Household Financial Planning Strategies for Managing Longevity Risk

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Abstract: This study examines how longevity risk, in conjunction with other post-retirement risks, impacts retirement consumption decisions and retirement wealth needs. We develop a theoretical model that directly examines the relationship between longevity risk and consumption/savings, and empirically test these theoretical implications by simulating retirement outcomes for representative households, including longevity, inflation, investment, health, and long-term care risks. Our study shows that the top third of households by longevity need approximately 20% more retirement wealth than those households who live only an average lifespan. Investigations of various risk mitigation strategies suggest that combination strategies, particularly those that include delayed retirement, can significantly reduce the retirement wealth target. This research provides valuable new insights on household financial planning strategies for managing longevity risk.

Key Words: Financial Planning, Household Risk Management, Retirement Plan, Longevity Risk

Introduction and Background

Longevity risk, the risk of living longer than expected, has important implications for household post-retirement financial planning. There have been dramatic improvements in longevity over the last 100 years, with average life expectancies in developed countries increasing by more than 20 years. In the earlier part of the 1900s, the increases in life expectancy were primarily attributable to improvements in mortality at the younger ages, resulting from advances in modern medicine - the introduction of antibiotics, vaccines, and improved sanitation. More recently, we have seen improvements at older ages, due to life-extending technologies and improved disease management. The rate of increase has slowed, but despite some disagreement on the details, experts see potential for further improvement. The Social Security Administration projects that, by 2075, both men and women will have three more years of life expectancy at age 65 than they do today. Our goal in this study is to understand the link between these extensions in life span and the wealth needed to successfully fund a longer retirement period.

As people live longer and healthier lives, one might expect that they would also extend their time in the labor force. Although retirement ages have increased slightly over the last decades, these changes have been more modest than the changes in life expectancies. As a result, most individuals will be retired for longer periods than previous generations. This obviously increases the overall cost of financing the retirement period, but national survey data suggests that household savings rates may be inadequate to fully cover this cost without significant reductions in retiree standard of living.

This paper contributes to the retirement and longevity literature by: 1) developing a theoretical model of retirement consumption that directly incorporates longevity risk; 2) analyzing how exposure to independent post-retirement risks effects optimal consumption and spending; 3) empirically testing these theoretical implications by simulating retirement wealth needs for representative retiree households who are exposed to longevity, inflation, investment, health, and long-term care risks among others; and 4) evaluating the efficacy of strategies that can finance or mitigate the financial risks of a long retirement period, such as delayed retirement, purchase of annuities, purchase of long-term care insurance, and various housing alternatives, including reverse mortgages and downsizing.

Although longevity risk clearly has significant implications for retiree households, the actuarial and insurance literature has primarily focused on the consequences for and potential risk management strategies to be used by institutional investors, such as pension funds, annuity providers, life/long term care insurance providers, and securitization providers (e.g. Lee-Carter (1992); Brouhns, Denuit and Vermunt (2002); Renshaw and Haberman (2003); Denuit, Devolder and Goderniaux (2007); Biffis (2005); Bauer, Borger and Russ (2009); Chen and Cox (2009); Cox, Lin, and Peterson (2009); and Deng, Brockett, and MacMinn (2012)).

Empirical studies of household portfolios often ignore longevity, relying on the assumption of an average life span. This assumption is justifiable if the objective of the research is to predict average outcomes for society or for households on average. However, individuals who make consumption and saving decisions based on an average lifespan will be wrong about half the time, facing a significant risk of running out of money in retirement. As documented in Bajtelsmit et al. (2012), married-couple households need significantly more retirement wealth to be highly confident of having enough to make it through retirement as compared to the amount they need on average.[1]

In this study, we focus on the relationship between life span and the wealth needed to successfully fund the retirement period, given the range of post-retirement risks faced by most households. While it is simplistic to conclude that those who live longer need more money to fully fund their retirement period, our objective is to better quantify this difference. We also seek to evaluate which household financial strategies can best address the financial strains of living longer than expected.

The remainder of the paper is organized as follows. In the next section, we present a theoretical model of retirement consumption with and without longevity risk and post-retirement shocks to consumption. We use this theoretical model to motivate the development of a simulation model that incorporates a variety of post-retirement risks and use this model to evaluate the financial impact of longevity risk on household retirement wealth needs and the efficacy of various financial strategies for managing this risk. We summarize the main conclusions in the last section of the paper.

Optimal Retirement Consumption with Longevity Risk

In this section, we first present the results of a two stage theoretical model of retirement consumption without longevity risk, then we add longevity risk by making survival to the second period uncertain, and finally we add consumption shocks to the model with longevity risk.[2] Comparative statics are used to motivate the simulation model design.

Basic Two-stage Retirement Consumption Model Without Longevity Risk

We model retirement consumption and savings in a two-stage setting in the same general framework of the seminal work of Irving Fisher (1930). In contrast to lifetime consumption models, we assume that the decision period begins at the start of the retirement period (time 0) and proceeds through two stages of retirement. This is consistent with survey evidence that suggests that the decision about how to spend down retirement assets is often made at or near

[1] Bajtelsmit, et al. (2012) and Bajtelsmit et al. (2013) simulate retirement periods for married-couple households incorporating many stochastic post-retirement risks, including longevity, investment, inflation, long-term care, and health risk. The 2012 study focuses on defining retirement adequacy and the 2013 study considers the effect of various retirement timing and benefit claiming strategies.

[2] To conserve the space, we only provide a condensed discussion on the theoretical model derivations. More details are available from the authors upon request.

the date of retirement. In our setup, the household begins retirement with initial wealth W_0, receives income Y_t and pays for consumption C_t in both periods (t=1,2). Sources of income may include employment income, Social Security benefits, employer retirement plans, savings, and/or investments. Using the standard specification of time-separable preference for the household's post-retirement life, utility of consumption for the household is given by:

$$U(C_1, C_2) = U(C_1) + \beta U(C_2) \quad (1)$$

Households are assumed to maximize lifetime utility of consumption. To simplify the notation, we assume that the same risk averse utility function $U(.)$ defines preferences in both periods and that $u'(.) > 0$ and $u''(.) < 0$. Utility from future consumption is discounted at rate $\beta \leq 1$. The discount factor is commonly expressed as $\beta = \frac{1}{1+\rho}$, where ρ represents the rate of time preference.

