Low Returns and Optimal Retirement Savings

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Abstract

Lifetime financial outcomes relate closely to the sequence of investment returns earned over the lifecycle. Higher return assumptions allow individuals to save at a lower rate, withdraw at a higher rate, retire with a lower wealth accumulation, and enjoy a higher standard of living throughout their lifetimes. Often analysis of this topic is based on the investment performance found in historical market returns. However, at the present bond yields are historically lower and equity prices are quite high, suggesting that individuals will likely experience lower returns in the future. Increases in life expectancy, especially among higher-income workers who must also rely more heavily on their private savings to smooth spending, further increases the cost of funding retirement income today. The implications are higher savings rates, lower withdrawal rates, the need for a larger nest egg at retirement, and a lower lifetime standard of living. We demonstrate this using a basic life cycle framework, and provide a more complex analysis of optimal savings rates that incorporates Social Security, tax rates before and after retirement, actual retirement spending patterns, and differences in expected longevity by income. We find that lower-income workers will need to save about 50 percent more if low rates of return persist in the future, and higher-income workers will need to save nearly twice as much in a low return environment compared to the optimal savings using historical returns.

Keywords: retirement planning, saving for retirement, sustainable spending, lifecycle finance

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This study explores how lower expected returns affect optimal saving and spending during working years, retirement replacement rates, retirement lifestyles, and the cost of bequests. This is important because the prices of bonds and stocks are much higher than in the recent past, suggesting a greater likelihood that portfolio returns will fall below the assumptions commonly used to estimate retirement savings adequacy. Basing retirement planning recommendations on historical returns can provide a misleading picture about what individuals at present will need to do to smooth their lifestyle and fund a successful retirement.

Workers face a number of unknowns when deciding how much to save for retirement. Future real returns on financial assets may be seen as following a continuum from reasonably certain (inflation-protected government bonds) to unknown (stocks).

Beginning with fixed income, Blanchett, Finke and Pfau (2013) estimate that the 10-year return on a bond portfolio can be predicted with 92 percent accuracy by using today's rates. Even if interest rates rise, the value of a bond portfolio itself will fall.

Workers also need to estimate future returns on more risky securities, and will generally draw from past risky asset returns to project the future. Stock returns over a 10-year horizon, however, can only be predicted with 27 percent accuracy by using today's valuations (10-year Shiller price/earnings ratio). Some may see this latitude in the ability to predict future returns as hope that risky assets will allow workers to achieve future portfolio returns near their historical average. Nonetheless, historical stock returns combined with low bond yields would suggest an equity risk premium well in excess of the historical experience, without further considering the implications of the valuation environment.

Can savers count on an elevated equity premium in the future in order to counteract the impact of low returns on safe assets? Increases in the price of risky assets over recent decades, however, suggests a lower expected equity premium than the historical average. For example, the total market capitalization of U.S. stocks grew from 50 percent to 141 percent of gross domestic product between 1980 and 2007 (Greenwood and Scharfstein, 2013). The increase in U.S. stock prices occurred was nearly three times the increase in net earnings during this time period.

In other words, stocks today are nearly three times as expensive as they were in 1980 for each dollar in profit. Equities will either need to become much more profitable in the future, or investors will need to continue to accept far lower dividend yields, for equity returns to approach their historical mean. Dividend yields today on the S&P 500 are less than half (2.1%) of the 4.4 percent historical dividend yield. In fact, when U.S. stocks historically have been as expensive as they are today, they have returned just 0.5 percent per year above inflation over subsequent 10-year time periods (Asness, 2012). Investors (or institutions) who are hoping that future returns on risky assets will counteract low yields on safe investments may be disappointed.

Even if stocks were able to deliver a risk premium near the historical average, they will still provide a lower nominal return according to the capital asset pricing model. Estimated returns according to CAPM are a combination of the risk-free rate and the risk premium. Since the risk free rate on 3-month Treasury Bills is currently 3.17 percent below the historical average (0.32% in 2016 vs. 3.49% between 1928 and 2015), nominal returns on equities in the future are expected to be 3.17 percentage points lower than the arithmetic historical average of 11.41 percent if the risk premium does not change.

We then begin with projecting future equity returns at 8.24 percent if the equity premium is as high as the historical average. In a comprehensive review of the U.S. equity premium over the 20th century, Fama and French (2002) estimate the expected equity risk premium as a function of the current stock price and both dividend and earnings growth. Since the only returns an investor can hope to receive from equity ownership are either future dividends payments or growth in future earnings, it is sensible to see the equity premium as a function of stock price and a firm's ability to pay money back to investors.

Fama and French note that historical U.S. equity returns can be split between two periods – 1875-1950 and 1951-2000. Between 1950 and 2000, growth in stock prices was 5.89 times greater than the growth in dividends. In earlier time periods, stock prices tended to rise in accordance with growth in dividends (or earnings). Recently, stock prices have risen more rapidly than a firm's earnings. The authors refer to this increase in stock prices as 'excess capital gain,' most of which occurred between 1980 and 2000.

Many investors and financial institutions became accustomed to returns that resulted from this excess capital gain during the 80s and 90s. But the rise in stock prices without a rise in stock earnings and dividends may have created an expectation of future returns that is inconsistent with the actual returns that stocks can provide at their current valuations. Stocks either need to fall significantly in value (by more than half) in order to maintain the historical equity premium, or investors will need to get used to a lower return on equity investments. Fama and French conclude that 'the high return for 1951 to 2000 seems to be the result of low expected future returns.'

Low asset returns also magnify the importance of fees on retirement savings. As recently as 1990, a 1 percent fee on 10-year Treasury bonds represented 12.2 percent of returns. Today, an investor pays 42 percent of returns at a 1 percent asset fee. Investors paid 8.85 percent in fees for each dollar of earnings from stock investments in 1980, and 29 percent in early 2017.

Are Investments More Expensive?

How will lower investment returns affect how workers plan for retirement? Figure 1 compares the cost of buying $1,000 of income from a 10-year Treasury Bond, the cost of buying $1,000 of stock dividends, and the cost of buying $1,000 or total corporate earnings during 20-year time periods beginning in 1955.

(Insert Figure 1)

The average cost of investment income in recent 20-year time periods suggests that it is more expensive to buy income from investments now than in the past, and that the era of high asset prices has persisted for a long period of time. There were a few periods during the 20th century when bond yields fell to a rate similar to the near zero yields of today, but these were generally caused by a flight to safety during each of the World Wars and the Great Depression. We now appear to be in a unique era in which low bond yields and high stock valuations are occurring in tandem for an extended period of time. This suggest an increase in demand for all financial assets.

Life Cycle Implications

A reasonable goal for most households is to save and spend in a manner that roughly smooths spending (as a proxy for the standard of living) over a lifetime. This implication of lifecycle finance is the primary motivation for retirement saving. Forward-looking workers will determine that their lifestyles cannot be maintained by Social Security alone, so they will set money aside during working years in order to avoid a spending reductions in retirement.

Among other factors, decisions about optimal lifetime saving and spending depend on future salary, retirement length, and the investment rate of return. For a given salary structure and length of life, higher investment returns will allow a household to save less while accumulating the same wealth at retirement. For example, assume a household earns $50,000 at age 25, expects

3 percent annual salary growth, and seeks $1 million at age 65. With a 5 percent investment return, this can be achieved with a 10 percent annual savings rate. But if returns are only 2 percent, the required savings rate increases to 18 percent to reach their goal.

Lower returns will also reduce the sustainable income that can be generated from $1 million at age 65. Figure 2 shows the amount of income a retiree can purchase using a bond ladder at real interest rates from 0 percent to 5 percent for a duration of 30 years (until age 95), 35 years, and 40 years (to age 105). Sustainable income falls from $61,954 to only $38,364 as rates fall from 5 percent to 1 percent. Extending the ladder to age 100 or 105 not only reduces the income that can be withdrawn each year at 5 percent ($58,164 and $55,503), but also increase the income spread compared to a 1 percent expected return ($33,667 and $30,154). Longer retirements are particularly hard hit by lower asset returns. Figure 3 also shows how optimal spending levels are reduced with lower rates of return as well as a desire to also fund a legacy goal.

(Insert Figure 2)

(Insert Figure 3)

As seen in Figure 4, income replacement rates at retirement will also fall with lower expected returns if the retiree is seeking to smooth the lifetime standard of living. Planners need to consider the need to adjust replacement rates downward if they anticipate a low return environment during the retirement planning process. While optimal replacement rates at a 6 percent real portfolio return are near the 70 percent replacement rate rule of thumb, a 2 percent real portfolio return will result in an optimal replacement rate of about 55 percent when there is no legacy objective. At a 0 percent real portfolio return, the optimal replacement rate is a bit above 40 percent. With a legacy goal of $500,000, the optimal replacement rate falls further to 31 percent.

