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# Utility Evaluation of Risk in Retirement Saving Accounts

James M. Poterba, Joshua Rauh, Steven F. Venti, and David A. Wise

The last two decades have witnessed a remarkable shift in the structure of retirement saving in the United States. In 1980, most workers with pension plans participated in defined benefit plans, with benefits determined by the worker's earnings history, years of service, and age at the time of retirement. The investment allocation of assets in defined benefit pension accounts was determined by professional money managers or corporate executives, and the worker controlled his retirement benefit only through the choice of retirement age and job change decisions.

Over the 1980s and 1990s, the U.S. pension system shifted toward a defined contribution structure, with 401(k) plans growing particularly rapidly. In the late 1990s, about 85 percent of pension plan contributions were directed to defined contribution personal retirement accounts. This shift transferred responsibility for investment decisions, contribution rates, and ultimately the draw-down of retirement assets from firms to workers. It replaced the link between retirement income, job change, and final earnings, which were important sources of worker risk, with a link between retirement account balances and the uncertain return on invested assets. The

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risk that workers bear as a result of fluctuations in the value of assets in retirement accounts has attracted considerable attention in the popular press, often with the claim that workers are now facing riskier retirement prospects than in the past.

This paper presents new evidence on the risk of different investment strategies when evaluated in terms of retirement wealth accumulation. We use two different approaches to describe the risk of investing 401(k) assets in a broadly diversified portfolio of common stocks, compared to a portfolio of index bonds. The first involves computing the empirical distribution of potential wealth values at retirement resulting from different investment strategies, and then making explicit comparisons of the wealth distributions. If the average return on one asset class, such as corporate stock, is substantially greater than the average return on another asset class, such as bonds, this approach shows that over long horizons, the higher-return asset class will outperform the lower-return asset class with very high probability. One criticism of this approach is that it does not adequately consider the potential cost to a retiree of the low levels of wealth at retirement that might emerge from the riskier, but higher-expected-return, strategy.

Our second evaluation approach is designed to address this issue. We assume that the value that the retiree assigns to the consumption stream after retirement can be parameterized using a simple utility function, in which utility is a function of the stock of wealth at retirement. We then use simulation methods to compute the distribution of wealth at retirement that might emerge under different portfolio investment strategies, and to evaluate the expected utility of this distribution. Comparing the expected utility, which recognizes the potential cost of a small probability of very unfavorable outcomes, provides an alternative to comparing the distributions as a method for evaluating different investment strategies.

We compare the distribution of retirement wealth and the expected utility of retirement wealth for three different investment strategies. The first involves holding only index bonds, the second holds only a portfolio of common stocks similar to the Standard & Poor 500 index (S&P 500), and the third invests in a fifty-fifty mix of index bonds and common stocks. We conduct our analysis at the household level, recognizing that retirement plan investment decisions have implications for all household members. We also treat the evaluation of risk as a collective household decision. To make the retirement wealth calculations as realistic as possible, our simulations are run through the lifetime profiles of Social Security earnings records for each of 759 Health and Retirement Survey (HRS) households. This allows for realistic variation in age-specific labor income flows. We also calculate the level of non-401(k) wealth holdings for these HRS households. We find that the expected utility of retirement wealth is very sensitive to the value of wealth held outside the defined contribution plan, including both liquid wealth and annuitized wealth such as prospective Social Security benefits or defined benefit plan payouts.

The paper is divided into seven sections. Section 1.1 describes our basic framework for evaluating the risks associated with the accumulation of retirement saving. The second section discusses our use of earnings histories for a subset of HRS households. These earnings histories are the basis for contribution flows into our hypothetical 401(k) account. Section 1.3 describes our decomposition of the wealth holdings of HRS households near retirement age. The wealth data provide the benchmark against which we evaluate the level of 401(k) assets. The fourth section describes our assumptions about the returns to both stocks and index bonds that are available for the retirement saver, and it outlines our simulation algorithm for generating the distribution of plan assets at retirement. Section 1.5 presents our results on the distribution of retirement plan balances and shows the stock of retirement wealth under different assumptions about portfolio allocation. The sixth section reports our expected utility calculations, focusing on different asset allocation strategies during the accumulation phase. A brief conclusion summarizes our findings and suggests several directions for future work, particularly the comparison between the risks of defined contribution and defined benefit retirement plans.

## 1.1 A Framework for Modeling Retirement Wealth Accumulation in Self-Directed Retirement Plans

To analyze the risk associated with the accumulation of retirement assets in defined contribution pension plans, we need to model the path of plan contributions over an individual's working life and to combine these contributions with information on the potential returns to holding 401(k) assets in different investment vehicles. We need to decide whether the unit of observation is the individual or the household and to specify the age at which contributions begin and end. For the initial analysis reported in this paper, we focus our attention on married couples. We do this because we suspect that this group is more homogeneous than nonmarried individuals, some of whom are never married and some of whom have lost a spouse. Married couples represent about 70 percent of individuals reaching retirement age. We assume that a fixed fraction of the household's earnings is contributed to a defined contribution plan. We do not address whether the contributions are due to one or both members of the couple participating in a defined contribution plan. We follow Poterba, Venti, and Wise (1998), who report that the average 401(k) contribution represents roughly 9 percent of contributing household earnings, including both employer and employee contributions.