$$\max_{C_1, C_2} U(C_1, C_2) = U(C_1) + \beta U(C_2) \quad (2)$$

The household is subject to the budget constraint $C_t \leq W_{t-1} + Y_t$ for each period.[3] Net wealth balances are assumed to accumulate by a gross interest factor of $(1 + r)$ at the end of each period such that $W_1 = (W_0 + Y_1 - C_1)(1 + r)$, and $W_2 = (W_1 + Y_2 - C_2)(1 + r)$.[4]

The two budget constraints can be consolidated into a single lifetime intertemporal budget constraint (IBC) that must be satisfied over the life span, i.e., the discounted present value of post-retirement spending must be covered by discounted present value of all resources, including initial wealth and future income, at the beginning of the retirement period.

$$C_1 + \frac{C_2}{1+r} \leq W_0 + Y_1 + \frac{Y_2}{1+r} \quad (3)$$

If the number of periods is known in advance and there is no uncertainty about the future, the result of this simple model is well-known by reference to the household savings literature (c.f. Frederick, Loewenstein, and O'Donoghue, 2002). Intuitively, the optimal decision is to smooth discounted consumption over the two periods. The higher the rate of time preference, the less

[3] This constraint can be relaxed if we allow for borrowing (c.f. Samuelson, 1958) or alternative sources for financing consumption (e.g. family or governmental aid).

[4] Due to these relationship, the optimization problem is equivalent to $\max_{W_1, W_2} U(C_1, C_2) = U(C_1) + \beta U(C_2)$

the individual is willing to shift consumption to the later period. Note that because we begin the model at the date of retirement, W_0 is given, so this model is indifferent to the methods by which a household arrives at their retirement wealth.

Two-stage Retirement Consumption Model with Longevity Risk

We now modify the basic model to shed light on how longevity risk may alter consumption and savings decisions. If we now assume that everyone lives at least an average life span to the end of stage 1 of retirement, but some people, with probability *q,* will live an extra-long lifespan to the end of stage 2, then the expected utility of retirement consumption is given by:

$$E[U(C_1, C_2)] = U(C_1) + q\beta U(C_2) \quad (4)$$

Note that if $q = 0$, or $q = 1$, this model is reduced to the regular one-stage or two-stage consumption model respectively (c.f. Frederick, Loewenstein, and O'Donoghue, 2002). Once the household reaches the last period of life, it will consume all available resources.

Case 1: *q* = 0

If $q = 0$, the household survives only to the end of the first retirement period. In this case, the optimal lifetime consumption decision is $\{C_1 = W_0 + Y_1 ;\ C_2 = 0\}$, and the optimal utility is $E[\mathrm{U}(\mathrm{C}_1,\mathrm{C}_2)]=\mathrm{U}(\mathrm{C}_1) = U(W_0 + Y_1)$.[5]

Although it is unrealistic to assume $q = 0$, this simplest case is consistent with survey evidence indicating underestimation of life expectancy. In a survey of more than 1,000 pre-retirees, the Society of Actuaries found that 75% of respondents estimated their personal life expectancy to be less than or equal to the actuarial average for their age group (SOA 2015, Table 43). Note that if households expect to live only an average lifespan, they fully consume their resources by the end of the first retirement period and will have no resources left to fund consumption during an unexpected longevity period.

Case 2: *q* =1

If $q = 1$, the household always survives to the end of the second retirement period, $C_2 = W_1 + Y_2$, and the IBC will hold with equality. The optimal solution is to spread discounted

[5] Note that when $q = 0$, it is certain that the household survives only to the end of the first retirement period. Therefore, the household will not have any income Y_2 in the second period.

consumption over the two periods such that $U'(C_1) = (1+r)\beta U'(C_2)$, which is the well-known consumption Euler equation in intertemporal optimization theory.

Case 3: $0 < q < 1$

A more realistic assumption is that the likelihood of surviving to the second retirement period is uncertain, i.e., $0 < q < 1$. In this case, the household optimization problem is:

$$\max_{C_1, C_2} \mathrm{E}[U(C_1, C_2)] = U(C_1) + q\beta U(C_2) \quad (5)$$

subject to

$$C_1 + \frac{C_2}{1+r} \leq W_0 + Y_1 + \frac{Y_2}{1+r}$$

The adjusted consumption Euler equation incorporating longevity risk is now: $U'(C_1) = (1+r)q\beta U'(C_2)$. There are three forces that affect the inter-temporal choices of the household: 1) the stronger the degree of time preference (lower β), the lower the incentive to save, which implies lower consumption in the second period of retirement C_2; 2) the higher the interest rate r, the more attractive it is to save, which reduces consumption in the first period C_1; 3) the higher the probability of living long, q, the more attractive it is to save, which also implies lower C_1. Graphical analyses of this problem and others in the following discussion are shown as in Figure 1. The indifference curves in this two-period setting are pairs of current and future consumption that offer the same level of utility. If $q = 0$, the optimal consumption choice is labeled as point *A* as a corner solution where the household will consume all available resources in stage 1. If $q = 1$, the optimal consumption choice moves to point *B* where the Euler equation is satisfied and the indifference utility curve is tangent to the budget constraint line. If $0 < q < 1$, then the optimal consumption choice moves to point *C* as a weighted average of *A* and *B*. Note that when there is uncertainty of living through the second stage, it is optimal to consume more in stage 1 and plan for less consumption in stage 2 as compared to the two-stage model without uncertainty. The movement from *A* to *C* can be decomposed into two parts: an income effect *AB* and an uncertainty of longevity effect *BC*.

[INSERT FIGURE 1 ABOUT HERE]

Further comparative statics analysis, as illustrated in Figure 1, sheds additional light on the effect of different assumptions:

- If the household starts with a lower initial wealth W_0^L, the consumption choice moves from point *C* to point *D* with lower consumption in both stages.
- With an increased probability of living longer, the consumption choice moves from point *C* to point *E*, with lower consumption in stage 1 and more saving for stage 2.
- With a higher discount factor β, the consumption choice moves from point *C* to point *F*, with more consumption in stage 1 and less saving for stage 2.

Many consumption choice models assume that income risk is the only source of uncertainty (c.f. Abowd and Card 1989; Low et al. 2010; Low and Pistaferri 2015). While income risk might be the most important source of consumption risk for young individuals, there are many post-retirement risks that can affect intertemporal retirement consumption decisions, including the risk of future liquidity constraints, shocks to asset prices (including home values), risk of medical and other unexpected expenditures, and risk of family dissolution (see, e.g., Palumbo, 1999; Voena, 2015).