(Insert Figure 4)

Finally, a perhaps counterintuitive, result of our life cycle simulations in a low-return environment is that households will need to accumulate more wealth by the time they retire in order to maintain even a lower standard of living in retirement– particularly if they hope to leave a legacy. At a 2 percent expected real rate of portfolio return, a household will need to save just over $1 million by retirement with a $500,000 legacy goal, while a household expecting a 6 percent real rate of return will need to save just over $750,000. The amount of savings required in a low return environment as shown in Figure 5 (the difference between income and spending) needs to be much higher to fund a larger nest egg in order to pay for a more expensive retirement. As noted, the amount that the household can spend each year in this more expensive retirement is also more modest.

(Insert Figure 5)

What is a reasonable portfolio return assumption? From the investor's perspective, the choice should be net of inflation, investment expenses, asset management fees, and taxes. Real interest rates can be found using the yield curve for Treasury Inflation-Protected Securities (TIPS). With a generous 1 percent and longer-term maturities, investment and asset management fees may result in negative real returns. Expected real equity returns may be in the range of perhaps 2-4 percent net of asset fees and inflation. It is reasonable to understand the planning consequences of a future 0 percent to 2 percent real future portfolio return.

Changes in Longevity

While the length of the retirement lifecycle stage is unknown at the time of retirement, the cost of funding an income stream rises with average expected longevity. If longevity rises, a worker faces three choices. They can retire at an older age. They can retire at the same age as yesterday's retiree and spend less. Or they can retire at the same age and accept a greater risk of outliving assets while maintaining the same lifestyle. Naturally, none of these choices results in a better retirement.

Life expectancies for Americans who reach the age of 65 rose significantly during the 20th Century. Figure 6, Panel A shows historical and projected life expectancies for 65-year-old men and women in the United States according to The Society of Actuaries 2012 immediate annuity mortality table, which assumes that mortality rates will decline by about 1 percent per year.

In addition to improvements in longevity, higher income earners are living longer than lower earners. Figure 6, Panel B shows the increase in life expectancies by percentile of household income. This relatively recent trend (Chetty et al., 2016) in which higher earning Americans are seeing the largest improvements in longevity raises the cost of retirement for those who rely the most on savings to maintain a constant lifestyle in retirement. Since Social Security provides a larger income replacement rate for lower-income workers, increases in longevity raise the cost of retirement for those who need to replace the largest portion of their retirement income with savings.

(Insert Figure 6)

The simultaneous improvement in longevity coupled with the decline in real interest rates on bonds raise the cost of buying an annuitized income stream in retirement. In Figure 7, we estimate the cost of buying $1 in income via an inflation-adjusted annuity through mortality weighted net present value of cash flows needed to fund average lifetime income. Uses historical mortality tables from the Social Security Administration, historical bond Treasury yields from the Federal Reserve, and historical implied inflation estimates from Cleveland Federal Reserve, we are able to calculate the cost of buying safe real income between 1982 and 2015. Observed annuity payouts offered by annuity companies differ slightly, but are very similar to the prices of annuities using data from www.immediateannuities.com.

(Insert Figure 7)

The combined effects of increasing longevity and falling real interest rate doubled the cost of buying safe income between 1982 and 2015. In other words, a retiree today who hopes to fund expenses through safe investments will need to save twice as much, all else equal, if they expect to retire at age 65.

It may be tempting for retirees to avoid annuitizing wealth at retirement when the cost of buying safe income is so high. In reality, annuitizing safe investments becomes even more important when interest rates are low. This is because the alternative to annuitization, building a bond ladder, is also more expensive when interest rates are low. But the difference between the cost of buying a bond ladder to fund spending, particularly spending at older ages, and buying income through an annuity widens as interest rates fall. In other words, the mortality credit that allows a retiree to spend a higher percentage of their income than they could receive from a bond ladder becomes relatively more important when interest rates are low.

Estimated Increases in Optimal Savings Rates

Many of the assumptions in the basic lifecycle model are not realistic. There is no Social Security income, which provides an income cushion that softens the blow of low asset returns. We do not consider differences in taxation before and after retirement, nor do we consider the natural decrease in spending that most retirees experience as their physical and cognitive abilities decline in old age.

To address these complexities, we create a model to estimate the required savings rate needed to fund a spending amount after tax that smooths consumption immediately after retirement and then maintains a typical retiree's subsequent declining spending path (Blanchett and Idzorek, 2015). We also incorporate the impact of progressive taxation at different levels of income before and after retirement, and estimate the amount of Social Security income a retiree at different levels of income can expect to receive. We assume that all savings are pre-tax (e.g., in a Traditional 401(k) or IRA). A more detailed description of assumptions is provided in the Appendix.

Following the empirical estimation of the actual decline in real spending that occurs during retirement Blanchett, (2014), we assume that real spending needs fall each year in retirement. Earnings paths are also based on empirically observed changes in earnings by age and level of income. Using actual estimates of worker earnings paths is particularly important for younger workers who, on average, experience the highest rates of earnings growth. We also assume that the amount of annual savings rises with income over the lifecycle.

Since longevity is expected to improve for future workers, we assume younger workers will have to fund more years of spending in retirement if they retire at a given age. Since higher-income workers will also live longer, we assume that higher earners will need to fund more years of retirement spending.

American retirees rarely annuitize their savings to provide guaranteed income throughout retirement. In the absence of annuitization, a certain percentage of retirees who either living a long time or who experience low returns from risky asset will outlive their savings. This requires us to establish an acceptable probability of depleting savings during retirement in order to maintain a lifetime spending path. In our simulations, we set this probability at 20 percent. A lower probability would result in higher estimate savings rates. Mortality rates for single households are based on gender-neutral mortality while mortality rates for a married household assume one male and one female that are the same age.

Asset returns are estimated using an autoregressive model (Blanchett, Finke, and Pfau, 2013). The return models are calibrated so that one return series approximates the historical averages, and includes three additional scenarios of low, medium, and high expected returns. The high scenario has returns that are similar to the long-term averages, but incorporate today's low bonds yields. We also include a 50 bps portfolio fee, so workers to pay higher fees on savings will need to save more than our estimates.

Asset allocation is assumed to decrease the allocation to risky assets as the worker nears retirement. The allocation is based on the Morningstar Moderate Lifetime Index glide path, which uses a holistic portfolio model that includes the present value of human capital as a bond-like asset to estimate optimal allocation over a life cycle (Morningstar, 2015).

We estimate savings rates for scenarios that include low, moderate and historical asset returns. In the low and moderate simulations, we assume that bond yields begin at a 2 percent real rate of return. In the low return scenario, the mean real return starts at 2 percent and follows a random distribution that rises to 3.5 percent at the 75^{th} percentile and 5.25 percent at the 95^{th} percentile (or falls to 1 percent at the 5^{th} percentile). In the moderate return scenario, the real return rises to 4 percent on average. Since rates of return on long-duration corporate securities are currently below the mean expectations in low return scenario, our projected savings rates using these rates of returns may underestimate the savings rates needed if the low return environment persists.

Analysis

Results from Table 1 shows optimal savings rate simulation results for workers at various ages and income levels who plan to retire at age 65. Optimal savings rates using historical data for joint households who begin saving at age 25 are between 4.3 percent for low ($25,000) earners up to 9 percent for high earners ($250,000), and between 6.8 percent and 8.8 percent for singles. Higher-income households must save more because Social Security replaces a smaller percentage of income and because of progressive taxation.

(Insert Table 1)

Assuming more realistic asset low returns increases the optimal savings rate by 63 percent to 7.0 percent for couples with $25,000 of household income and by 82 percent to a 16.4 percent savings rate for couples earning $250,000. Lower interest rates have a larger impact on optimal savings rates for higher earners. For most higher-income workers, a persistent low return environment would result in workers optimally contributing up to the limit of their employer-sponsored retirement contributions even if they begin saving at a young age. This is not the case if the worker relies on historical returns to estimate optimal savings.

The increase in savings needed to fund optimal retirement savings is even more dramatic if households don't begin saving for retirement until age 35 or 40. Optimal savings rates rise to 24.1 percent in a low return simulation compared to 14.3 percent using historical returns for a single worker for those who begin saving at age 35. If the household waits until age 40, the optimal savings rate rises to 27.5 percent. Even in a moderate return scenario, optimal savings rates are 24.8 percent for a single household and 22.8 percent for a couple. Either single or joint households who use historical asset returns to project optimal savings rates would save near the employee contribution limit for those with incomes about $100,000. At lower interest rates, this amount of savings is not nearly enough to sustain a lifestyle if they choose to retire at age 65.

Fortunately, most retirees are able to defer retirement to a later age. This allows them to save less during their working years, resulting in an improved lifestyle both before and after retirement. Despite deferring retirement until for a few years, increases in longevity will not necessarily result in fewer years spent in retirement. For this reason, a reasonable alternative is to delay retirement since doing so increases the number of years of savings (and asset growth), reduces expected longevity, and increases Social Security income. Table 2 show how optimal savings can be reduced (or lifestyle today can be improved) by delaying retirement for a household that begins to save at age 35.

