

Can 401(k) Plans Provide Adequate Retirement Resources?

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Abstract

Despite only having been in existence for 27 years – less than a typical working career – some analysts seem to have concluded that 401(k) plans are a failure. For example, some argue that the 401(k) is “coming up short” due to, among other factors, low contribution rates among those participating. A recent government report concludes that “low defined contribution plan savings may pose challenges to retirement security.” In addition, there are proposals to replace 401(k) plans with Guaranteed Retirement Accounts, in part due to belief that 401(k) plan participants will not be adequately prepared for retirement. This paper illustrates that moderate 401(k) contribution rates can lead to adequate income replacement rates in retirement for many workers; that adequate asset accumulation can be achieved using only a 401(k) plan; and that these results do not rely on earning an investment premium on risky assets. Using Monte Carlo simulation techniques, this study also illustrates the investment risk faced by participants who choose to invest their 401(k) contributions in risky assets, or who choose to make systematic withdrawals from an investment account in retirement rather than annuitize their account balance.

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Abstract

Despite only having been in existence for 27 years – less than a typical working career – some analysts seem to have concluded that 401(k) plans are a failure. For example, some argue that the 401(k) is “coming up short” due to, among other factors, low contribution rates among those participating. A recent government report concludes that “low defined contribution plan savings may pose challenges to retirement security.” In addition, there are proposals to replace 401(k) plans with Guaranteed Retirement Accounts, in part due to belief that 401(k) plan participants will not be adequately prepared for retirement. This paper illustrates that moderate 401(k) contribution rates can lead to adequate income replacement rates in retirement for many workers; that adequate asset accumulation can be achieved using only a 401(k) plan; and that these results do not rely on earning an investment premium on risky assets. Using Monte Carlo simulation techniques, this study also illustrates the investment risk faced by participants who choose to invest their 401(k) contributions in risky assets, or who choose to make systematic withdrawals from an investment account in retirement rather than annuitize their account balance.

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1. Introduction

When introduced in 1981, 401(k) plans were expected to be supplemental plans, used in conjunction with a defined benefit (DB) pension or a traditional defined contribution (DC) pension.¹ Increasingly, employees are provided pension benefits solely through a 401(k) plan. This development has raised concerns that 401(k) plans alone do not provide adequate financial resources in retirement. This paper illustrates that moderate 401(k) contribution rates can lead to adequate income replacement rates in retirement for many workers; that adequate asset accumulation can be achieved using only a 401(k) plan; and that these results do not rely on earning an investment premium on risky assets. Using Monte Carlo simulation techniques, this study also illustrates the investment risk faced by participants who choose to invest their 401(k) contributions in risky assets, or who choose to remain invested in risky assets rather than annuitize their account balance at retirement.

Despite only having been in existence for 27 years – less than a typical working career – some analysts appear to have concluded that 401(k) plans are a failure.² For example, Munnell and Sundén (2004, 2006) argue that the 401(k) is “coming up short” due to low participation rates, inadequate contributions, poor investment decisions, and individuals withdrawing money from their 401(k) when changing jobs. A recent government report echoes many of these sentiments by noting, “... workers may receive limited or no contributions from their employers, spend accumulated savings prior to retirement, or choose not to participate in a pension plan at all, ultimately arriving at retirement with insufficient savings to support themselves” (GAO,

¹ In U.S. Senate Committee on Finance (1986), the Committee states: “The committee also believes that excessive reliance on individual retirement savings (relative to employer-provided retirement savings) could result in inadequate retirement income security for many rank-and-file employees. In particular, the committee believes that qualified [401(k) plans] should be supplementary retirement savings arrangements for employees; such arrangements should not be the primary employer-maintained retirement plan.” See also Joint Committee on Taxation (1987), which includes similar language.

² See Tergesen (2008).

2007). In testimony before Congress, one academic proposed replacing 401(k) plans with Guaranteed Retirement Accounts, in part due to belief that 401(k) plan participants will not be adequately prepared for retirement (Ghilarducci, 2008).

This paper focuses on the question of whether or not 401(k) plans can provide adequately for retirement given the modest contributions rates of many participants.³ Munnell and Sundén (2006) points to two facts to support the conclusion that contributions to 401(k) plans are inadequate: (1) few 401(k) participants contribute the legal maximum to a 401(k) plan (\$15,000 in 2006) and (2) the modal contribution rate is a 6 percent employee deferral plus a 3 percent employer match. The proposition that 401(k)s are inadequate in Ghilarducci (2008) is based in part on the fact that a riskless portfolio has historically yielded a real return of 3 percent or less, and that such a low rate of return would require too high a level of savings to achieve adequacy (Ghilarducci, 2006, p. 126-127). To assess the validity of these arguments, this study simulates realistic savings behavior combined with both riskless and risky investments. In addition, Social Security benefits are fully integrated into the assessment of adequacy. Despite noting the importance of Social Security and that "... evaluations of income security should consider total retirement income from all sources, not just DC plans" (GAO, 2007, p. 4), GAO (2007) largely ignores Social Security when evaluating the adequacy of retirement savings in DC plans.

This study constructs representative earnings paths that roughly represent median earnings for workers with a high school degree, a bachelor's degree, and a graduate degree. For a given earnings path and marital status, individuals are assumed to follow a particular savings path. There is no attempt to derive the optimal path for retirement savings or to define the exact

³ Other aspects of the critique of the 401(k) system have been addressed elsewhere. For example, Brady and Sigrist (2008) show that neither the offering of pensions by employers nor the participation in pension by employees is randomly distributed across the workforce; instead, those most likely to have the ability to save and to be focused on saving for retirement are much more likely to be covered by a pension. Multiple studies have shown that most 401(k) assets are preserved at job change and at retirement. See, for example, Amromin and Smith (2003); Bershadker and Smith (2006); Holden and Reid (2008); Sabelhaus, Bogdan, and Holden (2008); and Vanguard (2008).

amount of resources needed to adequately fund retirement. Instead, this paper assumes saving behaviors that *a priori* seem reasonable to the author, and which are consistent with the observed behavior of 401(k) plan participants. Income in retirement is assumed to consist of Social Security benefits and income derived from financial assets accumulated in a 401(k) plan. Replacement rates are calculated under various scenarios. For example, replacement rates are calculated assuming: current-law Social Security benefits and reduced Social Security benefits; contributions are invested in a portfolio of TIPS and contributions are invested in a portfolio of corporate stocks and bonds; and, retirees purchase an annuity and retirees make systematic withdrawals from an investment account.

2. Assumptions Used in the Simulations⁴

The representative individuals in the simulations are assumed to be born on January 1, 1966. These individuals are age 40 in 2006, and reach their normal (Social Security) retirement age of 67 in 2033. Earnings paths are constructed that roughly represent median earnings for workers with different levels of education. For a given earnings path, individuals or married couples follow an assumed savings path. Married individuals are assumed to be the same age as their spouse. Retirement income is assumed to be derived from two sources: Social Security benefits and payments derived from assets accumulated in a 401(k) account. Retirement adequacy is assessed using a replacement rate that compares potential consumption after retirement to potential consumption prior to retirement. The relevant measure of pre-retirement potential consumption is calculated separately for renters and homeowners.

⁴ A technical appendix, available from the author upon request, explains in detail the construction of the representative earnings paths, the calculation of Social Security benefits, the calculation of Federal and state income tax, and the method of stochastic simulations.

2.1. Earnings Paths

The representative earnings paths are anchored at the approximate median earnings of workers age 40 with a high school degree, a bachelor's degree, and a graduate degree. In addition, a fourth earnings path one-third higher than the median graduate degree is calculated. The series are plotted in Figure 1. The names of the series reflect their origin: (1) HS-35K (high school graduate earning \$35,000 at age 40 in 2006 dollars); (2) Col-55K (college graduate earning \$55,000); (3) Grad-75K (worker with a graduate degree earning \$75,000); and (4) Scaled Grad-100K (scaled graduate degree worker earning \$100,000).

2.2. Savings

Table 1 summarizes the assumptions regarding the savings behavior used in the simulations. All savings are assumed to accumulate within – and receive the tax treatment of – a 401(k) plan. The contribution rate assumptions are behavior that *a priori* seemed reasonable to the author and which are consistent with pension plan participation and as documented in Brady and Sigrist (2008) and with employee deferrals and employer contribution rates as reported in Profit Sharing/401(k) Council of America (2008).

Those with higher earnings contribute a higher percentage of earnings to the 401(k) plan and start contributing at an earlier age. Similarly, because they have more earnings on a per person basis, single individuals are assumed to begin contributing at an earlier age than married couples with the same total earnings. Contributions to 401(k) plans as a percent of earnings, inclusive of any employer match, range from 4 percent a year for married couples with HS-35K earnings to 10 percent a year for single individuals and married couples with Scaled Grad-100K earnings. The age at which workers start contributing to a 401(k) plan ranges from 32 years of age for single individuals with Scaled Grad-100K earnings to 52 years of age for married couples with HS-35K earnings.

2.3. Social Security Benefits

Workers are assumed to work until normal Social Security retirement age, which is 67 years of age in 2033. Parameters for the calculation of Social Security benefits use either historic values (for 2006 and years prior) or are consistent with the Social Security Administrations's (SSA) 2006 intermediate projection (Social Security Administration, 2006). Most parameters used in the calculation are indexed to wage growth, using the average wage index (AWI). The SSA's intermediate projection has average real wages growing by a steady 1.1 percent a year after 2015, with nominal wage growth of 3.9 percent and inflation of 2.8 percent. The initial benefit is indexed to inflation in the years after retirement. For each earnings path, I calculate three Social Security benefit levels: assuming the earnings are for a single individual; assuming the earnings are for a single-earner married couple; and assuming the earnings are for a married couple with each spouse earning one-half of total earnings (hereafter, "dual-earner married couple").

2.4. Owner-Occupied Housing and Mortgage Payments

For homeowners, it is assumed that all individuals and couples: (1) purchase a home at age 35; (2) finance 100 percent of the purchase price using a 30-year fixed-rate mortgage charging a 7.0 percent rate of interest; and (3) pay off the mortgage at age 65.⁵ The purchase price of the home is assumed to vary by earnings path and is set (approximately) equal to the observed median purchase price in the second quarter of 2006, as reported by the National Association of Realtors (2006), in specific geographic regions. In 2006 dollars, the purchase prices are assumed to be \$300,000 for the Scaled Grad-100K earnings path (equal to the median purchase price of a home in the Northeast region); \$230,000 for the Grad-75K earnings path

⁵ According to tabulations of the Federal Reserve Board's 2004 *Survey of Consumer Finances* (SCF), of households with a household head age 65 to 74, 81 percent own their home; and, 60 percent of homeowners in this group, or 49 percent overall, own a home unencumbered by mortgage debt.

(median, all of U.S.); \$190 for the Col-55K earnings path (median, Southern region); and \$100,000 for the HS-35K earnings path (median, Buffalo, NY). The real price of the house is assumed to stay constant, with the nominal price increasing at the rate of inflation.⁶

2.5 Taxes

Payroll taxes are the sum of two taxes: the Social Security or Old Age, Survivor, and Disability Insurance (OASDI) tax of 6.2 percent of earnings up to the annual earnings base (\$94,200 in 2006);⁷ and the Medicare or Hospital Insurance (HI) tax of 1.45 percent on total earnings. Payroll taxes are applied only to earnings and do not effect disposable income after retirement.

For Federal income tax, it is assumed that 2006 tax law applies. That is, current law tax rates are applied in all periods, and the parameters of the tax code that are indexed are adjusted for inflation (without regard to rounding rules) in periods both before and after 2006. Without loss of generality, state income taxes are calculated using the Virginia income tax. Adjusted gross income (AGI) while working is assumed to be equal to earnings less employee 401(k) contributions. In retirement, AGI is set equal to distributions from the 401(k) account plus includable Social Security benefits.⁸

⁶ To check whether or not the assumptions regarding purchase price were reasonable, I calculated the percentage of pre-tax income represented by the sum of the total mortgage payment (both interest and principle payments) plus property taxes (assumed to 1.5 cents per dollar of value). For HS-35K workers, mortgage payments plus property taxes represented 29 percent of pre-tax income in the first year of the mortgage and represented 13 percent of pre-tax income in the final year of the mortgage. The corresponding numbers for the other earnings paths are: (1) 35 percent and 15 percent for Col-55K earners; (2) 32 percent and 14 percent for Grad-75K earners; and (3) 31 percent and 14 percent for Scaled-Grad earners. These ratios do not appear to be unreasonably high. If it is thought that the purchase prices are too low, then calculated replacement rates for homeowners would be understated.

⁷ For 2006 and prior years, historical earnings base numbers are used; after 2006, the earnings base is assumed to grow in line with SSA's intermediate projection. The earning base only affects the calculation of payroll taxes (and benefits) for singles and single-earner married couples with the Scaled-Grad-100K earnings profile, and even in this case only for a few years. Specifically, this earnings path exceeds the earnings base only in the years 2004 to 2014.

⁸ In the case of Virginia AGI, 100-percent of Social Security benefits are excludable. Forty-one states and the District of Columbia have broad-based personal income taxes. Of these, 26 states and the District of Columbia do not tax Social Security benefits. See Snell and Waisanen (2007).