We have thus far assumed that C_1 and C_2 are both decision variables within the complete control of the consumer. In reality, some consumption is for necessities such as a base level of food and shelter. Other consumption expenses are random variables that depend on inflation, healthcare costs, long-term care needs, etc. In addition, income may also depend on inflation and investment returns. If we assume that the main component of post-retirement income is from fairly safe income streams such as Social Security and pension benefits, then we can simplify the problem by focusing only on the random components of consumption.

Optimal Two-Period Consumption with Exogenous Health Care Cost Risk

In each stage of retirement, the household is expected to incur out-of-pocket medical expenses. In reality, some health care expenses are consumer choices and others may be necessities for survival. We follow Kotlikoff (1988) and Hubbard, Skinner and Zeldes (1994) by assuming that medical expenses M_t cover necessary health care expenditures that are incurred exogenously each year, and represent random shocks to expenditures on health care. For simplicity, we assume that these uncertain medical expenses, $\widetilde{M}(\mathrm{i.e.}\,\widetilde{M}(\mathrm{s}))$, occur only in the second period. Let $\pi(s)$ denote the probability of state s occurring, and $\sum_{s=1}^{N}\pi(s)=1$. The household's wealth minus medical expenses is the discretionary financial wealth.[6]

More formally, the problem is then:

$$\max_{C_1,C_2,} \mathrm{E}[U(C_1,C_2)] = U(C_1) + q\beta E\left[U(C_2(\widetilde{M}))\right] \quad (6)$$

subject to

$$C_1 + \frac{C_2(\widetilde{M}(s))}{1+r} \leq W_0 + Y_1 + \frac{Y_2-\widetilde{M}}{1+r}, \text{ with probability } \pi(s)$$

Using standard Lagrangian techniques, we obtain the stochastic version of the Euler equation considering longevity risk and the health care expenditures uncertainty, $'(C_1) = (1+r)q\beta E[U'(C_2(\widetilde{M}))]$. This is also illustrated in Figure 1, which shows that the consumption choice moves from point *C* to point *G* with lower expected consumption in stage 1 and more saving for stage 2 due to the uncertainty. Note that when the expected future expenditure is high, more initial wealth is needed to cover the future usage.

The Effect of Insurance on the Optimal Two-Period Consumption with Exogenous Health Care Risk.

We now consider the case in which the household can use some of their initial wealth to buy insurance against the exogenous health care risk at time 0 at premium p_M representing an actuarially fair premium rate. The insurance will remove the uncertainty for health care risk at cost of p_M.

More formally, the problem is then:

$$\max_{C_1,C_2,} \mathrm{E}[U(C_1,C_2)] = U(C_1) + q\beta E\left[U(C_2(\widetilde{M}))\right]$$

The household is subject to the adjusted budget constraint with insurance $C_t \leq W_{t-1} + Y_t$ for each period. $W_1 = (W_0 + Y_1 - C_1 - p_M)(1+r)$, and $W_2 = (W_1 + Y_2 - \widetilde{M} + \widetilde{M} - C_2)(1+r)$ reflecting the cost and coverage of insurance on the uncertainty. The adjusted intertemporal budget constraint (IBC) is $C_1 + \frac{C_2}{1+r} \leq W_0 - p_M + Y_1 + \frac{Y_2}{1+r}$ and the adjusted consumption Euler equation incorporating longevity risk and medical uncertainty with insurance is $U'(C_1) =$

[6]Note that we can also assume that, if a family's medical expenses in period t are so large that consumption above the minimum level cannot be attained, the family receives $(C_t - W_t - M_t)$ from the government. Naturally, in this case, the family owns no assets to carry into the next period.

$(1+r)q\beta U'(C_2)$. This problem and solution is illustrated in Figure 1 as well: the optimal consumption choice moves to point *H*. If the insurance is fairly priced, the consumption choice should have the same utility as point *C*. To the extent that the insurance includes a loading factor, the household will have slightly lower consumption in both periods.

Optimal Two-Period Consumption with Two Exogenous Risks

Now assume that there are two risky components, health care risk $\widetilde{M}$ as above and housing risk $\widetilde{H}$ (i.e. $\widetilde{H}(s)$) representing an independent random shock to expenditures on housing in the second period. The problem is then:

$\max_{C_1,C_2,} \mathrm{E}[U(C_1,C_2)] = U(C_1) + q\beta E\left[U(C_2(\widetilde{M},\widetilde{H}\,))\right]$

subject to

$C_1 + \frac{C_2(\widetilde{M},\widetilde{H}\,)}{1+r} \leq W_0 + Y_1 + \frac{Y_2-\widetilde{M}-\widetilde{H}}{1+r}$, with probability $\pi(s)$ for each state *s* occurring.

Similar to the case with only health uncertainty, we can derive $\mathrm{U}'(C_1) = (1+r)q\beta E[U'(C_2(\widetilde{M},\widetilde{H}\,))]$ as the adjusted stochastic consumption Euler equation considering longevity risk and the two uncertainties.

If we assume also that the household can use some of their initial wealth to buy insurance against the housing risk at time 0 at actuarially fair rate p_H, then their optimization problem is give by:

$\max_{C_1,C_2,} \mathrm{E}[U(C_1,C_2)] = E[U(C_1)] + q\beta E[U\left(C_2(\widetilde{M},\widetilde{H}\,)\right)]$ subject to the adjusted budget constraint with insurance: $W_1 = (W_0 + Y_1 - C_1 - p_M - p_H)(1+r)$, and $W_2 = (W_1 + Y_2 - \widetilde{M} - \widetilde{H} + \widetilde{M} + \widetilde{H} - C_2)(1+r)$ reflecting the cost and full coverage of the insurance, and we can derive the $U'(C_1) = (1+r)q\beta U'(C_2)$ as the adjusted consumption Euler equation consider longevity risk and both uncertainties with insurance. Notice that this is the same Euler equation we derived in the case without uncertainty, but the utility is reduced by the amount of insurance premium paid for hedging the uncertainties. This problem and solution is illustrated in Figure 1, with the optimal consumption decision moving to point I. Intuitively, since the insurance pays for the expected actuarial present value of the uncertainty, the expected utility would be higher due to the diversification effect and removing the penalty of uncertainty in the utility function.