(Insert Table 2)

A couple earning $250,000 could reduce their savings rate from 26 percent to 18.7 percent if they deferred retirement from age 60 to age 70. The benefits of deferring retirement are even greater in a low return environment. A couple using historical rates would need to save only 16.4 percent of income to retire at age 60 and 12.2 percent if they retired at age 70. Workers who are shown more realistic projections of return assumptions may be more likely to choose a later retirement date, while those who project their retirement savings using historical return rates may falsely believe that modest savings rates will allow them to retire at age 65.

Conclusion

Prices for stocks and bonds in recent decades have risen well above their historical averages. Higher asset prices imply lower expected future asset returns, and workers who rely on historical asset returns to project optimal savings rates and retirement dates are at risk of an unexpected shortfall. Improvements in longevity have also increased the cost of retiring at a given age. Workers, employers and policymakers who rely on historical asset returns to make saving recommendations may not recognize how sensitive optimal savings rates are to persistent low investment returns.

Using a simple life cycle framework, we show that low returns result in a significantly more modest lifestyle for workers before and after retirement. In a more realistic model of optimal, we estimate that lower return assumptions will result in much different optimal saving rates than if historical asset returns are used. Optimal savings would need to rise by roughly two-thirds for most Americans, and higher-income workers are most at risk of under-saving if they use historical asset return projections. Higher savings rates imply that workers will need to spend less today in order to maintain the same lifestyle in retirement.

Improvements in longevity and lower real returns on safe investments mean that buying a dollar of real, after-inflation income at age 65 in 2015 was twice as expensive as buying a dollar of real income in 1982. Retirement calculators often do not include this increase in the cost of retirement when projecting optimal savings rates for workers. Even if the comparatively higher U.S. equity premium persists in the future, lower rates of return on safe assets suggest a lower total real return on risky assets. And today's equity valuations imply a lower likelihood of that high equity premium enjoyed by yesterday's workers may not be as generous for workers in the future.

Workers who believe that asset returns in the future will be lower than in the past have two choices if they want to maintain their lifestyle in retirement. They can either save more, which will lead to a significant reduction in lifestyle in the present, or they can work longer. For many, the best response will be to do both. For example, we estimate that a couple earning $150,000 per year who begins saving at age 35 can save 13.8 percent of their income in order to maintain their lifestyle in retirement if they delay retirement to age 70.

Workers, employers, or policymakers using historical asset return data or outdated mortality assumptions may be significantly underestimating how much workers will need to save, and the age at which they will need to retire, in order to maintain their lifestyle in retirement. The risk of presenting unrealistic scenarios is that workers are unable to make the right tradeoffs when estimating how much they need to save in order to achieve retirement security.

Appendix 1: Methodology and Data Details

The model is similar to the one originally introduced by Blanchett and Idzorek (2015) to determine the funded status of participants in defined contribution plans.

Retirement Income Goal. The retirement income goal is based on the assumption that the individual wants to maintain the level of after-tax (i.e., take-home) pay during retirement equal to the after-tax income during the final year before retirement. Retirement is assumed to commence at age 65.

While some financial planning tools may use simple rules of thumb when estimating the income replacement level, such as 70 percent or 80 percent of final gross pay, in reality the number is going to vary significantly by household. The replacement level is generally less than 100 percent because a number of expenses that individuals incur when working disappear during retirement, such as Medicare taxes, Social Security taxes, and retirement saving (e.g., deferring in the DC plan), although the impact of these will vary by household. For example, an individual saving 25 percent of her pay before retirement will have a lower take-home pay, and therefore a lower retirement income goal, than an individual saving 5 percent.

The idea of appropriate replacement levels has been explored by Aon (2008) and Blanchett (2013), among others. Blanchett (2014) demonstrates that while a rule-of-thumb replacement level between 70 percent and 80 percent is reasonable, it isn't ideal. Moreover, the ideal replacement level is sensitive to the proportion of pretax expenses to after-tax expenses—in fact the range expands to 54 percent-87 percent for a set of reasonable cases. The range would expand further if additional information about the individual/household were available (e.g., if mortgage payments would be made in retirement).

Change in Annual Retirement Income Need. While most retirement income models assume that retiree consumption (i.e., the annual retirement income need) increases annually with inflation throughout retirement (i.e., constant real spending), research by Blanchett (2014), among others, suggests that actual retiree spending does not tend to increase by inflation throughout retirement. For example, Blanchett finds that retirees tend to decrease spending during retirement, in real terms (i.e., today's dollars), although the relationship varies by the total level of household spending. Blanchett introduces a formula in his paper (equation 1 in the piece, which is included below as equation A1.1) that is used to determine how the annual retirement spending need is assumed to change (ΔAS) during retirement for a given age (Age) and for a given target spending level ($SpendTar$).

$$\Delta AS = 0.00008(Age^2) - (0.0125 * Age) - 0.0066 \ln(SpendTar) + 54.6\% \quad \text{[A1.1]}$$

For the analysis the annual retiree real income need is assumed to change throughout retirement based on equation A1.1, where the maximum annual real change is +1 percent and the minimum annual real change is -1 percent. Figure A1.1 provides information about how the real retirement income need (i.e., in today's dollars) would change for three target spending levels: $25,000, $50,000, and $100,000 from ages 65 to 100.

Figure A1.1 here

If retiree spending increased annually by inflation, which is the most common retirement income need assumption, the annual real dollar retirement need would be a flat $1 in Figure A1.1. Using the spending curve introduced in equation A1.1, though, real retiree spending decreases early in retirement then increases later in retirement (due to an increase in medical expenses). It is important to note that while spending increases later in retirement, it is still below the initial spending level for each of the income levels in Figure A1.1.

Figure A1.1 also demonstrates that retirees with higher spending targets will decrease spending by a greater amount during retirement (e.g., \$100,000 versus \$25,000). This can be attributed to higher income retirees having a higher portion of expenditures in discretionary goods and an apparent desire of wealthier retirees to spend less (relatively speaking) at older ages. Incorporating spending curves partially offsets the differentials in the expected length of retirement for different income levels. For example, a lower income household will be forecasted to have a shorter retirement (versus a higher income household), but their retirement spending will be higher in relative terms (i.e., it doesn't decline as much).

Income Growth Model. Earnings are not generally constant over a worker's lifetime (i.e., they tend to increase in real terms). Therefore, to better replicate how an individual's earnings are likely to change over the worker's lifetime an 'earnings curve' is developed based on data from the IPUMS-CPS. In order to be included in the analysis individuals must be coded as employed, working at least 20 hours a week in all jobs, and must have annual total wage compensation of at least \$5,000. Worth noting is the income definition is for each individual (not a household) and it only includes wage income (i.e., it does not include non-wage income such as pension benefits).

The earnings curves are in today's dollars and represent how the wages of the worker are expected to change over the individual's working lifetime. Note, while the dataset reflects wages for workers across various ages today, we assume these curves persist over time. In reality there may be systemic differences in the wages a 30-year-old makes in 20 years versus the wages a 50-year-old is making today, but such considerations are beyond the scope of the analysis. It is assumed that individuals in a given percentile (e.g., the 15th percentile) in wages remains in that percentile for his or her entire working career.

(Insert Figure A1.2 here)

Earnings curves are especially important for younger workers (i.e., younger than 35), who are likely to experience significant increases in earnings over their working lifetimes. For example, a 25-year-old individual in the 85th percentile would have wages of approximately $50,000; however, these wages would approximately double by age 50. Required savings levels that do not account for increases in future compensation would likely suggest lower levels of required savings

For the analysis the individual's percentile wages are first determined using formula A1.2. Note all coefficients are significant at the 1 percent level.

$$IncPerc_i = -161.321 - 3.250Age + .047Age^2 - 10.956\ln(Inc) + 1.749\ln(Inc)^2 - .126(Age * ln(Inc)) \quad [A1.2]$$

The wages are then assumed to growth based on the earnings 'path' for that percentile, based on all coefficients significant at the 1 percent level. A1.3

$$IncGro_i = 77.216 - 2.881Age + .024Age^2 - .265IncPerc - .001IncPerc^2 - .009(Age * IncPerc) \quad [A1.3]$$

The change is constrained such that it is never greater than 5 percent in absolute terms.

Savings Growth Model. A common assumption in accumulation forecasts is that deferral rates remain constant as the individual ages; i.e., if the individual is 30 years old and deferring 6 percent, he or she will continue to defer 6 percent of salary until retirement. While total dollar saving may increase if wages are assumed to increase, saving a constant percentage of compensation doesn't track actual investor behavior. Figure A1.3 depicts percentile deferral rates (as a percentage of compensation) for participants in DC plans from ages 20 to 65. This analysis is based off 136,250 participants as of December 31, 2015 with individual participant data provided by a 401(k) recordkeeper.