We assume that the couple begins to participate in a 401(k) plan when the husband is twenty-eight and that they contribute in every year in which the household has Social Security earnings until the husband is sixty-three. Households do not make contributions when they are unemployed or when both members of the couple are retired or otherwise not in the labor force. When the husband is sixty-three, we assume that both members of the household retire, if they have not already, and that contributions cease.

We denote a couple's 401(k) contribution at age $a$ by $C_i(a)$, where we index each couple by $i$. A household's contribution $C_i(a) = .09 \cdot E_i(a)$, where $E_i(a)$ denotes Social Security covered earnings at age $a$. We express this contribution in year 2000 dollars. To find the 401(k) balance for the couple at age sixty-three ($a = 63$), we need to cumulate contributions over the course of the working life, with appropriate allowance for the returns on 401(k) assets at each age. Let $R_i(a)$ denote the return earned on 401(k) assets that were held at the beginning of the year when the husband in couple $i$ attained age $a$. The value of the couple's 401(k) assets when the husband is sixty-three is then given by

$$W_i(63) = \sum_{t=0}^{35}\left\{\prod_{j=0}^{t}[1 + R_i(63 - j)]\right\}C_i(63 - t). \tag{1}$$

We in turn assume that $R_i(a)$ is determined by the returns on stocks and index bonds. The couple may hold a portfolio of all stocks, in which case $R_i(a) = R_{\text{stock}}(a)$; all index bonds, in which case $R_i(a) = R_{\text{bond}}(a)$; or a fifty-fifty mix of the two asset classes, in which case $R_i(a) = .5 \cdot R_{\text{stock}}(a) + .5 \cdot R_{\text{bond}}(a)$. We discuss presently our calibration of the distribution of risky returns associated with holding stocks.

We report the distribution of $W_i(63)$, averaged over the 759 households in our sample, for the three different investment strategies. These three distributions provide some evidence on how each investment strategy might affect the retirement resources of households that pursued them. The difficulty with this approach, however, is that it does not capture the cost of low payouts in the event of unfavorable returns. To allow for differential valuation of wealth in different states of nature, we evaluate the wealth in the 401(k) account using a utility-of-terminal-wealth approach. We assume that the household's preferences over wealth at retirement (which we now write as $W$, dropping the household subscript for ease of notation) are described by a constant relative risk aversion (CRRA) utility function,

$$U(W) = \frac{W^{1-\alpha}}{1 - \alpha} \tag{2}$$

where $\alpha$ is the household's coefficient of relative risk aversion. The utility of household wealth at retirement is likely to depend on both 401(k) and non-401(k) wealth, and thus we need to modify equation (2) to allow for other wealth:

(3) $$U(W_{401(k)}, W_{non\text{-}401(k)}) = \frac{(W_{401(k)} + W_{non\text{-}401(k)})^{1-\alpha}}{1-\alpha}.$$

The difference in the utility associated with different levels of 401(k) wealth is likely to be very sensitive to the household's other wealth holdings, so in the empirical analysis that follows, we summarize the balance sheets of retirement-age households in the HRS.

To determine the expected utility associated with various investment strategies, we generate hypothetical thirty-five-year 401(k) return histories associated with the all index bonds, fifty-fifty bonds or stocks, and all stock investment strategies for each household in our sample. Each return history, denoted by $h$, generates an associated 401(k) wealth at age sixty-three, $W_{401(k),h}(63)$, and a corresponding utility level, $U_h$, where

(4) $$U_h = \frac{(W_{401(k),h} + W_{non\text{-}401(k)})^{1-\alpha}}{1-\alpha}.$$

We evaluate the expected utility of each portfolio strategy by the probability-weighted average of the utility outcomes associated with that strategy, and we denote these expected utility values $EU_{SP500}$, $EU_{Bonds}$, and $EU_{50\text{-}50}$, respectively. These utility levels can be compared directly for a given degree of risk tolerance. They can also be translated into certainty equivalent wealth levels ($Z$) by asking what certain wealth level would provide a utility level equal to the expected utility of the retirement wealth distribution. The certainty equivalent of an all-equity portfolio, for example, is given by

(5) $$Z_{SP500} = [EU_{SP500}(1-\alpha)]^{1/(1-\alpha)} - W_{non\text{-}401(k)}.$$

We present certainty equivalent calculations of this form to summarize our findings. Note that when the household has non-401(k) wealth, the certainty equivalent of the 401(k) wealth is the amount of 401(k) wealth that is needed, *in addition to the non-401(k) wealth,* to achieve a given utility level. We treat non-401(k) wealth as nonstochastic throughout our analysis.

