation, home ownership rates increase when we set housing transactions to zero, because in this case homeowners downsize their houses rather than becoming renters in response to a negative health shock. The homeowner's utility gain is $\phi = 0.089$. In other words, the same housing unit provides 8.9% more subjective utility if it is owner occupied rather than

[21] Here, we assume the symmetric elasticity across individuals. See Anderson and Zhang (2022), Hu and Zhang (2021), and Zhang (2020) for the role of income in the heterogeneous estimates of substitution elasticity.

[22] In an unreported experiment, we set $\eta = 1.5$ and re-simulate the model. We find that tier-one city retirees substitute out housing consumption and increase their health investment, while tier-three city retiree and rural residents decrease their health investment. As a result, the life expectancy of tier-one city retirees increases by 6.05 years in the private sector and by 4.04 years in the public sector, while the life expectancy of rural residents decreases by 2.01 years.

rented. This subjective utility gain is identified by matching the home ownership rate from the model with those in the data.

The estimated bequest motive is $L = 1.202$, indicating a mildly strong bequest motive. Modeling bequest in a similar way, Gomes and Michaelides (2005) uses a larger bequest motive parameter to match the wealth accumulation profiles observed in the US data. In the context of our model, a stronger bequest motive reduces health investment, thereby lowering life expectancy to a level which is below what we observe in the data.

6.3 Model Moments

We obtain model moments by running the regression of the mortality rate and the home ownership rate based on the simulated data, using the same regression specification as with the data moments.

Table 12: Targeted Moments: Model vs. Data

				Private sector			Public sector		
	const	$\frac{age-60}{10}$	$\left(\frac{age-60}{10}\right)^2$	tier 1	tier 2	tier 3	tier 1	tier 2	tier 3
Mortality rate									
Data	0.029	-0.016	0.036	-0.048	-0.041	-0.026	-0.060	-0.055	-0.050
Model	0.039	-0.007	0.022	-0.047	-0.044	-0.022	-0.073	-0.060	-0.050
Home ownership									
Data	0.945	-0.040	-0.009	-0.204	-0.129	-0.152	-0.166	-0.050	-0.060
Model	0.882	-0.042	0.023	-0.230	-0.120	-0.141	-0.321	-0.141	-0.156

Notes: Moments from the CHARLS and the simulated data generated from the structural model.

Table 12 reports the model moments and their corresponding data moments. As the table shows, our model matches the data fairly well, especially the heterogeneity across regions and sectors. The model well captures the lower mortality rates in larger cities than in small cities or rural areas, and in the public sector than in the private sector. As in the data, the mortality rate in each tier of cities is significantly lower than in the rural area.

The home ownership rates of the different groups are also matched fairly well. The home ownership rate of each group of urban retirees is lower than that of their rural counterparts. Relative to other urban retirees, tier-one city retirees have significantly lower home ownership rates. Home ownership rate is slightly lower in tier-three cities than in tier-two cities. All these salient features in the data are matched in our model. However, our model generates lower home ownership rates among retirees in the public sector than in the private sector, which is counterfactual.

Table 13: Model vs. Data – Levels

	Private sector				Public sector		
	Tier 1	Tier 2	Tier 3	Rural	Tier 1	Tier 2	Tier 3
Life expectancy							
Data	23.42	21.96	19.02	15.54	27.15	26.69	24.54
Model	24.06	23.59	18.30	14.16	27.22	25.78	24.46
Home ownership							
Data	0.61	0.69	0.66	0.82	0.65	0.77	0.76
Model	0.65	0.75	0.77	0.92	0.53	0.72	0.75

Notes: This table reports the average life expectancy and home ownership rate for each group in the data as well as in the estimated model.

The model also well matches the within-group averages in life expectancy and in home ownership rate, as shown in Table 13. Here the life expectancy is calculated with equation (2) based on the heterogeneous mortality generated from the model, and the home ownership rate is a simple average of all individuals within the group. For each group, the model generates the average life expectancy at 60 and home ownership rates that are well aligned with the data counterpart, except that home ownership rates from the model are a bit high among rural residents and private sector retirees in tier-three cities, and it is 12% below the home ownership rate in the data among tier-one city public sector retirees.

In addition, we examine how medical expenditures differ among the seven groups. Table 14 reports the total medical expenditures and OOP expenditures by groups, both in the data and in the model. Here, we normalize expenditures by the average income of all individuals in the seven groups to conceptualize the economic burden of medical expenses while keeping the numbers comparable between groups. As the first row of the table shows, the total medical expenditures are 0.60 and 0.46 for retirees of tier-one and tier-two cities in the private sector in the data, that is, the expenditures are 60% and 46% of the average income of the individuals in our CHARLS sample.

Total medical expenditure is higher in larger cities and the lowest in rural areas, which is consistent with the cross-region inequality in life expectancy. Total medical expenditure is higher among the public sector retirees, consistent with the between-sector inequality in life expectancy. Regarding OOP expenditures, it is clear in the data that rural residents spend less out-of-pocket on medical care, while the differences between city tiers and sectors are small. These data features of medical expenditures are captured by our model, although we do not target these statistics in parameter estimation.

Table 14: Model vs. Data – Medical Expenditures

	Private sector				Public sector		
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3
Medical exp. (total)							
Data	0.60	0.46	0.48	0.19	0.92	0.67	0.58
Model	0.70	0.65	0.47	0.15	1.05	0.81	0.56
Medical exp. (OOP)							
Data	0.23	0.22	0.23	0.11	0.29	0.28	0.27
Model	0.16	0.17	0.15	0.08	0.16	0.16	0.12

Notes: This table reports the averages of total medical expenditures and out-of-pocket medical expenditures for each group in the data, as well as in the estimated model. The expenditures are normalized by the average income of all individuals.

6.4 Housing Market Frictions

Our model captures three types of housing market frictions: the adjustment cost, the minimum housing size, and the home owner's utility gain. To understand their roles in determining life expectancy, we remove one type of friction at a time and examine the resulting life expectancy and home ownership rates. Results are reported in Table 15.