3. Baseline Simulation Results: TIPS Portfolio Annuitized at Retirement

For the baseline case, contributions to a 401(k) are assumed to be invested in inflation-indexed Treasury bonds, also known as Treasury inflation-protected securities (TIPS). Yields are assumed to be 2.4 percent real, which, through most of the projection period, yields a nominal rate of 5.2 percent.⁹

Upon retirement, it is assumed that the entire 401(k) balance is used to purchase an inflation-indexed immediate life annuity that provides an annual payment until death and adjusts the payment each year to account for changes in the cost of living. Because the SSA's intermediate projection assumes life expectancy at age 65 will increase 1.9 years for males and 1.5 years for females between 2005 and 2035, annuity prices in 2033 for a 67 year-old are assumed to be equal to annuity prices in 2006 for a 65 year-old. Married workers were assumed to purchase joint and 50-percent survivor annuities; that is, a surviving spouse would continue to receive one-half of the original annuity payment.¹⁰

3.1. Accumulations and Distributions

Table 2 reports the amount of assets accumulated by the time a worker retires and the amount of annuity income that the assets would generate. Those with higher earnings are assumed to accumulate more in assets because they have higher earnings, contribute a higher proportion of their earnings, and begin contributing earlier. Controlling for total earnings, single

⁹ As of October 30, 2006 the yield on 10-year TIPS was 2.39 percent. The SSA's intermediate projection includes an implied real rate of 2.9 percent after 2015. However, the real return in the projection is calculated as the rate earned on debts held in the trust fund less current inflation; it is not a projection of the yield on a TIPS security. For example, in 2005, the SSA's real rate was 0.8 percent, but the 10-year TIPS yield was 1.8 percent. Because I do not know the long run relationship between TIPS yields and SSA's real interest rate, I use the current yield of 2.4 percent in the calculations. This is also, presumably, the real interest rate that is consistent with the real annuity prices discussed below.

¹⁰ Pricing was obtained on 10/31/06 for an annuity with a single annual payment, with payments commencing one year after the initial investment, and with no guaranteed minimum payments or death benefit. The amount of annual income per \$100,000 invested is \$6,067 for single males, \$5,440 for single females, and \$5,250 for joint and 50-percent survivor annuities. (See <https://flagship.vanguard.com/VGApp/hnw/accounttypes/retirement/ATSAnuitiesOVContent.jsp>U.)

individuals accumulate more because they are assumed to begin saving at an earlier age. For married couples, assets at retirement (in 2006 dollars) range from \$28,245 for HS-35K earners to \$464,417 for Scaled Grad-100K earners. For single individuals, assets range from \$77,709 to \$559,562.

With their accumulated 401(k) assets, single males could purchase real annuities providing annual income ranging from \$4,587 for those with the HS-35K earnings path to \$33,032 for those with the Scaled Grad-100K earnings path. Because females typically live longer than males, annual annuity payments for single females are 12 percent lower. With less money to invest – both absolutely and on a per-person basis – married couples can purchase annuities with annual payments ranging from \$1,455 for HS-35K workers to \$23,919 for Scaled Grad-100K workers.

3.2. Replacement Rates

Pre-retirement potential consumption is calculated as average (from age 30 to 66) real net income.¹¹ Renters' pre-retirement net income is equal to earnings less taxes and savings. Homeowners' pre-retirement net income is equal to earnings less taxes, savings, and mortgage payments. For both renters and homeowners, net income in retirement is Social Security benefits and 401(k) distributions less any taxes, as it is assumed retirees no longer save and homeowners pay off their mortgage prior to retirement.¹²

Results from the baseline simulations are presented in Table 3. All reported dollar amounts are in 2006 dollars. Because real earnings increase over time in the earnings paths used,

¹¹ For a more thorough discussion of replacement rate measures, see Brady (2008).

¹² The measure of average income in retirement takes into account survival probabilities, and thus places greater weight on income received in the early years of retirement. For the baseline case, weighting by life expectancy has little effect on the measured replacement rate as gross income is constant in real dollars. For more detail on the formula used, see Section 6.3.2 below.

average real earnings for each series are higher than real earnings at age 40. For example, for the Col-55K earnings path, average real earnings after age 30 are \$58,306.

Prior to retirement, the percentage of gross earnings accounted for by savings and taxes for single individuals ranges from 26 percent for HS-35K workers to 36 percent for Scaled Grad-100K workers. Holding total earnings fixed, married individuals have a lower reduction in income from savings and taxes, ranging from 18 percent to 30 percent. For homeowners, mortgage payments, net of tax benefits, represent an additional 10 percent to 15 percent of average pre-retirement earnings. All told, savings, taxes, and mortgage payments reduce pre-retirement gross earnings, on average, from 30 percent to 46 percent.

In retirement, annual Social Security benefits for single individuals range from \$18,814 for the HS-35K earnings path to \$33,315 for the Scaled Grad-100K earnings path. Social Security benefits for married couples range from \$27,754 to \$49,973, in real 2006 dollars. In the case of single-earner married couples, benefits are higher than single individuals because the non-working spouse is eligible for benefits equal to 50-percent of the working spouse's benefit. In the case of dual-earner married couples, benefits are higher because each spouse earns half the amount of the single individual, and the progressive benefit formula results in benefits that replace a higher proportion of earnings. For example, for the Col-55K earnings path, single-earner married couples would receive \$39,187 annually and dual-earner married couples would receive \$32,547 annually, compared to \$26,124 for single individuals.

Adding in the annual annuity income derived from 401(k) accumulations, annual gross income ranges from \$23,077 for single females with HS-35K earnings to \$69,863 for single-earner married couples with Scaled Grad-100K earnings.

For single individuals with HS-35K earnings, taxes in retirement are negligible, while for those that have Scaled Grad-100K earnings taxes represent about 15 percent of gross income. For married couples, taxes are negligible for those with HS-35K and Col-55K earnings, and only

reduce income by 7 percent for those with Scaled Grad-100K earnings. Reductions in gross income decline in retirement because (1) retirees do not save; (2) retirees do not pay payroll taxes; (3) income taxes decline; and (4) homeowners are assumed to have paid off their mortgage. Income taxes are lower because: gross income is lower; because Social Security income is at least partially excludable from taxable income; and because of increased deductions and credits.

Replacement rates for single renters range from 83 to 92 percent. For married renters, replacement rates range from 83 to 102 percent of net income. Replacement rates for single homeowners range from 98 percent to 108 percent. For married homeowners, replacement rates range from 102 percent to 124 percent.

4. Judging Retirement Resource Adequacy

A starting point for judging retirement resource adequacy would be to assume that a retiree would want to replace 100 percent of his average real net earnings. The results presented above suggest that most workers can achieve, or come close to achieving, this goal by supplementing Social Security benefits with income from a 401(k) plan, with moderate 401(k) contribution rates, conservative investments, and starting contributions at some point after reaching age 30. However, 100 percent potential consumption replacement may not be the correct standard for adequacy.

The adequacy standard may be below 100 percent consumption replacement. First, there are work related expenses that may be eliminated or reduced in retirement. Second, with more leisure time, retirees may substitute home production for market purchases.¹³ Third, consumer durables purchased prior to retirement may continue to provide services well into retirement or need to be replaced less often in retirement. Perhaps most importantly, if workers raised children

¹³ See Hurst (2007) for a discussion of changes in consumption near retirement.

while working, household expenses presumably would be lower if these individuals or couples are no longer supporting minor children in retirement.¹⁴

The adequacy standard may also be above 100 percent consumption replacement. The primary argument in favor of individuals needing more net income in retirement is that they may experience higher out-of-pocket health care expenditures. This may be a factor both because the amount of health care services consumed by individuals likely increases in retirement, and because health care costs have tended to increase at a faster rate than general inflation.

On balance, a consumption replacement rate at or below 100 percent is likely to provide adequate retirement resources, particularly for individuals who have raised children and particularly for lower income individuals, provided that Medicare and Medicaid programs remain in their current form. However, even if out-of-pocket retiree health care costs increase markedly, it is not clear that the proper measure of 401(k) adequacy would be the extent to which it can fund both living expenses and health care costs, particularly if the resources needed to fund health care are a multiple of what would otherwise be needed to fund living expenses. If, for example, the adequacy of 401(k) plans is judged relative to traditional DB pension plans, 401(k) plans do no better or worse than traditional DB plans in hedging medical expenses. In addition, if rising retiree medical costs are a public policy concern, encouraging individuals to accumulate enough financial assets to self-insure against these risks may not be the optimal public policy response.

5. Sensitivity of Baseline Results to Changes in Assumptions

The simulations above require many assumptions, including assumptions about when an individual retires, the rate of return earned on savings, and the generosity of future Social

¹⁴ Scholz and Seshadri (2007) find that, controlling for lifetime earnings, children are an important determinant of household wealth.

Security benefits. An effort was made to make reasonable and defensible assumptions. This section investigates how sensitive the simulation results are to these assumptions. Table 4 summarizes the sensitivity analysis.

If the individual or couple decides to retire at age 65 in 2031, two years prior to their normal retirement age, replacement rates are reduced by 9 to 15 percentage points. For renters, early retirement results in replacement rates that range from 75 to 90 percent. For homeowners, early retirement replacement rates range from 88 to 110 percent. The results suggest that renters wishing to retire early may need to save more than assumed in the baseline scenario.

Changes in real interest rates can affect the amount of assets accumulated at retirement as well as the price of the annuity purchased at retirement.¹⁵ The replacement rates for single individuals and higher earners are more sensitive to the rate of return assumptions because 401(k) accumulations finance a higher percentage of retirement income. For example, a 40 basis point change in the rate of return coupled with a change in the annuity payment of 10 percent changes the replacement rates of married couples with HS-35K by 1 percentage point. In contrast, replacement rates of single individuals with Scaled Grad-100K earnings change by between 5 and 8 percentage points relative to the baseline assumptions.

The baseline simulation assumes Social Security benefits are determined under current law. If Social Security benefits are cut using “progressive indexing” starting in 2012,¹⁶ replacement rates would be reduced by 1 to 13 percentage points. Rates would range from 75 to 95 percent for renters and from 90 to 110 percent for homeowners. A 28 percent across-the-

¹⁵ The effect of short-run fluctuations in interest rates on annuity prices can be fully hedged by matching the cash flow of the bond portfolio to the expected payout of an annuity, and can be partially hedged by matching the duration of the TIPS portfolio to the life expectancy of the average annuitant. To assess the effect of long-run fluctuations in the risk-free rate, a full stochastic analysis was not done because adequate historical return information on TIPS does not exist. For example, the Federal Reserve Board’s H.15 release ([Uwww.federalreserve.gov/releases/h15/U](http://www.federalreserve.gov/releases/h15/U)) provides data on 10-year inflation-indexed U.S. Treasury securities beginning in 2003.

¹⁶ This paper simulates the progressive indexing proposal described in Purcell (2005) and is explained in detail in a technical appendix, which is available from the author upon request.

board cut in Social Security benefits would reduce replacement rates from 13 to 32 percentage points. Replacement rates would range from about 65 percent to 80 percent for renters and from about 75 percent to 90 percent for homeowners. Such benefits cuts would necessitate higher rates of savings to achieve adequacy.

6. Stochastic Simulations

This section uses stochastic simulations to illustrate the range of potential outcomes if 401(k) plan contributions are invested in risky assets. Specifically, Monte Carlo simulation techniques are used which assume that, in any given year, investment returns are a random draw from all possible investment returns. Assets are assumed to be invested in a portfolio that is one-half large corporate stocks and one-half corporate bonds, with the portfolio rebalanced annually.

Data on investment returns for large company stocks and corporate bonds from 1926 to 2004 were taken from Ibbotson Associates (2005). Investments are assumed to be in mutual funds, with mutual fund expenses plus transaction costs equal to 120 basis points for stock funds and 70 basis points for bond funds.¹⁷ Real historical returns are calculated as nominal returns in a given year less inflation experienced that year. Over the 1926 to 2004 period, the geometric mean real annual return for a portfolio with 50 percent large company stocks and 50 percent corporate bonds was 4.4 percent; the arithmetic mean real annual return was 5.2 percent; and the standard deviation of annual returns was 12.8 percent.

For ease in exposition, the simulations presented above – which assume that 401(k) assets are invested in TIPs and that an immediate inflation indexed annuity is purchased upon

¹⁷ In 2005, the average 401(k) participant incurred an asset-weighted stock mutual fund fee of 76 basis points in total expenses and an asset-weighted bond mutual fund fee of 58 basis points (see Holden and Hadley, 2006). These averages were increased to 120 basis points and 70 basis points, respectively, to account for both direct and indirect fund-portfolio trading expenses. Direct trading expenses include payments to brokers, as either direct fees or bid/ask spreads. Indirect trading expenses include the reduced price that a stock gets if large blocks of the stock are sold at a single time (for example, to meet cash flow needs due to share redemptions). See Edelen (1999) for a discussion of these costs. Intermediation costs are not restricted to mutual funds. Because of transaction costs and the costs of other investment services, no investor earns the pure market rate of return.

retirement – will be referred to as the “baseline case.” Simulations that assume 401(k) assets are invested in a portfolio that is 50 percent large company stocks and 50 percent corporate bonds, rebalanced annually, with systematic withdrawals taken from the account during retirement, will be referred to as the “investment account.”

6.1. Accumulation of Assets

For a single simulation of investment returns, random real rates of return are generated for each year over a 47-year period corresponding to the time period over which a simulated individual is aged 20 to 66. Nominal returns are calculated as the sum of real returns plus inflation. Inflation is either historical inflation (before 2006) or as projected in the SSA’s intermediate projection (2006 and after). Assumptions regarding savings behavior are the same as used in the baseline case and presented in Table 1. A single simulation produces eight account balances at retirement, one for each possible combination of marital status and earnings path. This process is then repeated 5,000 times to get a range of possible outcomes.

