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Modeling retirees' investment behaviors in the presence of health expenditure risk and financial crisis risk☆

Xiang Gao, Li Sun *

Research Center of Finance, Shanghai Business School, 2271 West Zhongshan Road, Shanghai, 200235, China

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ABSTRACT

This paper examines the impact of both health risks and financial market turmoil on individual investment decisions during retirement. Using a panel data set compiled from the U.S. Health and Retirement Survey, we find that health shocks increase retirees' disposable income uncertainty and compromise their risk-taking capacity. This is especially the case for those with moderate levels of wealth. However, we find that health risk alone cannot explain the empirically observed lower level of risky asset investment behaviors. It is the presence of extreme events in the financial markets, in combination with health risks, that significantly reduce retirees' incentives to invest in risky assets. Compared with younger investors, retirees' shorter investment horizon and higher health risks render them more vulnerable to the detrimental consequences of wealth evaporation caused by financial crises. Our results indicate that effective portfolio management for retirees must take into account both their health risks and the occurrence of financial market tail risks.

1. Introduction

According to conventional wisdom, people should invest more conservatively as they age. As a result, financial service organizations offer products that accommodate this general investing philosophy. For example, the Teachers Insurance and Annuity Association and College Retirement Equities Fund (TIAA-CREF) in the United States offers life-cycle funds, which systematically reduce the holdings of risky assets in participants' portfolios over time.[1] Cocco et al. (2005) provide a detailed analysis of this type of investment behavior by highlighting the key role played by background risk, especially the risk associated with labor income. Much of the related literature (e.g., Gomes and Michaelides, 2005; Angerer and Lam, 2009; Betermier et al., 2012; Palia et al., 2014) also posits that investors' human capital and its related risks are as important as their financial wealth in shaping portfolio choice decisions.

Although the results of these studies match the empirical evidence for working individuals, their prediction often overestimates the risky assets held during retirement (Cocco et al., 2005). This may be because the labor income risk faced by workers comes predominately from economic recessions or unemployment. In contrast, most retirees receive stable pension and Social Security benefits as their major source of income and do not have similar risks. Therefore, the absence of after-retirement income risk in these previous studies would imply a higher percentage of risky assets in retirees' portfolios, but this is not observed in the data. Our paper attempts to reconcile this inconsistency by conducting a thorough analysis of the factors that constrain retirees' investment behaviors and showing how these constraints affect retirees' asset allocation decisions.

We argue that for retirees, the major background risk shifts from fluctuations in job-related income to an increased likelihood of health shocks and higher medical expenses as they age. Incurring health-related expenses reduces retirees' otherwise stable pension and Social Security income and alters their budget constraints, and thus influences their consumption and investment behaviors. In addition to the constraints imposed by stochastic health expenditures, retirees are much more vulnerable to extreme market conditions, such as stock market crashes, than working individuals; the latter usually have a longer investment horizon to recover their losses and can alter their working hours and the retirement age to mitigate the impacts of tail events (Chai et al., 2012).

We construct a realistically calibrated life-cycle model that explicitly considers the joint impact of these two independent constraints—health expenditure risk and financial crisis risk—on retirees' portfolio construction. To our knowledge, this dual-risk perspective has not previously

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* Corresponding author.
E-mail addresses: gaoxiang@sbs.edu.cn (X. Gao), sunli@sbs.edu.cn (L. Sun).

[1] For a more detailed description, visit the TIAA webpage: https://www.tiaa.org/public/retire/financial-products/target-date-funds.

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been thoroughly studied. Our approach expands the life-cycle literature by explaining retirees' investment behaviors and justifies the use of rare-event hedging tools, such as put options, that can help retirees manage tail risks and reduce investment losses.

This paper complements the literature on the relationship between health status and portfolio choices. Rosen and Wu (2004) find that after controlling for risk preference, planning horizon, and the availability of health insurance, households in poor health are less likely to hold risky financial assets. Edwards (2008) concludes that adverse health shocks may explain 20% of the age-related decline in financial risk exposure after retirement. Coile and Milligan (2009) show that in the presence of health shocks, households reduce their ownership of housing, vehicles, financial assets, and businesses in favor of safe assets as they age. Yogo (2016) analyzes how retirees allocate wealth among bonds, stocks, and housing given stochastic health depreciation. While this literature offers insights into the impact of health on retirees' portfolio choices, the lack of research on health- financial market risk interactions yields an incomplete picture of how retirees' investment constraints shape their investment risk-taking behaviors.

This paper expands the literature on the impact of tail risks in financial markets. Prior studies in this field mostly focus on the implications of disaster risks in asset pricing. For example, Bollerslev and Todorov (2011) show that compensation for rare events accounts for a large fraction of the average equity and variance risk premium. Gabaix (2012) explains 10 puzzles in macro-finance by considering the time-varying severity of rare disasters. Oh et al. (2019) investigate tail-risk dynamics when there are price limits in the stock market. Relatively few studies examine how rare events influence investors' decisions in a life-cycle context. Kolusheva (2011) develops a life-cycle model that considers possible rare events in both stock and labor markets, with the aim of analyzing investors' consumption and asset allocation decisions. Chai et al. (2012) investigate how the combination of financial and economic crises would affect households' consumption, working, retirement, asset allocation, and annuitization decisions in both the short and long term. Alan (2012) finds that less educated households with large labor income loss are more vulnerable to stock market crashes.

In sum, the model we present is novel in two important ways. First, previous studies usually span the whole life cycle, from early working life to death, and thus make consistent and simplified assumptions about retirees. Our model, in contrast, focuses specifically on retirees. Second, prior studies often attribute fluctuations in labor income to macroeconomic conditions, but this is not the major source of background risk for retirees. For many retired investors, health-related shocks constitute the major source of uncertainty for their disposable income, and thus should function as an amplifier in the process of transferring market downside risk to their portfolios.

In our model's calibration, retirees' income and stochastic health expenditures are obtained from the Health and Retirement Survey (HRS). This is a comprehensive, biannual panel survey that collects detailed information on the income, wealth, and health status of the American elderly. Using data from the HRS, we define the medical expense ratio used in our model as the ratio of households' annual health expenditure to their income and estimate its distribution. Substantial heterogeneity exists in retirees' health expenditure ratio, with a mean level of 0.197 and a standard deviation of 1.406 for the entire sample. Tail risk in the financial market is modeled as a nonzero probability π^{crash} that the stock market will crash and, when it happens, trigger substantial loss compared with losses commonly seen from stock market turmoil.

We first build a model in which retirees do not have health risks. We find that retirees reduce their risky asset holdings as their financial wealth increases, and there is no decline in risk-taking behavior as they age. These results are consistent with the literature (Cocco et al., 2005), in which labor income is analogous to the safe asset compared with risky financial assets. However, the results cannot explain the empirical pattern whereby risky assets increase with wealth level and slightly decrease with age.

Next, we consider the case in which retirees face stochastic health expenditures but do not confront financial crisis risk. We find that as the health risk and associated health expenditures increase with age, retirees reduce their stock holdings over time. This trend is in line with the results of two studies that use dynamic life-cycle models to study households' consumption, health expenditure, and portfolio choice problems (Cocco et al., 2005; Hugonnier et al., 2012). However, these studies, including the results generated by our second case, imply that retired investors will hold a much higher level of risky asset investment than the level observed in the actual data.

Third, we solve for and simulate a model in which retirees face both health expenditure shock and tail risk in the financial market. Our particular interest is identifying how and to what extent a realistically calibrated financial crisis, together with health shocks, can affect retirees' investment behaviors. The optimal policy rule indicates that retirees would increase their risky asset share as their wealth levels rise and begin to reduce their risky investment share once their normalized wealth reaches a threshold of 4.5. The mean value of the risky asset share, calculated from 10,000 simulations, follows a path that is similar to the empirical data. This mean value increases from 25% to 30% when retirees turn 75, then declines to 20% as they approach 90.

As an extension of the aforementioned case, we examine the impact of the dual risks on a heterogeneous population. In the HRS data, the mean health expenditure to income ratio is 0.13 and 0.27 for retirees in good health and poor health, respectively. By incorporating these realistic health expenditure calibrations into our benchmark model, we are able to quantitatively analyze the mechanism through which health status factors into retirees' asset allocation decisions. Retirees with good health status have a much lower health expenditure ratio, which leaves them with a higher net income after accounting for health-related expenses. This net income acts as a risk-free asset and, ceteris paribus, a higher level will allow healthier retirees to take more financial risks and invest more in risky assets. If financial crisis risk is added, the simulated results not only generate the difference between the risky share of investments held by the two groups, but also better match the levels of risky assets held by the two groups of retirees compared with the benchmark case.