Table 15: Housing Market Frictions

	Private sector				Public sector		
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3
Life expectancy at 60							
Model (benchmark)	24.06	23.59	18.30	14.16	27.22	25.78	24.46
Housing adjustment cost=0	29.88	26.64	19.08	14.38	31.04	28.64	24.95
Minimum housing=0	19.28	19.62	17.62	14.48	25.08	25.54	23.42
Homeowner's utility gain=0	24.03	23.73	18.42	14.17	27.04	26.09	24.48
Home Ownership Rate							
Model (benchmark)	0.648	0.753	0.768	0.920	0.534	0.724	0.751
Housing adjustment cost=0	0.808	0.912	0.823	0.923	0.831	0.908	0.826
Minimum housing=0	0.931	0.934	0.975	0.977	0.782	0.915	0.964
Homeowner's utility gain=0	0.501	0.729	0.764	0.912	0.450	0.668	0.746

Notes: This table reports life expectancy and home ownership rates when one housing market frictions are removed at a time.

Compared to the benchmark case where the housing adjustment cost is $\lambda = 0.054$, both the life expectancy and the home ownership rate are higher for each group when we set $\lambda = 0$. As

noted in the literature, the adjustment cost makes the adjustment lumpy. In the context of our model, individuals economize on housing adjustment costs either by suppressing medical expenditures or exiting the housing market to finance medical expenditures. The former reduces life expectancy and the latter decreases home ownership rates. These effects are removed when the adjustment cost is set to zero.

The impacts of removing adjustment costs are unequal, most significant in tier-one cities and least significant in rural areas, which widens the rural-urban gap in life expectancy. The removal of adjustment costs has a greater impact in larger cities because the Yuan amount of housing adjustment costs is higher in larger cities where housing values are higher, increasing home ownership rates more. This, in turn, generates an even larger housing wealth effect in larger cities, further increasing life expectancy in these cities.

Setting the minimum housing size to zero (i.e., $\underline{DP} = 0$) significantly increases the home ownership rate, and it decreases life expectancy except for the rural group, as shown in Table 15. The removal of minimum housing size removes a large entry barrier, thus increasing home ownership rates and generating more housing wealth effect. However, home ownership comes with adjustment costs and the need to economize on health expenditures in order to avoid adjustment costs. As a result, life expectancy is decreased in cities, especially in tier-one and tier-two cities where home ownership rates are low in the benchmark model. However, life expectancy increases slightly in rural areas, indicating a stronger housing wealth effect relative to the costs associated with home ownership.

Setting the homeowner's utility gain ϕ to zero decreases home ownership rates, especially in tier-one cities. As shown in the initial wealth distribution (Table 9), tier-one city retirees own significantly more housing wealth than other groups, so they need to economize more on health expenditures in order to keep the home ownership status and avoid adjustment costs. With the removal of homeowner's utility gain, they have significantly less incentive to own homes, which has two effects. Firstly, it reduces the need to economize on health expenditure, thereby increasing life expectancy. Secondly, it decreases the housing wealth effect, which decreases health expenditure and life expectancy. Because of these two opposing effects, setting the homeowner's utility gain to zero has a marginal impact on life expectancy.

7 Socioeconomic Factors and Inequality

This section turns to a key question in our study – what drives the large inequality in life expectancy at age sixty in China? To assess the contributing role of each of the six heterogeneous socioeconomic factors introduced in Section 5, we keep the heterogeneity of only one factor at a time, while turning off the heterogeneity of all other factors. This approach allows us to gauge how much of the inequality in life expectancy can be driven by one single heterogeneous

socioeconomic factor.

We use the rural residents as the base group, turning off heterogeneity by imposing the socioeconomic factors of the rural residents on other groups. By design, this controlled experiment changes the life expectancy of all the groups except the base group, i.e., the rural group. There is a caveat in interpreting the results of these experiments – the results will be different if we use a different base group.

We begin with the heterogeneous initial health, i.e., the within-group distribution of health status at age 60, which differs across groups as illustrated in Figure 2, turning off the remaining heterogeneity. As shown in the second row of Table 16, the heterogeneity in initial health contributes only marginally to the inequality in life expectancy. With all the other heterogeneity turned off, the life expectancy of urban retirees is only 0.11 years higher than that of the rural group. Evidently, even some groups of urban residents are healthier on average at retirement, this initial difference has a very small effect on the overall inequality in life expectancy.

Table 16: Contributing Factors of Inequality in Life Expectancy

	Private sector				Public sector			T1 pub	urban	public
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3	-rural	-rural	-private
(1) Model (benchmark)	24.06	23.59	18.30	14.16	27.22	25.78	24.46	13.07	9.74	3.84
(2) Hetero initial health	14.31	14.26	14.23	14.16	14.27	14.25	14.27	0.11	0.11	-0.01
(3) Hetero initial wealth	17.09	16.71	15.13	14.16	18.12	17.51	15.49	3.97	2.52	0.73
(4) Hetero income	24.16	17.94	17.05	14.16	25.99	18.66	17.63	11.83	6.08	1.04
(5) Hetero housing cost	12.35	12.67	12.79	14.16	12.35	12.67	12.79	-1.81	-1.56	0.00
(6) Hetero income & housing cost	15.35	14.02	14.21	14.16	17.62	14.49	14.52	3.47	0.88	1.02
(7) Hetero housing inv. market	21.97	18.52	14.91	14.16	21.97	18.52	14.91	7.82	4.31	0.00
(8) Hetero OOP medical cost	17.86	17.05	16.32	14.16	21.17	18.54	18.18	7.01	4.03	2.22

Notes: This table reports life expectancy at sixty years of age for the seven groups in the benchmark model and from the experiments. In the row of "Hetero initial health", groups differ only in the health distribution at retirement. Other rows are similarly defined. "T1 $pub - rural$" is the difference in life expectancy between public sector retirees in tier-one cities and rural residents."$rural - urban$" shows the difference in life expectancy between the averages of urban retirees and the rural residents, and the "$public - private$" shows the difference between the average of the public sector retirees and the average of the private sector retirees.

Next, we turn to the heterogeneous initial wealth. As reported earlier in Table 9, urban residents, especially those of large cities, are significantly wealthier than rural residents at retirement. The third row of Table 16 indicates this initial wealth inequality is translated into noteworthy inequality in life expectancy. For instance, it leads to a gap in life expectancy of about 4 years between rural residents and tier-one city retirees from the public sector. In larger cities, retirees live longer partly because they are wealthier at retirement. Public sector retirees live 0.73 years longer than private sector retirees in this controlled experiment, reflecting the fact that they are wealthier at retirement.

Income heterogeneity turns out to be the most important driver of inequality in life expectancy. As shown in the fourth row of Table 16, solely driven by income heterogeneity, the difference between tier-one city public sector retirees and rural residents is 11.83 years, while

the difference is 13.7 years in the benchmark model where all types of heterogeneity exist. The average rural-urban gap is 6.08 years, which is 62% of the gap of 9.74 years in the benchmark model. The income heterogeneity also leads to a gap of about one year between the public and the private sectors.