Results from these simulations are presented in Table 5. On average, over all 5,000 simulations, the investment account outperforms the baseline case. Retirees who began saving at age 52 could expect to have 24 percent more in accumulated assets compared to the baseline case, and retirees who began saving at age 32 and would be expected to have 73 percent more in accumulated assets compared to the baseline case. However, higher average returns are associated with higher risk. In the highest ten percent of simulations, returns were substantially higher for the investment account than for the baseline case – with accumulated assets twice as high for those starting contributions at age 52 and nearly four times as high for those starting contributions at age 32. In the lowest ten percent of simulations, the investment account substantially underperformed the baseline case, with accumulated assets 27 percent lower for those starting contributions at age 52 and 30 percent lower for those starting contributions at age

32. An alternative measure of the risk is the percentage of cases in which the baseline case outperformed the investment account. This ranged from 28 percent of the time for investors with the shortest investment horizon to 18 percent of the time for investors with the longest investment horizon.

6.2. Distribution of Assets

The baseline case assumes that, upon retirement, all accumulated 401(k) assets are used to purchase an inflation-indexed annuity. In contrast, the investment account is assumed to remain invested but with the annual distributions taken from the account. Although bequests do not affect calculated replacement rates, for completeness it is assumed that any remaining account balance is left to heirs upon death of a single individual. For married couples, it is assumed payments continue until the surviving spouse dies, with any remaining account balance left to heirs.

6.2.1. Investment Account Payout Formula

Annual withdrawals from the investment account are based on remaining life expectancy. Conditional on survival to age t , withdrawals from the account are equal to:¹⁸

$$W_t^I = A_{t-1} * \frac{1}{L_t^s} \quad (3)$$

where W_t^I = withdrawal from the investment account (indicated by the superscript I) at time t ;
 A_{t-1} = account balance at age $t-1$ (i.e., Dec 31 of previous year);
 L_t^s = life expectancy conditional on surviving to age t , by gender/marital status;¹⁹
 s indexes the gender/marital status of the individual;

¹⁸ This is essentially the formula used by the IRS to determine required minimum distributions (RMD) from IRAs and 401(k) plans (which must begin in the year after the beneficiary attains age 70-1/2. Specifically, the balance as of January 1 determines the RMD for that year, and the distribution must be made by December 31. The t subscripts in the formula represent end-of-year measures, so the withdrawal is based on $t-1$ account balances (assumed to also be equal to the balance on January 1) and withdrawals take place at time t , that is, December 31 of year t .

¹⁹ Life expectancy is taken from 2003 mortality statistics reported by the National Center for Health Statistics in Arias (2006). For married couples, the average of male and female conditional life expectancy is used.

Account balances evolve in the following manner:

$$A_t = A_{t-1} * (1 + r_t) - W_t^I \quad (4)$$

where r_t = rate of return earned on the portfolio at age t

All who die in a given year are assumed to die in the middle of that year.²⁰ Thus, in the event of the death of a single individual at age t , or, in the case of a married couple, in the event of death of the surviving spouse at age t , the amount of the bequest is calculated as:

$$B_t = A_{t-1} * (1 + (0.5) * r_t) \quad (5)$$

Because the life expectancy tables in Arias (2006) end at age 100, it is assumed any individuals surviving to age 100 die at the end of that year, with any remaining balance bequeathed to heirs.

6.2.2. Comparison of Payment Streams

Payouts from an investment account differ from real immediate life annuity payments for two reasons. First, the payout formula is different. Annuities pay a fixed amount until death, with no payments to heirs upon the death of the annuitant. The investment account pays an amount that varies by age but, in the event of death, heirs get any remaining balance. The second difference is the amount of investment risk. A real immediate life annuity bears no investment risk, other than the risk that the insurance company cannot make the promised payments: as long as the insurance company remains solvent, the payment stream an annuitant will receive while alive is known with certainty. Payments from the investment account are not known with certainty: they vary not only by age, but also depend on the investment returns of the risky assets held in the account.

To separate out the effect of the payment formula from the effect of investment risk, this section first compares the payment stream from a real annuity to the payment stream from an

²⁰ Distributions from the account occur annually. An individual dying the day after a distribution would have fewer assets to bequeath than an individual dying the day before a distribution. The representative individuals in these examples are assumed to die in the middle of the year, which is roughly equivalent to what the average value of bequests would be from many individuals with deaths spread out over the entire year.

account with no investment risk. It then compares payments from a real annuity to payouts from an account invested in risky assets.

Conditional on survival and reported separately for males, females, and married couples, Figure 2 plots the payment stream from \$100,000 invested at age 67 (in 2033) in an inflation-indexed annuity and from \$100,000 invested at age 67 in TIPS that yield 2.4 percent real.²¹ A single male would receive a real annuity payment of \$5,903 a year (the solid red line).²² Payouts from the TIPS account (the solid blue line) would equal \$5,790 in the first year with payments increasing to \$5,889 in the sixth year and then declining thereafter, falling under \$5,000 at age 82 and under \$4,000 at age 86. Conditional on the survival of the annuitant, the annuity is able pay more in every period than the TIPS account. This is because there is a risk of death and, in the event of death, payments cease. For the average male, the solid green line plots the probability that a man alive at age 67 will be alive at later ages. For example, there is a 51 percent chance of surviving to age 82 and a 35 percent chance of surviving to age 86. The dashed red line shows, for the average male, the expected payout from the annuity taking into account the probability of death. For the TIPS account, the expected payouts are the same whether or not the individual survives. This illustrates the trade off based on the payout method: conditional on surviving, the annuity pays more, but the expected payout is less.²³

The payment comparison is similar for single females, but both annuity payments and payments from the TIPS account differ from males because women typically live longer than

²¹ Provided bonds exist with sufficient amount of time to maturity, interest rate risk can be avoided by “laddering” the TIPS. That is, by holding bonds with a variety of maturity dates, it would be possible to ensure that interest payments and proceeds from maturing bonds would provide enough cash flow to fund the payout stream without the need to sell any of the bonds in the secondary market.

²² The quoted price for a \$100,000 investment yielded a real annuity of \$6,069 a year with payments commencing in one year. After the first payment, subsequent payments are adjusted for inflation. However, when measured in *current* dollars, and assuming 2.8 percent inflation the first payment is worth \$5,903 ($\$6,069/1.028$) because it occurs one year from the date of investment.

²³ An actuarially fair annuity would have the same expected payout as the TIPS account. This is discussed in more detail below.

men. The annuity pays \$5,292 a year in current dollars (the solid red line).²⁴ Payouts from the TIPS account (the solid blue line) would equal 4,922 in the first year and increase to \$5,296 in the tenth year before falling off. Women have a 54 percent chance to live to age 85 and a 36 percent chance to live to age 89 (the solid green line). The annuity pays more in nearly every year, but the expected payout (the dashed red line) is less than the payout from the TIPS account.

The payment comparison for married couples differs from the comparison for single individuals (the two bottom panels of Figure 2). Conditional on both spouses surviving, the withdrawals from the TIPS account exceed joint annuity payments until age 79 (at which point the probability that both spouses are alive has fallen to 47 percent). If one spouse dies and the other spouse survives, the real annuity payment is cut in half, but payments from the TIPS account continue using the same payout formula. For survivors, payments from the TIPS account exceed the survivor annuity until age 91 (at which point the probability that one spouse is alive is 35 percent). The dashed red line represents expected payments from the real annuity, and in both of the lower panels of Figure 2, it takes account both expected joint annuity payments and expected survivor annuity payments. As with single individuals, total payouts from the TIPS account (withdrawals plus bequests) exceed expected payments from the real annuity. However, unlike single individuals, there are many cases where the TIPS account pays out more than the inflation-indexed annuity even conditional on survival.

Conditional on survival, Figure 3 compares the payment streams from a real annuity and from an account invested in risky assets. As before, 5,000 simulations are run assuming the portfolio is invested 50 percent in stock mutual funds and 50 percent bond in mutual funds, with the portfolio rebalanced annually. Ranking payment streams is more difficult than ranking

²⁴ The quoted price for a \$100,000 investment yielded a real annuity of \$5,440 a year with payments commencing in one year. After the first payment, subsequent payments are adjusted for inflation. However, when measured in *current* dollars, and assuming 2.8 percent inflation the first payment is worth \$5,292 ($\$5,440/1.028$) because it occurs one year from the date of investment.

accumulations, as both the timing and the total amount of payments are important. To rank and evaluate payout streams, this paper borrows a measure of present discounted value (PDV) of withdrawals used by Dus, Maurer, and Mitchell (2005), which takes into account life expectancy as well as the time value of money, and is calculated as:

$$\text{PDV Withdrawals} = \sum_{t=67}^{t=100} \frac{W_t^I * \text{Pr}(\text{alive})_t}{(1 + r^*)^{(t-66)}} \quad (6)$$

where t = age

W_t^I = withdrawal from the investment account at age t

$\text{Pr}(\text{alive})_t$ = probability individual who is alive at age 67 is alive at age t

r^* = risk-free rate of return (=5.2%; 2.4% real + 2.8% inflation)

In each panel of the chart, the average payout by year is presented for the top and bottom 10 percent of investment account simulation results ranked by the PDV of withdrawals (the light blue lines) and the middle 10 percent of simulations (the dark blue lines). Thus, the shaded area approximates a 90 percent confidence interval for investment account payouts.

For men (Figure 3, top left panel), average payouts from the investment account for the middle decile of simulations exceed real annuity payments from age 68 to age 86 (at which point the probability of survival is 35 percent). Higher expected payouts are associated with more risk. In the top 10 percent of simulations, expected payouts from the investment account greatly exceed real annuity payments early on and do not fall below annuity payments until age 96. In the bottom 10 percent of simulations, withdrawals from the investment account are below real annuity payments in all periods.

The comparison of payouts for women (Figure 3, top right panel) is similar to the comparison for men. Average payouts from the investment account for the middle decile of simulations exceed annuity payments from age 69 to age 92 (at which point the probability of survival is 24 percent). But the payouts are quite variable, with the top 10 percent of simulation

having much higher payouts and the payouts from the bottom 10 percent of simulations below the annuity payment in every year.

The tradeoffs between an annuity and an investment are much different for a married couple (bottom two panels of Figure 3).²⁵ Conditional on both spouses surviving, the average payout from the middle decile of investment account simulations exceeds joint annuity payments from age 67 to age 90 (at which point the probability that both spouses are alive is 6 percent) and, conditional on one spouse surviving, exceed survivor annuity payments from age 67 to age 96 (at which point the probability of one spouse surviving is 13 percent). As with the simulations for single individuals, there is a good deal of uncertainty surrounding payouts. However, for a surviving spouse, even payouts corresponding to the lowest 10 percent of simulations were higher than the survivor annuity payments from age 67 to age 88.

6.2.3. Present Discounted Value Measures of Payment Streams

The previous section presented visual comparisons of the payout streams from an immediate life annuity, an account invested in TIPS, and an account invested in risky assets. To facilitate the comparison of these payment streams, this section summarizes the payment streams by using measures of present discounted value (PDV) used by Dus, Maurer, and Mitchell (2005), which take account of both the time value of money and the probability of survival. The measure of the present discounted value of withdrawals was presented above.²⁶

In the case of the investment account, any remaining balance at the time of death is bequeathed to the heir. Similar to withdrawals, the PDV of bequest is calculated as:

²⁵ Both Kotlikoff and Spivak (1981) and Brown and Poterba (2000) illustrate that married couples typically would value actuarially fair annuities less than would single individuals.

²⁶ The PDV of withdrawal formula for annuities differs slightly from the formula for the investment account. As noted in above, the life expectancy tables in Arias (2006) end at age 100. For the investment account, it is assumed that any remaining balance at age 100 is bequeathed to heirs. For the annuity, the value of payments after age 100 for those that survive to age 100 is estimated as the conditional life expectancy at age 100 (in years) multiplied by the annual annuity payment. The value of payments after age 100 is included in the value of withdrawals and is assumed to be paid at age 100.

$$\text{PDV Bequest} = \sum_{t=67}^{t=100} \frac{B_t * \Pr(\text{die})_t}{(1 + r^*)^{(t-66)}} \quad (7)$$

where B_t = bequest at age t (defined in equation (5) above); and

$\Pr(\text{die})_t$ = probability individual who is alive at age 67 dies after age $t-1$ and before age t

Upon death, annuity payments cease and there are no death benefits paid. Thus, the PDV of bequests in the case of an annuity is always equal to \$0.

To help quantify the risks involved in the various payout methods, Dus, Maurer, and Mitchell (2005) also develops a measure of shortfall relative to the amount of payment that would be received for an equivalent investment in an inflation-indexed, or real, annuity. The measure is:

$$\begin{aligned} \text{Shortfall}_t &= 1 \text{ if } W_t^I < W_t^A \\ &= 0 \text{ otherwise} \end{aligned} \quad (8)$$

where W_t^A = real annuity payment at age t

To summarize the number of years that a shortfall would be expected for any individual, this study defines the shortfall count as:

$$\text{Shortfall Count} = \sum_{t=67}^{t=100} \text{Shortfall}_t * \Pr(\text{alive})_t \quad (10)$$

To summarize the size of the shortfall when it does occur, Dus, Maurer, and Mitchell (2005) defines a measure of the PDV of the shortfall:

$$\text{PDV Shortfall} = \sum_{t=67}^{t=100} \frac{SF_t * \Pr(\text{alive})_t}{(1 + r)^{(t-66)}} \quad (9)$$

where $SF_t = W_t^A - W_t^I$ if $W_t^I < W_t^A$
 $= 0$ otherwise

Table 6 presents these measures for males, females, and married couples. For males, the PDV of withdrawals (or payments) from a real annuity purchased for \$100,000 is \$73,438, with the PDV of withdrawals slightly higher for females and slightly lower for married couples.

Payments cease upon death, so the PDV of bequests is \$0. Annuities return less than a \$1 in present value for every \$1 invested primarily due to adverse selection: individuals who purchase annuities tend to live longer than the average person. To account for this fact, financial institutions use annuitant life tables, rather than population life tables, to price the annuities. The PDV measure uses life expectancy for the population as a whole; it represents the present value for the average person, not the present value for the average person who purchases an annuity.