Figure A1.3 here

Figure A1.3 provides strong evidence that similar to income, savings rates are not constant over time. Therefore, as instead of assuming a constant savings rate over an individual's working lifetime, it is assumed that the deferral rate changes ($Def\Delta$) throughout the accumulation period based on a participant's age (Age) using equation A1.4. The coefficients in equation A1.4 are based on the participant data used to create Figure A1.3. All coefficients were significant at the 1 percent level.

$$Def\Delta = 4.9513 - .101Age + 7.401E\text{-}04Age^2 \qquad [A1.4]$$

The formula assumes that savings rates increase by approximately 25 percent over 10 years. For example, a 35-year-old savings 10 percent would be assumed to be savings 12.27 percent at age 45 and 1.56 percent by age 55.

Retirement Period. Improvements in life expectancies are important when estimating the retirement period since retirement is likely to last longer for an individual who is currently 25 years old and retiring in 40 years, versus an individual who is retiring today at age 65. The base mortality table used for this analysis is the Social Security Administration 2013 Periodic Life Table. The mortality rates are assumed to decline based on the G2 projection scale in the Society of Actuaries 2012 Individual Annuity Mortality Table. These improvement factors vary by age and are included in Figure A1.4 below.

(Insert Figure A1.4)

In addition to improvements in mortality rates there has also been a noted change in life expectancies for different income levels. For example, Waldron (2007) notes that men born in 1941 in the top half of the earnings distribution would be expected to live 5.8 years longer than men in the bottom half of the distribution (which is up significantly from the difference of 1.2 years for men born in 1912). Bosworth and Burke (2014) note a difference in life expectancies of approximately 10 years for men and approximately six years for women between the top and bottom income deciles. Figure 2 (in the main text) provided strong evidence that wealthier (i.e., higher income) individuals are likely to live longer in retirement than less wealthy retirees. Therefore, the duration of retirement should vary by income level.

While we previously estimated income percentiles for individuals ($IncPerc_i$) to estimate earnings curves, research on mortality differences has focused on total household income, of which wages are only one important component. However, since the analysis as based on wages, and wages are predominant source of income for the vast majority of households saving for retirement (i.e., still working), we base our income percentiles for mortality based on total household wages. We use equation A1.5 to estimate household income percentiles, which is based on a multivariate regression using data from the IPUMS-CPS. Each of the regression coefficients was significant at the .01 percent level and the R^2 of the model was 94.61 percent when fitted to the 1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 95th percentiles from ages 20 to 70.

$$HHIncPerc_s = -412.760 - 2.256Age + .033Age^2 + 63.289\ln(HHInc) - 1.165\ln(HHInc)^2 - .102Age * \ln(Inc) \quad \text{[A1.5]}$$

The income percentile is matched to the expected improvement in mortality based on the values in Figure 2. If gender is not available an average of male and female is used. The 'improved' mortality rates (i.e., the Social Security Administration 2013 Periodic Life Table mortality rates reduced by the appropriate G2 factor based on years to retirement) are then further adjusted (by a constant factor) so that the life expectancy for that individual is consistent with the life expectancy differential for that income percentile. These mortality rates are then used to determine a retirement period such that the probability of outliving of living the retirement period is 25 percent. Mortality rates for joint couples are assumed to be independent.

Returns Model. There are three types of return series created for this analysis. First, for bond returns, the first step in the model is to select an initial bond yield (i.e., seed value) for the simulation. This is the bond yield that exists at the beginning of the retirement simulation; based on approximately on 10-year U.S. bonds. For simulation purposes, the historical yield seed is assumed to be 5 percent, which is the long-term approximate average and current yield see is assumed to be 2.0 percent.

Given an initial bond yield, the yields for the subsequent years are based on equation 1, where $\varepsilon_{\mathrm{Yld}}$ is an independent white noise that follows a normal distribution with a mean of 0 percent and a standard deviation of 1.25 percent. The resulting annual bond yield (Yld_t) is assumed to be bounded between a minimum of 1.0 percent and a maximum of 10.0 percent.

$$Yld_t = \alpha + \beta_1 Yld_{t-1} + \beta_2 {Yld_{t-1}}^2 + \varepsilon_Y \quad [1.1]$$

The coefficients in equation vary by return model-type, as noted below.

	Historical	**Low**	**Mid**	**High**
α	0.25%	0.30%	0.30%	0.40%
β_1	0.95	0.55	0.65	0.50
β_2	0.00	0.50	0.50	0.65

After the bond yield for a given year is determined the bond return (r_{bond}) is estimated using equation 1.2, where $\varepsilon_{\text{bond}}$ is assumed to have a mean of 0.0 percent and standard deviation of 1.5 percent.

$$r_{bond} = Yld_{t-1} + -8.0(Yld_t - Yld_{t-1}) + \varepsilon_{bond} \qquad [1.2]$$

It is worth noting the 1.5 percent standard deviation for the error term (ε_{b}) is not the assumed standard deviation for the asset class (bonds in this case), rather the standard deviation for the errors around the regression estimates. The actual standard deviation of bond returns is 10.0 percent. The actual standard deviation is higher because other factors (such as the yield and the change in yield) are affecting the actual variability of returns.

Next, the stock return model is based on the yield for a given year plus the assumed equity risk premium (ERP). Historical ERPs have varied significantly by country, as noted in Table 1, with the U.S. having a higher than average ERP. Therefore, we assume varying levels of ERP for the analysis…

	Historical	**Low**	**Mid**	**High**
ERP	5.5%	3.5%	4.5%	5.5%

The return for stocks each year is based on equation 1.3, where $\varepsilon_{\text{stock}}$ is assumed to have a mean of 5 percent and standard deviation of 20 percent, where Yld_t is the average yield for all years in that scenario.

$$r_{stocks,t} = \overleftarrow{Yld_t} + \varepsilon_{stocks} \qquad [1.3]$$

Finally, the inflation model is based on the loose historical relation between bond yields and inflation and is included in equation 1.4, where ε_{i} is an independent white noise that follows a standard normal distribution with a mean of 0 percent and a standard deviation of 0.5 percent.

$$r_i = 0.6\% + + 0.5Yld_{t-1} + \varepsilon_i \qquad [1.4]$$

Additional Assumptions. Social Security retirement benefits are estimated based on the highest assumed average 35 years of compensation for the participant. Lifetime earnings are estimated based on the participant's income percentile (equation A1.1) and the change over the lifetime is based on equation A1.2. Social Security retirement benefits are estimated based on the 2015 bend points, and are assumed to commence upon retirement (age 65).

The required level of retirement savings is determined using a solver routine. The objective for each routine is to determine the amount of savings or balance required to achieve an 80 percent probability of success during retirement. While 80 percent may seem like a relatively aggressive estimate (e.g., some researchers use probability-of-success metrics that exceed 95%) it is important to look at the combined impact of the assumptions, and not just focus on a single assumption in isolation. For example, two of the most important assumptions when estimating the cost of retirement are the assumed length of retirement and the target safety level (i.e., the target probability of success). Since the length of retirement period is relatively conservative (i.e., much longer than true life expectancy) the target success level doesn't need to be as conservative (e.g., it is possible to target an 80% chance of success versus a 95% chance of success). It is also important not to be too conservative with respect to assumptions (e.g., assuming a 99% probability of success) given the potential impact on consumption during retirement. After all, dying at an advanced age with a major portion of savings untouched is another form of retirement 'failure' (except, of course, in the case of a planned bequest).

For simplicity purposes all savings are assumed to be Roth contributions. For some scenarios the individual is unlikely to have accounts available to fund Roth (e.g., if they need to save $50,000). The portfolio allocation is assumed to follow the Morningstar Moderate Lifetime Index glide path. The portfolio fee is 50 bps.

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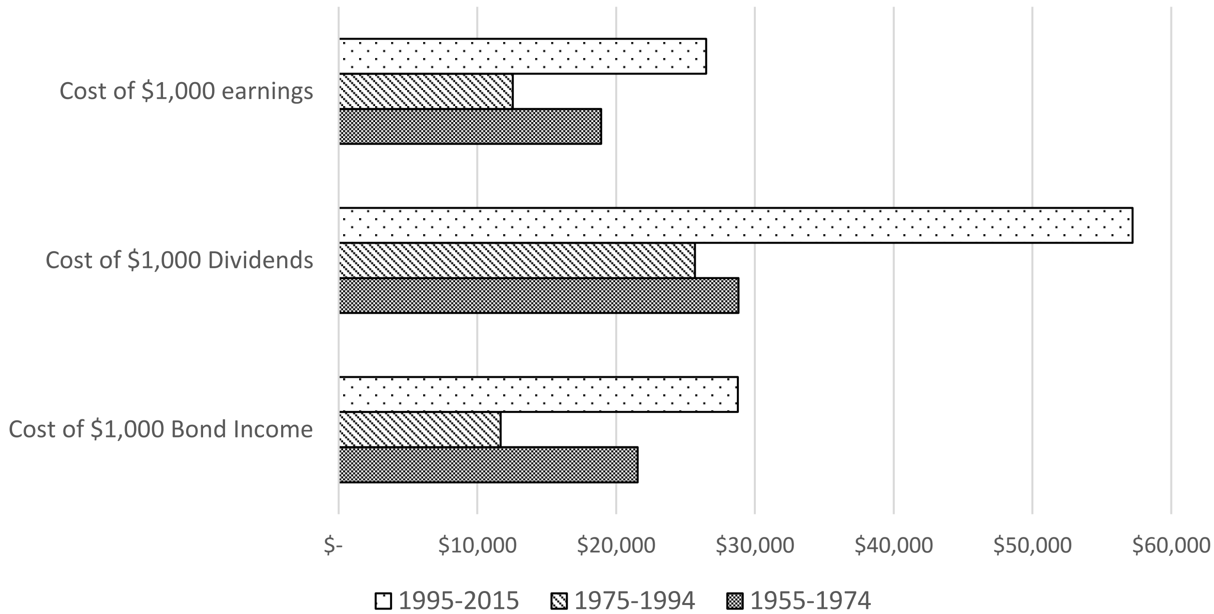