In the heterogeneous housing cost experiment, life expectancy is the highest among rural residents, and the lowest in tier-one cities. The rural-urban gap is non-trivial – 1.56 years on average. As we demonstrate in the simple static model, the effect of housing costs on health investment depends critically on the elasticity of substitution between consumption and health in the utility function. Our estimated elasticity of $\eta = 0.475$ implies it is not optimal for large city residents to take better health as a substitute for the costly housing consumption. Thus, everything else equal, they invest less in health to support housing consumption, which lowers their life expectancy.

We also conduct an experiment where both income and housing costs are heterogeneous while the remaining heterogeneity is turned off. This is motivated by the urban economics theory that higher income in larger cities is a compensation for the higher housing costs in a spatial equilibrium. As shown in the sixth row of Table 16, on average, city residents live 0.88 years longer than rural residents at age sixty, indicating their income slightly over-compensates the high housing costs once life expectancy is taken into account in the context of a spatial equilibrium. The over-compensation is more significant among tier-one city residents who outlive rural residents by 3.47 years. Tier-two city residents are slightly outlived by tier-three city residents, indicating their housing costs are under-compensated. It should be noted that, in the context of a simple spatial equilibrium in the absence of friction, residents in different cities enjoy the same level of utility. In reality, various forms of migration costs exist. In particular, the Hukou system in China creates barriers for individuals to relocate between cities. Therefore, the large inequality in life expectancy driven by heterogeneous income and housing costs might be indicative of highly unequal levels of utility cross-sectionaly.

When the housing investment market is the only source of heterogeneity, tier-one city residents outlive rural residents by 7.82 years, indicating a large wealth effect of house price appreciation on life expectancy. The rural-urban gap is also large – 4.31 years, which is 44% of the rural-urban gap of 9.74 in the benchmark model. House price appreciation rate is significantly higher in tier-one cities than tier-three cities, which is translated into a gap of more than 7 years in life expectancy. The large role played by the heterogeneous housing investment market is hardly surprising given the dominating importance of housing in total wealth in China, and the large cross-region difference in house price appreciation.

Lastly, as shown in the eighth row, when the OOP share in total medical expenditure is the only source of heterogeneity, tier-one city retirees from the public sector, the most advantaged group in terms of OOP share, outlive rural residents, the most disadvantaged group, by 7.01

years. On average, the rural-urban gap is 4.03 years. Thus, we conclude that rural residents' poor medical insurance coverage is an important determinant of their low life expectancy. The public sector retirees outlive the private sector counterpart by 2.22 years, 57.7% of the gap of 3.84 in the benchmark model, i.e., the better medical insurance coverage in the public sector is the most important determinant of the public-private gap.

8 Counterfactual Experiments

Using the estimated model, we conduct counterfactual experiments to show how medical expenditures and life expectancy are impacted differently among the seven groups of individuals by a 30% decline in house price, a more generous coverage of publicly funded medical insurance, and an equalization of medical insurance coverage to the level enjoyed by retirees of the public sector of tier one city. The decline in house prices assumed in the first experiment is an ongoing predicament in the Chinese economy.[23] We gain insight into its impacts on health expenditures and life expectancy through the lens of our model. The last two experiments regarding the coverage of medical insurance provide an analysis on the effectiveness of medical insurance reforms aiming to further increase the level of insurance coverage and to decrease inequality.

8.1 Medical Expenditures

This subsection reports the responses in medical expenditures to an experimental change. The responses depend on the state variables of each individual. Because individuals are distributed in state space, their responses are highly heterogeneous. We aggregate these responses based on the distribution of individuals in state space and report the average responses of the seven groups.

We report both the contemporaneous and long-term effects. To compute the contemporaneous effects, we use the distribution of individuals prior to the experimental changes. For the long-term effects, we re-simulate the economy to obtain the new distribution of individuals in the state space, which captures the long-term effect of individuals' re-optimization. Essentially, the long-term effects reflect the new economy where all the pre-experiment retirees have died and left the economy[24]

Table 17 reports the percentage changes in total medical expenditures and OOP medical expenditures. As the table shows, the decline in house prices has a large negative effect on

[23]China's housing market decline might be even more serious than official data suggest. See the Bloomberg report https://fortune.com/2023/08/17/china-home-sales-worse-than-official-data-real-estate-crisis/.

[24]The new distribution depends on the distribution of health and wealth at the initial age, i.e., age sixty. We use the same initial distribution as in the benchmark model, then simulate forward to generate a new distribution for individuals at each age.

Table 17: Percentage Changes in Medical Expenditures

	Private sector				Public sector		
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3
House price decline (30%)							
Total medical exp. *contempo.*	-33.52	-35.46	-28.51	-60.60	-22.48	-26.08	-15.16
long-term	-8.43	-12.47	-12.88	-44.64	-2.49	-10.99	-10.06
OOP medical exp. *contempo.*	-29.86	-31.30	-26.06	-52.42	-18.46	-22.37	-12.49
long-term	-7.85	-9.81	-10.29	-36.66	-2.63	-8.71	-5.39
OOP **share decline** (30%)							
Total medical exp. *contempo.*	106.67	114.44	57.73	201.87	82.79	90.32	110.67
long-term	23.96	27.35	16.56	87.61	5.48	25.26	22.37
OOP medical exp. *contempo.*	44.47	47.26	7.96	92.59	27.47	35.54	45.57
long-term	-14.24	-12.58	-20.66	21.79	-24.46	-13.60	-15.32
OOP **share equalization**							
Total medical exp. *contempo.*	104.92	143.06	136.02	665.94	0.00	55.26	95.60
long-term	29.08	30.95	35.70	264.60	0.00	16.51	19.49
OOP medical exp. *contempo.*	39.64	44.06	18.78	178.38	0.00	19.27	34.51
long-term	-15.06	-24.37	-31.03	34.25	0.00	-14.13	-15.85

Notes: This table reports the percentage changes of medical expenditures in response to each of the three experimental changes. *contempo.* represents the contemporaneos changes.

medical expenditures for each group. This is a typical (negative) housing wealth effect. The large effect is not surprising given the concentration of wealth in the housing market among the individuals we study. The effect is strongest among rural residents: total medical expenditures and OOP expenditures are contemporaneously decreased by 60. 6% and 52. 42%, reflecting the fact that rural residents have the highest home ownership rate among the seven groups. A comparison between contemporaneous and long-term effects reveals that the negative impacts of a drop in house price are mitigated in the long term and the mitigation is significant. For instance, the total medical expenditures of tier-one private sector retirees drop by 33.52% contemporaneously, but decrease by 8.43% in the long-term. The significantly mitigated long-term effects indicate that individuals partly rebuild their wealth through savings after they suffer the 30% loss in housing wealth.