Total payments, inclusive of the PDV of bequest, are higher for the TIPS account. In fact, the PDV of total payments is exactly equal to \$100,000.²⁷ This is because the account earns a rate of return equal to the discount rate, and all assets are paid out as either a withdrawal or a bequest. Focusing solely on withdrawals, the PDV of withdrawals for a TIPS portfolio is 10 percent lower than a real annuity for males and 8 percent lower for females. The TIPS portfolio's PDV of shortfall conditional on a shortfall occurring is about \$6,700 for men and about \$5,700 for women. Mortality risk imposes a tradeoff: for the average person, a real annuity offers higher expected payments for the annuitant, but the TIPS portfolio offers higher total payments (inclusive of payments to heirs).

Again, it can be seen that the tradeoffs are different for married couples. Not only is the PDV of total payments higher with a TIPS portfolio, but the PDV of withdrawals is higher as well.²⁸ Simply pooling mortality risk within a couple provides expected withdrawals that are 21 percent higher for the average couple than market-wide risk pooling in the presence of adverse

²⁷ An actuarially fair annuity would also have a PDV of total payments of \$100,000. The ratio of the PDV of payments and the cost of the annuity has been referred to as the “moneys-worth” ratio (Mitchell, et al, 1999), and the extent to which the ratio falls below 100 percent measures the difference between the price of an actuarially fair annuity and a market-rate annuity. It is of note that the literature has typically found a money's worth of about 85 cents on the dollar for nominal annuities. This paper finds a much lower money's worth for inflation-adjusted annuities than for nominal annuities. This is presumably due to either more serious adverse selection in the case of real annuities or the inability of the insurer to completely hedge inflation risk using the pool of available TIPS securities.

²⁸ Both Kotlikoff and Spivak (1981) and Brown and Poterba (2000) illustrate that married couples face different incentives to annuitize than do single individuals.

selection.²⁹ There are still some risks, as it is expected that TIPS withdrawals will be less than annuity payments is 9.4 years. However, for married couples the TIPS portfolio's PDV of shortfall conditional on a shortfall occurring is only about \$2,600.

Invested in risky assets, the investment account earns, on average, much higher returns than TIPS. Per \$100,000 invested, the expected PDV of total payments ranges from just under \$130,000 for men to over \$138,000 for married couples. In all cases the expected PDV of withdrawals exceed that of the real annuity. Withdrawals are expected to fall below that of a real annuity in 2.6 years for women, 2.0 years for men, and 0.2 years for married couples. Conditional on a shortfall occurring, the PDV of shortfall is under \$1,000 for males and females, and under \$100 for a married couple. Again these higher average returns entail more risk: in the lowest 10 percent of simulations, the PDV of total payments from a \$100,000 investment is under \$75,000 for males, females, and married couples.

6.3. Replacement Rates in Retirement: Combining Accumulation and Distribution

This section combines the simulation results from the accumulation phase and the distribution phase – as well as the calculation of Social Security benefits and taxes – to compare net income streams in retirement for each of the simulated individuals and couples. Again, 5,000 simulations are run, with each simulation run from age 22 to age 100.

6.3.1. Net Income Streams

For workers with HS-35K earnings, Figure 4 plots net retirement income conditional on survival for the baseline case and for the top, middle, and bottom deciles of simulations for the investment account. The shaded area represents an approximate 90 percent confidence area for possible results from the investment account. Results are plotted for single men, single women,

²⁹ These calculations assume that spouses' mortality risks are not correlated.

married couples with both members surviving, and for surviving spouses in the case where only one spouse is alive.

For single males with HS-35K earnings, the average net income for the middle decile of investment account simulations is higher than the baseline case until age 91, when likelihood of survival is 16 percent, and higher for single females until age 96, when survival probability is 10 percent. Again, this higher median return comes with risk, as actual payments can be higher or lower. However, the overall risk is fairly low, as Social Security benefits provide a floor beneath which net income cannot fall. Average net income for the top decile of investment account simulations is 127 percent of the baseline case at age 67, rises to 156 percent at age 81, and does not fall below the baseline case until age 98. For women, the top decile of simulations shows a similar pattern of net income, although net income remains higher than the baseline case even at the end of the simulation. For men, average net income for the bottom decile of simulations is 96 percent of the baseline case at age 67, falling to 82 percent by age 100. For women, it is 95 percent of the baseline case at age 67 and falls to 85 percent at age 100.

In the case of married couples with HS-35K earning where both spouses are surviving, the relative performance of the investment account and the baseline case are similar, but, because Social Security benefits make up an even larger proportion of retirement income, the total amount of risk associated with the investment account is much less. Average net income for the middle decile of investment account simulations is higher until age 93, when there is a 2 percent chance that both spouses are alive. As a percent of net income in the baseline case, the range of possible results from the investment account is much lower than is the case for single individuals, ranging as high as 117, but no lower than 95 percent.

When a spouse dies, the surviving spouse has less net income than the couple. In the baseline case, net income for the surviving spouse is lower for two reasons. First, Social Security benefits are reduced by one-third for single-earner couples (from 150% of calculated

benefits of the working spouse to 100%), and reduced by one-half for dual earner couples (the surviving spouse continues to get his or her own benefit, but does not get the spouse's benefit). Second, payments from the annuity are cut in half because it is assumed that the annuity is a joint-and-50-percent-survivor annuity. In the case of the investment account, Social Security benefits are exactly the same as the baseline case, but payments from the investment account continue unchanged until both spouses die.

In the case of married couples with HS-35K earnings where only one spouse is surviving, the investment account performs even better relative to the baseline case than it does for single individuals and married couples where both individuals are surviving. Median net income from the investment account is higher than the baseline case until age 98, when the chance of one spouse surviving is 8 percent. However, in contrast to other cases, the average net income of the lowest decile of simulations is higher than baseline case from age 67 to age 90, and never falls below 96 percent of the baseline case.

Figure 5, Figure 6, and Figure 7 plot the same net income streams for Col-55K earners, Grad-75K earners, and Scaled-Grad 100K earners, respectively. As with HS-35k earners: (1) the average net income from the investment account for the middle decile of simulations is higher than the baseline case until retirees are in their mid-to-late 90s; (2) married couples with an investment account have less overall risk than single individuals because more of their income is from Social Security benefits; (3) the ratio of net income from the investment account to net income from the baseline case is higher for married couples with one surviving spouse than for all other cases.

As lifetime earnings increase, the main difference in the investment account simulations relative to the baseline case is that, as a percent of net income, both the rewards and the risks of the investment account are increased. This is because, as lifetime earnings increase, Social Security benefits become a smaller portion of income and distributions from 401(k) accounts

become a larger portion of income. For a single male with Col-55K earnings, average net income for the middle decile of investment account simulations peaks at 118 percent of the baseline case net income and average net income for the top decile peaks at 176 percent of the baseline case. For a single male with Scaled Grad-100K earnings, the same ratios peak at 131 percent and 273 percent, respectively. The risk of shortfall also increases with earnings. Average net income for the bottom decile of investment account simulations falls to 77 percent at age 100 for a single male with Col-55K earnings, compared to 63 percent at age 100 for a single male with Scaled Grad-100K earnings. Again, married couples face lower risks as a percent of the baseline case net income. For example, even for the bottom decile of simulations the ratio of average net income from the investment account to net income from the baseline case never falls below 85 percent for the surviving spouse of a one-earner married couple, regardless of lifetime earnings.

6.3.2. Replacement Rate Measures

As discussed in Section 3, the replacement rate measures average real net income in retirement as a percentage of average real net income prior to retirement (from age 30 to 66). The measure of average real net income in retirement takes into account survival probabilities, and thus places greater weight on income received in the early years of retirement. Specifically, the formula is:

$$\text{Average Retirement Net Income} = \frac{\sum_{t=67}^{t=100} (B_t + S_t - T_t) * \text{Pr}(alive)_t}{\sum_{t=67}^{t=100} \text{Pr}(alive)_t} \quad (10)$$

where B = real Social Security benefit
 S = real income from accumulated savings
 T = real federal and state income taxes

For single renters and homeowners, Table 7 reports replacement rate measures for the baseline case and the investment account. The replacement rates for females are slightly lower than for males in all cases because females have longer life expectancy, decreasing both annuity payments and the rate at which assets are distributed from the investment account. The investment account produces higher expected replacement rates than the baseline case. For example, the expected replacement rate for single male renters with HS-35K earnings is 98 percent for the investment account, compared to 87 percent in the baseline case. However, the investment account involves risk and, for the bottom decile of simulations, the expected replacement rate for this individual is 81 percent. As illustrated above, higher earners are subject to more risk with the investment account. For the bottom decile of simulations, the expected replacement rate for a single male with Scaled Grad-100K earnings is 79 percent, relative to 86 percent in the baseline case.

Table 8 reports replacement rates for married couples when both spouses survive. Because distributions from 401(k) plans are a smaller portion of their total retirement income, the investment account generates less variance in replacement rates for married couples. For example, even in the lowest decile of simulations, the investment account averages a replacement rate of 87 percent for dual-earner married renters with HS-35K earnings, compared to an 88 percent replacement rate in the baseline case. For dual-earner married renters with Scaled Grad-100K earnings, the lowest decile of investment account simulations averages a replacement rate of 91 percent, compared to 94 percent for the baseline case.

Table 9 presents results for married couples when only one spouse survives. Relative to the baseline case, the investment account offers surviving spouses much higher average returns and less risk than for either single individuals or married couples when both survive. For survivors, even the worst ten percent of investment account simulations produces a higher average replacement than does the baseline case.

6.4 Discussion of Stochastic Simulation Results

The stochastic simulations illustrate investment risk by showing a range of potential outcomes. The simulations should not be used to assess adequate retirement savings. The amount of savings deemed adequate *ex ante* should not vary with the type of investment chosen. The amount an individual decides to contribute to a 401(k) should be determined assuming that the investments will earn the risk-free rate of return and assuming that an annuity is purchased at retirement. The portfolio allocation of the 401(k) account is a separate decision and should be based on the individual's assessment as to whether or not the higher expected returns of a given investment compensate for any additional risk.

Ex ante a dollar invested in corporate stocks or corporate bonds is worth the same as a dollar invested in TIPS. Thus, *ex ante*, asset allocation should not affect the rate of savings deemed to be adequate. *Ex post* a dollar invested in corporate stocks or corporate bonds could be worth more or less than a dollar invested in TIPS. The actual returns realized will cause individuals invested in risky assets to adjust future behavior.

The higher expected rate of return on risky assets should not cause those invested in corporate equities or corporate bonds to plan on saving less than those investing in TIPS. The popular financial press often treats investment risk as the solution to an equation comparing savings and the amount resources “needed” in retirement. That is, it is often implied that an investor should first determine the rate of return needed, and then pick investments with that average return (and associated level of risk). For example:

“Richard needs average gains of 8% over 10-1/2 years on his Roth IRA, 401(k) and other investments to [finance his retirement goals]. ... [A financial planner] thinks he should be willing to take on more risk in hopes of boosting his returns.” (Marantos, 2002)

This line of reasoning is incorrect. If there is a mismatch between saving rates and asset accumulation goals, either savings rates or goals need to be adjusted. The level of risk in a portfolio should not be affected by these calculations.

Assessing the savings needs of a 401(k) plan participant is analogous to determining the present discounted value of future liabilities for a defined benefit pension plan. Traditional methods of pension accounting varied the discount rate for valuing future pension liabilities with the type of assets used to fund the pension. That is, if the pension fund was invested in equities, future liabilities would be discounted at the average return of equities; if it was invested in bonds, future liabilities would be discounted at the average return of bonds. Investment risk was not factored in. Financial economists objected to this method, arguing that all liabilities should be discounted at the risk-free rate of return, regardless of the asset allocation of the pension fund. Discounting future liabilities at differential rates based on asset allocation leads to the illogical conclusion that a dollar invested in stocks was worth more than a dollar invested in bonds. Similarly, an individual should not assume that investing in risky assets is a way to reduce the amount needed to save for retirement in a 401(k).

However, just as a dollar invested in a risky asset should not be valued more than a dollar invested in a safe asset, neither should it be valued less. *Ex ante*, a voluntary rational decision to invest in risky assets cannot make an investor worse off than investing in the safe asset.³⁰ Willingly taking on risk implies that an investor prefers adjusting future consumption to account for actual realized returns to having the (certain) consumption path associated with the risk-free investment.

Although not explicit, some recent studies seem to suggest that investors who choose riskier portfolios require more savings. For example, VanDerhei (2006) concludes that

³⁰ If the individual does not have enough information to rationally choose, it would be appropriate for the state to provide the necessary information or to provide investor education. If the individual is incapable of making a rational decision, it would be appropriate for the state to make the decision for the individual.

investment in equities and a lack of annuitization can lead to higher required “initial retirement wealth,” or a higher “necessary replacement rate.” Ernst & Young (2008) illustrates that those without guaranteed lifetime income need to reduce their standard of living to insure that they have only a 5-percent probability of outliving their assets. These studies imply that, *ex ante*, a dollar invested in risky assets is worth less than a dollar invested in the risk-free asset.

In addition to providing no additional insight regarding adequate savings rates, the stochastic simulation results cannot, by themselves, indicate whether an individual “should” invest in the riskless asset or “should” invest in risky assets. To make that determination requires information on the individuals’ preferences, including tolerance for risk and desire to leave bequests, and the individual’s beliefs regarding life expectancy and future market returns. Nonetheless, the results suggest some insights into which individuals would be more or less likely to take on investment risk.