The remainder of the paper proceeds as follows: Section 2 sets up the model. Section 3 describes parameter values and calibrates our model using HRS data. Section 4 presents the optimal policy rule for retirees' investment behaviors under different scenarios, followed by a discussion of incorporating either heterogeneous health status or potential catastrophic health events. Section 5 presents our simulation results and compares them with stylized patterns found in the empirical distribution of retirees' risky asset holdings. Section 6 concludes.

2. The model

2.1. Retirees' preferences

Retiree i's preference is characterized by a time-separable power utility function:

$$U_1^i = E_1 \sum_{t=1}^{T} \beta^{t-1} \left(\prod_{j=1}^{t-1} p_{j-1} \right) \frac{C_{it}^{1-\gamma}}{1-\gamma}. \tag{1}$$

The retiree is assumed to live a maximum of T periods. In each period, there is a possibility that the retiree will die. Let p_t denote the probability that the retiree is alive at date $t+1$, conditional on being alive at date t. The retiree maximizes his or her expected life utility with a constant relative risk aversion γ and a time preference parameter β.

2.2. Modeling health risk

In each period, retirees receive their respective income, $Y_{i,t}$. Previous literature (e.g., Carroll, 1997; Chang et al., 2018) shows that, for working individuals, the risky labor income flow can be modeled as a deterministic or common component and a stochastic component. For retirees, the income process is quite different, as they have a relatively stable stream of pension and Social Security income each year. However, as retirees age, they face larger and more frequent health shocks than younger people. As noted by Baltagi (2010), health care is a necessity, hence health expenditures are often unavoidable. Consequently, the stochastic health expenses are analogous to negative shocks to the retirees' otherwise stable income process.

We model the magnitude of a health shock to be proportional to their income, where $Y_i \times h_{i,t}$ represents the out-of-pocket expense. Disposable income after health shock can be specified as

$$Y_{i,t} = Y_i - Y_i \times h_{i,t}, \tag{2}$$

where $h_{i,t} \in [0,1]$. When $h_{i,t} = 0$, there will be no health shock for the period; health expenditure will be zero, and the retiree's disposable income will be equal to his or her pension and Social Security income. When $h_{i,t} > 0$, there is a health shock for the period, and the retiree's disposable income will be reduced by the realized magnitude of the shock. $h_{i,t}$ is bounded by 1, so the maximum health expenditure will not exceed the current income $Y_{i,t}$. In each period, the health expenditure ratio $h_{i,t}$ can have different realized values, and the retiree knows the value of $h_{i,t}$ only when he or she enters into that period. However, the retiree has prior knowledge of the distribution of $h_{i,t}$, and hence optimizes his or her behavior based on expectations of $h_{i,t}$. The distribution of $h_{i,t}$ is estimated using data from the HRS and will be discussed in detail in Section 3.2.

2.3. The financial market

In each period, retired investors can invest in two assets in the financial market: a riskless asset and a risky asset. The riskless asset has a period return of r_f. The period return of the risky asset depends on which of the following two states emerge: a non-crisis state characterized by a mean risk premium of μ and an innovation component η_{t+1}:

$$\tilde{r}_t^{noncrash} = r_f + \mu + \eta_{t+1}, \tag{3}$$

where η_{t+1} is assumed to be independent and identically distributed as $N(0,\sigma_\eta^2)$; and a crisis state that occurs with a non-zero probability of π^{crash}. Given that the crisis indeed happens, the stock market will have a return of $\tilde{r}^{crash}$. Combining these two states, we can express the risky asset return as

$$\tilde{r}_t = \begin{cases} \tilde{r}^{noncrash}, \textit{with probability } 1-\pi^{crash} \\ \tilde{r}^{crash}, \textit{with probability } \pi^{crash} \end{cases}. \tag{4}$$

The parameters of r_f, μ, σ_η^2, π^{crash}, $\tilde{r}^{noncrash}$, and $\tilde{r}^{crash}$ will be described in Section 3.1.

2.4. Retirees' optimization problem

Retirees make their optimal consumption and asset allocation decisions under the constraints of their income being reduced by stochastic health expenditures, and they also face the risk of rare events in the financial markets. The timing of the events is specified as follows: at the beginning of each period t, the representative retiree i starts with financial wealth of $W_{i,t}$, receives pension and Social Security income $Y_{i,t}$, and observes the realized health shock $h_{i,t}$ to his or her period income for the period. The uncertainty associated with the disposable income dissipates once the retiree enters period t. Following Deaton (1991) and Cocco et al. (2005), we denote the total available resources as cash-at-hand $X_{i,t}$, where $X_{i,t} = W_{i,t} + Y_{i,t}$. $X_{i,t}$ is the total amount of available resources for the retiree during the period t. The retiree's problem is to decide how much to consume in the current period, which is denoted by $C_{i,t}$. The resources not consumed will be saved and used to generate the next period's financial wealth, $W_{i,t+1}$. The financial market offers two available asset choices for the savings: one risk-free asset and one risky asset. The retiree needs to make an allocation decision (i.e., the portfolio share that will be invested in risky assets $\alpha_{i,t}$). After making the consumption decision and the asset allocation decision, his or her financial wealth at the beginning of the next period $t+1$ becomes

$$W_{i,t+1} = r^p_{i,t+1}(W_{i,t} + Y_{i,t} - C_{i,t}). \tag{5}$$

The return of the portfolio from time t to time $t+1$ is given by

$$\tilde{r}^p_{i,t+1} = \alpha_{it}\tilde{r}_{t+1} + (1-\alpha_{it})r_f, \tag{6}$$

where α_{it} is the portfolio share invested in the risky asset and $1-\alpha_{it}$ is the portfolio share invested in the risk-free asset. Assuming the retiree faces borrowing constraints and cannot short sell the risk-free asset, α is restrained to 1. The retiree's optimization problem is to maximize the objective function (1), subject to constraints (2) through (6). The state variables are $\{t, X_t, Y_t\}$, and the control (choice) variables are $\{C_t, \alpha_t\}$. For each period, the optimal rules of consumption and portfolio share are functions of the state variables t, X_t, *and* Y_t.

The Bellman equation for a retiree's optimization problem is given by

$$V_{it}(X_{i,t}) = \max_{C_{it}\geq 0, 0\leq\alpha_{it}\leq 1}\left[U(C_{i,t}) + \beta p_t E_t V_{i,t+1}\left(X_{i,t+1}\right)\right], 0\leq t\leq T, \tag{7}$$

where $V_{it}(X_{i,t})$ is the value function, denoting the maximized utility given $X_{i,t}$. The next period total resource $X_{i,t+1}$ is

$$X_{i,t+1} = W_{i,t+1} + Y_{i,t+1} \times (1-h_{i,t+1}). \tag{8}$$

When substituting (5) and (6) into (8), $X_{i,t+1}$ can be expressed as

$$X_{i,t+1} = (X_{it} - C_{it})\left[\alpha_{it}r_{t+1} + (1-\alpha_{it})r_f\right] + Y_i \times (1-h_{i,t+1}), \tag{9}$$

where $X_{i,t+1}$ depends on the amount of savings in the period, the return on the savings (which in turn depends on the portfolio choice α_{it}), and the next period's health shock.

Since the model does not have a closed-form analytical solution, we use a numerical method to find the value function and associated optimal policy rules. Unlike an infinite-period dynamic programming problem, this model has finite periods because the retiree can live only a maximum of T years. Specifically, the retiree retires at 65 and is expected to live 30 years after retirement. A finite period setting allows us to solve the model recursively from the last period. The procedure is as follows: we set the retiree's last period value function V_T equal to zero as he dies at time T and we assume there is no bequest motive. Given this condition, we substitute $V_T = 0$ into the Bellman equation (7) and calculate the optimal value for V_{T-1}, which is the utility function evaluated with total cash-at-hand at $T-1$. Having found V_{T-1}, we can solve for V_{T-2}, and so on. The process continues until $V_1(x)$, the value function at the beginning of the period, is found. The value functions of a finite-horizon discrete Markov decision model are always well defined. By finding the value functions for each period, we can also obtain the optimal consumption and portfolio choice for each period that generate the value function.