Figure 1: Average cost of purchasing $1,000 in 10-year Treasury income, dividends, and corporate earnings

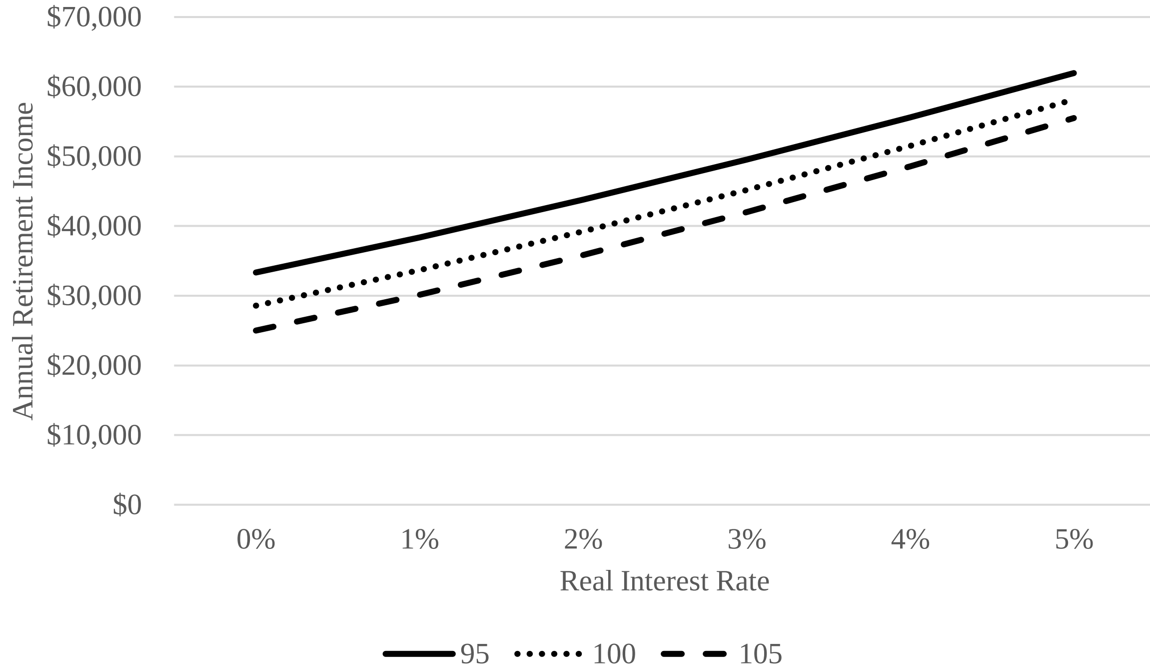


Figure 2: Cost of funding retirement income with a $1 million bond ladder

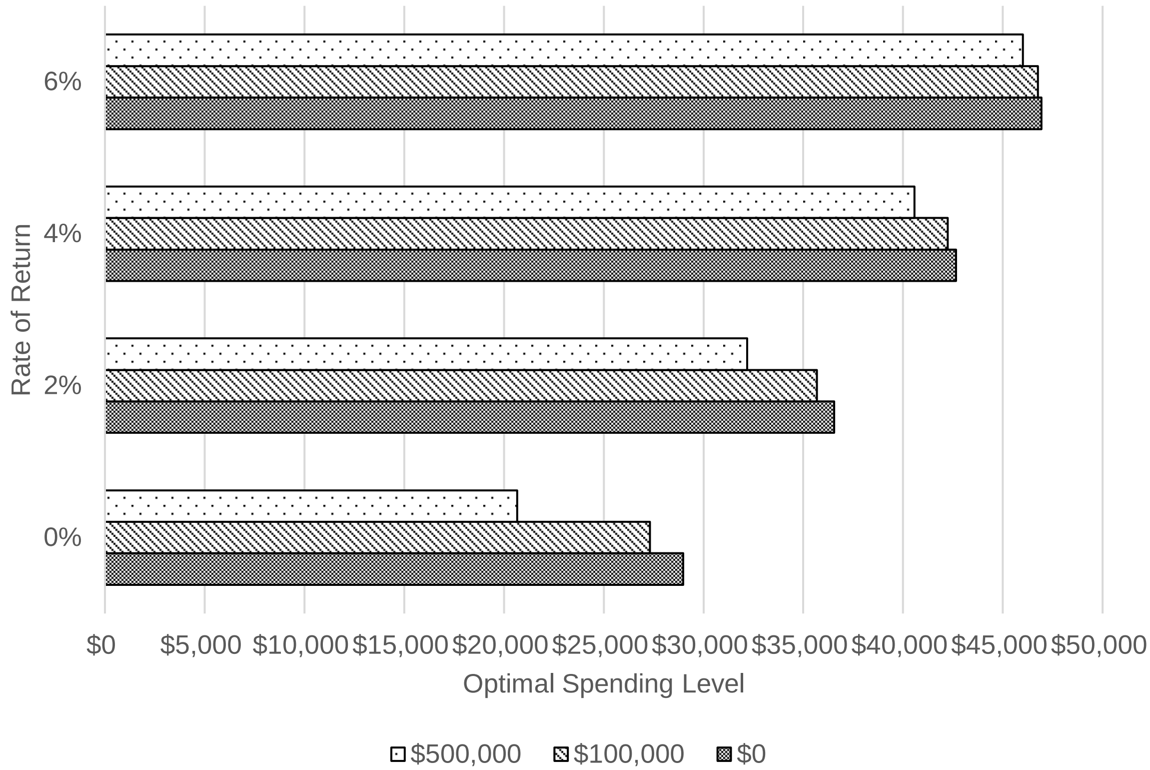


Figure 3: Optimal spending by expected real portfolio return and legacy goal