There are several conclusions that can be drawn from the theoretical analysis above. First, the existence of an exogenous shock to consumption during the second retirement period reduces optimal consumption in the first period of retirement. However, to the extent that this shock is unanticipated, the household will have made suboptimal consumption decisions in the earlier part of retirement and will have inadequate resources to fully pay for this consumption shock. Second, the availability of actuarially fair insurance against the second-period shock essentially enforces the consumption spreading that could have been implemented with full foresight. As in the standard insurance literature, expected utility is higher with insurance than for the case without insurance (c.f. Kaas et al. 2008). In essence, with uncertain outcomes, individuals tend to prefer consumption smoothing across periods due to the fact that individuals usually have diminishing marginal utility. Insurance helps people smooth their consumption against an accident and therefore increase the expected utility across periods. This also holds with multiple exogenous shocks. Although not illustrated here, insurance covering more than one post-retirement risk would be expected to result in further improvements to the expected utility as the insurer should be able to diversify across the different risks and pass on some of the savings to the insured.

In the following section, we explore the practical implications of these theoretical results with a Monte Carlo simulation that incorporates longevity risk and multiple exogenous consumption shocks in retirement.

Simulating Post-Retirement Risks and Retirement Wealth Needed

The primary focus of this empirical analysis is to quantify the financial issues faced by the longest-lived. We consider a hypothetical retiree household that anticipates receiving income in retirement from various sources, which may include Social Security, defined benefit pensions, annuities, employment income, and investments, and at the same time faces multiple risks, including inflation, longevity risk, health risk, long-term care risk, and market related risks (inflation, housing costs, investment returns).[7] Note that the household portfolio is dynamic by nature, and the household may be able to take action to mitigate various risks, as will be discussed in a later section. The basic model construct is a detailed cash flow forecast for a married-couple household's retirement period. Post-retirement risks are introduced through the use of Monte Carlo simulation.

[7] Roche, Tompaidis and Yang (2013) develop a model with similar assumptions.

Base Case Assumptions

For each of two representative households, the parameters for income, wealth, expenses, and retirement plan participation are selected based on national data. The base case assumes that a married couple, age 66 at the outset of the simulation, have income and wealth corresponding to either the median pre-retiree household ($60,000 income and $100,000 non-housing wealth)[8] or the 75th percentile household ($105,000 income and $250,000 non-housing wealth). Households are assumed to enter retirement with no mortgage, and housing equity is assumed to be three times pre-retirement income at age 66. We assume initially that the household has two financial goals: 1) to maintain their pre-retirement standard of living in retirement while meeting all normal and unexpected expenses, and 2) to make it through retirement without running out of money.[9] The design of the model allows estimation of retirement wealth needs, probability of shortfall, the effect of various risk mitigation strategies on retirement outcomes, and, evaluation of the differences in outcomes for the longest-lived households.

Post-retirement Risks

Stochastic elements are incorporated in the cash flow forecasts by imposing risky distributions on various elements for each year of a hypothetical retirement. The advantage of this methodology is that, instead of assuming that everyone gets the average outcome, we can see the impact of risks that, while uncommon, can have a devastating impact on household finances.

For each household scenario, we run the cash flows for 50,000 hypothetical life paths, with annual random draws from appropriate distributions for each of the risk factors. Parameters for each of the stochastically-modeled risks are drawn from historical data and are described in Appendix A. Based on the outcomes of these many different possible lifepaths, we can measure the probability that the household is able to meet all expenses in retirement, as well as estimate the amount of pre-retirement wealth that would have been sufficient to meet those needs at

[8] Median and 75th percentile estimates are based on 2015 Census statistics. Although we provide the median non-housing wealth levels here, our forecast output is focused on how much they would have needed in retirement wealth to meet all their expenses for the respective scenarios. Non-housing wealth is important, however, in that households who wish to purchase an annuity are assumed to use a proportion of their wealth to do so. Thus, lower wealth levels limit the amount of the potential annuity purchase and payment.

[9] Households are assumed to be able to access investment wealth and also to sell their home to cover expenses once they don't need to live in it (e.g. surviving spouse or both spouses are permanently in long-term care).

various levels of confidence. The approach we take in our analysis is to first estimate the amount of wealth that would be needed for the base case that assumes no change in standard of living and no reliance on financial products to mitigate the risk. We then alter the assumptions and report on improvements, if any, resulting from various strategies and products.

- The following list summarizes the scenarios modeled in the remainder of the paper. To compare the wealth needed by longevity, we report the simulation outcomes by tercile for households with short, average, or long life spans.
- Base cases with normal retirement age: Both spouses retire and collect Social Security at age 66; homeowner; no mortgage; no annuities; no long-term-care (LTC) insurance.
- Base cases with delayed retirement: Both spouses retire and collect Social Security at age 70; homeowners; no mortgage; no annuities; no LTC insurance.
- Downsize housing: Downsize housing by 30% at retirement (reduces property taxes and insurance; no mortgage payment). Net difference in housing values, after transaction costs, is added to investment wealth at the time of sale.
- Reverse mortgage: The household enters into a reverse mortgage arrangement at age 75; life annuity payment is determined based on joint life expectancy at the time of purchase.
- Long-term care insurance: Purchase LTC insurance (for both spouses or wife only) at age 66, with $250,000 lifetime caps. Age-rated level premiums paid until individual enters care.
- Annuities: Household uses 50% of retirement wealth to purchase an immediate annuity at retirement (66 or 70) or a deferred annuity at retirement (with payout at 70, 75, 80, 85);

Results for Different Longevity Profiles

We first present the results of the simulated outcomes for the two base case households, initially assuming that the retired household maintains spending at the level of their pre-retirement standard of living and takes no actions to manage post-retirement risks. For each of the reported scenarios below, we estimate the amount of non-housing wealth that would have been sufficient to meet the household's spending objectives with 90% confidence (or alternatively stated, to run out of money in less than 10% of the simulated lifepaths).

Table 1 shows the approximate required wealth for the base case households, for normal (age 66) and delayed (age 70) retirement and Social Security claiming.[10] We find that delaying

[10] In order to make the delayed retirement simulation results more directly comparable to the age 66 retirement age simulations, we report the amount that would be needed at age 66 for all cases. When retirement is delayed to age 70, the household is assumed to continue to receive employment income to cover their expenditure needs, save for retirement, and earn investment returns on invested assets.

retirement to age 70 reduces the amount needed at age 66 by about 1/3 for both household income levels. In this table, the first two columns summarize the median and 90th percentile outcomes for the full 50,000 simulated lifepaths.

To retire at age 66 with 90% confidence of meeting their needs, the median household needs approximately $430,000 in pre-retirement savings, and the higher-income household needs about $880,000. This latter value is so much greater because the household is assumed to be financing a higher standard of living than the median income couple, and also because Social Security replaces a smaller percentage of their preretirement income. If retirement is delayed to age 70, the wealth needed at age 66 is reduced to $290,000 for the median household and $610,000 for the higher-income household. These values reflect the shorter retirement period as well as the additional four years that they will contribute to savings prior to retirement.