First, perhaps counter-intuitively, the simulations in this paper suggest that workers with lower lifetime earnings would be the most inclined to invest in risky assets and the least likely to voluntarily purchase an annuity in retirement, all else equal.³¹ This is because most of their wealth is in the form of an inflation-protected annuity (future Social Security benefits), making 401(k) assets a smaller portion of wealth and making any risks incurred in 401(k) investments smaller as a percentage of retirement income.

Second, because of asymmetric information and adverse selection, annuities offered in the private insurance markets will not be actuarially fair for the average individual. This is illustrated by the fact that the PDV of payments produced by a dollar invested in an annuity is less than a dollar. Because annuities bought in the private market are not actuarially fair for the average individual, the cheapest way to increase annuity income in retirement is to delay

³¹ “All else” includes risk tolerance. For example, if risk tolerance increases with income or wealth, all else would not be equal. In this case, lower-income households would not necessarily be more likely to invest in risky assets.

claiming Social Security benefits. Social Security benefits can be claimed as early as age 62, but, if initial receipt of benefits is delayed, benefits are increased using actuarially fair adjustments until the individual attains age 70. If a portion of retirement assets are earmarked for the purchase of an annuity in the private marketplace, it would be better to use those assets to fund retirement consumption and delay claiming Social Security benefits until the assets were exhausted or age 70, whichever comes first.³²

Third, the simulation results also show that married couples face a different trade-off than single individuals when choosing to annuitize their wealth. Even if annuity prices are not actuarially fair for the average individual, individuals may prefer an annuity if they only value payments they receive and place no value on payments made to heirs. For single individuals, conditional on survival, the expected payout from a dollar invested in a real annuity is greater than the expected payout from a dollar invested in a portfolio of TIPS securities. However, for married couples, the ranking of expected payouts conditioned on survival are reversed. In addition, the investment account is relatively more attractive to the surviving spouse. As most individuals approaching retirement are married,³³ these facts may help explain the “puzzle” of few individuals choosing to annuitize their wealth at retirement.³⁴

The simulations illustrate both the higher average returns and the variance of those returns when investing in corporate equity and bonds. An important caveat is that the variance that is modeled is across time periods rather than across individuals. That is, the simulations do not illustrate that some individuals will experience better investment returns than others. The simulations assume all individuals are invested in the same investment portfolio; thus, there is no

³² An alternative option is discussed in Novack (2008). Under current law, an individual can claim Social Security benefits, but then repay the benefits, without interest, and restart benefits at a later age with the higher level of benefits.

³³ For example, Brady and Pierce (forthcoming) find that, of taxpayers aged 55 to 70 who do not receive Social Security benefits, 72 percent are married.

³⁴ As noted above, Both Kotlikoff and Spivak (1981) and Brown and Poterba (2000) illustrate that married couples face different incentives to annuitize than do married couples.

variance in returns across individuals. However, depending on the time period one invests over, the entire market would experience different rates of investment returns. Thus, all workers retiring in a given year would either have experienced historical returns that were above average, average, or below average. To the extent that individuals investing over the same time period experience different rates of return, it would represent an additional source of variation, and that source of variation is not modeled.

7. Conclusion

Some analysts have concluded that, with typical contribution rates and without investments in risky assets, 401(k) plans cannot provide retirees with adequate resources. To assess these claims, this paper uses simulations to calculate the amount of retirement income that could be generated by 401(k) participants with different levels of earnings using realistic assumptions of participant behavior, and to illustrate the amount of income that can be generated from both riskless and risky investments. Annuities are priced using actual market prices rather than assuming that actuarially fair annuities exist. Investment returns on risky assets account for investment fees, rather than assuming that the market return is available without any transaction costs. The simulations incorporate Social Security benefits and the replacement rate measures used to assess adequacy account for taxes and savings and are calculated for both renters and homeowners.

This study constructs representative earnings paths for individuals and married couples that roughly represent median earnings for workers with a high school degree, a bachelor's degree, and a graduate degree; and a fourth earnings path is created that is one-third higher than median graduate degree earnings. Depending on earnings, assumed total contributions rates to the 401(k) account, including employer contributions, range from 4 percent of earnings to 10 percent of earnings. Contributions to the account begin at age 32 to the highest earners and at

age 52 for the lowest earners. Income in retirement consists of Social Security benefits and income generated by the 401(k) plan account.

In the baseline case, it is assumed that 401(k) participants invest in TIPS securities that provide a real yield of 2.4 percent and, at the time of retirement, use accumulated assets to purchase an annuity in the private market. For single individuals who rent, net income in retirement replaces about 85 to 90 percent of net pre-retirement income. Homeowners have higher replacement rates for net earnings because it is assumed that they pay off their mortgage prior to retirement and do not need to replace pre-retirement income used to pay mortgage principle and interest. For single individuals who are homeowners, net income in retirement replaces about 100 to 110 percent of net pre-retirement income. Because they get higher Social Security benefits controlling for total earnings, married couples achieve even higher replacement rates. For married renters, replacement rates range from about 90 to 100 percent, and for married homeowners, from about 100 to 115 percent. Thus, for most workers, moderate 401(k) contribution rates can lead to adequate income replacement rates in retirement, and this result does not rely on earning an investment premium on risky assets.

Investment in risky assets increases the expected return of investments. For example, with baseline assumptions, a single female with earnings comparable to median earnings for workers with a bachelor's degree would replace 87 of pre-retirement net income in retirement. If she instead invested in risky assets, she would expect to increase her net income in retirement by nearly 20 percent. Associated with the higher average returns, these investments subject the participant to risks. However, because Social Security provides the bulk of most individual's retirement income and represents a floor beneath which retirement income cannot fall, the risk as a percentage of total retirement assets is not as large as would be suggested by examining the 401(k) plan distributions separately. For example, even if this individual experienced the investment returns of the bottom decile of simulations, her net income in retirement would be 95

percent of the baseline case at age 67, not fall below 90 percent of the baseline case until age 92 (when the probability of survival would be 20 percent), and would be 85 percent at age 100 (when the probability of survival would be 3 percent).

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Table 1: Savings Behavior Assumptions by Earnings Path and Marital Status

Earnings Path	Single		Married	
	<i>Age start savings</i>	<i>Savings as percent of earnings</i>	<i>Age start savings</i>	<i>Savings as percent of earnings</i>
HS-35K	42	6% (6% employee; 0% employer)	52	4% (4% employee; 0% employer)
Col-55K	42	9% (6% employee; 3% employer)	47	6% (4% employee; 2% employer)
Grad-75K	32	9% (5% employee; 4% employer)	37	9% (5% employee; 4% employer)
Scaled Grad-100K	32	10% (5% employee; 5% employer)	37	10% (5% employee; 5% employer)

Source: Author's assumptions

Table 2: 401(k) Asset Accumulation and Annuity Income in Baseline Simulation: Certain Investment Returns¹

Marital Status	Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
401(k) Balance at Retirement (2006\$)				
Single	\$77,709	\$188,867	\$377,704	\$559,562
Married	28,245	96,160	313,481	464,417
Real Annuity (2006 \$)				
Single Male	\$4,587	\$11,149	\$22,297	\$33,032
Single Female	4,263	10,362	20,722	30,699
Married	1,455	4,953	16,146	23,919

Source: Author's calculations

¹ Assumes savings are invested in inflation-indexed bond earning 2.4% real; inflation rates taken from history and Social Security Administration's Intermediate Projection. At retirement, real annuity purchased, with pricing for annuity taken from Vanguard's annuity website on October 31, 2006. Assumes single individuals buy single life annuity and married individuals buy Joint and 50% Survivor annuity.

Table 3: Results From Baseline Simulation: Certain Investment Returns

	Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
WORKING				
Average Real Pre-Tax Earnings (over age 30, 2006\$)				
All Cases	\$36,219	\$58,306	\$77,156	\$102,874
Average Real Earnings After Tax and Savings (2006\$)				
Single	\$26,850	\$40,227	\$51,005	\$65,646
Married 1-Earner	29,434	44,688	56,644	72,250
Married 50/50 Earners	29,643	44,953	56,909	72,446
Average Real Earnings After Tax, Savings, and Mortgage (2006\$)				
Single	\$22,522	\$33,080	\$42,693	\$55,439
Married 1-Earner	24,897	36,399	46,845	60,590
Married 50/50 Earners	25,106	36,644	47,084	60,737
RETIREMENT				
Annual Social Security Benefit (2006 \$)				
Single	\$18,814	\$26,124	\$29,250	\$33,315
Married 1-Earner	28,221	39,187	43,875	49,973
Married 50/50 earners	24,754	32,547	39,214	48,342
Average Real Benefit plus Annuity (2006\$)				
Single Male	\$23,401	\$37,274	\$51,546	\$66,347
Single Female	23,077	36,486	49,972	64,015
Married 1-Earner	29,676	44,139	60,020	73,892
Married 50/50 Earners	26,209	37,500	55,359	72,261
Average Real Benefit plus Annuity After Tax (2006\$)				
Single Male	\$23,392	\$35,680	\$46,096	\$56,150
Single Female	23,071	35,068	45,206	54,517
Married 1-Earner	29,676	44,139	58,064	69,390
Married 50/50 Earners	26,209	37,500	53,683	67,863
REPLACEMENT RATE				
Renters				
Single Male	87%	89%	90%	86%
Single Female	86	87	89	83
Married 1-Earner	101	99	103	96
Married 50/50 Earners	88	83	94	94
Homeowners				
Single Male	104%	108%	108%	101%
Single Female	102	106	106	98
Married 1-Earner	119	121	124	115
Married 50/50 Earners	104	102	114	112

Source: Author's calculation

¹ Assumes savings are invested in inflation-indexed bond earning 2.4% real; inflation rates taken from history and Social Security Administration's Intermediate projection. At retirement, real annuity purchased, with pricing for annuity taken from Vanguard's annuity website on October 31, 2006

Table 4: Sensitivity of Baseline Simulation Results to Changes in Assumptions¹

	Replacement Rate by Earnings Path and Difference from Baseline Simulation															
	Renters								Home Owners							
	HS-35K		Col-55K		Grad-75K		Scaled Grad		HS-35K		Col-55K		Grad-75K		Scaled Grad	
	Rate	Diff	Rate	Diff	Rate	Diff	Rate	Diff	Rate	Diff	Rate	Diff	Rate	Diff	Rate	Diff
Retire at Age 65																
Single Male	75%	-12%	77%	-11%	80%	-10%	76%	-10%	90%	-14%	95%	-13%	97%	-11%	91%	-10%
Single Female	74	-12	76	-11	78	-10	74	-9	89	-13	94	-12	95	-11	88	-10
Married Single-Earner	86	-15	85	-14	90	-13	84	-12	103	-16	106	-16	110	-14	101	-13
Married Dual-Earners	76	-13	71	-12	82	-12	81	-12	91	-14	89	-14	101	-13	98	-13
Real Rate of Return 2.0% and Annuity Rate Reduced 10%																
Single Male	85	-2	86	-3	86	-4	80	-5	101	-3	104	-4	103	-5	95	-7
Single Female	84	-2	84	-3	84	-4	78	-5	100	-3	103	-3	101	-5	93	-6
Married Single-Earner	100	-1	97	-1	99	-3	92	-4	118	-1	119	-2	120	-4	110	-4
Married Dual-Earners	88	-1	82	-1	91	-3	90	-4	104	-1	101	-2	110	-4	107	-4
Real Rate of Return 2.8% and Annuity Rate Increased 10%																
Single Male	90	+3	92	+3	95	+4	92	+6	107	+3	112	+4	113	+5	109	+8
Single Female	88	+2	90	+3	93	+4	89	+6	105	+3	110	+4	111	+5	105	+7
Married Single-Earner	101	+1	100	+2	106	+4	100	+4	120	+1	123	+2	128	+4	119	+5
Married Dual-Earners	89	+1	85	+2	98	+4	98	+4	105	+1	104	+2	118	+4	116	+5
Progressive Indexation of Social Security Benefits (Beginning in 2012)																
Single Male	82	-5	81	-8	84	-6	80	-5	98	-6	99	-9	100	-8	94	-8
Single Female	81	-5	80	-7	82	-6	77	-6	97	-6	97	-9	98	-8	91	-8
Married Single-Earner	94	-7	88	-10	93	-9	86	-10	112	-7	108	-13	112	-12	103	-11
Married Dual-Earners	88	-1	81	-2	89	-5	87	-7	104	-1	99	-4	108	-6	104	-7
28% Across-the-Board Cut in Social Security Benefits																
Single Male	68	-19	71	-18	76	-15	73	-13	80	24	86	-22	89	-19	84	-17
Single Female	66	-20	70	-17	74	-15	69	-14	79	-23	84	-22	87	-19	82	-16
Married Single-Earner	74	-26	74	-24	83	-19	79	-17	87	-32	91	-30	100	-24	94	-20
Married Dual-Earners	65	-23	63	-20	76	-18	77	-17	77	-27	77	-25	92	-22	92	-19

Source: Author's calculation

¹ Other than changed assumptions, all other assumptions as in baseline simulation.