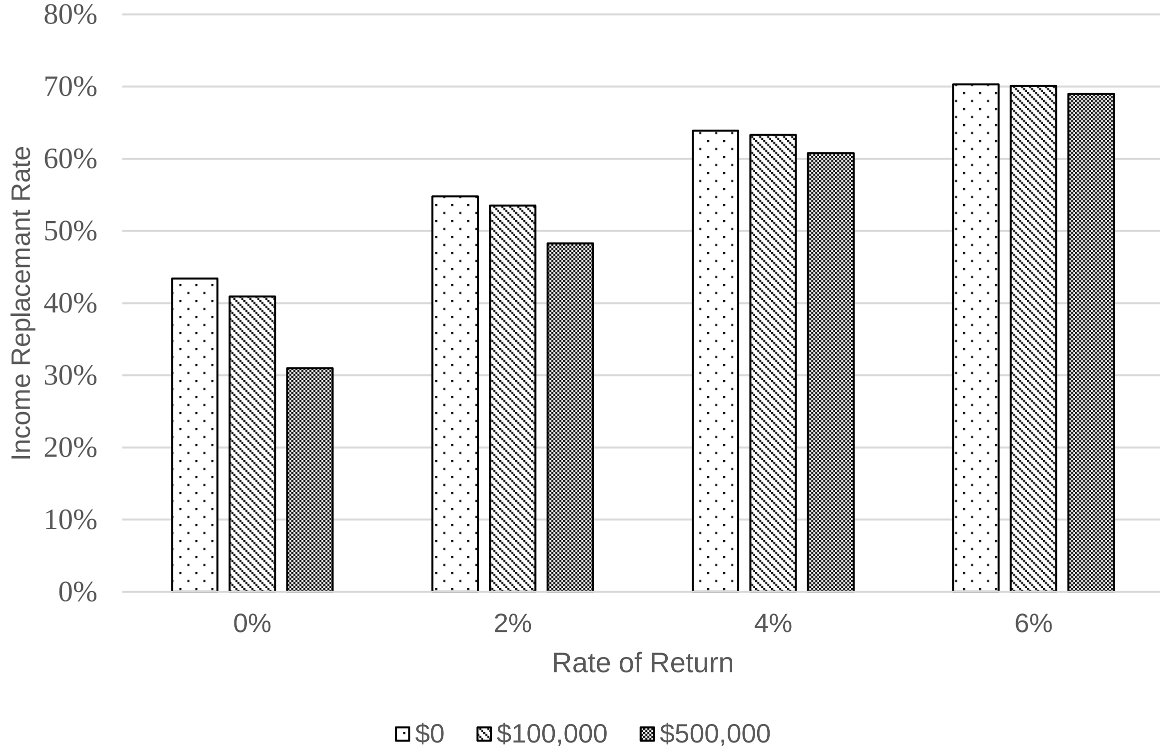


Figure 4: Income replacement rates and legacy goal

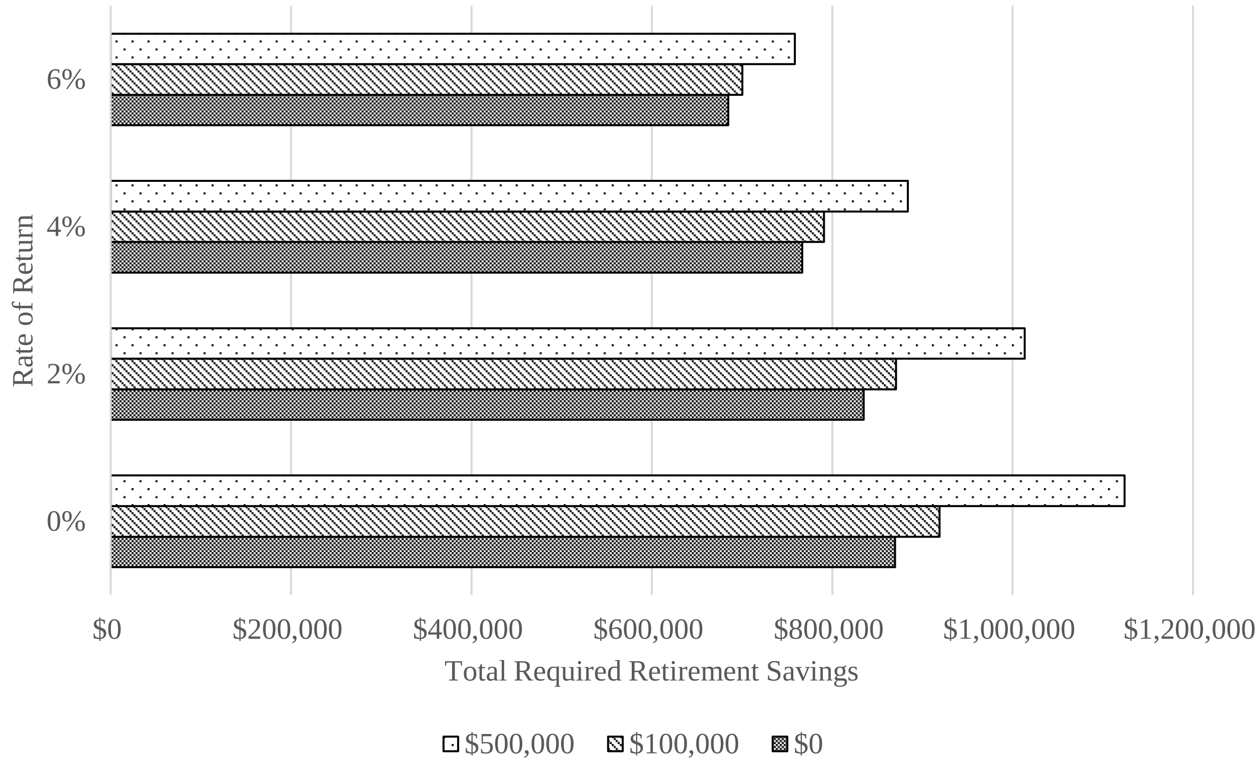
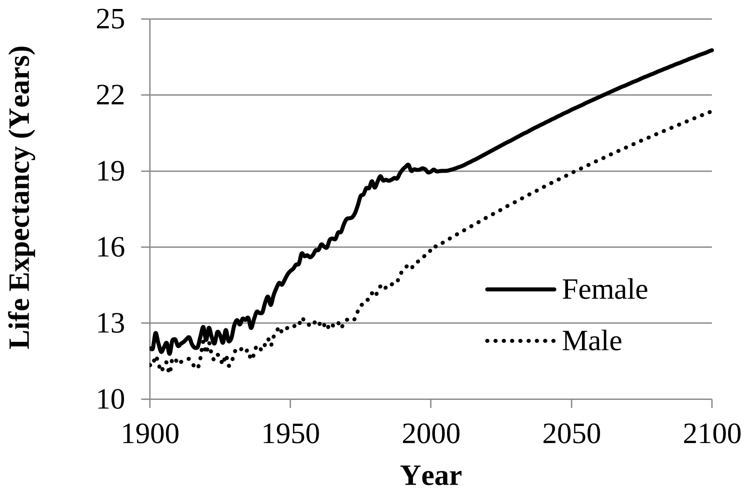


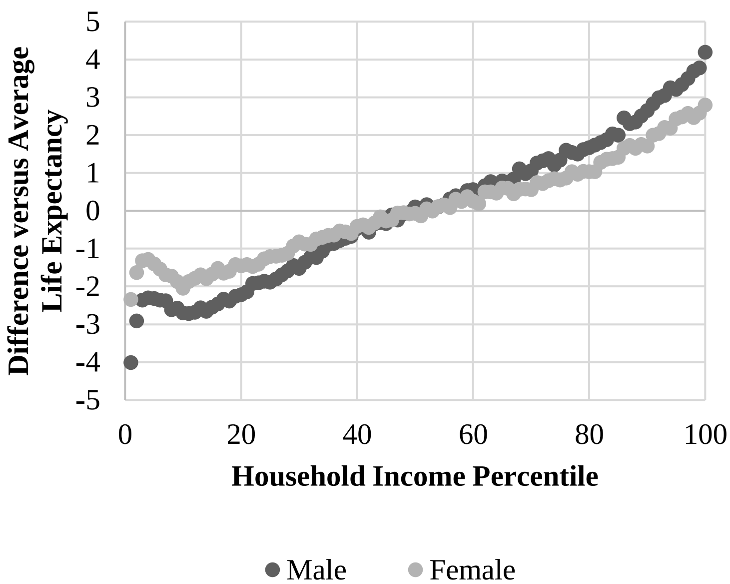
Figure 5: Total savings required to fund lifetime spending goal at retirement by legacy goal amount