As demonstrated in the literature (Carroll, 1997; Cocco et al., 2005), it is possible to reduce the state variable space by normalizing the wealth with respect to the permanent income, which in this case is the pension and Social Security income Y. Results in Section 4 will be expressed in terms of the normalized version of the cash-at-hand variable and the consumption variable.

3. Parameters and model calibration

3.1. Financial market parameters

For retirees' risk preferences and standard financial market parameters, we use the standard values obtained from Cocco et al. (2005) and Kolusheva (2011). Table A1 in the Appendix provides a summary of the values of the benchmark parameters. The coefficient of relative risk aversion is set to be 7; the risk-free rate, mean of stock market return, and standard deviation of stock market return are set to be 0.02, 0.06, and 0.157, respectively. The retiree dies with a probability of 1 at age 95. Prior to this age, the conditional survival probability value, p_j, is obtained from the mortality tables published by the National Center for Health Statistics.[2]

The parameter values for π^{crash} and $\tilde{r}^{crash}$ are obtained from Barro and Ursúa (2017) and Kolusheva (2011), where market crashes are defined as peak-to-trough cumulative real returns of −25% or less. Kolusheva (2011) finds that the unconditional probability of a stock market crash is 10.11%, and the probability of a stock market crash with no economic contraction is 7.47%. We set the stock return of a market crash, $\tilde{r}^{crash}$, to be −20%, close to the upper bound of the market crash return documented by Barro and Ursúa (2017). We set the probability of a crash to be 8%, close to the value found by Kolusheva (2011). With these parameters, the market crash can happen with a probability of 8%, and the return will be −20% when it happens. Similar optimal policy rules can be drawn when the crash return is set to −25%, and the crash probability is 10%. The only parameter that needs to be estimated from the data is the magnitude and distributional properties of the health expenditure shock.

3.2. Health expenditure calibration

3.2.1. Health expenditure data

We use data from the HRS between 1992 and 2016 to characterize the empirical distribution of the health expenditure ratio. The HRS is a biannual study conducted by the Institute for Social Research at the University of Michigan and funded by the National Institute on Aging. This survey provides a comprehensive set of variables, including the demographics, health, income, wealth, and pensions of the American elderly. The survey was first conducted in 1992 and interviews 22,000 Americans aged 50 or older. Based on when the respondent was born, the HRS further divides the respondents into different cohorts. The largest cohort is the HRS cohort, those born between 1931 and 1941. Other cohorts include the Study of Assets and Health Dynamics (AHEAD), born before 1924; Children of Depression (CODA), born between 1924 and 1930; War Baby (WBs), born from 1942 to 1947; Early Baby Boomers (EBBs), born between 1948 and 1953; Mid Baby Boomers (MBB), born between 1954 and 1959; and Late Baby Boomers (LBB), born between 1960 and 1965. In this study, we use the data from all of the cohorts and restrict our sample to the retired households. For married couples, retirement status means that both partners are retired.

Table 1 provides summary statistics for some key variables for retirees. Health expenditure E, which includes all out-of-pocket medical expenses, has a mean annual value of $3020 and a standard deviation of $9,469, implying that a large variation in the health expenses exists among retirees.[3] For pension and Social Security income, the mean value is $26,624. Financial wealth, which is the sum of the dollar amounts held in checking and savings accounts, CDs, money market funds, bonds, stocks, and mutual funds, has a mean value of $143,365. Total net worth is the difference between total assets and total liabilities and has a mean value of $389,828. Since this study focuses on the portfolio choice problem, financial wealth is the most relevant wealth measure as the allocation is made from financial wealth, not total household wealth, which includes non-liquid assets.

We use pension and Social Security income as a proxy for the permanent income (P) of retirees. Table A2 in the Appendix provides a more detailed description of this variable for different cohorts over the years. The numbers show that income is relatively stable over time after adjusting for inflation, which is consistent with the assumption that permanent income does not grow or decline significantly. Permanent income can be used to normalize cash-at-hand, which is the key state variable for this model. The health expense ratio is calculated as the ratio of annual health expenditure E to permanent income P. To determine the distribution of a shock's magnitude, we calculate the medical expense ratio for each household in each period. Table 2 provides summary statistics for this ratio.

The overall sample has a mean annual health expenditure to permanent income ratio of 0.197, a median of 0.048, and a standard deviation of 1.406. As health expenditures are closely related to health status, we divide the sample into two subsamples according to the respondents' health status. The HRS has a self-reported health status variable, ranging from 1 to 5, with 1 as excellent health and 5 as poor health. If a retiree reports their health as excellent, very good, or good, the health status is set to be good. If a retiree reports their health as fair or poor, the health status is set to be poor. We then calculate the health expenditure ratio for these two groups separately. The good health group has a mean health expenditure ratio of 0.140, whereas the poor health group's ratio is 0.278, substantially higher than that of the good health group.

In addition to health status, another factor that can significantly affect the medical expense ratio is age. Older people, especially those at the end of their life span, may incur large healthcare expenses that are not covered by Medicare or private health insurance. An example is long-term care expenses, which are not typically covered by standard insurance programs. To access the age effect, we divide the whole sample into two groups: those between 65 and 85 years old and those who are older than 85.[4] The younger group has an average health expenditure ratio of 0.166, while the older group has an average ratio of 0.274. If we further divide the age group into different health categories, substantial heterogeneity exists among different groups. The healthy younger retirees have an average health expenditure to income ratio of 0.122, whereas, for the older group with poor health, this ratio climbs to 0.535.

Fig. 1 shows the empirical frequency distribution of the health expenditure ratio for the overall sample, and we fit it to a lognormal distribution with a mean value equal to −2.913 and a standard deviation of 1.449. The parameters of the fitted distribution are used as inputs for the model calibration to characterize the shocks to the retirees' income. The results in the next section assume that all retirees face the same health shock distribution. In an extension section of this study, we calibrate this ratio and solve the model for the good health and poor health groups separately.

3.2.2. Problem with health ratio calibration

Among several known distributions, the lognormal distribution best fits the health expenditure ratio. However, the Kolmogorov-Smirnov (K–S) test still rejects the hypothesis that the health expenditure ratio comes from a lognormal distribution. One reason for this is that the parameters specified in the K–S test are estimated from the actual data, which violates the assumption that the parameters should be prespecified and not come from the data. In a robustness check, we apply the Monte-Carlo simulation to find the expected value of the value function. In the simulation, we do not calibrate the health expenditure

[2] See the detailed data at https://www.cdc.gov/nchs/nvss/mortality_tables.htm.

[3] Table A3 in the Appendix provides more detailed summary statistics for the medical expenses of different cohorts over time.

[4] According to the statistics provided by the National Center for Health Statistics (https://www.cdc.gov/nchs/), for people currently aged 65 years, life expectancy is 19.4 years for both sexes. Here, we use 85 years of age as the dividing age for our age-specific analysis, as most of the survey participants were already 65 when they were interviewed, making their life expectancy about 20 years. Many health studies also use 85 years as a dividing age to examine elders' health status and find that people over 85 years old have a higher risk for decline in mental ability, death from chronic diseases, cancers, and injuries (Kravitz et al., 2012; DeSantis et al., 2019; Burns and Kakara, 2018).

Table 1
Summary statistics for key variables of retirees. This table presents summary statistics for key variables of the HRS from 1992 to 2016. Values are in 2016 dollars and adjusted using CPI data obtained from the Federal Reserve Bank of St. Louis.

Variable	Mean	Median	Standard Deviation	Minimum	Maximum	N
Age	74.8	75.0	9.4	36.0	109.0	52,200
Education	12.1	12.0	3.2	0	17.0	52,200
Health Expenditure	3020.3	1073.6	9469.3	0	971,216.3	52,200
Social Security/Pension Income	26,624.8	18,913.1	292,378.9	0	66,067,172.3	52,200
Total Income	40,399.8	24,620.5	298,344.1	0	66,067,172.3	52,200
Stock	73,081.8	0	425,528.7	0	31,370,819.7	52,200
Financial Net Worth	143,365.9	9571.3	597,123.1	−1,541,198.0	43,878,616.3	52,200
Net Home Equity	119,026.8	68,820.3	251,544.8	−346,570.6	26,860,880.9	52,200
Total Net Worth	389,827.9	141,167.3	977,114.6	−987,413.0	51,0158,283.8	52,200

Table 2
Summary statistics for the medical expense ratio. This table presents the summary statistics of the medical expense ratio for the overall sample and the subsamples from the HRS.