The decline of the OOP share by 30% effectively lowers the price of medical expenditure, which tilts the allocation of resources towards health. As a result, the contemporaneous medical expenditures increase drastically. The increases are most significant among the rural group, the group that faces the highest OOP share and spends the least on health prior to the experimental change.

The decline of the OOP share has quite different long-term impacts relative to the contemporaneous effects. For total medical expenditures, the drastic contemporaneous increase is significantly mitigated in the long term. For the OOP expenditure, the drastic contemporaneous increase is reversed except for the rural group, the group that spends much less on health than the other groups prior to the experiment. The contrast between the contemporaneous and the long-term effects clearly indicates the improvement in health status, which reduces medical expenditures in the long run.

The third experiment, i.e., equalization of the OOP share to the level of tier-one city public sector retirees who have the lowest OOP share, is designed to further assess the role played by the unequal OOP share in shaping the inequality in life expectancy. As the bottom block of Table 17 shows, each group of individuals significantly increase their contemporaneous total medical expenditures as well as the OOP expenditures, except the tier-one city public sector group whose OOP share remains unchanged. The effects are stronger among groups whose pre-experiment OOP share is higher, i.e., private sector retirees in tier-two and tier-three cities. The effects are the strongest among the rural residents, the group that faces the highest OOP share prior to the experimental change. The contemporaneous increase of total medical expenditure among the rural group is a staggering 665.94%, reflecting the large pre-experiment gap in the OOP share between the rural group and the tier-one city public sector retirees.

The effects of the equalization of the OOP share on total medical expenditures are also significantly mitigated in the long term. For the OOP medical expenditure, the effects of equalization are again reversed except for the rural group.

Table 18: Changes in Life Expectancy (years)

	Private sector				Public sector		
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3
House price decline (30%)	-0.81	-2.79	-1.97	-0.87	-0.09	-1.41	-3.23
OOP share decline (30%)	1.40	1.59	4.92	2.61	1.14	1.58	1.58
OOP share equalization	2.36	3.51	7.16	7.01	0.00	1.83	1.77

Notes: This table reports the long-term changes in life expectancy in response to each of the three experimental changes.

8.2 Life Expectancy

Table 18 reports the long-term changes in life expectancy after the experimental changes. We do not report the contemporaneous effect because it is zero by construction – changes in medical expenditures do not affect contemporaneous mortality.

As the table indicates, the drop in house price reduces life expectancy for each of the seven groups, and the effects are stronger among tier-two and tier-three retirees, ranging between 1.41 and 3.23 years. The impacts are the mildest among tier-one city retirees, because they are groups in better financial conditions and their home ownership rates are the lowest. The impact on the rural group is relatively mild, a 0.87-year decline, despite the fact that rural residents cut the medical expenditures the most. This is a result of the non-linearity in health transition – an individual's health stock in our model is a combination of the exogenous transition and the endogenous medical expenditures. When medical expenditures are near zero, the exogenous transition is the key determinant of health, and further cutting the endogenous expenditures decreases health only marginally.

The decline in *OOP* share by 30% leads to nontrivial increases in life expectancy. The most significant effect, an increase of 4.92 years, is observed among tier-three city private sector retirees. Within each city tier, private sector retirees gain more than their public sector counterparts, which is because their pre-experiment *OOP* share is larger. The life expectancy of the rural group increases by 2.61 years.

The effects of equalization by imposing the *OOP* share of the tier-one city public sector retirees on the other groups are more significant. For private sector retirees, the life expectancy is increased by 2.36-7.16 years. Life expectancy of public sector retirees increases by 1.83 years in tier-two cities and 1.77 years in tier-three cities. The gain is larger among retirees in the private sector simply because their *OOP* share is cut more to reach the level of tier-one city public sector retirees. The life expectancy of rural residents increases by 7.01 years.

In addition, we examine how the inequality in life expectancy is changed in these experiments. As shown in Table 19, the house price decline narrows the rural-urban gap, although

it increases the gap between the rural group and the tier-one city public sector retirees. The decline in house prices widens the public-private gap from 3.84 years in the benchmark model to 4.12 years. It also significantly widens the gap between tier-one and tier-three cities. In general, the drop in house prices leads to more unequal life expectancy across urban groups, because wealthier individuals, especially tier-one city public sector retirees, are able to better mitigate the impact of the house price drop on medical expenditures.

Table 19: Inequality in Life Expectancy

	Private sector				Public sector			T1 pub	urban	public
	tier 1	tier 2	tier 3	rural	tier 1	tier 2	tier 3	-rural	-rural	-private
Model (benchmark)	24.06	23.59	18.30	14.16	27.22	25.78	24.46	13.07	9.74	3.84
House price decline	23.25	20.80	16.33	13.29	27.14	24.36	21.23	13.85	8.90	4.12
OOP share decline	25.47	25.17	23.21	16.77	28.36	27.36	26.05	11.59	9.17	2.64
OOP share equal.	26.43	27.10	25.46	21.17	27.22	27.61	26.23	6.06	5.51	0.69

Notes: This table reports life expectancy at sixty years of age for the seven groups in the benchmark model and from the experiments. "T1 $pub - rural$" is the difference in life expectancy between public sector retirees in tier-one cities and rural residents."$rural - urban$" shows the difference in life expectancy between the averages of urban retirees and the rural residents, and the "$public - private$" shows the difference between the average of the public sector retirees and the average of the private sector retirees.

The universal decline of the OOP share by 30% narrows both the rural-urban gap and the public-private gap. It also narrows the gap between city tiers. The heterogeneous effects of a universal decline in the OOP share result from the diminishing marginal product of health investment, which is captured by the curvature parameter ψ in our health production function.

The equalized OOP share also narrows the between-group gaps in life expectancy, and the effects are significantly stronger than the universal decline in the OOP share. It nearly eliminates the public-private gap and brings the gap between city tiers below one year. It also narrows the rural-urban gap from 9.74 years to 5.51 years.[25] The remaining gap indicates rural residents' disadvantageous position in income and wealth takes a toll on their life expectancy.