Panel A: Historical life expectancies



Source: Social Security Adminstration

Panel B: Differences by household income



Source: Human Longevity Project

Figure 6: Life expectancies for a 65-year old man and woman

Source: Blanchett, Finke and Pfau, 2017

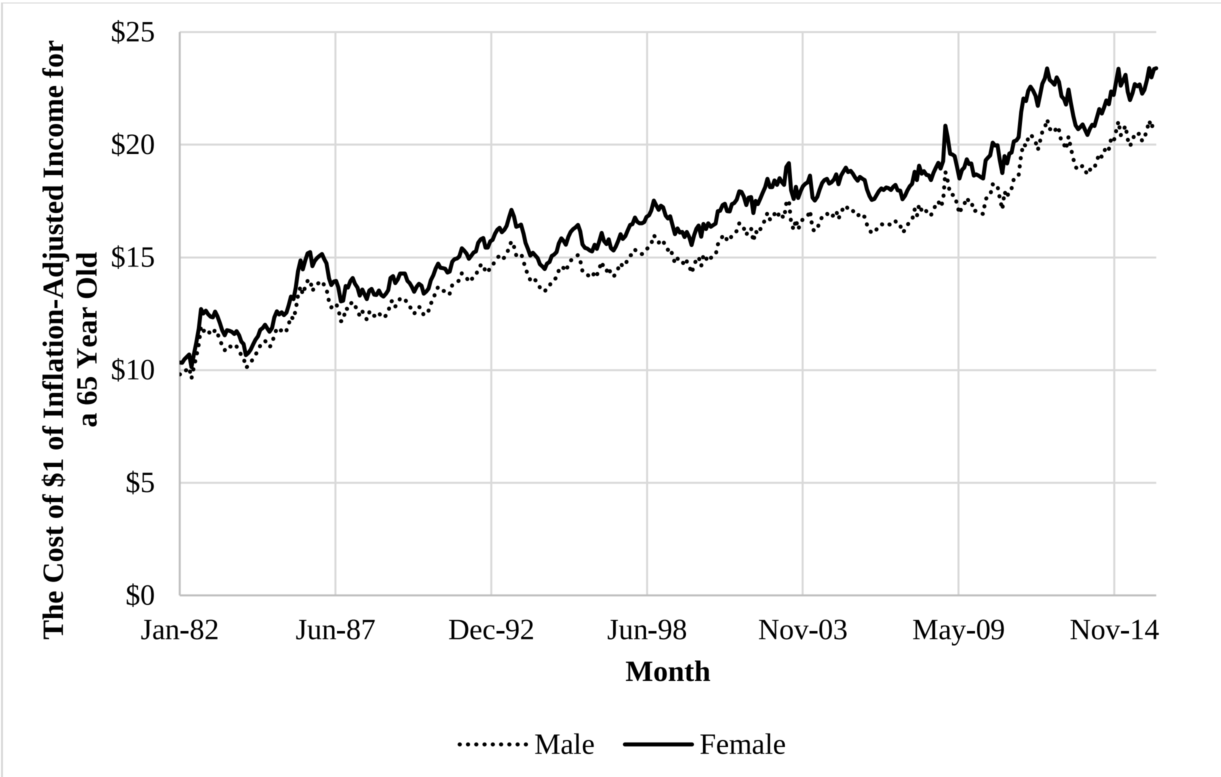


Figure 7: The cost of buying $1 in real annuity income at age 65

Source: Blanchett, Finke and Pfau, 2017

Appendix Tables

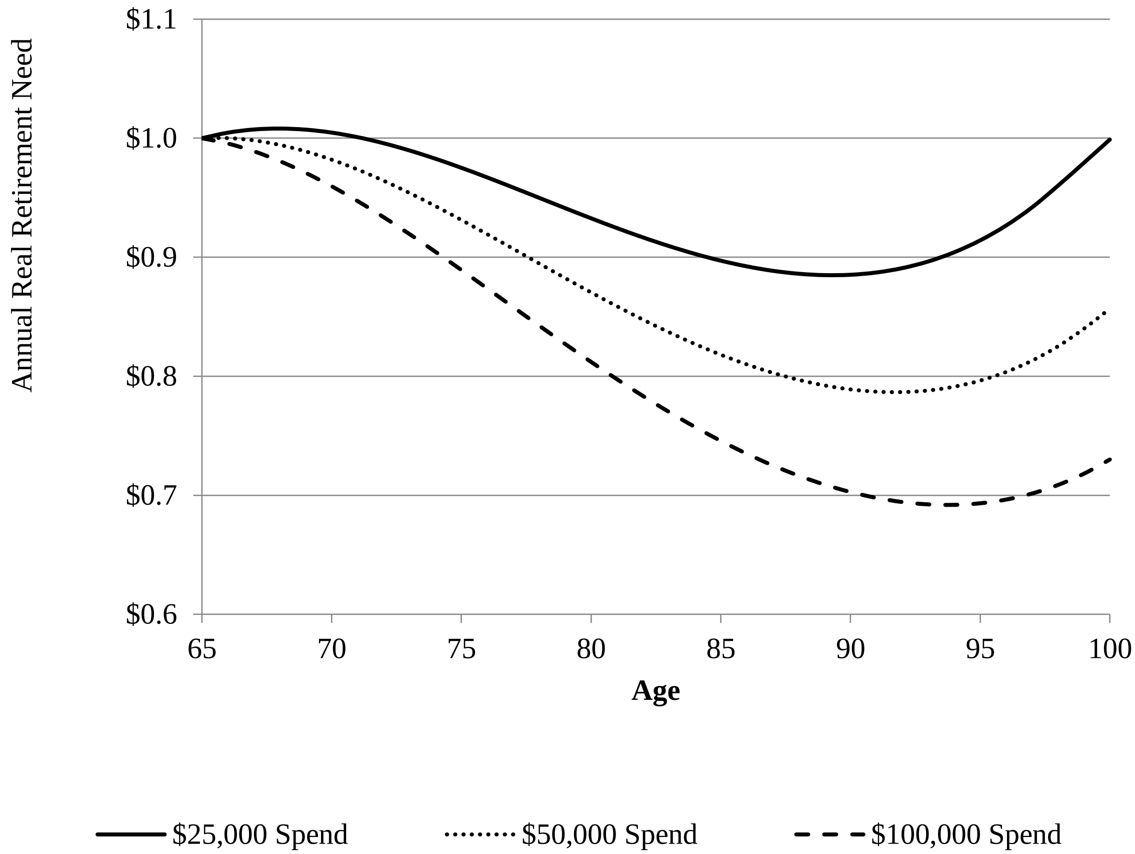


Figure A1.1: Lifetime real income target for various spending levels

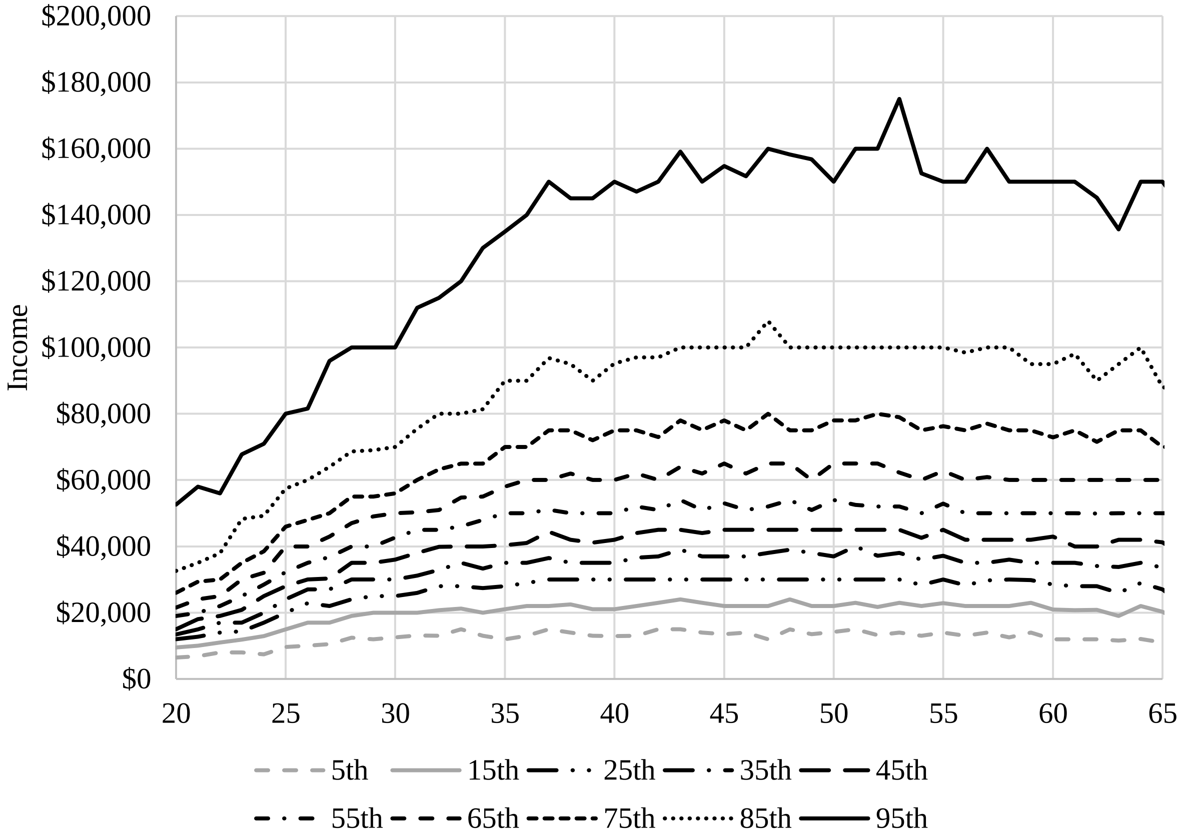


Figure A1.2: Earnings curves at various income percentiles

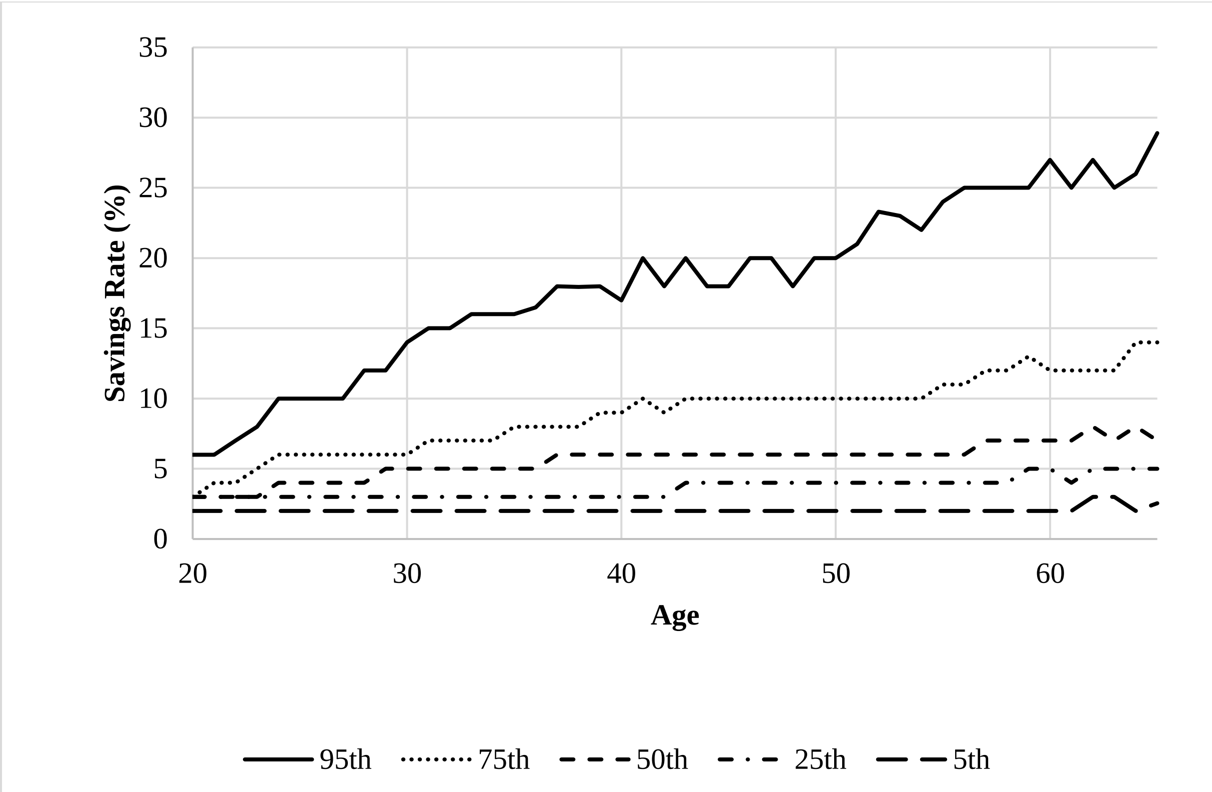


Figure A1.3: Deferral rates by age for various percentiles

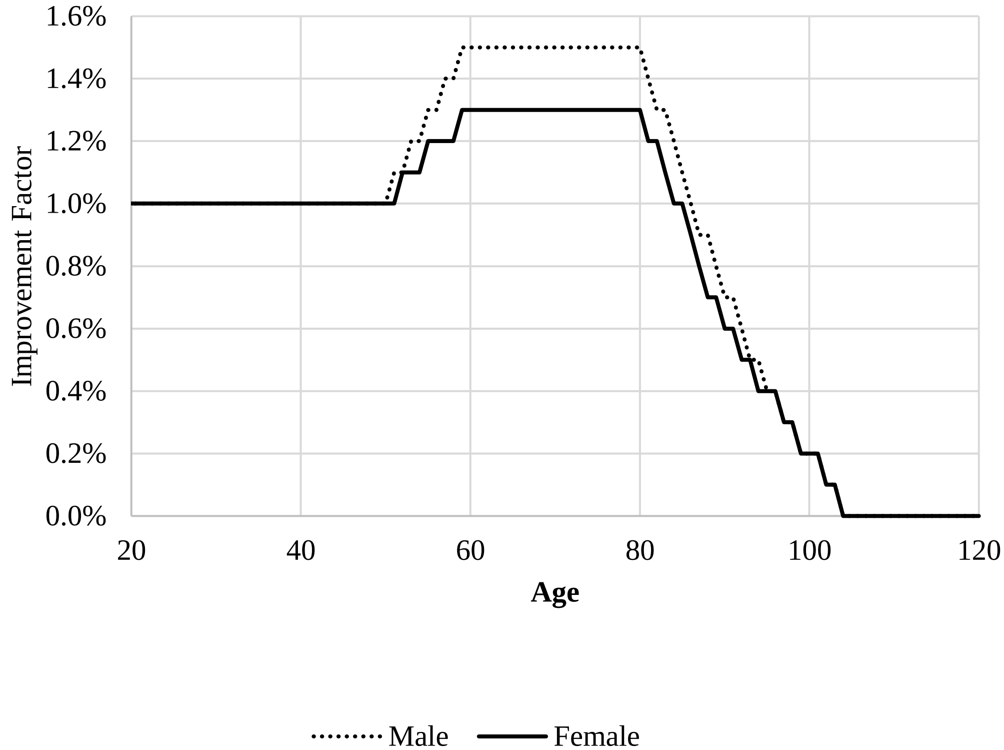


Figure A1.4: Mortality improvement factors

Table 1. Target total pre-tax savings rates for various households just starting to save for retirement

25 Years Old

	Single Household			Joint Household		
	Returns			Returns		
Household Income ($0,000s)	Historical	Low	Mid	Historical	Low	Mid
$25	6.8%	11.3%	9.0%	4.3%	7.0%	5.7%
$50	8.1%	14.2%	11.2%	6.4%	10.9%	8.6%
$100	8.2%	14.9%	11.4%	6.9%	12.5%	9.7%
$150	8.8%	15.9%	12.1%	8.0%	14.2%	11.2%
$200	9.0%	16.4%	12.7%	8.7%	15.6%	12.0%
$250	9.3%	16.8%	13.0%	9.0%	16.4%	12.7%

30 Years Old

	Single Household			Joint Household		
	Returns			Returns		
Household Income ($0,000s)	Historical	Low	Mid	Historical	Low	Mid
$25	7.4%	12.2%	9.9%	4.2%	6.6%	5.5%
$50	9.9%	17.0%	13.5%	7.2%	12.1%	9.6%
$100	10.1%	17.6%	14.0%	8.5%	14.3%	11.5%
$150	11.0%	18.7%	14.6%	9.6%	16.9%	13.2%
$200	11.4%	19.2%	15.4%	10.6%	18.1%	14.2%
$250	11.7%	19.5%	15.7%	11.3%	18.8%	15.0%

35 Years Old

	Single Household			Joint Household		
	Returns			Returns		
Household Income ($0,000s)	Historical	Low	Mid	Historical	Low	Mid
$25	8.9%	13.6%	11.3%	4.2%	6.3%	5.0%
$50	12.1%	18.1%	15.8%	8.6%	13.1%	11.1%