Sample	Mean	Median	Standard Deviation	Minimum	Maximum	N
Overall Sample:	0.197	0.048	1.406	0	154.505	48,147
By Health Status:						
Excellent/Good	0.140	0.040	0.726	0	44.151	28,223
Fair/Poor	0.278	0.065	2.005	0	154.505	19,924
Subsample A: 65 ≤ Age ≤ 85						
	0.166	0.046	0.951	0	63.320	41,069
By Health Status:						
Excellent/Good:	0.122	0.038	0.631	0	44.151	24,215
Fair/Poor:	0.231	0.063	1.276	0	63.319	16,854
Subsample B: Age>85						
	0.274	0.065	2.860	0	154.505	7078
By Health Status:						
Excellent/Good:	0.251	0.048	1.136	0	32.000	4008
Fair/Poor:	0.535	0.080	4.133	0	154.505	3070

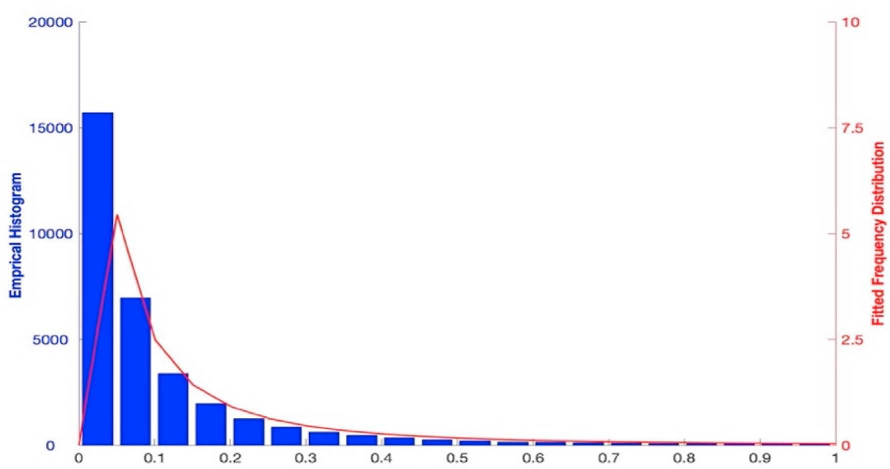

Fig. 1. Histogram of the empirical medical expense ratio with a fitted lognormal distribution. This figure presents the empirical frequency distribution of the medical expense ratio for the whole sample.

ratio to any parametric distribution. Instead, we randomly draw 500 samples from the empirical distribution of the health expenditure ratio and incorporate them in the numerical analysis. This method does not rely on any parameterization assumption but can reasonably capture the distributional property of retirees' health expenses. The simulation analysis generates results similar to those obtained when the health expenditure ratio is calibrated to the lognormal distribution.

4. Policy functions

4.1. Policy functions for all retirees: three risk cases

Using the parameter value discussed in Section 3, we solve the model numerically to obtain the optimal rules of consumption and portfolio choice. We first solve the policy rule for case I where retirees face only the financial crisis risk, that is, no health expenditure risk exists. In this scenario, there will be no uncertainty in retirees' disposable income.

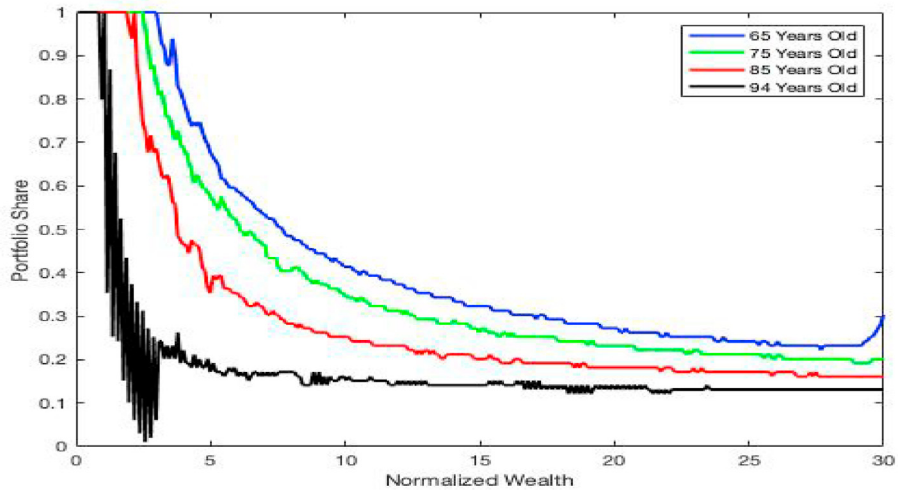

Fig. 2. Policy functions with only financial crisis risk. This figure plots the policy functions for portfolio share invested in stocks when retirees face financial crisis risk alone.

Fig. 2 presents the dynamics of optimal portfolio shares at different levels of normalized wealth for different age groups.

Fig. 2 also indicates that retirees in different age groups should invest all they have in risky assets when they are at low levels of wealth and start to reduce their risky asset holding as their wealth level increases. This result is similar to the prediction made by life cycle models that treat human capital as background risk (e.g., Cocco et al., 2005). The reason is that a retiree's main income is derived from pension and Social Security, which resemble risk-free assets if health shock is absent. Retirees with little wealth should then tilt their asset allocations toward risky securities if they already have a fairly large proportion of risk-free assets in their overall portfolio. As retirees' normalized wealth increases, the amount of financial wealth dominates, and retirees should choose to invest less in risky assets. These predictions, however, fail to capture the positive relationship between wealth and risky asset shares observed in the empirical data shown in Table 3.

To account for the variations in retirees' actual disposable income, we consider a model that adds uncertainty to their disposable income caused by the stochastic health expenditure. This is our case II. We solve it under the assumption that retirees face only the health expenditure risk, that is, no financial crisis risk is present. As shown in Fig. 3, health risk changes the negative relationship between wealth and risky asset shares in case I to positive within a certain range of normalized wealth. Specifically, when the normalized wealth is above 1, the portfolio share of stocks increases with wealth for all age groups (except for the 94-year-old group), and this share gradually declines after the normalized wealth reaches the value of 4.5.

Incorporating health risk generates more realistic predictions for retirees' risky asset holdings; however, a major problem with case II's prediction is that the optimal portfolio share of the risky asset investment, α, is much higher than the actual observed values shown in Table 3. For example, for people who are recently retired, α increases from 20% to 90% when normalized wealth reaches 4 and stays above 50% when normalized wealth levels further increase. For those who are 75 years old, the optimal share also increases to a significantly high level of 75% when normalized wealth is around 5, which again is not consistent with what we observe in the real data, where retirees' mean risky share would not exceed 40% when normalized wealth is below 12. The substantially high level of risky asset share derived from case II implies that normal market conditions would not be able to generate the actual investment behaviors of retirees we observe in the real data because it fails to capture the extreme market risk, which plays an important role in determining retirees' risk-taking behavior.

The previous two cases indicate that considering either case alone is insufficient for finding the true constraints faced by most retirees. In the following discussion, we present the results of the model in which both health expenditure risk and financial crisis risk are present. Fig. 4 demonstrates that for all age groups, the optimal portfolio share drops slightly and has large fluctuations when the normalized wealth is low and gradually increases as the normalized wealth approaches 4.5. Above the normalized wealth of 4.5, it begins to decline slowly, leveling out when the normalized wealth is higher than 15. When comparing these findings to case I in Fig. 2 or case II in Fig. 3, where only a single type of risk is considered, the optimal investment policy derived from the full dual-risk model can better capture the dynamics of retirees' stock investment behavior. This is especially pertinent when the normalized wealth lies

Table 3
Mean portfolio shares for stock holding. This table divides the retirees into 10 decile groups based on their normalized wealth level. Panel A presents the mean stock holding ratio for different wealth deciles from the entire sample, Panel B presents the mean stock holding ratio for different wealth deciles by age, and Panel C presents the mean stock holding ratio for different wealth deciles by health status.