## 1.2 Earnings Profiles for Current Retirees

Calibrating the expected utility of various 401(k) portfolio strategies requires information on both the earnings histories and the non-401(k) wealth held by these households. We obtained these data for households in the 2000 wave of the HRS. The HRS is a longitudinal study of the economic and health status of older Americans. In the first wave of the study (1992), in-home interviews were conducted for respondents in the 1931–41 birth cohorts and their spouses. Follow-up surveys were administered by telephone every two years. The fifth wave of the survey was completed in

2000, and the core final data for this wave were released in September 2002. This wave provides the most recent and complete source of information on the balance sheet of U.S. households around retirement age.

Table 1.1 shows the relationship between the number of households in various waves of the HRS and the corresponding household counts for the U.S. population. There were 7,580 households in the first wave of the HRS, but various factors, the most important of which are death or voluntary termination of survey participation, reduced the sample size in subsequent waves. By the 2000 wave, respondents from only 6,074 of the original households remained. After accounting for household splits due to divorce and excluding five observations with missing birth years, we had a sample of 6,195 households in 2000. The sampling probabilities for these households suggest that they represent 16.7 million U.S. households. Among these households, 4.3 million had a household head, which we define as the husband in the case of married couples, with less than a high school education; 8.6 million had a household head with maximum education attainment of high school or some college; and 3.8 million had a household head with a college or postgraduate education. Because life-cycle earnings profiles differ for households with different levels of education, we present separate earnings histories for these three groups.

We construct an earnings profile for each household using data from the Social Security administrative records file. These data are available for 4,233 of the 6,195 households in the 2000 wave of the HRS and contain Social Security earnings from 1951 to 1991. Appendix table 1A.1 provides a detailed breakdown of the number of sample households in the HRS that satisfy our further data requirements and are included in our sample.

**Table 1.1 Sample composition and education attainment, Health and Retirement Survey (HRS)**

| | Survey households | Population counterpart |
|---|---|---|
| HRS Wave 1 (1992) | 7,580 | 18.6 million |
| HRS Wave 5 (2000) | 6,074 | n.a. |
| Excluding households with missing birth years and accounting for household splits (Wave 5) | 6,195 | 16.7 million |
| Head < high school | 1,823 | 4.3 million |
| Head high school or some college | 3,103 | 8.6 million |
| Head college degree or more | 1,269 | 3.8 million |
| With Social Security earnings history | 4,233 | 11.6 million |
| Head < high school | 1,228 | 3.0 million |
| Head high school or some college | 2,123 | 6.0 million |
| Head college degree or more | 882 | 2.7 million |

*Note:* n.a. = not available.

*Source:* Authors' tabulations from HRS.

Throughout our analysis, we deflate historical nominal wages by the Consumer Price Index (CPI) to construct real wages at each age. For years after 1991 in which a member of the household was still working, we multiply reported HRS wage and salary earnings by a scaling factor equal to the ratio of Social Security administrative earnings in 1991 to reported HRS earnings in the same year. We thereby construct a proxy for Social Security earnings for 1993, 1995, 1997, and 1999. We assume that in even-numbered years for which we do not have a survey response, earnings remained at the same level as in the previous year.

We want to base our simulations on households who have completed their working lives, and potentially to consider their wealth at retirement relative to their final earnings. We therefore construct a measure of final earnings that we view as representative of household labor earnings near retirement. This measure is defined as household earnings in the year before the household's reported retirement year. In dual-earner households, this is the year in which the first retirement takes place. Retirement of either the primary or the secondary earner can therefore trigger the final earnings calculation.

A number of the HRS households reported that all members of the household were still working in 2000, so that we could not define final earnings for them. Extrapolating the HRS data to the nation as a whole using HRS weights, out of 16.7 million households in the survey, 9.0 million had at least one member of the household working, and 2.6 million had two earners. Another group, 0.9 million households, contained someone who reported both working and being retired. These individuals are presumably working part-time or have partially reentered the labor force. Out of 2.1 million couples for whom we could compute final earnings, and in which the husband was aged sixty-three to sixty-seven, 1.3 million had at least one person working, 0.5 million had both working, and 0.2 million had at least one person claiming to be both retired and working.