Table 5: Accumulation Results from Stochastic Simulations

	SINGLE				MARRIED			
	Earnings Path				Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
Balance at the end of 2032 (2006\$)								
Investment Account¹								
<i>Expected Value</i>	\$113,679	\$276,301	\$653,018	\$967,434	\$ 35,060	\$129,342	\$499,425	\$739,889
<i>By Decile</i>								
Top	216,736	526,857	1,394,984	2,066,643	56,896	228,518	1,013,163	1,500,983
Middle	104,249	253,369	575,095	851,993	33,495	121,112	449,302	665,633
Bottom	54,851	133,305	263,562	390,462	20,521	68,513	219,223	324,775
Baseline Case²	77,709	188,867	377,704	559,562	28,245	96,160	313,481	464,417
Difference between Investment Account¹ and Baseline Case² (percent)								
Investment Account¹								
<i>Expected Value</i>	46.3%	46.3%	72.9%	72.9%	24.1%	34.5%	59.3%	59.3%
<i>By Decile</i>								
Top	178.9	179.0	269.3	269.3	101.4	137.6	223.2	223.2
Middle	34.2	34.2	52.3	52.3	18.6	25.9	43.3	43.3
Bottom	-29.4	-29.4	-30.2	-30.2	-27.3	-28.8	-30.1	-30.1
Percent of Simulations where Baseline Case² Accumulates More Assets Than Investment Account¹								
Percent of Simulations	21.5%	21.5%	17.6%	17.6%	27.6%	24.4%	19.2%	19.2%

Source: Author's calculation

¹ Assumes savings are invested in portfolio that is 50-percent stocks and 50-percent bonds. Five-thousand stochastic simulations are run assuming real returns after investment expenses are drawn from a distribution of returns with mean and standard deviation equal to historical experience (5.2% mean, 12.8% standard deviation); inflation rates taken from history and Social Security Administration's Intermediate projection.

² Assumes savings are invested in inflation-indexed bond earning 2.4% real; inflation rates taken from history and Social Security Administration's Intermediate projection.

Table 6:

Comparison of Present Discounted Value¹ of Annuity, TIPS Portfolio, and Investment Account
(\$100,000 investment at age 66; payout age 67 to 100)

Option	PDV of Withdrawal	PDV of Bequest	PDV of Total Payments	Years of Shortfall Weighted by Probability Alive	PDV of Shortfall Conditional on Shortfall
Male					
Real Immediate Life Annuity²	\$73,438	\$0	\$73,438	0.0	\$0
TIPS Portfolio³	66,658	33,342	100,000	15.6	6,719
Investment Account^{3,4}					
<i>Expected Value</i>	84,424	45,147	129,572	2.0	923
<i>Top Decile</i>	137,168	79,277	216,445	1.1	199
<i>Middle Decile</i>	80,854	42,555	123,409	2.6	1,367
<i>Bottom Decile</i>	50,129	24,212	74,341	15.6	23,248
Female					
Real Immediate Life Annuity²	\$76,112	\$0	\$76,112	0.0	\$0
TIPS Portfolio³	70,214	29,786	100,000	17.7	5,700
Investment Account^{3,4}					
<i>Expected Value</i>	92,645	42,968	135,612	2.6	872
<i>Top Decile</i>	157,577	80,105	237,682	1.0	366
<i>Middle Decile</i>	87,941	40,083	128,024	2.8	1,045
<i>Bottom Decile</i>	52,165	21,294	73,460	18.2	23,746
Married Couple					
Real Immediate Life Annuity²	\$69,079	\$0	\$69,079	0.0	\$0
TIPS Portfolio³	83,614	16,386	100,000	9.4	2,551
Investment Account^{3,4}					
<i>Expected Value</i>	111,404	26,810	138,215	0.2	88
<i>Top Decile</i>	192,057	55,643	247,700	0.0	1
<i>Middle Decile</i>	105,483	24,362	129,845	0.4	145
<i>Bottom Decile</i>	61,587	11,164	72,750	14.1	11,867

Source: Author's calculation

¹ PDV at time of purchase. Takes into account both probability alive and time cost of money, using nominal interest rate of 5.2%: 2.8% inflation plus 2.4% real.

² Pays amount that increases with inflation until death. For married individuals, pays ½ the total payment if one spouse dies. There are no payments upon death. Pricing for annuity taken from Vanguard's annuity website on October 31, 2006. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65; inflation rates taken from Social Security Administration's Intermediate Projection.

³ Assumes investment account that annually pays out 1/E[T] of the account balance, where E[T] is life expectancy conditional on age; upon death, account balance is left to heirs. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65.

⁴ Account invested in portfolio that is 50-percent stocks and 50-percent bonds. Five-thousand stochastic simulation are run assuming real returns after investment expenses are drawn from a distribution of returns with mean and standard deviation equal to historical experience (5.2% mean, 12.8% standard deviation); inflation rates taken from Social Security Administration's Intermediate Projection.

Table 7:
Replacement Rates for Single Individuals from Baseline Case¹ and Stochastic Simulations²

	Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
<i>Single Male Renters</i>				
Baseline Case¹	87%	89%	90%	86%
Investment Account²				
Expected Value	98	106	119	118
<i>Top Decile</i>	126	139	194	203
<i>Middle Decile</i>	95	102	110	108
<i>Bottom Decile</i>	81	83	84	79
<i>Single Male Homeowners</i>				
Baseline Case¹	104%	108%	108%	101%
Investment Account²				
Expected Value	117	128	142	139
<i>Top Decile</i>	150	169	232	240
<i>Middle Decile</i>	114	124	132	128
<i>Bottom Decile</i>	97	101	100	93
<i>Percent of Simulations where PDV Withdrawals Greater for Investment Account</i>				
Percent of Simulations	79%	79%	83%	83%
<i>Single Female Renters</i>				
Baseline Case¹	86%	87%	89%	83%
Investment Account²				
Expected Value	97	104	117	115
<i>Top Decile</i>	125	139	192	200
<i>Middle Decile</i>	94	100	109	106
<i>Bottom Decile</i>	80	81	82	77
<i>Single Female Homeowners</i>				
Baseline Case¹	102%	106%	106%	98%
Investment Account²				
Expected Value	116	127	140	136
<i>Top Decile</i>	149	169	229	237
<i>Middle Decile</i>	112	122	130	125
<i>Bottom Decile</i>	96	99	98	91
<i>Percent of Simulations where PDV Withdrawals Greater for Investment Account</i>				
Percent of Simulations	79%	79%	83%	83%

¹ Pays amount that increases with inflation until death. There are no payments upon death. Pricing for annuity taken from Vanguard's annuity website on October 31, 2006. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65; inflation rates taken from Social Security Administration's Intermediate Projection.

² Assumes investment account that annually pays out $1/E[T]$ of the account balance, where $E[T]$ is life expectancy conditional on age; upon death, account balance is left to heirs. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65. Account invested in portfolio that is 50-percent stocks and 50-percent bonds. Five-thousand stochastic simulation are run assuming real returns after investment expenses are drawn from a distribution of returns with mean and standard deviation equal to historical experience (5.2% mean, 12.8% standard deviation); inflation rates taken from Social Security Administration's Intermediate Projection.

Table 8:
Replacement Rates for Married Couples from Baseline Case¹ and Stochastic Simulations²

	Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
<i>Single-Earner Married Couple Renters</i>				
Baseline Case¹	101%	99%	103%	96%
Investment Account²				
Expected Value	104	107	127	122
<i>Top Decile</i>	111	124	173	173
<i>Middle Decile</i>	103	105	122	117
<i>Bottom Decile</i>	100	96	99	93
<i>Single-Earner Married Couple Homeowners</i>				
Baseline Case¹	119%	121%	124%	115%
Investment Account²				
Expected Value	123	131	154	145
<i>Top Decile</i>	131	153	210	207
<i>Middle Decile</i>	122	129	148	140
<i>Bottom Decile</i>	118	118	120	111
<i>Dual-Earner Married Couple Renters</i>				
Baseline Case¹	88%	83%	94%	94%
Investment Account²				
Expected Value	91	91	119	120
<i>Top Decile</i>	98	109	166	171
<i>Middle Decile</i>	91	90	114	115
<i>Bottom Decile</i>	87	81	90	91
<i>Dual-Earner Married Homeowners</i>				
Baseline Case¹	104%	102%	114%	112%
Investment Account²				
Expected Value	108	112	143	143
<i>Top Decile</i>	116	134	201	204
<i>Middle Decile</i>	107	110	138	137
<i>Bottom Decile</i>	103	99	109	108
<i>Percent of Simulations where PDV Withdrawals Greater for Investment Account</i>				
Percent of Simulations	84%	85%	87%	87%

¹ Pays amount that increases with inflation until death. Pays ½ the total payment if one spouse dies. There are no payments upon death. Pricing for annuity taken from Vanguard's annuity website on October 31, 2006. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65; inflation rates taken from Social Security Administration's Intermediate Projection.

² Assumes investment account that annually pays out 1/E[T] of the account balance, where E[T] is the average life expectancy for men and women conditional on age. Payments continue until both spouses die; upon death of both spouses, account balance is left to heirs. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65. Account invested in portfolio that is 50-percent stocks and 50-percent bonds. Five-thousand stochastic simulation are run assuming real returns after investment expenses are drawn from a distribution of returns with mean and standard deviation equal to historical experience (5.2% mean, 12.8% standard deviation); inflation rates taken from Social Security Administration's Intermediate Projection.

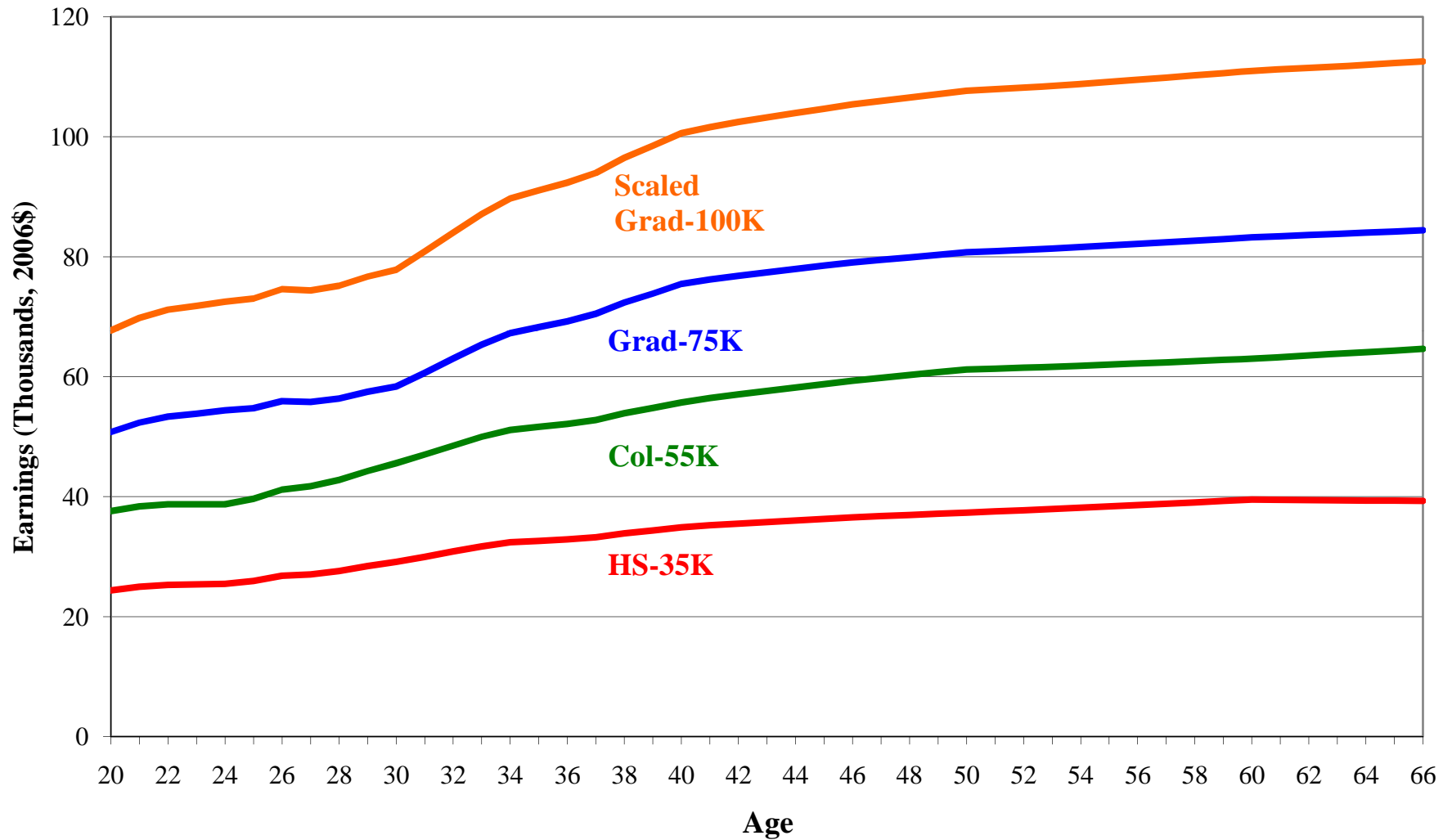
Table 9:
Replacement Rates for Married Survivors from Baseline Case¹ and Stochastic Simulations²

	Earnings Path			
	HS-35K	Col-55K	Grad-75K	Scaled Grad-100K
<i>Single-Earner Married Survivor Renters</i>				
Baseline Case¹	66%	64%	64%	59%
Investment Account²				
Expected Value	72	77	95	93
<i>Top Decile</i>	81	96	151	157
<i>Middle Decile</i>	71	75	90	86
<i>Bottom Decile</i>	67	65	69	64
<i>Single-Earner Married Survivor Homeowners</i>				
Baseline Case¹	78%	79%	77%	71%
Investment Account²				
Expected Value	85	95	115	111
<i>Top Decile</i>	96	118	183	187
<i>Middle Decile</i>	84	92	109	102
<i>Bottom Decile</i>	79	80	83	77
<i>Dual-Earner Married Survivor Renters</i>				
Baseline Case¹	44%	42%	48%	47%
Investment Account²				
Expected Value	50	55	80	83
<i>Top Decile</i>	59	73	137	147
<i>Middle Decile</i>	49	53	73	75
<i>Bottom Decile</i>	45	43	51	52
<i>Dual-Earner Married Survivor Homeowners</i>				
Baseline Case¹	52%	51%	57%	56%
Investment Account²				
Expected Value	58	67	96	99
<i>Top Decile</i>	69	90	166	175
<i>Middle Decile</i>	57	64	88	90
<i>Bottom Decile</i>	53	52	62	62
<i>Percent of Simulations where PDV Withdrawals Greater for Investment Account</i>				
Percent of Simulations	98%	98%	98%	98%

¹ Pays amount that increases with inflation until death. Pays ½ the total payment if one spouse dies. There are no payments upon death. Pricing for annuity taken from Vanguard's annuity website on October 31, 2006. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65; inflation rates taken from Social Security Administration's Intermediate Projection.