[INSERT TABLE 1 ABOUT HERE]

Figure 2 illustrates the retirement wealth needed for the two base-case households over all 50,000 possible lifepaths. The median household needs less wealth on average because they are financing a lower standard of living than the higher-income household. In addition, the median households' *range* of needs exhibits less variance, primarily because Social Security replaces a larger percentage of their preretirement income than it does for the higher-income couple. To be 50% confident of meeting their needs, the median household needs about one-third as much in savings at retirement as they do to be 90% confident. For the 75th percentile household, they need about 25% less. This illustrates an important point: if the household plans for the amount needed on average, they have a 50% chance of running out of money before the second spouse dies.

Because living longer exposes retirees to more years of regular household expenses and also greater risk of health and LTC shocks, we are particularly interested in what happens to those who live the longest. To investigate this issue, we split the simulated household lifepaths into thirds based on the age of the longest-lived spouse. The bottom tercile includes the results from all lifepaths in which both spouses died before age 86. The oldest tercile includes all lifepaths in which at least one spouse lived to age 92 or older.[11]

[11] See also Census Bureau (2017) projections. Note that joint life expectancy for a married couple is several years longer than individual life expectancy.

[INSERT FIGURE 2 ABOUT HERE]

The results for the longest-lived tercile are given in the right hand column of Table 1. Not surprisingly, we find that living longer costs more. To meet the objective of being 90% confident of covering all future expenses, the longest-lived households at the median income level need $520,000 at age 66, almost twice as much as they would need if they were short-lived ($280,000) and about $90,000 more than our estimate over all potential life paths. We see similar outcomes for the higher-income household, although the dollar differences are larger and the proportional differences are smaller.

We now explore several risk management strategies related to housing, long-term care insurance, and annuities that could potentially mitigate the financial costs of unexpected longevity.

Housing Strategies

For most households, housing wealth represents a significant percentage of total wealth, and most households have historically entered retirement without mortgage debt. In our base case model, we assume that households do not tap housing equity to meet expenses and that they only sell the home if a surviving spouse is permanently in LTC. We consider two options for using housing wealth to finance living expenses:

1) Downsizing: In these scenarios, we assume that the couple sells their primary residence and uses 70% of the proceeds after closing costs to buy a smaller home, resulting in housing costs (property taxes, insurance, and repairs) that are 70% of their previous housing expenses. The remaining cash is added to investment wealth.

2) Reverse annuity mortgage: In these scenarios, we assume that the couple accesses their housing equity to obtain a fixed joint and survivor 100% life annuity stream at age 75.

Table 2 summarizes the results for the housing-related scenarios based on the wealth needed to 90% confident of meeting all projected household expenses. We include the base case results from the previous section in the shaded column (both income levels, normal and delayed retirement) to facilitate direct comparison. For both household income levels and for both normal and delayed retirement, we can make similar conclusions from this analysis.

Downsizing housing has only a small effect on wealth needed at retirement ($20,000 to $50,000 depending on the retirement age and household income level). This makes sense when you consider that housing expenses are not a large category of expenditures when there is no mortgage payment. The effect is greater for the delayed retirement scenarios because downsizing in advance of formal retirement allows the household to spend less and save more during their last few working years. Downsizing results in a similar decrease in retirement wealth needed across each of the longevity terciles.

In contrast, we find that reverse mortgages have a beneficial effect, significantly reducing the amount of wealth needed at retirement. Based on our simulations, the amount of non-housing wealth needed at age 66 can be reduced by from 17% to 26%, depending on the income level and retirement age. For example, the higher income couple in the base case needed $880,000 to retire successfully at age 66 with 90% confidence. If they take a reverse mortgage at age 75, the amount of non-housing wealth needed is reduced by about $100,000. If they plan to retire at age 70 and take a reverse mortgage at age 75, the amount of wealth needed to be 90% confident of meeting all of their expenses goes from $610,000 to $480,000, a reduction of $130,000[12].

There are two issues that should be noted regarding reverse mortgages. Under current rules, the loan-to-value ratios for reverse mortgages are low enough that the household continues to have significant equity in their home and can benefit from increases in home value throughout their retirement period. In general, the reduction in wealth needed is less than the actual housing wealth that is being mortgaged. This reflects both the cost of the mortgage itself and also the risk that is being taken on by the financial institution. The annuity itself is fixed and is not assumed to have a guaranteed number of payments. Therefore, as with any life annuity, short-lived households will get a worse "deal" on this strategy, but the benefit to long-lived households of receiving more years of annuity payments is eroded by inflation. When we consider the financial effects of reverse mortgages by longevity tercile, the longest-lived households see the greatest reduction in wealth needed.

[INSERT TABLE 2 ABOUT HERE]

[12] We also tested alternative timing for the reverse mortgage. Delaying increases the annuity payment to the household, but decreases the expected number of payments. For households with limited wealth, it may be optimal for the reverse mortgage to be taken out in the first year in which expenses exceed retirement income.

Long-term Care Insurance

One of the more serious "shocks" faced by retiree households is the risk of an extended stay in long-term care. Strategies that focus on controlling regular household expenses can reduce annual income shortfalls, but do little to mitigate the effect of this risk on household finances. Long-term care (LTC) insurance is a product that will pay some or all of these expenses, but is not widely purchased in today's marketplace, partially due to its relatively high cost and lack of awareness by the public. LTC insurance can be purchased by healthy individuals at older ages, but insurer data suggests that the likelihood of being turned down for coverage increases substantially with age.[13]

Our simulation scenarios for LTC strategies are limited to consideration of the higher-income household only (pre-retirement income = $105,000) because premium costs are generally prohibitive for lower income households and may not make sense for those households that expect to qualify for future Medicaid coverage. Our model incorporates price quotes for healthy applicants from a major LTC insurer with contracts that include a lifetime cap ($250,000) and level premiums from the date of purchase (age 66) until the insured enters care. Based on average annual costs for residential care in a LTC facility, this is approximately three years of coverage.[14]

As summarized in Table 3, we find that the purchase of LTC insurance has no significant effect on wealth needed at retirement. Given that insurers price these policies based on LTC risk and life expectancy, which are both built into our simulation model, this result is not surprising, i.e., it implies that the present value of the premiums and the present value of the expected LTC costs are approximately equivalent. Based on other metrics, however, a household might still find the purchase of a LTC product to be an important retirement strategy. As with many other types of insurance products, the household is able to spread the cost of the future risky outcome over many years of payments and rely on the insurer to pool the risk of unusually long periods

[13] LTC Insurance used to have more generous benefits and lower lifetime premiums due to a variety of factors. A popular plan option was the unlimited or lifetime benefit period, and these policies provided true insurance against the financial shock of extended LTC. After experiencing significant underwriting losses, insurers changed their plan designs to cap benefits. While the odds are low, some people do require long-term care that lasts a very long time, exposing households to significant downside risk.