Table 1.2 presents summary information on the median earnings profiles for households in our sample, including years with no earnings because of unemployment or retirement. The table also reports the number of HRS households that are used to estimate the earnings profiles. We present tabulations for four different sets of households in the HRS universe. The first, in the first column, is the earnings profile for all HRS households with Social Security earnings histories, regardless of their household structure and whether they had left the labor force by 2000. The second column shows the earnings profile for households with at least one labor force leaver and for which it is therefore possible to compute final earnings—this represents 3,749 of the 4,233 households with earnings profiles. The third column further tightens the selection criterion by limiting the analysis to married couple households at the time of the 2000 HRS survey. This reduces the sample size to 2,275 households. Finally, in the last column we restrict the

**Table 1.2** **Average income trajectories for Health and Retirement Survey households in 2000**

| | Median including zeros | | | | Mean including zeros | | | |
|---|---|---|---|---|---|---|---|---|
| Age range | Households with SS histories | Households with final earnings | Couples with final earnings | Couples with final earnings, male 63–67 | Households with SS histories | Households with final earnings | Couples with final earnings | Couples with final earnings, male 63–67 |
| | *Less than high school education ($ thousands)* | | | | | | | |
| 25–27 | 9.8 | 12.3 | 21.2 | 18.6 | 13.0 | 14.2 | 19.5 | 17.6 |
| 28–30 | 14.4 | 16.9 | 25.4 | 24.4 | 15.8 | 17.1 | 23.7 | 21.5 |
| 31–33 | 17.3 | 20.3 | 26.8 | 28.2 | 18.1 | 19.7 | 26.9 | 26.8 |
| 34–36 | 19.9 | 22.9 | 29.5 | 33.1 | 20.6 | 22.4 | 30.4 | 30.7 |
| 37–39 | 21.7 | 24.8 | 34.4 | 34.9 | 22.8 | 25.0 | 34.3 | 34.0 |
| 40–42 | 22.8 | 26.3 | 37.6 | 42.1 | 24.5 | 27.1 | 37.4 | 38.2 |
| 43–45 | 21.6 | 26.1 | 40.0 | 42.3 | 25.2 | 28.0 | 38.9 | 40.4 |
| 46–48 | 20.8 | 24.7 | 42.0 | 41.2 | 25.7 | 28.6 | 40.3 | 39.4 |
| 49–51 | 19.8 | 24.2 | 40.0 | 41.2 | 25.1 | 28.2 | 39.6 | 40.1 |
| 52–54 | 17.6 | 21.7 | 38.4 | 40.1 | 24.2 | 27.3 | 38.4 | 38.7 |
| 55–57 | 13.8 | 18.7 | 32.7 | 33.7 | 21.7 | 24.7 | 34.6 | 34.9 |
| 58–60 | 6.1 | 11.8 | 25.8 | 29.2 | 17.9 | 20.6 | 28.8 | 31.1 |
| 61–63 | 0.0 | 1.1 | 6.6 | 11.6 | 11.3 | 13.3 | 18.1 | 20.3 |
| 64–66 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 4.9 | 7.3 | 4.2 |
| | *High school degree and/or some college ($ thousands)* | | | | | | | |
| 25–27 | 20.4 | 21.8 | 26.5 | 26.4 | 18.8 | 19.6 | 26.3 | 25.2 |
| 28–30 | 24.9 | 25.7 | 28.3 | 26.8 | 21.5 | 22.4 | 30.0 | 27.9 |
| 31–33 | 26.3 | 26.7 | 33.6 | 34.6 | 23.8 | 24.9 | 33.1 | 33.9 |
| 34–36 | 28.4 | 30.2 | 36.4 | 36.3 | 26.7 | 28.0 | 36.8 | 36.4 |
| 37–39 | 32.9 | 34.0 | 41.2 | 41.5 | 30.0 | 31.7 | 41.4 | 41.0 |
| 40–42 | 34.0 | 35.6 | 45.6 | 47.5 | 32.5 | 34.4 | 44.8 | 45.8 |
| 43–45 | 34.7 | 37.0 | 48.0 | 49.7 | 34.3 | 36.3 | 47.4 | 48.3 |
| 46–48 | 34.9 | 38.0 | 50.6 | 51.6 | 35.8 | 37.9 | 49.9 | 48.6 |
| 49–51 | 33.7 | 36.7 | 51.2 | 50.7 | 35.8 | 38.1 | 50.3 | 49.1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 52–54 | 31.0 | 33.9 | 49.0 | 50.3 | 35.2 | 37.5 | 49.8 | 49.5 |
| 55–57 | 26.0 | 29.1 | 44.7 | 44.3 | 33.2 | 35.6 | 46.8 | 48.0 |
| 58–60 | 15.0 | 18.6 | 32.8 | 37.3 | 27.4 | 29.6 | 39.1 | 46.5 |
| 61–63 | 0.0 | 0.1 | 4.6 | 19.9 | 15.7 | 17.0 | 22.8 | 33.5 |
| 64–66 | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 6.8 | 9.3 | 8.6 |
| *College degree and/or some postgraduate ($ thousands)* | | | | | | | | |
| 25–27 | 20.9 | 22.4 | 24.8 | 24.8 | 19.5 | 20.3 | 23.6 | 22.1 |
| 28–30 | 26.2 | 26.5 | 28.7 | 26.8 | 23.5 | 24.5 | 29.0 | 26.4 |
| 31–33 | 27.4 | 29.1 | 33.6 | 32.5 | 26.2 | 27.7 | 32.5 | 30.8 |
| 34–36 | 34.0 | 34.7 | 37.0 | 36.0 | 30.2 | 31.9 | 37.0 | 33.5 |
| 37–39 | 36.6 | 37.7 | 42.5 | 41.1 | 34.3 | 36.4 | 42.2 | 39.4 |
| 40–42 | 41.9 | 43.7 | 48.4 | 48.1 | 38.7 | 41.2 | 47.9 | 47.1 |
| 43–45 | 46.2 | 47.3 | 54.5 | 53.8 | 42.7 | 45.5 | 52.8 | 51.2 |
| 46–48 | 49.0 | 51.8 | 59.1 | 58.1 | 46.7 | 50.0 | 58.5 | 53.8 |
| 49–51 | 53.0 | 56.9 | 63.1 | 62.7 | 48.6 | 52.0 | 60.5 | 56.6 |
| 52–54 | 51.7 | 56.0 | 63.5 | 65.5 | 50.7 | 54.4 | 63.5 | 59.4 |
| 55–57 | 46.5 | 51.2 | 62.0 | 59.8 | 53.0 | 56.9 | 64.4 | 59.4 |
| 58–60 | 24.2 | 30.2 | 40.8 | 44.8 | 40.3 | 43.2 | 49.6 | 55.0 |
| 61–63 | 0.0 | 0.4 | 3.1 | 21.7 | 23.4 | 25.2 | 30.3 | 45.4 |
| 64–66 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 11.8 | 14.9 | 12.8 |
| *Sample size information by education group* | | | | | | | | |
| Less than HS | 1,228 | 1,027 | 595 | 180 | 1,228 | 1,027 | 595 | 180 |
| HS/some college | 2,123 | 1,912 | 1,116 | 390 | 2,123 | 1,912 | 1,116 | 390 |
| College/postgraduate | 882 | 810 | 564 | 189 | 882 | 810 | 564 | 189 |
| Total | 4,233 | 3,749 | 2,275 | 759 | 4,233 | 3,749 | 2,275 | 759 |
| *Weighted sample size by education group (millions of households)* | | | | | | | | |
| Less than HS | 3.0 | 2.5 | 1.5 | 0.4 | 3.0 | 2.5 | 1.5 | 0.4 |
| HS/some college | 6.0 | 5.4 | 3.2 | 1.1 | 6.0 | 5.4 | 3.2 | 1.1 |
| College/postgraduate | 2.7 | 2.5 | 1.8 | 0.6 | 2.7 | 2.5 | 1.8 | 0.6 |
| Total | 11.6 | 10.4 | 6.4 | 2.1 | 11.6 | 10.4 | 6.4 | 2.1 |