Decile	1	2	3	4	5	6	7	8	9	10
Mean WRatio	0.023	0.103	0.269	0.595	1.167	2.132	3.669	6.382	12.221	50.50
Panel A: Mean Stock Holding Ratio										
All Sample:	0.021	0.041	0.052	0.083	0.142	0.194	0.248	0.323	0.398	0.523
Panel B: By Age Group:										
$55 \leq$ Age<65	0.051	0.036	0.071	0.111	0.155	0.276	0.330	0.354	0.434	0.524
$65 \leq$ Age<75	0.023	0.035	0.052	0.092	0.170	0.207	0.272	0.346	0.419	0.512
$75 \leq$ Age<85	0.013	0.048	0.049	0.078	0.130	0.184	0.225	0.318	0.409	0.516
Age $\geq$ 85	0.009	0.037	0.048	0.061	0.090	0.153	0.212	0.281	0.337	0.546
Panel C: By Health Status:										
Excellent/Good	0.021	0.035	0.056	0.091	0.159	0.214	0.265	0.332	0.413	0.539
Fair/Poor	0.020	0.048	0.045	0.072	0.111	0.156	0.213	0.305	0.365	0.482

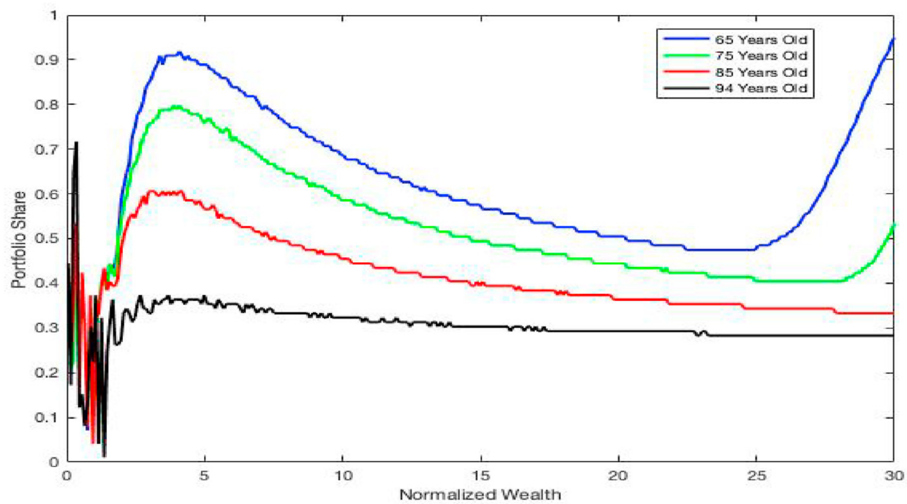

Fig. 3. Policy functions with only health risk. This figure plots the policy functions for portfolio share invested in stocks when retirees face health risks but no financial crisis risk.

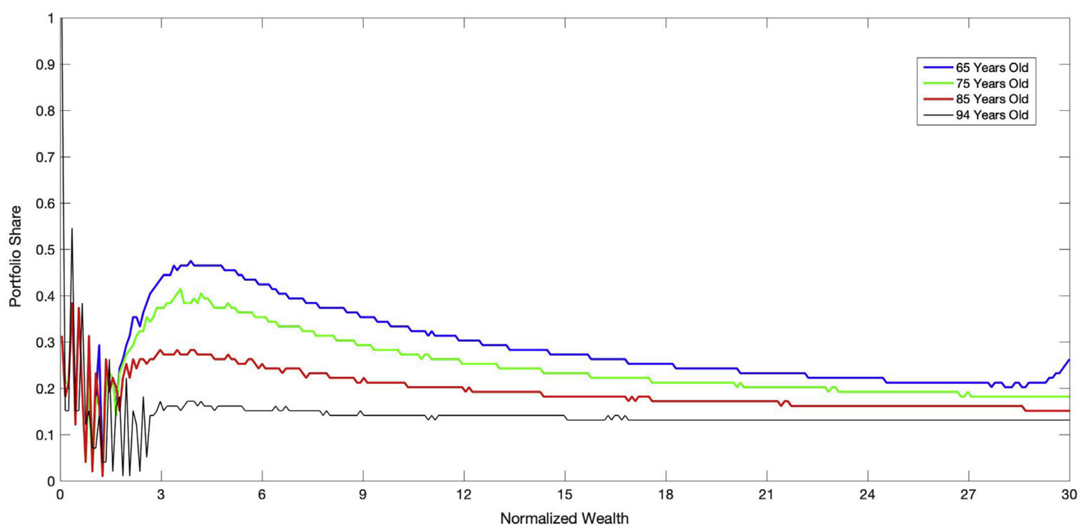

Fig. 4. Policy functions with both health risk and financial crisis risk. This figure plots the policy functions for portfolio share invested in stocks when retirees face both health risks and financial crisis risks.

between 1 and 4.5, which contains 70% of retirees in the HRS data.

Fig. 4 shows that, for the 65-year-old retirees' age group, the portfolio share of risky assets increases from 20% to around 45% and remains at 30% as normalized wealth further increases. For the 75-year-old retirees' age group, the portfolio share increases to 35% when the normalized wealth level reaches 3 and stays at a relatively constant level of 20% when the normalized wealth level is higher than 15. Furthermore, at each level of normalized wealth, the optimal risky asset share generated by the full model declines with age, which echoes the empirical patterns shown in Panel B of Table 3.

Despite the better predictions generated by this model for the majority of retirees, it fails to explain the behavior of retirees whose normalized wealth is very high. For example, for retirees whose normalized wealth is 30, the simulated portfolio share of risky assets predicted by the model is 20%, while in the HRS data the average actual holdings of risky assets exceed 50% of their financial wealth. We further examine the very wealthy retirees and find that they not only report a better health status, but they also have a higher health-expenditure-to-income ratio, which indicates that wealthy retirees have better health and spend relatively more of their income on medical expenses. However, the very wealthy retirees have a much lower health expenditure to wealth ratio,[5] suggesting that the health shock as measured by the percentage of permanent income might not be an important source of background risk for them; therefore, its effect on their financial risk-taking behavior is limited.

In addition, preference heterogeneity is absent in our model, and we assume every retiree faces the same impact in a crisis. However, as Alan (2012) points out, the expectation of rare financial disasters does not seem to affect wealthy households' behavior in the same way that less educated and less wealthy households are affected. It is possible that wealthier retirees (as defined by those with a very high normalized financial wealth ratio) are more tolerant of financial risks, more knowledgeable about financial markets, and better equipped with risk management tools to mitigate the detrimental effects of a financial crisis. Therefore, they behave more like agents in our non-financial crisis scenario as shown in Fig. 3, where their predicted average risky asset share would be as high as 50%, consistent with the empirical results of the very

[5] Retirees in the top decile of normalized wealth distribution have a health expenditure to wealth ratio of 0.01. This ratio is 0.544 for all other retirees.

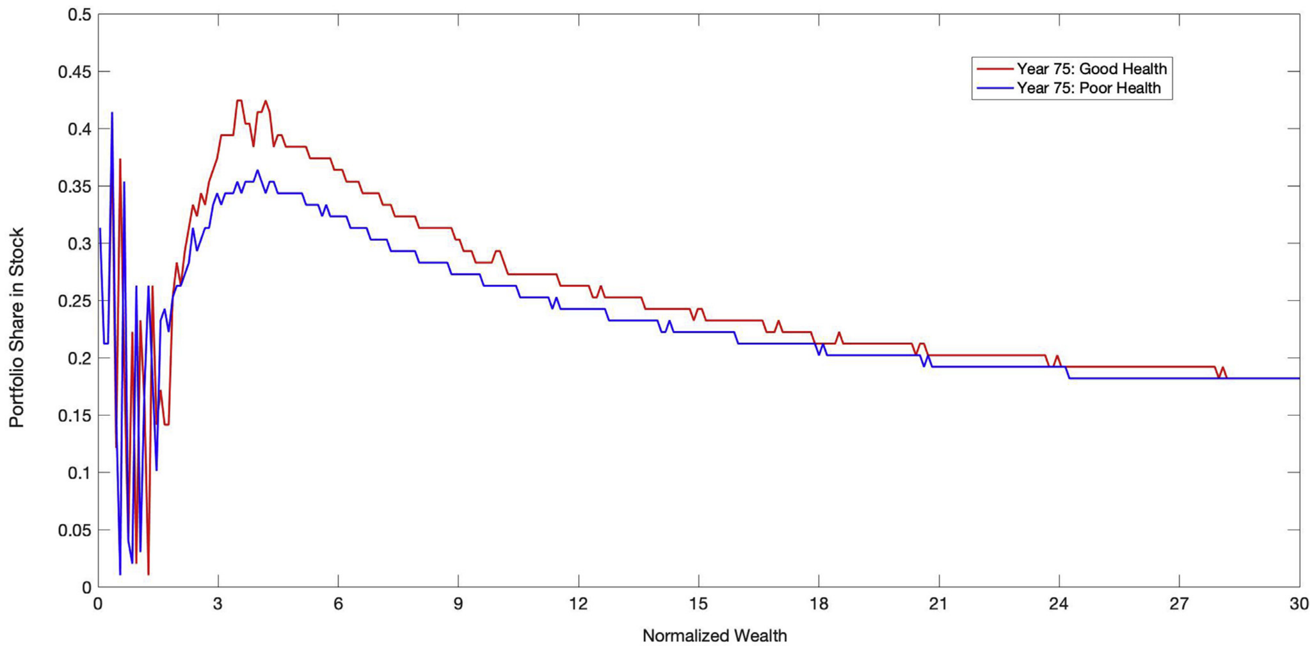

Fig. 5. Portfolio shares of retirees with good vs. poor health (with financial crisis risk). This figure plots portfolio shares for retirees with good health vs. poor health at the age of 75 when financial crisis risk is considered.

wealthy retirees' risky asset holdings presented in Table 3.