The last two experiments have important implications for policies designed to reduce inequality in life expectancy. A universal decline in the OOP share can reduce the inequality without receiving push-backs from the public sector retirees or employees who are enjoying more generous medical insurance coverage. However, inequality remains large under this type of policy. An equalized OOP share can almost eliminate the inequality in life expectancy among urban residents, and it is also an effective policy to reduce the rural-urban gap. If the policy

[25]It is noteworthy that the life expectancy is 21.17 years among rural residents after imposing the OOP share of tier-one city public sector retirees on rural residents, which is identical to the life expectancy of tier-one city public sector retirees in the case of OOP share heterogeneity reported in Table 16.

goal is to also eliminate the rural-urban gap, then rural residents need to be further subsidized.

9 Conclusion

We have presented data facts on heterogeneous mortality rates among retirees from different sectors in different tiers of cities, as well as rural residents. Because of the heterogeneous mortality rates, life expectancy is higher among public sector retirees, and it is higher in tier-one cities and the lowest among rural residents. These salient data features are endogenously generated in our dynamic model with endogenous health investment and housing investment that incorporates cross-sectional heterogeneity in terms of health and wealth at retirement, post-retirement income and housing costs, housing investment markets, and out-of-pocket medical expenditures.

Based on the structurally estimated model parameters, we show that the most important contributor to the overall inequality in life expectancy is the heterogeneity in post-retirement income. Heterogeneity in the out-of-pocket medical expenditures explains a large fraction of the inequality between the private sector and the public sector. Heterogeneity in housing investment return is an important driver of the rural-urban gap in life expectancy as well as the inequality in life expectancy between different tiers of cities.

Our results indicate that larger city residents tend to invest more in health due to their higher income and larger wealth accumulation on the one hand, but they tend to invest less in health because of the higher housing costs on the other hand. The former effect tends to be stronger in China as retirees in larger cities live longer in the data as well as in our model.

Counterfactual experiments show that a drop in house prices has a negative effect on life expectancy, and the effect is stronger among retirees in tier-two and tier-three cities. The drop in house prices tends to increase the inequality in life expectancy among urban retirees. A universal decline in the out-of-pocket share in total medical expenditures increases total medical expenditures significantly, but it tends to lower the out-of-pocket expenditures in the long term. The decline in out-of-pocket share increases life expectancy significantly – a 30% decline increases life expectancy by 4.92 years among private sector retirees in tier-three cities. It also reduces the inequality in life expectancy because private sector retirees and rural residents gain more from the smaller out-of-pocket share. Finally, the equalization of medical insurance coverage between groups has a large effect on life expectancy, both in terms of level and inequality. It nearly eliminates the inequality among urban retirees and narrows the rural-urban gap in life expectancy by nearly 50%.

Our results are based on a model in which the publicly funded health care is exogenous. It should be interesting to extend our current model such that the publicly funded health care is endogenous, funded by the tax revenue. Such a framework would be suitable for a quantitative

study of the welfare effects of the publicly funded health care system. Another interesting extension of our study is to include pre-retirement health decisions, including the choice of time investment in health. The allocation of time between health investment and work could be particularly important in light of the rising incidents of work-related diseases and deaths.[26]

The inequality in life expectancy studied in our paper has important implications on the pricing of insurance products such as life insurance and annuity. Because the pricing of these products is contingent on life expectancy, a natural question to ask is whether the pricing should be contingent on city tiers and sectors of employment in China. We leave the explorations to future studies.

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[26] See the report of the World Health Organization: https://www.who.int/news/item/17-05-2021-long-working-hours-increasing-deaths-from-heart-disease-and-stroke-who-ilo.

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A Evolution of Health Care System

We summarize the evolution of the health care system in China in Figure A.1. As the figure illustrates, China's health care system consisted of three types of schemes in the pre-reform era. The first type was the Free Medical Service available to government employees and retirees, a non-contributory scheme that covers almost 100 percent of medical costs. The second type was the Labour Medical Insurance Scheme for employees and retirees of the state-owned and collectively owned enterprises. Because it was mostly funded by the enterprises with limited subsidy from regional governments, the coverage of the Labour Medical Insurance Scheme differed by region, province, and enterprise, and it was much less generous compared with the Free Medical Service. The third type was the Rural Co-op Medical Scheme, which provided basic coverage to rural residents.[27] There existed a small fraction of self-employed or unemployed urban residents who received no medical insurance coverage. Overall, this health care system in the pre-reform era featured large inequality among the three types.

While this basic structure remained mostly unchanged until the end of the 1990s, inequality in health care coverage increased significantly in the same period of time. This is because a large fraction of urban residents lost their Labour Medical Insurance due to the privatization of small state-owned and collectively-owned enterprises, and because the majority of rural residents dropped out of the Rural Co-op Medical Scheme.[28] The Urban Private sector grew tremendously during this period of time, but employees in the private firms and the self-employed were still completely excluded from the publicly funded health care system.

As shown in Figure A.1, in 1998, the Chinese government started to merge the Free Medical Service and the Labour Medical Insurance Scheme into one single insurance plan for all the employed urban residents, namely, the Urban Employee Basic Medical Insurance (UEBMI).[29] This is a contributory scheme that typically requires 6% contributions from employers and 2% contributions from employees, while the contribution percentages are subject to the discretion of regional governments. The UEBMI funds are mostly administered at the prefecture level, while the goal set by the central government is to administer the funds at the provincial level.[30] The reform is still on-going as government employees still receive various subsidies that are not