sample to married couples in which the husband was between sixty-three and sixty-seven in 2000. This limits the sample to only 759 households. This is a relatively homogeneous sample that we use for much of our subsequent analysis. The earnings trajectories for this subsample display a smaller education premium than those for the larger sample. This might be because less-educated workers who have already retired have above-average lifetime earnings trajectories. In future work we plan to explore these subsample differences in further detail, and to generalize our procedures to the sample of all households.

The entries in the columns of table 1.2 track median earnings for each of the education groups and subsamples that we consider. Not surprisingly, there are very substantial differences in the level, and the shape, of the earnings profiles across subgroups. The peak earning level for couples in our sample is up to 6 percent higher than the peak earning level for all couples with final earnings and up to two times higher than that of all households with earnings histories (including singles). The ratio of peak median earnings to salary early in life is highest for the group with the highest education levels. Median earnings of couples in which the better-educated spouse has at least a college degree are up to a third higher around age sixty than those in couples in which neither has a college degree. The better-educated households have lower earnings than the less-educated groups, however, between ages twenty-five and thirty, when the highly educated group is presumably still accumulating educational human capital.

For comparison, panels A and B of figure 1.1 show the age-earnings profiles for couples with final earnings and a husband between the ages of sixty-three and sixty-seven in 2000. These figures exclude years in which a household has zero earnings. Panel A of figure 1.1 shows median income relative to age twenty-eight earnings, and Panel B of figure 1.1 shows median income in year 2000 dollars. All three educational groups show a decline in the last third of the working life even excluding household-year observations with zero earnings. The shape of the age-earnings profile matters for our computations of 401(k) balances at retirement, and it also affects the interpretation of financial magnitudes that are normalized by final earnings. We therefore analyze the three education groups separately in our simulation of 401(k) balances at retirement. We include years of zero earnings in our simulations to account realistically for work interruptions and retirement.