4.2. Policy functions for retirees in good vs. poor health status

As discussed in Section 3.2.1, the health expenditure ratio can differ substantially for retirees with different health statuses. This section examines the impact of heterogeneity in health status on retirees' optimal portfolio choices.

Figure A1 in the appendix presents the empirical distribution as well as the fitted distribution of the health expenditure ratio for the good health group versus the poor health group. Each group is fitted to a lognormal distribution. For the good health group, $\mu = -3.123$ best captures the features of the data, while for the poor health group, $\mu = -2.549$ fits better. Using these parametric values, we solve the model for the good and poor health groups separately. Fig. 5 presents the mean optimal portfolio share in stock for the good and poor health groups. The simulated results are consistent with the empirical findings presented in Panel C of Table 3. For a given level of financial wealth, retirees with excellent/good health status consistently hold a higher level of risky assets than retirees with fair/poor health status.

While the above-mentioned findings have been partially documented in previous literature (e.g., Rosen and Wu, 2004; Colie and Milligan, 2009), our model specifications and realistic health expenditure calibrations provide additional insights on the mechanism through which health status affects retirees' portfolio choices. To illustrate this, consider two retirees with the same level of financial wealth and pension income. Our expenditure calibration reflects that, on average, the health-expenditure income ratio for the retiree with good health status is 14 percentage points lower than retirees with poor health status, and the health shock volatility is also lower for the healthy retiree. In other words, the healthier retiree would have a lower level of health expenditure, which results in a relatively larger risk-free asset position from his or her retirement income. In turn, this large position will induce healthier retirees to take more financial risk and therefore lead to a larger risky

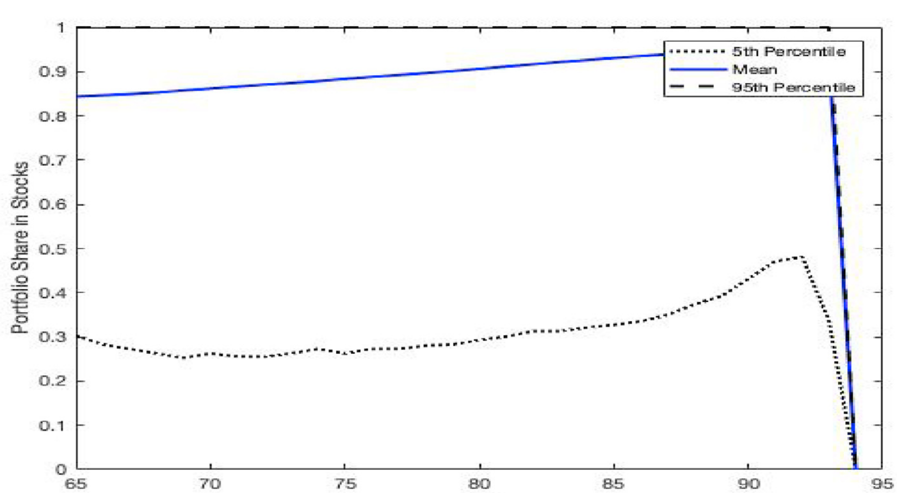

Fig. 6. Risky asset shares with only financial crisis risk. This figure plots the simulated mean, the 5th percentile, and the 95th percentile of the cross-sectional distribution of retirees' portfolio share in risky assets at every year of their retirement when only financial crisis risk is present.

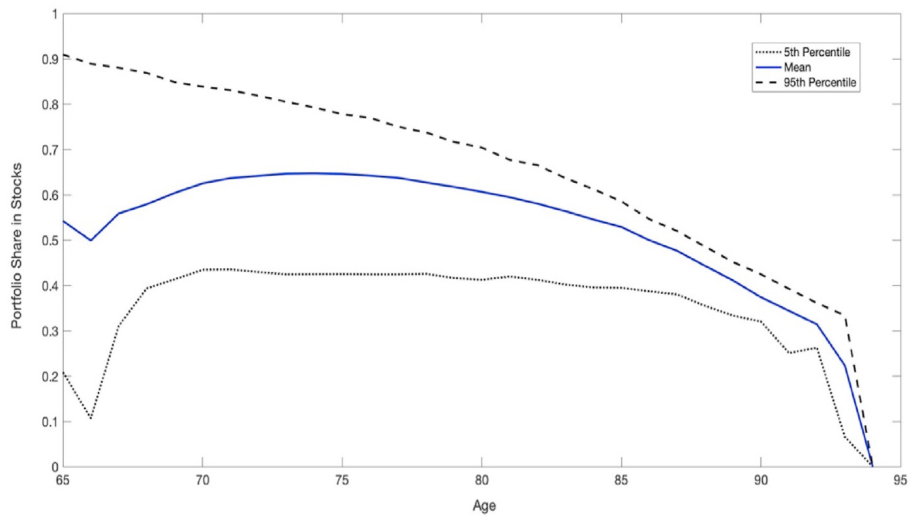

Fig. 7. Risky asset shares with only health expenditure risk. This figure plots the simulated mean, the 5th percentile, and the 95th percentile of the cross-sectional distribution of retirees' portfolio share in risky assets at every year of their retirement when only health risk is present.

Table 4
Portfolio shares for different cohorts by age. This table presents the mean portfolio share for different cohorts by age using the data from the HRS. The AHEAD cohort was born before 1924; the CODA cohort was born between 1924 and 1930; the HRS cohort was born between 1931 and 1941; the WB cohort was born between 1942 and 1947.

	Age														
COHORT	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94
AHEAD	0.240	0.311	0.172	0.149	0.204	0.210	0.200	0.199	0.181	0.201	0.220	0.195	0.182	0.194	0.272
CODA	–	0.243	0.222	0.172	0.214	0.203	0.219	0.210	0.178	0.192	0.208	0.198	0.169	0.133	–
HRS	0.240	0.237	0.202	0.204	0.175	0.186	0.180	0.175	0.204	0.201	0.184	0.175	–	–	–
WB	0.214	0.153	0.134	0.145	0.230										

asset share in the portfolio.

We also find that the effect of health status on portfolio choices is larger for retirees in the middle range of the wealth distribution, shown in Fig. 5. The optimal policy predicts that when retirees' normalized wealth exceeds 5, the difference in the risky asset share for the two groups gradually diminishes. This pattern is consistent with the empirical data shown in Panel C of Table 3. For example, for the good health group in the 5th and 6th decile of the wealth distribution, the risky-asset share is 40% higher (measured as a percentage of the poor group's risky asset share) than that of the poor health group. However, for retirees in the top decile of the wealth distribution, the good health group would have a risky asset share only 12% higher.

4.3. *The role of catastrophic health expenditure*

In our model, we assume that the maximum health expenditure does not exceed the current income. However, in the real world, this assumption might be violated if a retiree's income level is low or if a catastrophic medical event happens, forcing a large spending on health care. In this section, we consider an extreme scenario where retirees' health expenditures exceed their income. Empirically, we find this accounts for 1.7% of the total number of observations. In this case, the retiree not only spends all of his current income, but also his financial wealth to cover the high medical expenses. As we assume the retiree faces borrowing constraints in the model, their cash-at-hand cannot be negative, so the maximum a retiree can spend is his wealth. We model this situation by setting the probability of such an event at 2% (close to the empirical probability of 1.7%). If the event indeed happens, the retiree will spend all his current income on health expenditure, and he will lose 50% of his wealth (we take the average between 0% loss of wealth and 100% loss of wealth).