² Assumes investment account that annually pays out 1/E[T] of the account balance, where E[T] is the average life expectancy for men and women conditional on age. Payments continue until both spouses die; upon death of both spouses, account balance is left to heirs. Life expectancy in 2033 at age 67 expected to equal life expectancy in 2006 at age 65. Account invested in portfolio that is 50-percent stocks and 50-percent bonds. Five-thousand stochastic simulation are run assuming real returns after investment expenses are drawn from a distribution of returns with mean and standard deviation equal to historical experience (5.2% mean, 12.8% standard deviation); inflation rates taken from Social Security Administration's Intermediate Projection.

Figure 1: Representative Earnings Paths



Source: Constructed by author

Figure 2: Real Annuity Payouts Compared to TIPS Portfolio Payouts
(annual payment/withdrawal, conditional on survival, \$100,000 investment)

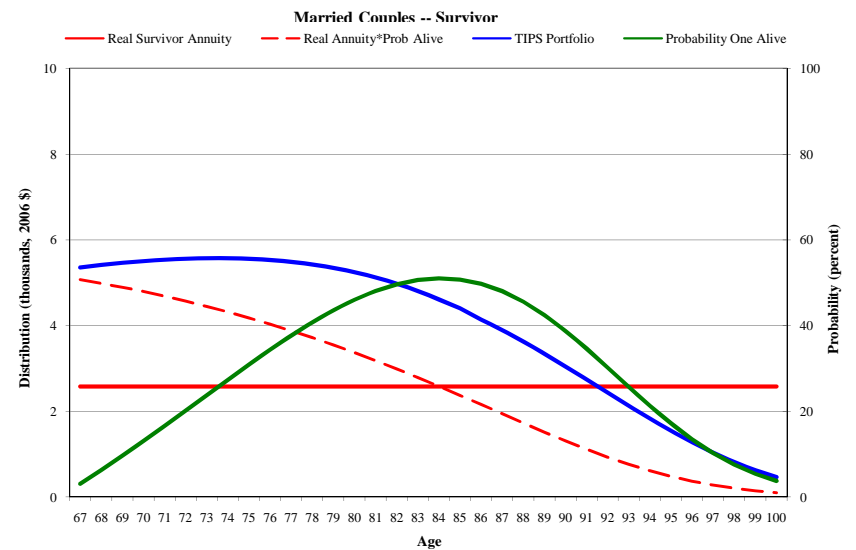
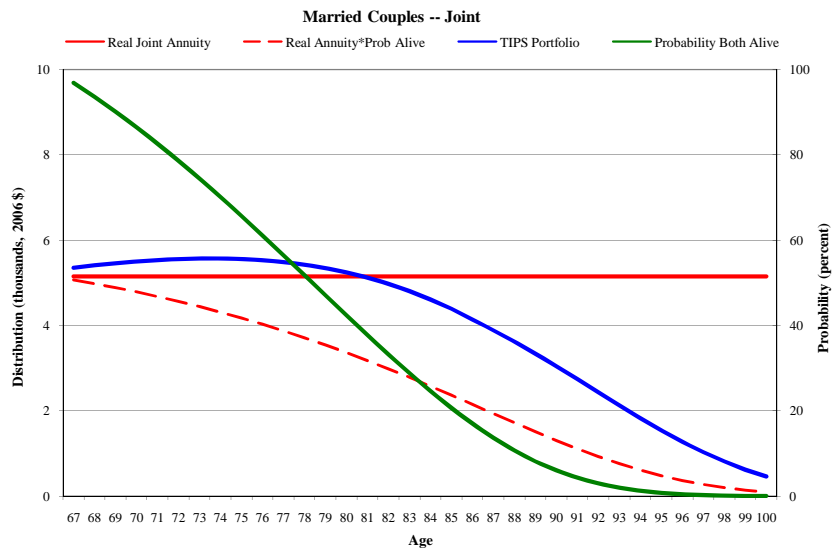
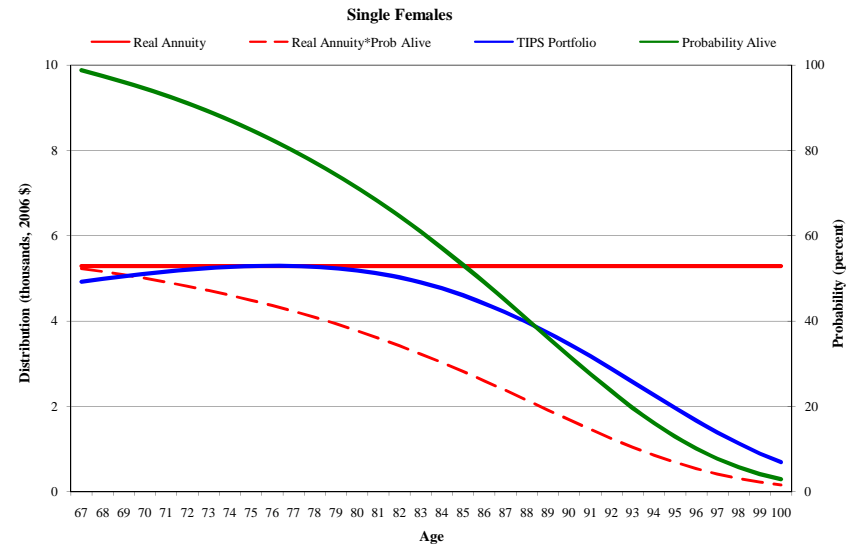
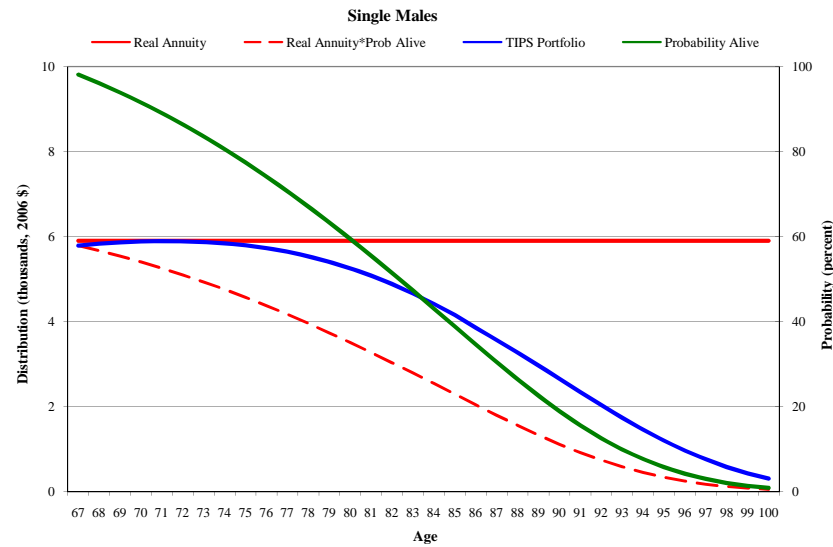


Figure 3: Real Annuity Payouts Compared to Investment Portfolio Payouts
 (annual payment/withdrawal, conditional on survival, \$100,000 investment; investment account ranked by decile)

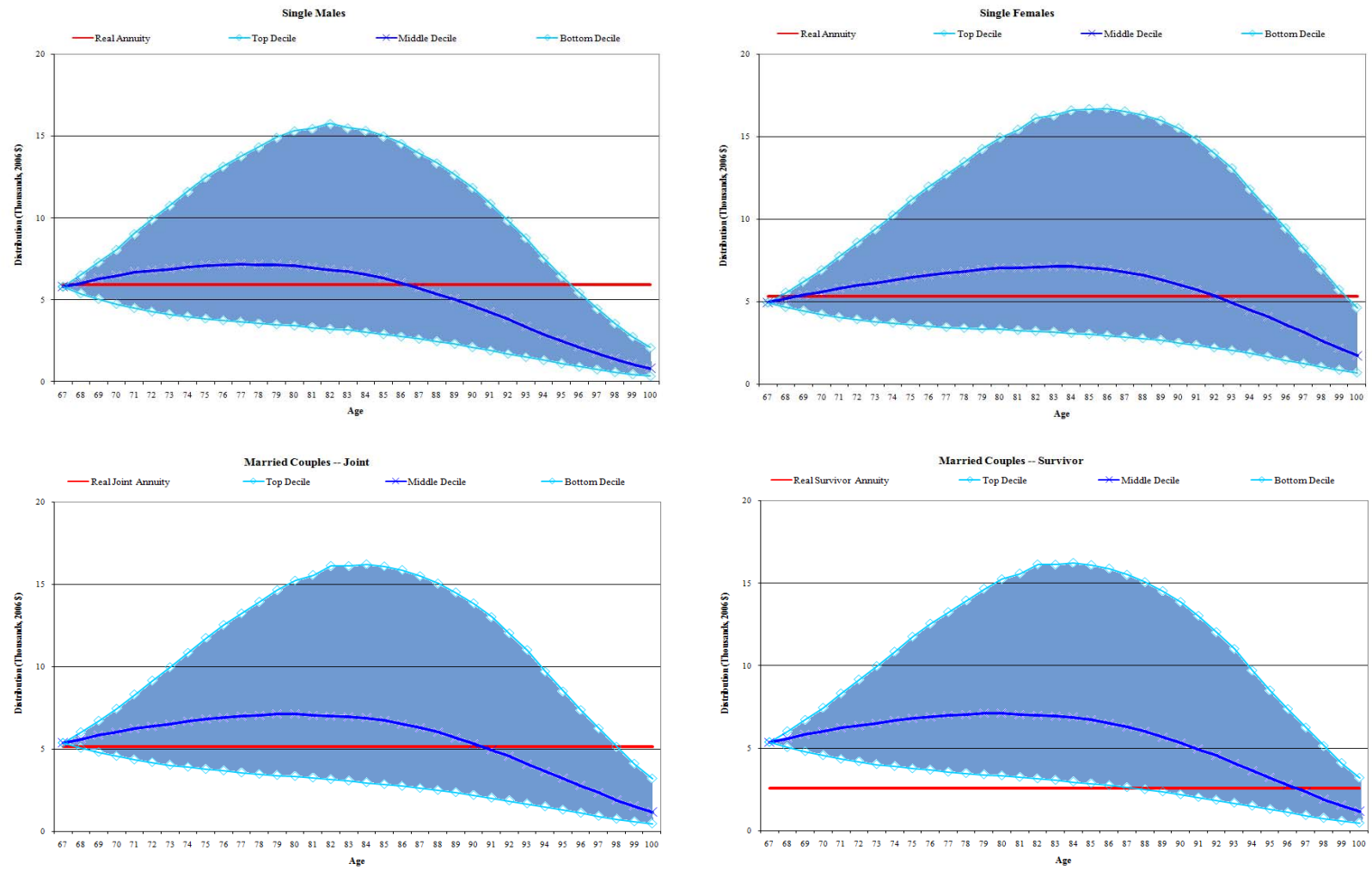
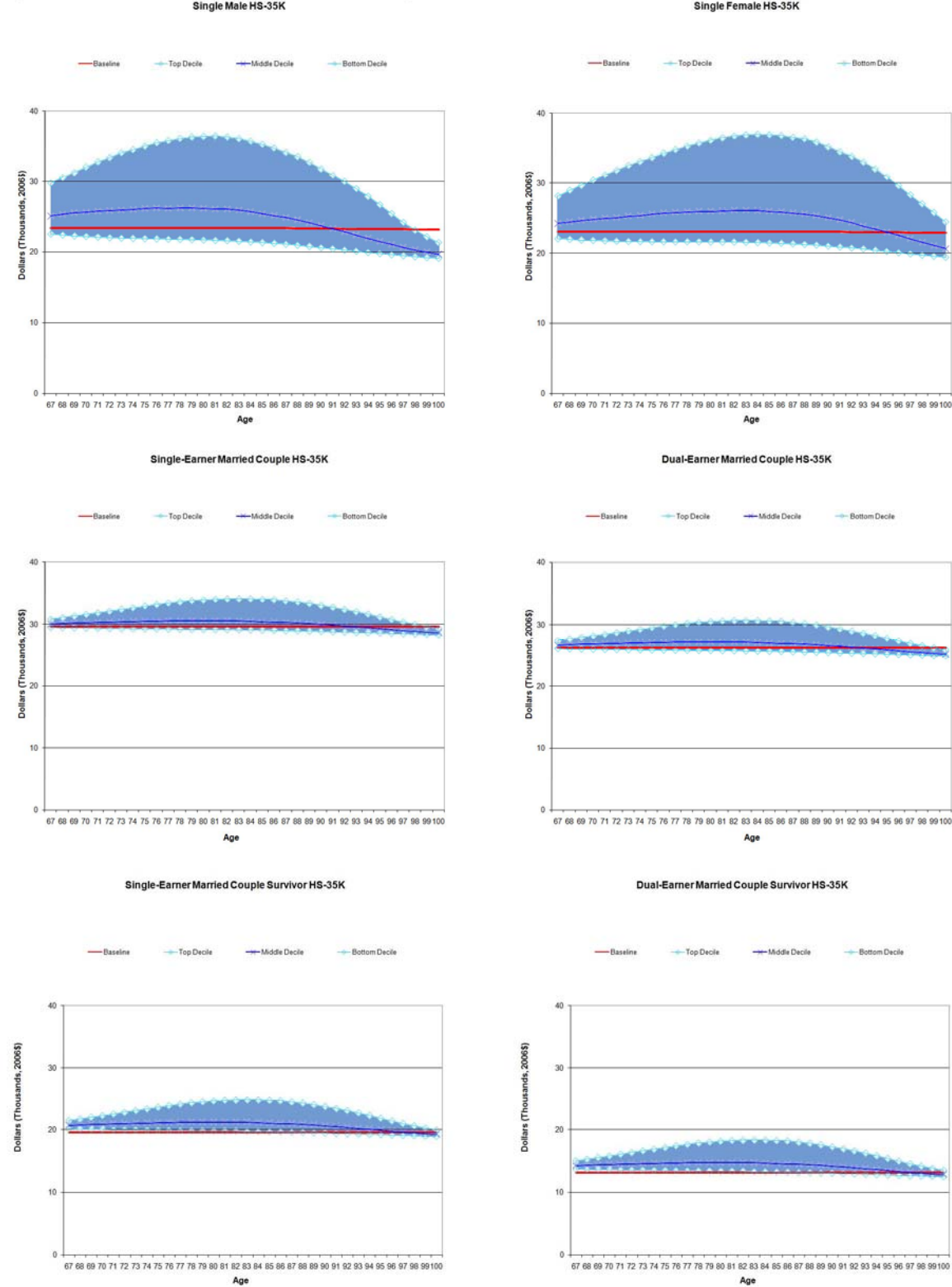
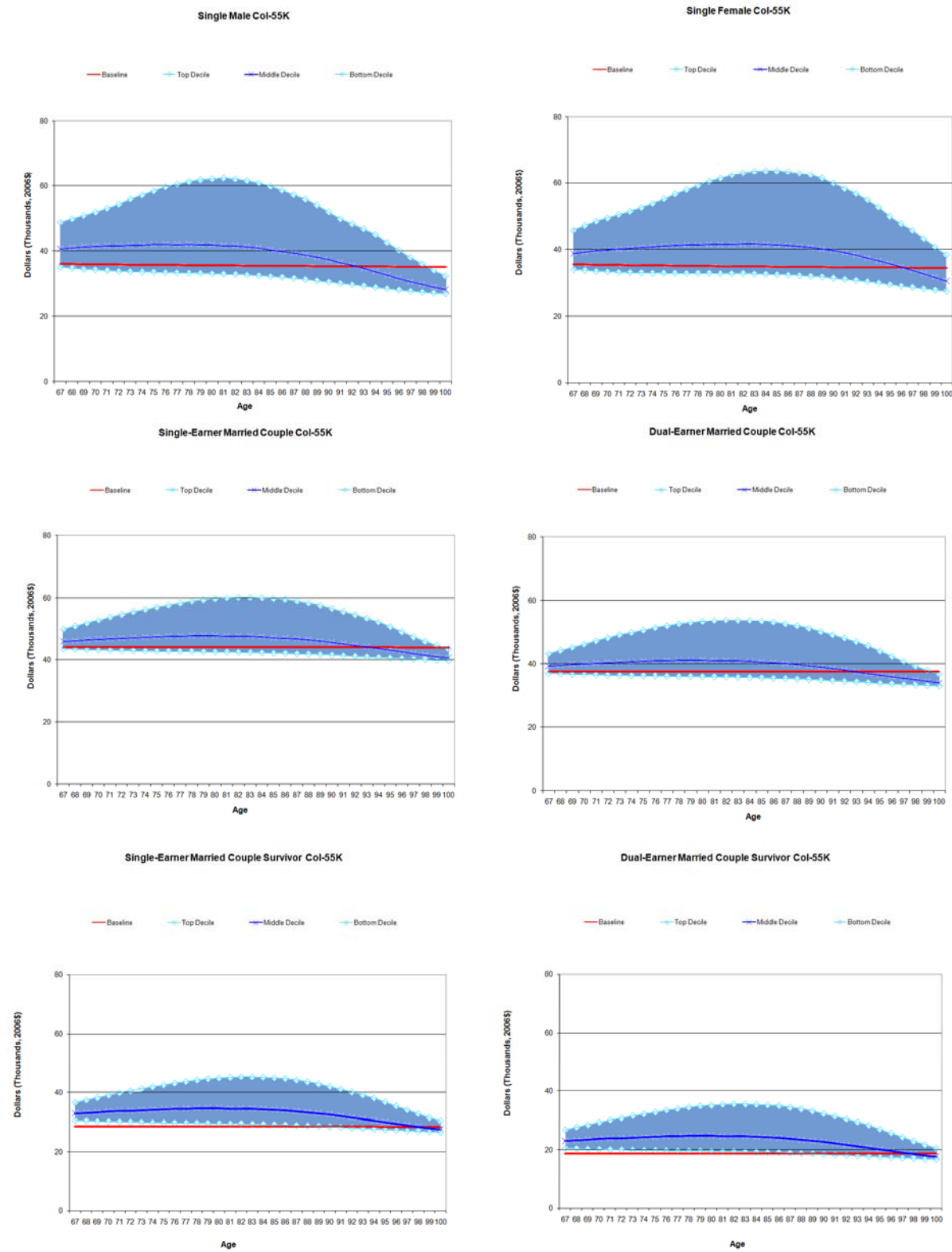