## 1.3 Household Balance Sheets and Non-401(k) Wealth for HRS Respondents

We now consider the household balance sheet, to calibrate the non-401(k) wealth that affects the expected utility of retirement wealth. We classify total household wealth into seven categories: the present discounted value of Social Security payments, the present discounted value of

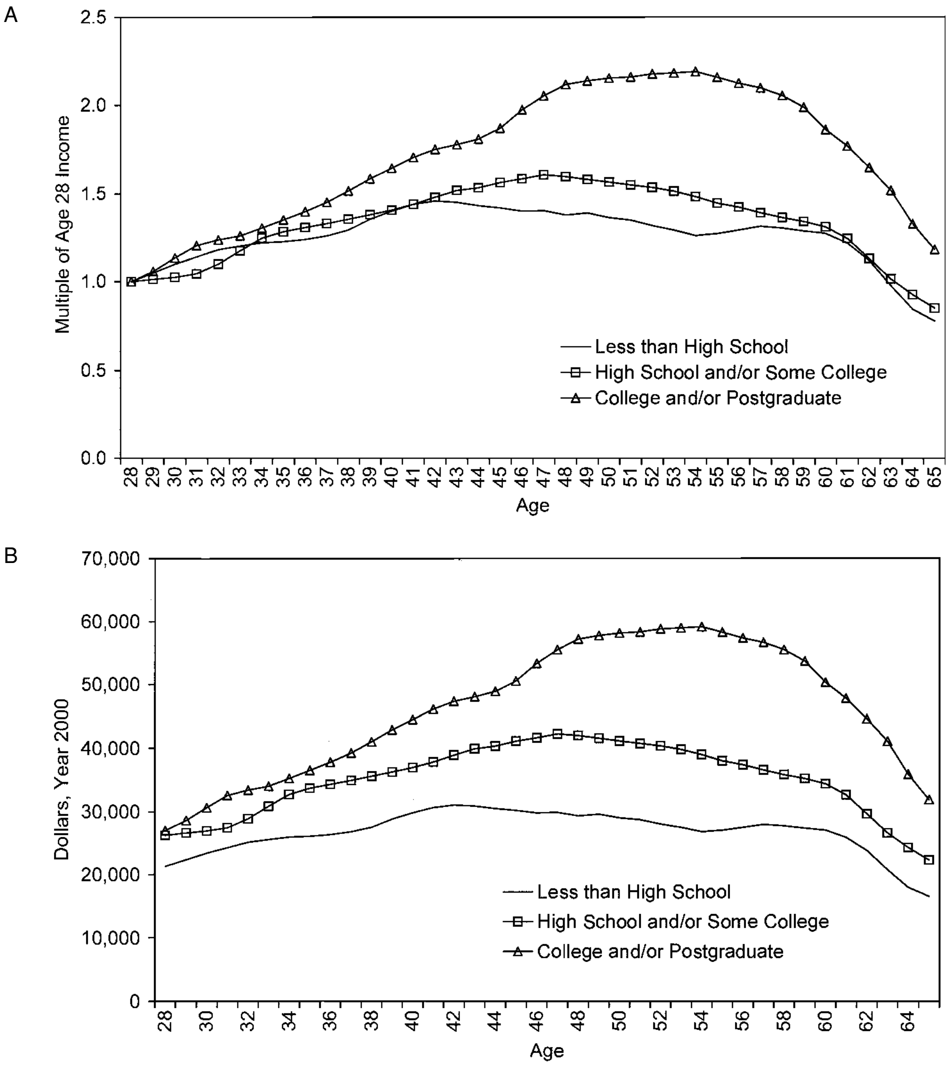


**Fig. 1.1** ***A*, Median household income in the HRS relative to age twenty-eight earnings, three-year moving average; *B*, median household income in the HRS in year 2000 dollars, three-year moving average**

defined benefit pensions, the present discounted value of other annuities, the current value of retirement accounts, all other net financial wealth, housing equity, and all other wealth.

The retirement account category includes individual retirement accounts (IRAs), 401(k)s, and other defined contribution (DC) accounts. Data on DC plan balances were collected for each respondent in the employment module of the HRS, and then aggregated to the household level.

Amounts classified as DC wealth include the balances of workers at their present job, plus any balances that workers or retirees left to accumulate in the plans of former employers. “Other net financial wealth” includes stocks, equity mutual funds, bonds, fixed-income mutual funds, checking and saving accounts, money market mutual funds and certificates of deposit. We refer to this category below as “financial wealth” despite the fact that it excludes annuitized wealth and retirement account assets. Net housing wealth equals gross home value less mortgages and home loans on the primary residence. The other wealth category includes the net-of-debt value of real estate other than household’s principal residence, the value of businesses or farms net of any outstanding debt, all assets held in trusts not otherwise classified, vehicles, and all “other” HRS wealth, which includes jewelry and expected repayment on personal loans.