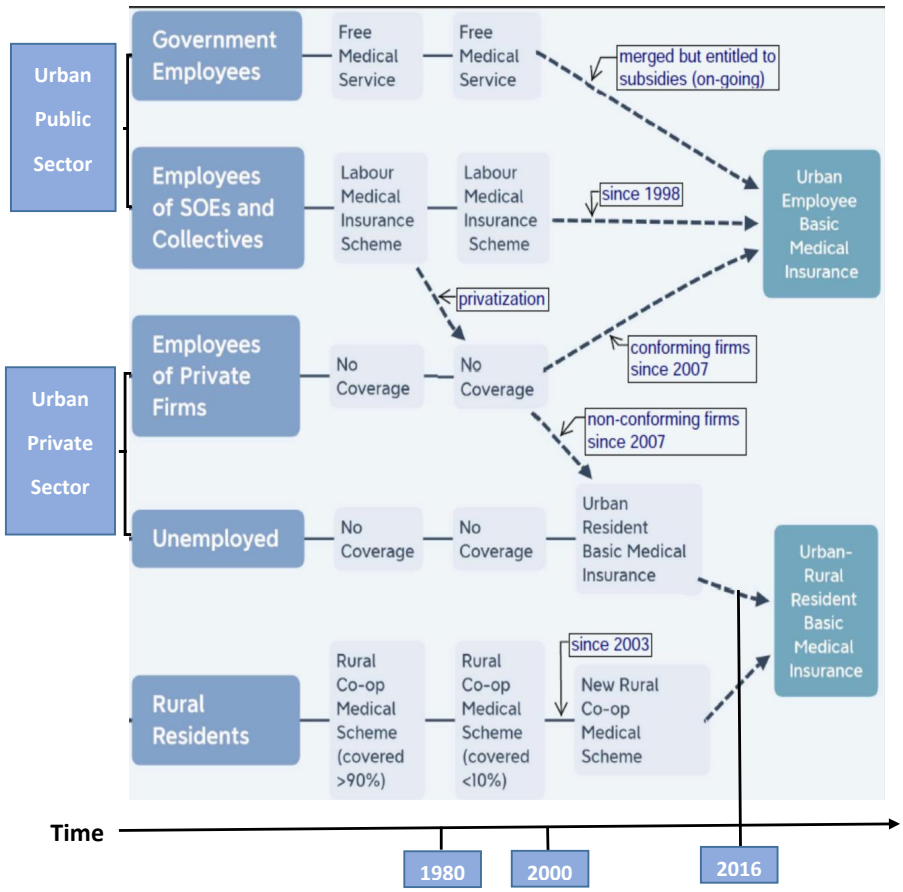
[27] The Rural Co-op Medical scheme consisted of three tiers of medical facilities: village health stations, township health centers, and county hospitals. A village health station was funded by the village administration and by premiums paid by villagers. Township and county hospitals were funded by subsidies from the corresponding regional governments and revenues generated by the services they provided. See Liu et al. (1995).

[28] Transition of the health care system in rural China up to 1990s is well described in Liu et al. (1995), and the transition in urban China in the same period of time is discussed in Grogan (1995).

[29] A decisive document is "*Decision of the State Council on Establishing a Basic Medical Insurance System for Urban Employees*" issued by the State Council in 1998 (https://www.gov.cn/banshi/2005-08/04/content_20256.htm).

[30] https://www.gov.cn/zhengce/content/2021-06/17/content_5618799.htm.

Figure A.1: Evolution Health Care System in China



Note: The figure illustrates the evolution of the health care system in China.

accessible to ordinary UEBMI enrollees.[31]

In principle, private sector employees should also enroll in the UEBMI. However, in reality, many small private enterprises choose not to conform to the governmental policy.[32] As a result these private sector employees were uninsured until 2007, when the State Council commenced the Urban Residence Basic Medical Insurance (URBMI).[33] The URBMI provides coverage to unemployed urban residents as well as minors and the elderly. It is jointly funded by the central government through earmarked transfers, the regional government, and the premium payments

[31] As stated explicitly in the document jointly issued to provincial governments in 2000 by the Ministry of Labour and Social Security and the Ministry of Finance, government civil servants should receive health care subsidies in addition to the coverage offered by UEBMI (https://www.gov.cn/gongbao/content/2000/content_60249.htm).

[32] Private sector employers tended to use loopholes or outright evasion to avoid making contributions for their employees until the recent few years.

[33] The commencement of the URBMI was marked by the issuance of "*Guiding Opinions on Carrying out the Pilot Program of Basic Medical Insurance System for Urban Residents*" (https://www.gov.cn/gongbao/content/2007/content_719882.htm).

of enrollees. A large fraction of private sector employees not covered by the UEBMI choose to enroll in the URBMI.

Another major achievement in health care reform is the establishment of the New Rural Co-op Medical Scheme (NRCMS) which provides coverage for rural residents, jointly funded by the central government, regional governments, and the premium payments of enrollees. The NRCMS started in 2003.[34] Within 10 years, the NRCMS covered 99% of rural residents in China.[35]

Since 2016, the central government started to integrate URBMI and NRCMS into Urban and Rural Resident Basic Medical Insurance (URRBMI). As Figure A.1 indicates, after the integration, the current health care system in China includes two major types: the URRBMI and the UEBMI, applicable to non-retirees as well as retirees.

B Appendix Tables

B.1 City Tiers

Table B.1 shows lists of tier-one, tier-two, and tier-three cities.

B.2 Self-reported Health Status

To gauge the objectivity of the self-reported health status, we run an ordered Probit regression of self-reported health status on various diseases and disabilities. Table B.2 reports the results of the validation check. The diseases and disabilities all show significantly negative correlations with self-reported health status, indicating good reliability and validity of the self-reported health status.

B.3 Out-of-pocket Share (Tobit)

Our baseline regression estimates OOP share by OLS. For robustness, we re-run regressions using the Tobit model. Table B.3 reports the results. Again, retirees from the public sector enjoy a much lower OOP share than the other groups.

[34] The inception of the NRCMS is the issuance of "*Opinions of the Ministry of Health, the Ministry of Finance and the Ministry of Agriculture on the Establishment of a New Rural Cooperative Medical System*" (https://www.gov.cn/zwgk/2005-08/12/content_21850.htm).