Figure 4: Net Retirement Income, Conditional on Survival, by Accumulation/Distribution Deciles, Marital Status, and Sex for HS-35K



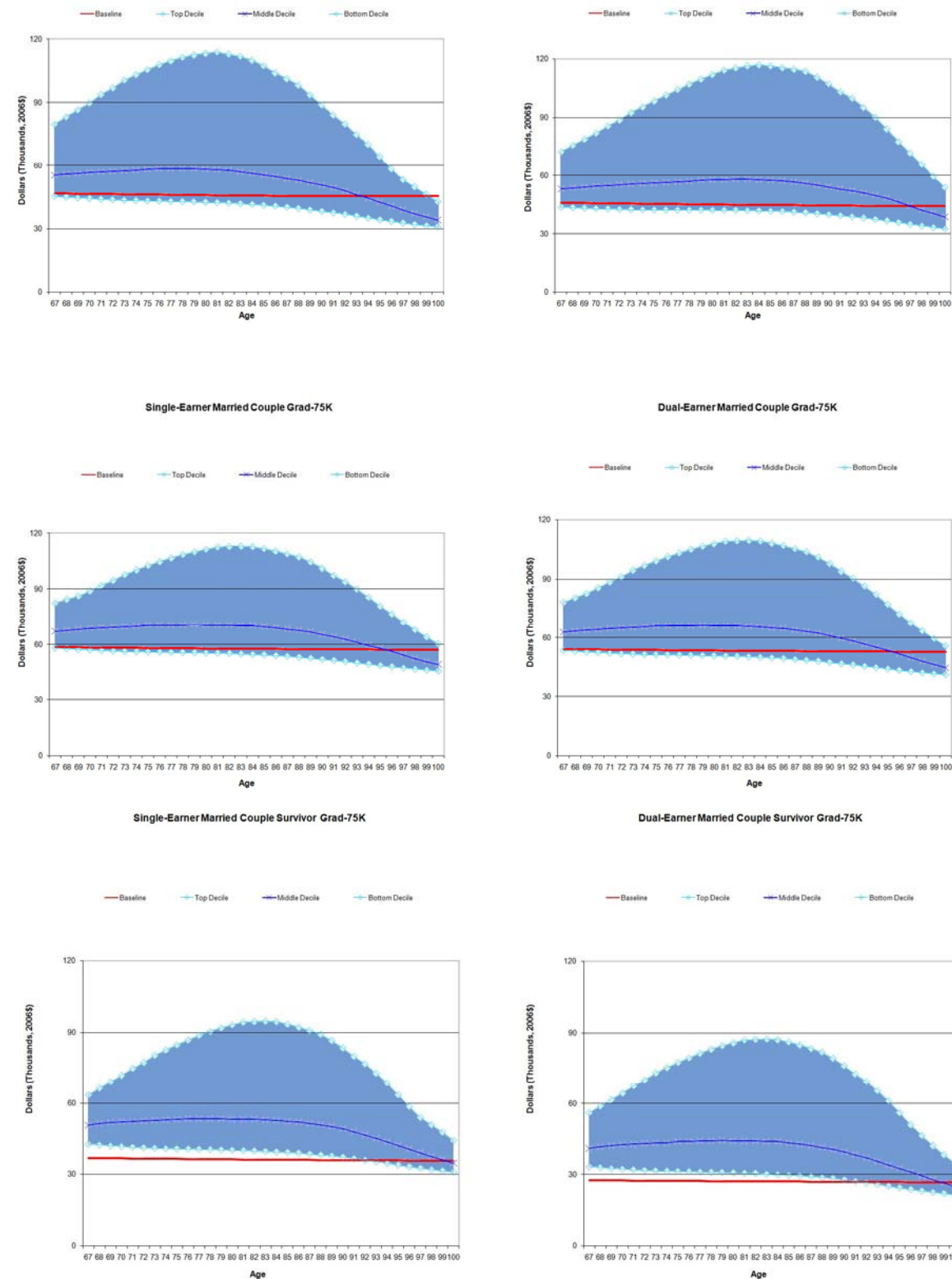
Source: Author's Calculation

Figure 5: Net Retirement Income, Conditional on Survival, by Accumulation/Distribution Deciles, Marital Status, and Sex for Col-55K



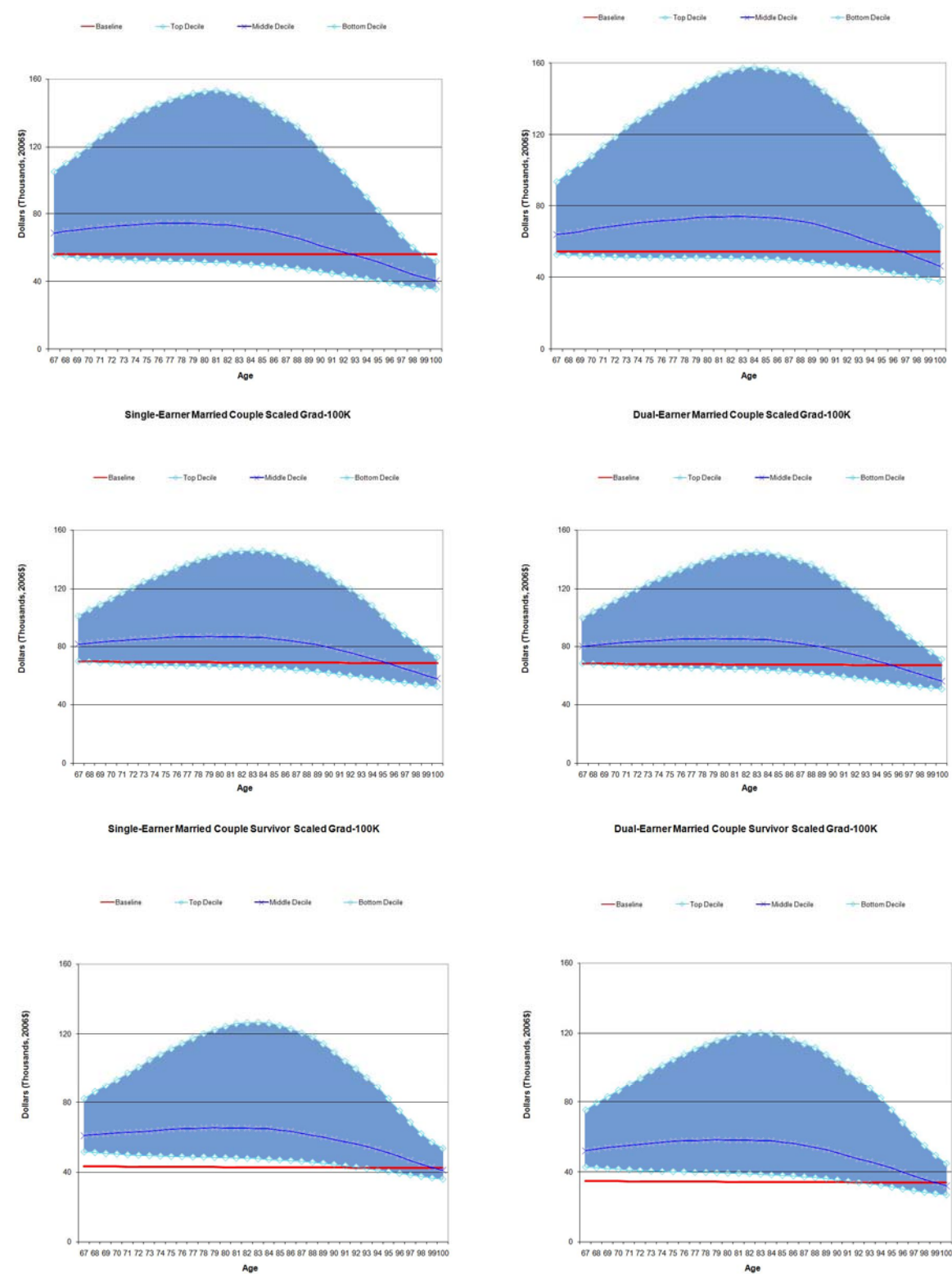
Source: Author's Calculation

Figure 6: Net Retirement Income, Conditional on Survival, by Accumulation/Distribution Deciles, Marital Status, and Sex for Grad-75K



Source: Author's Calculation

Figure 7: Net Retirement Income, Conditional on Survival, by Accumulation/Distribution Deciles, Marital Status, and Sex for Scaled Grad-100K



Source: Author's Calculation