The present discounted value (PDV) of Social Security wealth is calculated based on the reported current Social Security payments for members of the household already receiving Social Security, plus reported expected Social Security payments for other members not yet receiving Social Security. We do not use actual Social Security earnings histories to compute expected or accrued Social Security payments for individuals still in the labor force in 2000. Actual earnings histories end in 1991, and there is uncertainty about the date of retirement for individuals still in the labor force. We used cohort mortality tables for individuals born in 1930 to value Social Security payment streams. Distinct mortality probabilities for men and women were taken from the Social Security Administration (SSA) life tables for the U.S. Social Security area, as reported by Bell and Miller (2002). The SSA’s intermediate-cost scenario discount rates (3.0 percent real, 6.0 percent nominal) were applied to discount future payments, and payments were assumed to be indexed using an expected inflation rate of 3 percent. In these calculations, we take the joint-and-survivor properties of Social Security into account. We assume that as long as both members of the couple are alive, each respondent receives his or her current or projected Social Security benefits. When only one member of the couple is alive, we assume that the household receives benefits equal to the maximum of the two spouses’ benefits.

Of the 6,195 observations represented in HRS wave 5, 2,293 reported receiving a defined benefit (DB) pension, while 478 reported expecting to receive a DB pension at some future date. Thus, out of the 16.7 million represented households, 7.7 million received or were expecting to receive DB pensions. To determine the PDV of reported DB wealth, we took a similar approach to our valuation of Social Security wealth and valued the annuitized payment streams using the same mortality tables and discounting assumptions. Although some DB plans have cost of living adjustments, most are not indexed to inflation. We therefore assume that all DB pensions have a fixed nominal payout. We make the same assumption for any other annuities owned by household members.

**Table 1.3** **Household balance sheets, Health and Retirement Survey households in 2000 ($ thousands)**

| Wealth component | All households | Households with SS histories | Households with final earnings | Couples with final earnings | Couples with final earnings, male 63–67 |
|---|---|---|---|---|---|
| *Medians* | | | | | |
| Social Security | 159.9 | 162.1 | 172.3 | 222.3 | 242.0 |
| DB pension | 0.0 | 0.0 | 0.0 | 27.6 | 35.4 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 4.5 | 4.6 | 8.0 | 24.5 | 30.0 |
| IRA | 0.0 | 0.0 | 0.0 | 8.0 | 11.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 30.0 | 29.0 | 35.0 | 70.0 | 88.8 |
| Housing equity | 15.0 | 15.0 | 16.0 | 26.0 | 30.0 |
| Other wealth | 15.0 | 15.0 | 16.0 | 26.0 | 30.0 |
| SS + DB + other annuity | 215.3 | 218.4 | 225.9 | 285.4 | 316.4 |
| + other financial | 286.3 | 285.5 | 300.1 | 405.3 | 460.6 |
| Total (excl. retirement accts) | 422.0 | 414.5 | 436.6 | 582.4 | 652.3 |
| Total | 454.8 | 447.6 | 470.7 | 636.4 | 713.2 |
| Final earnings | | | 35.1 | 48.2 | 45.8 |
| *Means* | | | | | |
| Social Security | 160.7 | 163.2 | 170.8 | 207.2 | 228.9 |
| DB pension | 136.3 | 145.8 | 145.0 | 195.3 | 182.6 |
| Other annuity | 5.0 | 5.2 | 4.8 | 5.2 | 5.1 |
| Retirement accounts | 94.3 | 94.5 | 101.4 | 135.0 | 154.3 |
| IRA | 66.0 | 65.6 | 69.4 | 92.5 | 106.8 |
| 401(k) and other DC | 28.3 | 28.9 | 31.9 | 42.5 | 47.5 |
| Other financial wealth | 181.6 | 187.6 | 200.3 | 253.3 | 287.2 |
| Housing equity | 104.2 | 95.5 | 97.8 | 121.3 | 123.7 |
| Other wealth | 129.5 | 108.0 | 113.3 | 141.9 | 141.6 |
| SS + DB + other annuity | 302.0 | 314.3 | 320.5 | 407.8 | 416.6 |
| + other financial | 483.7 | 501.9 | 520.8 | 661.1 | 703.8 |
| Total (excl. retirement accts) | 717.4 | 705.4 | 732.0 | 924.3 | 969.1 |
| Total | 811.7 | 799.9 | 833.3 | 1,059.3 | 1,123.4 |
| Final earnings | | | 44.6 | 56.0 | 55.1 |
| *Sample size* | | | | | |
| No. of households | 6,195 | 4,233 | 3,749 | 2,275 | 759 |
| Weighted size ('000s) | 16,709.5 | 11,648.1 | 10,390.1 | 6,403.2 | 2,084.4 |

*Source:* Authors' tabulations from 2000 wave of the Health and Retirement Survey.

Table 1.3 presents information on mean and median wealth levels for the four groups of HRS households whose earnings histories were shown in table 1.2. The Social Security earnings history sample is slightly less wealthy than the sample consisting of all households, but the households generally become wealthier as we move from the entire HRS to our most restricted sample of couples with husbands between the ages of sixty-three and sixty-seven in 2000. We focus on this group in the subsequent analysis, since this is the group that is at, or slightly older than, the typical age of retirement in the most recent HRS survey wave. For this group, we find the median value of a DB pension of $35,400. The mean value, $182,600, is much greater, reflecting the right skewness of the distribution of pension values. For Social Security wealth, the median ($242,000) is actually greater than the mean ($228,900), which reflects the upper limit on Social Security benefits.