We find that the prediction of this augment depends further on the correlation between catastrophic health incidence and financial crisis incidence. If a catastrophic health event happens during normal market conditions, the retirees' optimal behavior would not change much ex-ante. However, if the catastrophic health event coincides with financial market turmoil (i.e., during the crisis state), then the optimal policy generated by our model implies that retirees should hold no risky asset ex-ante. A zero α might be unrealistic, however, it implies that retirees facing two extreme risks simultaneously would reduce their risky asset share substantially, which is consistent with the empirical data.

5. Simulation results

In this section, we simulate the dynamic profiles of consumption and investment for a hypothetical group of 10,000 retirees under the three risk scenarios discussed above. Each retiree's initial normalized wealth is drawn from an empirical distribution generated by the wealth data from the HRS.[6] We first simulate for case I where retirees are exposed only to financial crisis risk. Fig. 6 presents the resulting mean value, as well as the 5th and the 95th percentiles of the cross-sectional distribution of risky asset shares. This mean share starts from 0.85 at age 65, slightly increases over retirees' remaining life span, and drops to zero at the end of life.

Simulation results under the first case scenario do not match real-world data both in terms of the age profile and the level of risky asset share. As discussed in Section 4.1, without health expenditure shocks, one can think of all future pension and Social Security income as retirees' risk-free asset, which induces them to hold a large number of risky assets

[6] Figure A2 in the Appendix presents the empirical distribution of the normalized wealth ratio from the HRS.

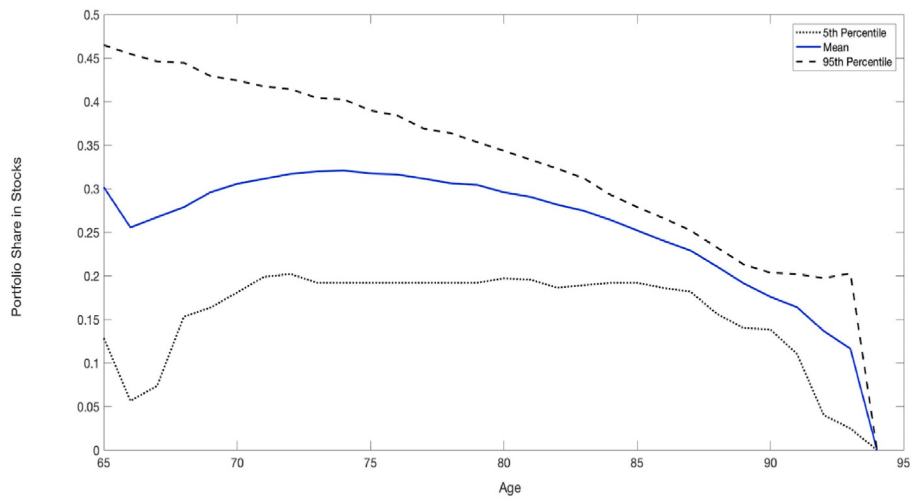

Fig. 8. Risky asset shares with both health expenditure risk and financial crisis risk. This figure plots the simulated mean, the 5th percentile, and the 95th percentile of the cross-sectional distribution of retirees' risky-asset share at every year in their retirement life when the financial crisis and health risk coexist.

when their labor income is abundant relative to their financial wealth—in other words, when their normalized wealth level is low. As shown in Figure A2, a large proportion of retirees have low normalized wealth in the HRS data and therefore they should hold more risky assets according to case-I policy rules. This prediction is inconsistent with the empirical observations. Our simulation results indicate that financial risk alone is not the reason why retirees reduce risky asset holdings.

Next, we simulate the portfolio shares for case II where retirees are exposed to stochastic health expenditure shocks and present the results in Fig. 7. The mean risky asset share declines slightly right after retirement, rises back to around 60% while retirees are in their 70s, and gradually falls as retirees approach their end of life. The risky asset holdings vis-à-vis age profile is generally consistent with the real-world data summarized in Table 4, implying that health issues are the main reason behind the decline in risky assets for retirees as they age.[7] However, the level of mean risky asset share is unrealistically high for retirees before they reach 90 years old. This high simulated level is, nevertheless, in line with Cocco et al.'s (2005) findings, where they consider a disastrous retirement income draw that incorporates uncertainty in retirees' income process.

The above results indicate that health expenditure shocks are important constraints for retirees. However, health shocks alone fail to explain why retirees, especially the less wealthy ones, would choose to hold a much lower level of risky assets in the real world. We argue that it is not the normal market fluctuations that deter their risk-taking behavior; it is the detrimental effect brought about by tail events in the market that cause them to choose a safer portfolio.

Last, we simulate and present the results that consider both health expenditure risk and financial crisis risk. Fig. 8 indicates that, compared with case II, the mean risky asset share, simulated from the dual-risk model, decreases substantially to the levels that are consistent with empirical data. In the early years of the retirement stage, the mean risky asset share stays relatively the same as retirees age. After the mid-retirement age, the mean risky asset share begins to gradually decline with age, which again matches the slightly declining trend observed in the empirical data presented in Table 4.

Fig. 8 also demonstrates that the heterogeneity of asset choices amongst retirees is higher during the early stage of retirement. For retirees age 65–70 years old, the 5th percentile of α increases gradually from 10% to 20%, and the 95th percentile of α stays above 40%. From ages 70–90, the 5th and the 95th percentiles begin to converge to the mean level, with the 5th percentile value decreasing from 20% to 15% and the 95th percentile value decreasing from 40% to 20% when retirees reach 90 years old. The simulation results from the full model provide evidence that retirees' investment behaviors are constrained by their own health expenditure risk as well as the tail risk in the financial market.

Of note is the bequest motive. Since this feature is not considered in our model, retirees are expected to spend all their wealth before the end of their lives. Accordingly, we observe that in the simulation, α plunges after retirees reach their 90s and it equals zero at age 95, the last year of life in our model. As Cocco et al. (2005) point out, the effect of bequests, in general, does not have a significant impact on retirees' saving decisions (except for assigning a large value to the bequest parameter). When we incorporate the bequest motive into the model, we find that the risky share of retirees' portfolios does not change significantly. However, the sharp decline of α to zero between ages 90 and 95 would be much less steep and more closely match what is suggested in Table 4 for retirees between ages 90 and 95.

6. Conclusion

Life-cycle models that incorporate human capital risks have provided valuable insights into households' saving and portfolio choice problems. While most studies carefully model and calibrate the labor income process during the investors' working life, the income process in the retirement phase is often simplified. Unlike working individuals, health risk serves as an important source of background risk affecting retirees' risk-taking behavior. In this paper, we analyze the impact of a realistically calibrated health expenditure shock to retirees' income, which acts similarly as the labor income risk for working individuals. They are similar since this shock would also tilt retirees' portfolios toward safer assets. Our model can generate the heterogeneity in the portfolio share of risky assets for retirees with different health status, which matches the empirical evidence. It can also explain the positive relationship between wealth and risky assets for a large proportion of the observations in the HRS sample of retirees.

However, we find that the health expenditure risk alone is not sufficient to induce retirees to hold the lower share of risky assets in their portfolios as observed in the data. It is the combinational effect of health risk and financial crisis risk that truly captures the constraints retirees face and generates simulation results that are more in line with the empirical evidence. Failure to consider the joint impact of these dual

[7] We also consider a baseline case where both health and financial crisis risks are absent. It has a similar age pattern as shown in Fig. 6, and the mean risky share does not decline with age. The results are available upon request.

risks would undermine our understanding of retirees' asset allocation behaviors and reduce the effectiveness of risk management for their portfolios.

Declaration of competing interest

None.

Appendix A

Table A1
Benchmark parameter values. This table presents the benchmark parameters for the model. The preference parameter and financial market parameters are obtained from Cocco et al. (2005). Health expenditure parameters are calibrated to data from the HRS.