[35] https://www.gov.cn/xinwen/2014-05/26/content_2686847.htm

Table B.1: City List

province	city	tier	province	city	tier	province	city	tier
Shanghai	Shanghai	1	Yunnan	Lincang	3	Jiangsu	Taizhou	3
Beijing	Beijing	1	Yunnan	Lijiang	3	Jiangsu	Yancheng	3
Guangdong	Shenzhen	1	Yunnan	Baoshan	3	Jiangsu	Lianyungang	3
Guangdong	Guangzhou	1	Yunnan	Zhaotong	3	Jiangxi	Shangrao	3
Tianjin	Tianjin	2	Neimenggu	Xingan	3	Jiangxi	Jiujiang	3
Yunnan	Kunming	2	Neimenggu	Hulunbeidong	3	Jiangxi	Jian	3
Sichuan	Chengdong	2	Neimenggu	Huhehaote	3	Jiangxi	Jingdezhen	3
Shandong	Jinan	2	Neimenggu	Chifeng	3	Jiangxi	Ganzhou	3
Shandong	Qingdao	2	Neimenggu	Xilinguole	3	Hebei	Cangzhou	3
Guangdong	Foshan	2	Jilin	Jilin	3	Henan	Xinyang	3
Guangxi	Nanning	2	Jilin	Siping	3	Henan	Zhoukou	3
Jiangsu	Suzhou	2	Sichuan	Liangshan	3	Henan	Luoyang	3
Jiangxi	Nanchang	2	Sichuan	Yibin	3	Henan	Puyang	3
Hebei	Shijiazhuang	2	Sichuan	Meishan	3	Henan	Jiaozuo	3
Henan	Zhengzhou	2	Sichuan	Mianyang	3	Zhejiang	Taizhou	3
Zhejiang	Ningbo	2	Sichuan	Ziyang	3	Zhejiang	Jiaxing	3
Zhejiang	Hangzhou	2	Anhui	Bozhou	3	Zhejiang	Huzhou	3
Hunan	Changsha	2	Anhui	Liuan	3	Hubei	Dongshi	3
Fujian	Fuzhou	2	Anhui	Suzhou	3	Hubei	Jingmen	3
Liaoning	Dalian	2	Anhui	Chaohu	3	Hubei	Xiangfan	3
Zhongqing	Zhongqing	2	Anhui	Huainan	3	Hubei	Huanggang	3
Heilongjiang	Hadongbin	2	Shandong	Linyi	3	Hunan	Loudi	3
Heilongjiang	Hadongbin	2	Shandong	Weihai	3	Hunan	Yueyang	3
			Shandong	Dezhou	3	Hunan	Changde	3
			Shandong	Zaozhuang	3	Hunan	Yiyang	3
			Shandong	Weifang	3	Hunan	Shaoyang	3
			Shandong	Liaocheng	3	Gansu	Lanzhou	3
			Shanxi	Linfen	3	Gansu	Dingxi	3
			Shanxi	Xinzhou	3	Gansu	Zhangye	3
			Shanxi	Yuncheng	3	Fujian	Zhangzhou	3
			Guangdong	Jiangmen	3	Guizhou	Qiandongnan	3
			Guangdong	Qingyuan	3	Guizhou	Qiannan	3
			Guangdong	Chaozhou	3	Liaoning	Benxi	3
			Guangdong	Maoming	3	Liaoning	Jinzhou	3
			Guangxi	Guilin	3	Liaoning	Anshan	3
			Guangxi	Yulin	3	Shanxi	Baoji	3
			Xinjiang	Akesu	3	Shanxi	Yulin	3
			Jiangsu	Suqian	3	Shanxi	Hanzhong	3
			Jiangsu	Xuzhou	3	Heilongjiang	Jiamusi	3
			Jiangsu	Yangzhou	3	Heilongjiang	Jixi	3
						Heilongjiang	Qiqihadong	3

Table B.2: Health Validation Checks

	(1) health		(2) health		(3) health	
Physical Disabilities	-0.526***	(0.04)	-0.457***	(0.04)	-0.451***	(0.04)
Brain Damage/Mental Retardation	-0.519***	(0.05)	-0.287***	(0.05)	-0.303***	(0.05)
Vision Problem	-0.398***	(0.03)	-0.262***	(0.04)	-0.238***	(0.04)
Hearing Problem	-0.377***	(0.03)	-0.262***	(0.03)	-0.204***	(0.03)
Speech Impediment	-0.338***	(0.12)	-0.346***	(0.12)	-0.354***	(0.12)
Hypertension			-0.260***	(0.02)	-0.230***	(0.02)
Dyslipidemia			-0.088***	(0.03)	-0.095***	(0.03)
Disabetes or High Blood Sugar			-0.397***	(0.03)	-0.389***	(0.03)
Cancer or Malignant Tumor			-0.602***	(0.09)	-0.605***	(0.09)
Chronic Lung Diseases			-0.327***	(0.03)	-0.302***	(0.03)
Liver Disease			-0.285***	(0.04)	-0.293***	(0.04)
Heart Problems			-0.438***	(0.02)	-0.422***	(0.02)
Stroke			-0.553***	(0.06)	-0.529***	(0.06)
Kidney Diease			-0.341***	(0.03)	-0.352***	(0.03)
Stomach or Other Digestive Disease			-0.418***	(0.02)	-0.428***	(0.02)
Emotional, Nervous, or Psychiatric Problems			-0.521***	(0.07)	-0.526***	(0.07)
Memory-Related Disease			-0.336***	(0.08)	-0.272***	(0.08)
Arthritis or Rheumatism			-0.387***	(0.02)	-0.380***	(0.02)
Asthma			-0.338***	(0.05)	-0.314***	(0.05)
Age					0.115***	(0.02)
Age-squared					-0.017	(0.01)
/						
cut1	-5.571***	(0.26)	-14.767***	(0.39)	-14.374***	(0.39)
cut2	-4.752***	(0.26)	-13.878***	(0.39)	-13.480***	(0.39)
cut3	-3.674***	(0.26)	-12.677***	(0.38)	-12.275***	(0.38)
cut4	-2.450***	(0.26)	-11.291***	(0.38)	-10.886***	(0.38)
Observations	19883		19883		19865	

Notes: This table reports the ordered probit regression model to estimate how self-reported health status depends on disabilities, diseases, and other variables. Robust standard errors are in parentheses. Age is defined as (actual age - 60)/10. Significance * .10, ** .05, *** .01.

Table B.3: Out-of-pocket Expenditure Share: Tobit

	(1)		(2)		(3)	
OOP share						
Age	-0.038	(0.034)	-0.026	(0.033)	-0.125***	(0.042)
Age-squared	-0.089***	(0.018)	-0.083***	(0.018)	-0.046**	(0.023)
Health: 1 Very poor	0.503***	(0.050)	0.396***	(0.050)	0.316***	(0.059)
Health: 2 Poor	0.584***	(0.033)	0.503***	(0.032)	0.440***	(0.038)
Health: 4 Good	-0.813***	(0.044)	-0.760***	(0.043)	-0.754***	(0.050)
Health: 5 Very good	-1.138***	(0.054)	-1.128***	(0.053)	-1.065***	(0.064)
Health: 1 Very poor × Age	0.011	(0.051)	0.000	(0.050)	-0.024	(0.064)
Health: 2 Poor × Age	-0.067**	(0.032)	-0.079**	(0.032)	-0.041	(0.040)
Health: 4 Good × Age	0.224***	(0.044)	0.199***	(0.043)	0.161***	(0.055)
Health: 5 Very good × Age	0.187***	(0.056)	0.198***	(0.055)	0.203***	(0.070)
City: 1st tier (private)			-0.570***	(0.084)	-0.584***	(0.109)
City: 2nd tier (private)			-0.503***	(0.047)	-0.425***	(0.060)
City: 3rd tier (private)			-0.369***	(0.031)	-0.251***	(0.039)
City: 1st tier (public)			-0.975***	(0.105)	-1.010***	(0.139)
City: 2nd tier (public)			-0.691***	(0.057)	-0.637***	(0.068)
City: 3rd tier (public)			-0.634***	(0.043)	-0.544***	(0.052)
ln Income					-0.002	(0.005)
ln Wealth					-0.051***	(0.009)
Housing share					-0.122	(0.078)
Constant	0.817***	(0.031)	1.085***	(0.033)	1.732***	(0.117)
/						
var(e.shareofp)	2.127***	(0.055)	2.043***	(0.053)	1.917***	(0.061)
Observations	19111		19111		12509	