[14] Simulations using a higher lifetime cap do not result in significantly different outcomes for the households.

of care across many policyholders. Having the insurance in place can reduce the financial strain on a spouse who might otherwise struggle to pay for both their own household expenses and the costs of formal care for their husband or wife. The LTC insurance will extend the number of years that household resources will last. Furthermore, if household resources are depleted by an extended illness of one spouse, the surviving spouse will have the ability to pay for his or her own future LTC costs.

Although LTC insurance is a risk management strategy that might otherwise be thought to alleviate financial risk for the longest-lived, the product designs considered here, consistent with what is available in the market, do not provide true catastrophic coverage and therefore do not completely cover the tail risk of extended long-term care stays. We therefore see very little difference between the wealth needed for the full sample of life paths versus the subsample of life paths in which one of the spouses lives to be over age 90.

[INSERT TABLE 3 ABOUT HERE]

Joint and Survivor Annuities

To test whether the purchase of a life annuity can help mitigate post-retirement income shortfall risk, we run simulations that include the purchase of an immediate or deferred 100% joint and survivor annuity purchased at the date of retirement.[15] We assume that the household annuitizes 50% of its non-housing wealth at the age 66 retirement date ($50,000 for the median household and $125,000 for the 75th percentile household). Because of the smaller number of expected payments for the deferred annuities, the same amount of wealth can buy a larger future annual annuity payment than for the immediate annuities. From the simulation results reported in Table 4, we conclude that the purchase of an annuity actually increases wealth needed at retirement due to the extra cost of insurance loading in the pricing of the annuities. Nevertheless, annuities provide some incremental benefit in that they ensure an ongoing source of supplemental income even after wealth is depleted. This should be weighed against the increased risk of having insufficient resources to cover emergencies. Although this should be

[15] Because the simulation is over a long time period, but the annuities are purchased at the retirement date, the assumed discount rate used to price the annuity (3.8%) is lower than long-run averages but higher than rates currently in effect. To be consistent with other assumptions in the model, the Social Security mortality assumptions for men and women are used to price the annuity.

most beneficial to the longest-lived households, the fixed payment becomes less and less beneficial over time as it fails to keep up with inflation.

It is important to note that, in our model, investment returns are assumed to be drawn from a lognormal distribution with mean and standard deviation consistent with historical returns. For the period January 1947 through December 2010, the bonds returned an average of 6.5 percent with a standard deviation of 9.3 percent. The 6.5% bond return is obviously higher than the current rates, but we also observe a relatively high standard deviation of 9.3%.

In contrast, the annuities are assumed to be purchased at or near the date of retirement, so pricing should reflect rates that are closer to the current economic environment. At any given time period, annuities are priced assuming a lower discount rate than the yield on long-term bonds at the same point in time. The difference between the actual rate of return on an insurer's investment portfolio and the rate credited to the annuity owner can be seen as a measure of the insurer's premium loading (covering profit, administrative expenses, and risk e.g. from adverse selection in the annuity market). If insurer investment returns are higher in the future, this would increase annuity payouts and reduce retirement income shortfalls. Another reason that annuities do not add value to retirees in this type of model is because longevity risk is incorporated in the simulation. In some hypothetical lifespans, the person dies young and in others lives too long, so on average, they live to their assumed mortality. The primary advantage of the annuity is that it ensures that the second-to-die ends up with some income.

[INSERT TABLE 4 ABOUT HERE]

Combination Strategies

In the previous results sections, we considered many different risk mitigation strategies in isolation and found that most made only modest differences in the wealth needed at retirement to achieve desired levels of financial security. Some of these strategies impacted regular cash flows (by reducing expenses or increasing income) and others focused on mitigating the risk of large shocks to expenses. In practice, retiree households are likely to manage post-retirement risks using several combined products or strategies. Consistent with our theoretical model, we expect that a combination strategy will achieve better reduction in household portfolio risk. In this section, we consider the combined effect of various strategies. Table 5 summarizes the results of two combination strategies that were found to be most effective for the 75th percentile base case household. The table is organized to show the wealth needed as we incrementally add each additional strategy relative to the base case with no risk mitigation. In the upper part of the table, Combination Strategy #1 quantifies the combined effect of delaying retirement, downsizing housing, and buying LTC insurance for the wife only. The base case level of retirement wealth needed to be 90% confident of meeting all expense needs in retirement is $880,000 without any risk management and is reduced to only $450,000 for this combination, a reduction of 49%. Combination Strategy #2 reports the results for delaying retirement, taking a reverse mortgage at age 75, and purchasing LTC for the wife only. This set of strategies reduces the average wealth needed by 80%, and the amount needed to be 90% confident by 74% (from $880,000 to only $230,000), resulting in the best outcome of the combination strategies we tested.

As noted previously, the base case households who survive the longest need significantly more wealth to meet all their retirement financial needs. When we consider the effect of these combination risk management strategies, the longest-lived households still need more than their short-lived counterparts, but the dollar reduction in wealth needed is comparable to the reduction seen for the full range of longevity. For example, we find that at the 90% confidence level, Combination Strategy #2 reduces the amount of wealth needed for the oldest longevity tercile from $990,000 to $340,000.

[INSERT TABLE 5 ABOUT HERE]

Although we have focused these results on the estimate of wealth that would have been sufficient to maintain a household's standard of living with a high degree of confidence, there are other metrics of comparison that can be used to assess the benefits and costs of retirement risk management alternatives. For example, at the level of retirement wealth observed in national data, the probability of having any wealth left at death for the base case with age 66 retirement is only 16% of all life paths. However, delaying retirement increases this probability to 38%. Combination Strategy #1 increases the probability to 57 percent and Combination Strategy #2 results has a 63 percent probability of resulting in positive wealth at death. We find similar improvements in the number of years before wealth runs out and the average age that wealth runs out.