$100	12.5%	20.4%	17.1%	10.0%	16.8%	13.4%
$150	13.2%	22.2%	17.8%	11.8%	19.0%	15.4%
$200	13.9%	23.7%	18.4%	12.8%	21.1%	17.4%
$250	14.3%	24.1%	18.8%	13.7%	23.5%	18.3%

40 Years Old

	Single Household			Joint Household		
	Returns			Returns		
Household Income ($0,000s)	Historical	Low	Mid	Historical	Low	Mid
$25	10.4%	14.8%	12.8%	4.3%	6.3%	4.9%
$50	13.9%	19.4%	17.5%	9.4%	12.4%	11.2%
$100	16.5%	25.6%	20.4%	12.6%	19.0%	16.5%
$150	17.6%	26.4%	22.8%	14.5%	23.8%	18.6%

$200	18.1%	27.3%	24.3%	$200	16.4%	25.5%	20.1%
$250	18.5%	27.5%	24.8%	$250	17.6%	26.4%	22.8%

Source: Blanchett, Finke and Pfau, 2017

Table 2. Impact of retirement ages on target total pre-tax savings rates for a 35-year-old

Retire at Age 60

	Single Household Returns			Joint Household Returns		
Household Income ($0,000s)	Low	Mid	Historical	Low	Mid	Historical
$25	21.7%	17.8%	14.1%	18.3%	14.9%	12.0%
$50	24.6%	19.1%	16.9%	21.4%	18.2%	15.0%
$100	25.9%	20.7%	16.3%	24.8%	19.2%	15.0%
$150	25.8%	20.1%	16.2%	25.6%	19.6%	15.5%
$200	25.9%	20.5%	16.3%	25.9%	19.9%	16.1%
$250	25.9%	20.7%	16.4%	26.0%	20.5%	16.4%

Retire at Age 65

	Single Household Returns			Joint Household Returns		
Household Income ($0,000s)	Low	Mid	Historical	Low	Mid	Historical
$25	13.6%	11.3%	9.1%	6.3%	5.0%	4.3%
$50	18.1%	15.8%	12.3%	13.1%	11.1%	8.9%
$100	20.4%	17.1%	13.2%	16.8%	13.4%	10.7%
$150	22.2%	17.8%	13.8%	19.0%	15.4%	12.1%
$200	23.7%	18.4%	14.3%	21.1%	17.4%	13.4%
$250	24.1%	18.8%	14.8%	23.5%	18.3%	14.2%

Retire at Age 70

	Single Household Returns			Joint Household Returns		
Household Income ($0,000s)	Low	Mid	Historical	Low	Mid	Historical
$25	6.2%	4.8%	4.2%	0.0%	0.0%	0.0%
$50	12.7%	10.6%	8.7%	3.8%	2.8%	2.0%
$100	15.9%	12.8%	10.3%	9.1%	7.4%	6.3%
$150	18.3%	14.7%	11.7%	13.8%	11.3%	9.1%
$200	19.8%	16.6%	12.8%	17.2%	13.8%	11.1%
$250	21.4%	17.6%	13.6%	18.7%	15.4%	12.2%

Source: Blanchett, Finke and Pfau, 2017.