Notes: This table reports the regression model to estimate how the out-of-pocket expenditure share depends on health status, age and its interaction with health status, and other variables. Age is defined as (actual age - 60)/10. Robust standard errors are in parentheses. Significance * .10, ** .05, *** .01.

C Details on the Static Model

The appendix shows details on the derivations of results from the static model in Section 4.1.

C.1 Health Investment

In the optimization problem given by equations (5)-(6) in Section 4.1, the optimal allocation between consumption and health investment satisfies

$$(1-\xi) = \frac{u_H}{u_C}, \tag{22}$$

where u_H and u_C are the marginal utility of health and consumption, respectively. Using the utility function given by equation (6), we have the following expressions for the marginal utilities:

$$\begin{aligned} u_C &= (1-\alpha)\left(\frac{\xi}{(1-\xi)q}\right)^{\xi(1-\frac{1}{\eta})} C^{-\frac{1}{\eta}} \left[(1-\alpha)\left(\frac{\xi}{q(1-\xi)}\right)^{\xi(1-1/\eta)} C^{1-1/\eta} + \alpha H^{1-1/\eta}\right]^{\frac{1}{\eta-1}}, \\ u_H &= \alpha H^{-\frac{1}{\eta}} \left[(1-\alpha)\left(\frac{\xi}{q(1-\xi)}\right)^{\xi(1-1/\eta)} C^{1-1/\eta} + \alpha H^{1-1/\eta}\right]^{\frac{1}{\eta-1}}. \end{aligned}$$

Thus, we have

$$\frac{u_H}{u_C} = \frac{\alpha H^{-\frac{1}{\eta}}}{(1-\alpha)\left(\frac{\xi}{(1-\xi)q}\right)^{\xi(1-\frac{1}{\eta})} C^{-\frac{1}{\eta}}}. \tag{23}$$

Substitute equation (23) into equation (22), we obtain

$$(1-\xi) = \frac{\alpha}{1-\alpha}\left(\frac{q(1-\xi)}{\xi}\right)^{\xi(1-\frac{1}{\eta})}\left(\frac{C}{H}\right)^{\frac{1}{\eta}},$$

which is equivalent to

$$\frac{C}{H} = \left((1-\xi)\frac{1-\alpha}{\alpha}\right)^{\eta}\left(\frac{\xi}{1-\xi}\frac{1}{q}\right)^{\xi(\eta-1)}. \tag{24}$$

We substitute out C in equation (24) using the budget constraint of $C = (1-\xi)(y-H)$. After rearrangement, we obtain

$$H = \frac{y}{\left(\frac{1-\alpha}{\alpha}\right)^{\eta}\left(\frac{1}{\xi^{\xi}(1-\xi)^{1-\xi}}\right)^{1-\eta} q^{\xi(1-\eta)} + 1},$$

which is equation (7) in the main text.

C.2 Optimized Utility

Next, we derived the optimized utility (i.e., the indirect utility) in the static model. The utility function given by equation (6) can be written into

$$u(C,H) = \left[(1-\alpha)\left(\frac{\xi}{q(1-\xi)}\right)^{\xi(1-1/\eta)}\left(\frac{C}{H}\right)^{1-1/\eta}+\alpha\right]^{\frac{1}{1-1/\eta}}H,$$

which becomes the following after substituting out $\frac{C}{H}$ with the necessary condition of optimization given by equation (24)

$$u(C,H) = \left[(1-\alpha)\left(\frac{1-\alpha}{\alpha}\xi^{\xi}(1-\xi)^{1-\xi}\right)^{\eta-1}\left(\frac{1}{q}\right)^{\xi(\eta-1)}+\alpha\right]^{\frac{1}{1-1/\eta}}H. \tag{25}$$

When η approaches zero, the term in brackets of equation (25) becomes one because it is raised to the power of zero, thus

$$u^{\star} = \lim_{\eta\to 0} u(C^{\star},H^{\star}) = H^{\star}, \tag{26}$$

where we use $C^{\star}$ and $H^{\star}$ to denoted optimal consumption and health investment, and $u^{\star}$ is the optimized utility. Note that the optimal health investment when $\eta = 0$ is given by equation (9).

Given the spatial equilibrium condition that $u^{\star}$ should be the same across regions, equation (26) indicates $H^{\star}$ should also be the same across regions.

D Model Computation and Estimation

This appendix describes the computation and estimation of the structural model that generates results reported in Section 6.

The model is computed recursively through backward induction, starting from the bequest function. In each period, we search over the grid of state space to find the maximum of the value function and the corresponding policy functions. The policy functions are saved and used in the simulation.

For the grid of state space, we use 60 grid points for the bond and 90 grid points for the housing asset, and we use 5 grid points for health stock, which correspond to the five health statuses. We discretize the stochastic house price process using 3 states. Given that we have 7 groups in the model, overall, the grid space is $60 \times 90 \times 5 \times 3 \times 7$. The model is solved with Fortran parallel computing.

The structural parameters are estimated via the simulated method of moments. In total, there are 9 structural parameters, and the total number of moments is 18, corresponding to the regression coefficients reported in column (1) and column (2) of Table 10.

Given a set of parameters, we solve for policy functions and simulate the model to generate artificial data on health, death, home ownership, and portfolio composition. Then, we run regressions based on the simulated data to obtain the coefficients, naming them the simulated moments. The distance between the model and data is calculated as the Euclidean norm of the simulated moments and the data moments, which are coefficients in Table 10. We use the inverse of the variance of moments as the weighting matrix. Thus, moments with smaller variances receive more weight. We search for the parameters that minimize the distance using the Simplex algorithm.