Conclusions

In this paper, we present a theoretical retirement consumption model with longevity risk and expenditure shocks and identify factors that influence optimal retirement consumption. We then empirically test the implications from the theoretical model by using a Monte Carlo simulation to estimate the retirement wealth that would be needed to fully fund expected household retirement cash flow needs, incorporating a variety of post-retirement risks, including investments, inflation, longevity, health, and long-term care risks. Our results show that, as compared to those who live an average life span, households that are in the top third by longevity need to have about 20 percent more wealth at retirement to fully fund their needs. In addition to financing more years of regular expenses, those who live longer have a greater chance of experiencing shocks such as unexpected health costs, extended periods of long-term care, or economic downturns.

The base case results suggest that the median and 75th percentile households will not be able to retire at age 66 and maintain their preretirement standards of living in retirement. As compared to the $610,000 and $880,000 they would need to have at age 66 respectively based on our simulation, these households have only $100,000 and $250,000 respectively in non-housing wealth. For particularly long-lived households, the difference between needs and reality is even greater.

Fortunately, our analysis suggests that there are strategies that can be used to finance or mitigate the financial risks of a longer retirement period. Delaying retirement 4 years reduces the retirement wealth needed to fully fund the retirement period by about one-third. Although strategies related to housing, annuities, and long-term care insurance are found to be only marginally beneficial alone, we find that combination strategies have the largest impact, potentially reducing wealth needed at retirement by as much as two-thirds.

A major conclusion from this research is that the risk of living long should be more carefully incorporated in household retirement planning and financial advising. Most people, if they plan at all, appear to anticipate an average life span. Given that one-third of married-couple households are expected to have at least one spouse live to age 92, and that these long-lived households will need substantially more wealth to maintain the pre-retirement standard of living through old age, managing this risk is an increasingly important component of retirement planning. Financial products that provide lifetime income or that cover specific future expenses can help households have more successful post-retirement periods. It is worth noting that, while most people entering retirement are married, the simulation framework and implications for various risk management products are also relevant to single retirees. Although singles do not have the longer joint longevity profile, they also do not have the benefit of income and expense pooling that married couples enjoy. It is therefore important for all financial planners and advisors to develop strategies to help their clients manage longevity risk.

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Table 1 Base Case Results: Wealth Needed at Age 66 to be 50% and 90% Confident of Meeting All Simulated Household Expenses, By Retirement Age and Longevity (in $000)

	Retire and Claim Social Security at Age 66		Retire and Claim Social Security at Age 70	
MEDIAN HOUSEHOLD (preretirement income = $60,000)	50% confidence	90% confidence	50% confidence	90% confidence
All	$290	$430	$170	$290
Youngest 1/3 by Age of Second-to-Die	$220	$280	$110	$170
Middle 1/3 by Age of Second-to-Die	$300	$370	$180	$250
Oldest 1/3 by Age of Second-to-Die	$400	$520	$260	$380
75th PERCENTILE HOUSEHOLD (preretirement income =$105,000)	50% confidence	90% confidence	50% confidence	90% confidence
All	$660	$880	$410	$610
Youngest 1/3 by Age of Second-to-Die	$520	$630	$300	$400
Middle 1/3 by Age of Second-to-Die	$700	$790	$440	$530
Oldest 1/3 by Age of Second-to-Die	$840	$990	$570	$710

Source: Authors' calculations based on Monte Carlo simulation.

Table 2 Effect of Housing Strategies on Wealth Needed at Age 66 to be 90% Confident of Meeting All Simulated Household Expenses, by Retirement Age and Longevity (in $000)

	Retire and Claim Social Security at Age 66			Retire and Claim Social Security at Age 70		
MEDIAN HOUSEHOLD (preretirement income = $60,000)	Base Case	Downsize Housing 30%	Reverse Mortgage at Age 75	Base Case	Downsize Housing 30%	Reverse Mortgage at Age 75
Base Case						
All	$430	$400	$380	$290	$270	$230
Youngest 1/3 by Age of 2nd-to-Die	$280	$250	$240	$170	$150	$120
Middle 1/3 by Age of 2nd-to-Die	$370	$350	$330	$250	$220	$190
Oldest 1/3 by Age of 2nd-to-Die	$520	$500	$490	$380	$360	$330
75th PERCENTILE HOUSEHOLD (preretirement income =$105,000)	Base Case	Downsize Housing 30%	Reverse Mortgage at Age 75	Base Case	Downsize Housing 30%	Reverse Mortgage at Age 75
All	$880	$830	$780	$610	$560	$480
Youngest 1/3 by Age of 2nd-to-Die	$630	$590	$560	$400	$360	$300
Middle 1/3 by Age of 2nd-to-Die	$790	$750	$700	$530	$490	$410
Oldest 1/3 by Age of 2nd-to-Die	$990	$930	$880	$710	$660	$570

Source: Authors' calculations based on Monte Carlo simulation.

Table 3 Effect of Long-term Care Insurance ($250K Lifetime Cap) on Wealth Needed at Age 66 to be 90% Confident of Meeting All Simulated Household Expenses for the 75th Percentile Household (Preretirement Income = $105,000), by Retirement Age and Longevity (in $000)

	Retire and Claim Social Security at Age 66			Retire and Claim Social Security at Age 70		
75th PERCENTILE HOUSEHOLD (preretirement income =$105,000)	Base Case (Neither Has LTC Insurance)	Both Have LTC Insurance	Wife Has LTC Insurance	Base Case (Neither Has LTC Insurance)	Both Have LTC Insurance	Wife Has LTC Insurance
All	$880	$880	$880	$610	$620	$610
Youngest 1/3 by Age of 2nd-to-Die	$630	$650	$640	$400	$400	$400
Middle 1/3 by Age of 2nd-to-Die	$790	$790	$790	$530	$540	$530
Oldest 1/3 by Age of 2nd-to-Die	$990	$990	$990	$710	$730	$710

Source: Authors' calculations based on Monte Carlo simulation.