Description	Parameter Value
Preference Parameters:	
Retirement age (K)	65
Discount factor (δ)	0.96
Risk aversion (γ)	7
Health Expenditure Parameters:	
Mean of health expenditure ratio (μ_h)	0.197
Standard Deviation of health expenditure ratio (σ_h)	1.406
Financial Market Parameters:	
Riskless rate (r_f)	0.02
Mean of stock return (μ)	0.06
Standard Deviation of Stock return (σ_θ)	0.157
Crash Probability (π^{crash})	0.08
Return if the market crashes ($\tilde{r}^{crash}$)	−0.20

Table A2
Summary statistics for pension and Social Security income. This table presents summary statistics for pension and Social Security income for different cohorts of the HRS from 1992 to 2016. The AHEAD cohort was born before 1924; the CODA cohort was born between 1924 and 1930; the HRS cohort was born between 1931 and 1941; the WB cohort was born between 1942 and 1947; the EBB cohort was born between 1948 and 1953; the MBB cohort was born between 1954 and 1959; the LBB cohort was born between 1960 and 1965.

COHORT	1996	2000	2004	2008	2012	2016
AHEAD						
Mean	15,849.8	17,659.0	20,030.6	20,965.9	20,561.6	19,675.9
Median	12,600.0	13,992.0	14,544.0	14,963.9	15,409.0	15,600.0
Standard Deviation	14,507.0	17,650.2	68,159.1	35,674.9	28,851.7	15,186.1
N	941	1769	1777	1238	816	398
CODA						
Mean	–	20,347.8	26,573.3	23,689.0	23,096.0	24,726.0
Median	–	16,224.0	17,328.0	18,000.0	18,000.0	18,870.23
Standard Deviation	–	16,716.3	61,154.9	20,445.9	23,617.5	22,623.0
N	–	690	772	724	677	470
HRS						
Mean	14,348.2	19,318.6	23,570.0	48,175.8	26,629.5	28,192.3
Median	10,191.0	14,727.0	16,812.0	18,960.0	20,448.0	21,762.0
Standard Deviation	19,110.0	17,416.8	50,057.6	1,162,872.1	21,662.1	23,017.2
N	1040	1409	2218	2665	3097	2928
War Babies						
Mean	–	9954.0	14,194.5	22,430.3	30,071.9	36,017.9
Median	–	3090.0	6114.0	12,637.3	22,170.0	30,180.0
Standard Deviation	–	13,621.7	19,911.6	46,514.4	26,878.3	28,523.0
N	–	68	142	288	490	605
Early Baby Boomer						
Mean	–	–	2851.5	8934.5	12,475.7	20,362.6
Median	–	–	0	0	5234.1	13,200
Standard Deviation	–	–	8778.2	16,344.9	22,775.6	24,852.9
N	–	–	97	137	503	809
Mid Baby Boomer						
Mean	–	–	–	–	6014.8	8222.4
Median	–	–	–	–	0	0
Standard Deviation	–	–	–	–	13,463.4	15,935.9
N	–	–	–	–	226	405
Late Baby Boomer						
Mean	–	–	–	–	–	1558.9
Median	–	–	–	–	–	0
Standard Deviation	–	–	–	–	–	6141.6
N	–	–	–	–	–	181

Table A3
Summary statistics for health expenditures. This table presents summary statistics for annual health expenditure for different cohorts of the HRS from 1996 to 2016. The AHEAD cohort was born before 1924; the CODA cohort was born between 1924 and 1930; the HRS cohort was born between 1931 and 1941; the WB cohort was born between 1942 and 1947; the EBB cohort was born between 1948 and 1953; the MBB cohort was born between 1954 and 1959; the LBB cohort was born between 1960 and 1965.

COHORT	1996	2000	2004	2008	2012	2016
AHEAD						
Mean	1754.3	1842.7	4280.0	3991.8	5159.9	6386.5
Median	540.0	776.0	1220.0	966.0	985.0	900.0
Standard Deviation	4765.3	4333.7	10,391.7	13,151.6	13,596.5	17,072.1
N	941	1769	1777	1238	816	398
CODA						
Mean	–	1384.5	3744.2	2464.7	2905.9	4497.7
Median	–	692.3	1254.8	982.0	1037.0	1000.0
Standard Deviation	–	2371.6	14,380.2	6633.6	7394.5	12,924.3
N	–	690	772	724	677	470
HRS						
Mean	1821.4	1587.5	2860.9	2229.2	2394.4	2737.4
Median	660.0	740.0	1100.0	990.0	1152.0	1100.0
Standard Deviation	4851.2	3649.3	8571.0	5486.4	4642.7	6676.7
N	1040	1409	2218	2665	3097	2928
War Babies						
Mean	–	1058.5	2094.5	2086.8	2618.8	1904.8
Median	–	380.0	472.5	742.5	1250.0	1050.0
Standard Deviation	–	1477.9	5918.6	8055.4	4374.7	2292.6
N	–	68	142	288	490	605
Early Baby Boomer						
Mean	–	–	4314.1	1488.2	1884.7	1940.2
Median	–	–	535.5	700.0	545.0	640.0
Standard Deviation	–	–	10,467.6	2250.0	4090.8	4135.2
N	–	–	97	137	503	809
Mid Baby Boomer						
Mean	–	–	–	–	1441.1	1207.4
Median	–	–	–	–	393.0	240.0
Standard Deviation	–	–	–	–	4107.9	3155.4
N	–	–	–	–	226	405
Late Baby Boomer						
Mean						1124.1
Median						96.0
Standard Deviation						3102.8
N	–	–	–	–	–	181

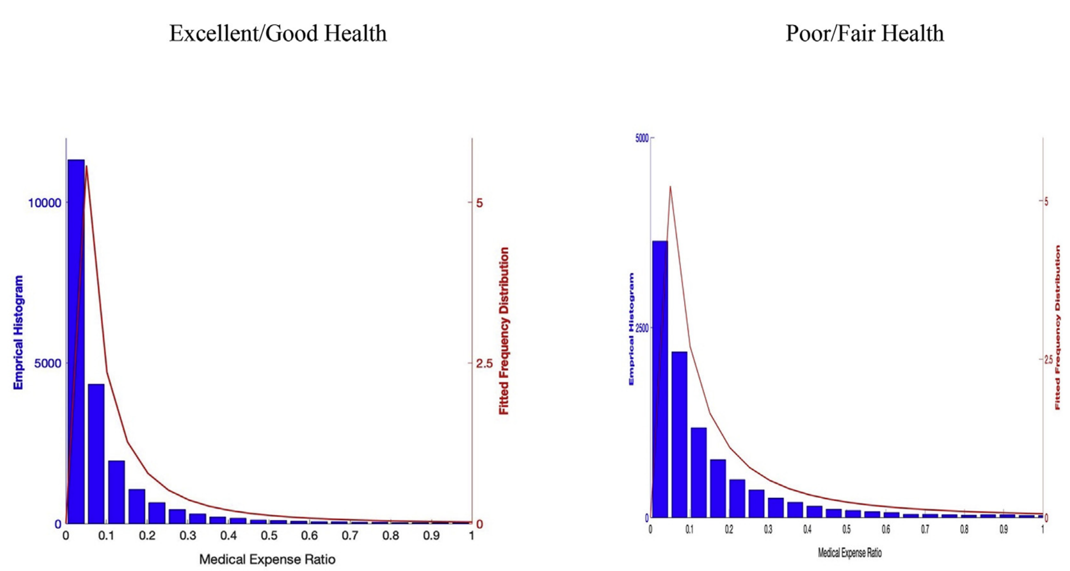

Fig. A1. Medical expense ratio by health status. This figure displays the histogram of the medical expense ratio and the fitted lognormal distribution for the excellent/good health group and the fair/poor health group.

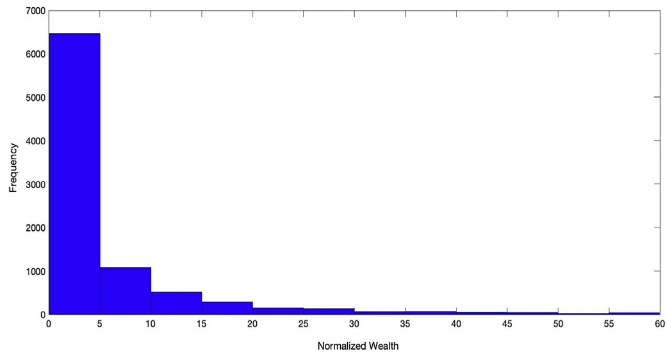

Fig. A2. Initial wealth distribution. This figure presents the empirical distribution of the normalized wealth ratio from the HRS. The normalized wealth ratio is calculated by dividing total household financial wealth by pension and Social Security income.

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