Table 4 Effect of Buying Life Annuity at Age 66 on Wealth Needed at Age 66 to be 90% Confident of Meeting All Simulated Household Expenses, by Retirement Age and Longevity (in $000)

	Retire and Claim Social Security at Age 66			Retire and Claim Social Security at Age 70		
MEDIAN HOUSEHOLD (preretirement income = $60,000)	Base Case (No Annuity)	Immediate Annuity, Age 66	Deferred Annuity, Age 80	Base Case (No Annuity)	Immediate Annuity, Age 66	Deferred Annuity, Age 80
All	$430	$420	$450	$290	$310	$320
Youngest 1/3 by Age of 2nd-to-Die	$280	$270	$310	$170	$190	$210
Middle 1/3 by Age of 2nd-to-Die	$370	$360	$390	$250	$270	$280
Oldest 1/3 by Age of 2nd-to-Die	$520	$510	$540	$380	$400	$410
75th PERCENTILE HOUSEHOLD (preretirement income =$105,000)	Base Case (No Annuity)	Immediate Annuity, Age 66	Deferred Annuity, Age 80	Base Case (No Annuity)	Immediate Annuity, Age 66	Deferred Annuity, Age 80
All	$880	$850	$930	$610	$640	$680
Youngest 1/3 by Age of 2nd-to-Die	$630	$630	$720	$400	$450	$510
Middle 1/3 by Age of 2nd-to-Die	$790	$770	$850	$530	$570	$620
Oldest 1/3 by Age of 2nd-to-Die	$990	$950	$1,030	$710	$740	$770

Source: Authors' calculations based on Monte Carlo simulation. The median household and 75th percentile households are assumed to spend $50,000 and $125,000 respectively of their wealth at the date of retirement to purchase a 100% joint and survivorship annuity, either immediate or deferred. Immediate annuities begin payment at the date of retirement. Deferred annuities begin payments at the ages indicated and are priced to reflect the shorter expected payout period.

Table 5 The Effect of Combination Risk Management Strategies on Wealth Needed at Age 66 to be 50% and 90% Confident of Meeting All Simulated Household Expenses, by Longevity (in $000), 75th Percentile Household (Preretirement Income = $105,000).

	All		Tercile, by Age of Second-to-Die: Youngest 1/3		Middle 1/3		Oldest 1/3	
	50% Conf.	**90% Conf.**	**50% Conf.**	**90% Conf.**	**50% Conf.**	**90% Conf.**	**50% Conf.**	**90% Conf.**
Base Case: Retire at Age 66	$660	$880	$520	$630	$700	$790	$840	$990
Combination Strategy 1								
Delay Retirement to Age 70	$410	$610	$300	$400	$440	$530	$570	$710
+ Downsize Housing 30%	$370	$560	$260	$360	$400	$490	$520	$660
+ LTC for Wife $250 Cap	$290	$450	$170	$250	$290	$380	$410	$540
Combination Strategy 2								
Delay Retirement to Age 70	$410	$610	$300	$400	$440	$530	$570	$710
+ Reverse Mortgage at Age 75	$310	$480	$220	$300	$330	$410	$440	$570
+ LTC for Wife $250 Cap	$130	$230	$90	$140	$130	$200	$190	$340

Source: Authors' calculations based on Monte Carlo simulations.

Appendix A Summary of Simulation Model Assumptions-Stochastic Risks

Stochastic Risks	Model Parameters
Household Cash Flows	First year after-tax retirement expenditures age-based from Consumer Expenditure Survey. Retirement cash flows paid first from income sources and then, if income is insufficient, from taxable withdrawals from retirement savings. Future years' income and expenditures increase with stochastic inflation and may be affected by other risks. if one spouse goes into LTC, the discretionary expenses for the remaining spouse (covering everything except housing and health care) are reduced by 25 percent.
General Inflation	General inflation is simulated for each year and applies to all expenses except health care and LTC costs.[a]
Health Costs and Inflation	Both spouses are assumed to have Medicare coverage. Out-of-pocket health expenditures are stochastically determined for each year of retirement, with the minimum set at approximately the cost of Medicare Part B premiums. Future health expenditures for each year are forecast to increase with simulated medical inflation. [b]
LTC Costs and Inflation	LTC is defined in this simulation to be out-of-pocket costs of assisted living or nursing home care beyond what is covered by Medicare. The annual cost of LTC in the base year is $80,000, approximately the national average data for skilled nursing with a semi-private room (Genworth, 2014), and increases over the retirement period with simulated medical inflation. LTC costs for each year are determined in a two-step process. The probability of needing care in a given year is assumed to depend on age and gender. If a person enters care, their length of stay is 3 months, 1 year, or 5 years. [c]
Housing	Households are assumed to be homeowners who enter retirement with no mortgage. Home market value is three times income and increases annually with inflation. When neither spouse is living in the home, e.g., one person is deceased and the other is in LTC, the house is assumed to be sold, for 90 percent of market value, one year after the last person vacates the home.
Mortality	Mortality risk in each year for each spouse is stochastically generated based on the Social Security Administration's (SSA's) actuarial life table, given the individual's current age and gender.
Investment/Market	Investment wealth is tax-deferred savings of all forms including IRAs and employer defined-contribution (DC) plans. It is accessible to the household and can be drawn down in retirement as taxable income. In any years in which the household has more income than it needs to meet its expenses, the extra is assumed to be invested. Investment wealth is allocated between stocks (split equally between large cap and small cap) and long-term corporate bonds with annual rebalancing such that the percent in equities is always 100 minus current age (e.g., at age 66 the equity portion is 100 – 66 = 34 percent). Returns on each asset class in each year of the simulation are stochastically modeled based on the historical distribution of investment returns. [d]

[a] General inflation is assumed to be normally distributed with mean, standard deviation, and correlation with the previous year based on historical inflation (CPI-U) from January 1947 through October 2011 (mean: 3.71 percent; standard deviation: 1.22 percent; correlation with the previous year's general inflation: 0.60).

[b] In the first year, health care costs are simulated with a mean of $2,000; standard deviation of $2,000; a minimum of $1,560, which is approximately the cost of Medicare Part B premiums; and a maximum of $100,000 (an extremely rare event). Medical inflation is assumed to be normally distributed with a mean, standard deviation, correlation with general inflation, and correlation with the previous year's medical inflation, based on Medical Care cost component of the CPI, from January 1947 through October 2011 (mean: 5.43 percent; standard deviation: 1.06 percent; correlation with the previous year's medical inflation: 0.78; correlation with the current year's general inflation: 0.73; correlation with last year's general inflation: 0.77).

[c] The distributional assumptions for LTC risk are modeled based on Leora et al. (2014). Although there is some evidence of higher mortality for people in LTC, we have not included this assumption in our analysis.

[d] Investment returns are assumed to be drawn from a lognormal distribution with mean and standard deviation consistent with historical returns. For the period January 1947 through December 2010, the large cap/small cap portfolio returned an average of 14.2 percent with a standard deviation of 15.2 percent, and bonds averaged 6.5 percent with a standard deviation of 9.3 percent. Historical bond-stock correlation was statistically insignificant during this period, so is not incorporated in the simulation. Some experts believe that future asset market returns may be lower than historical averages, in which case, the estimated wealth needed to support retirement needs should be viewed as a lower bound.