Table 1.3 also shows several wealth aggregates. First, we compute annuitized wealth as the sum of the present discount values of Social Security, DB pensions, and other annuities. We also present the sum of annuitized wealth and all other financial wealth, as well as aggregates reflecting all wealth and all wealth excluding retirement account assets. When we calibrate our simulations with individual households' non-401(k) wealth, we focus on two wealth components: annuitized wealth and all wealth excluding retirement account assets. We do not wish to include retirement account assets in the calibration of non-401(k) wealth on the grounds that we are using our simulations to construct values of retirement accounts. By using the observed values of these wealth components from the HRS, and treating them as nonrandom when we evaluate the expected utility of 401(k) retirement balances, we are implicitly assuming that changes in 401(k) wealth values do not affect other components of wealth. In future work, we plan to allow for correlation between the returns on assets in 401(k) accounts and the returns on other components of the household balance sheet.

Table 1.3 also shows final income for the various HRS subsamples. Presently we report the ratio of the wealth components to final income, so the variation in final income is of independent interest. In the upper panel of table 1.3, the ratio of median Social Security wealth to final income is a little over five, while the ratio of broadly defined net financial wealth to final income is about three. These statistics suggest the importance of recognizing wealth sources other than DC plans in analyzing the risks of portfolio strategies.

Although table 1.3 shows net housing wealth as a balance sheet component, its role in providing resources for retirement consumption is not clear. Several studies, such as Venti and Wise (2001a, 2004) and the references cited therein, suggest that retired households do not typically draw down their housing wealth to finance nonhousing consumption. This work suggests focusing only on nonhousing wealth as we consider the wealth available to support retirement spending. One way to conceptualize this approach is to assume the utility from housing consumption as additively separable from all other consumption in the household's utility function and to further assume that owner-occupied housing generates only housing consumption. The difficulty with this approach is that it is possible that households view their housing equity as a reserve asset that can be tapped to support other consumption in the event of financial difficulty. In this case, housing equity should be combined with financial assets in calculating the household's assets outside defined contribution plans. To allow for this possibility, we present results in which we consider housing as well as other financial assets as the household's non-401(k) wealth at retirement.

Table 1.4 presents information on wealth holdings across different education subsamples. The results suggest that there are important differences across groups. The table focuses on the subsample of HRS couples that have earnings records and in which the husband is between sixty-three and

**Table 1.4 Household balance sheets, Health and Retirement Survey households with final earnings, males aged 63–67**

| | All education levels | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|---|
| *Medians* | | | | |
| Social Security | 242.0 | 217.0 | 248.5 | 248.8 |
| DB pension | 35.4 | 0.0 | 46.6 | 100.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 30.0 | 0.0 | 29.0 | 126.1 |
| IRA | 11.0 | 0.0 | 9.5 | 80.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 88.8 | 8.1 | 71.0 | 328.0 |
| Housing equity | 91.0 | 60.0 | 87.0 | 130.0 |
| Other wealth | 30.0 | 18.0 | 25.0 | 70.0 |
| SS + DB + other annuity | 316.4 | 240.8 | 323.6 | 375.5 |
| + other financial | 460.6 | 257.3 | 441.2 | 838.9 |
| Total (excl. retirement accts) | 652.3 | 362.3 | 601.7 | 1,102.4 |
| Total | 713.2 | 378.7 | 673.6 | 1,303.4 |
| Final earnings | 45.8 | 35.7 | 46.2 | 56.8 |
| *Means* | | | | |
| Social Security | 228.9 | 206.8 | 234.4 | 235.0 |
| DB pension | 182.6 | 57.2 | 112.6 | 416.7 |
| Other annuity | 5.1 | 1.1 | 5.7 | 7.1 |
| Retirement accounts | 154.3 | 39.5 | 114.2 | 321.4 |
| IRA | 106.8 | 31.2 | 89.0 | 200.0 |
| 401(k) and other DC | 47.5 | 8.3 | 25.2 | 121.4 |
| Other financial wealth | 287.2 | 68.9 | 180.4 | 665.1 |
| Housing equity | 123.7 | 71.9 | 106.7 | 197.1 |
| Other wealth | 141.6 | 78.0 | 92.9 | 286.2 |
| SS + DB + other annuity | 416.6 | 265.1 | 352.7 | 658.8 |
| + other financial | 703.8 | 334.1 | 533.1 | 1,323.9 |
| Total (excl. retirement accts) | 969.1 | 484.0 | 732.7 | 1,807.2 |
| Total | 1,123.4 | 523.5 | 846.9 | 2,128.6 |
| Final earnings | 55.1 | 37.5 | 55.0 | 68.7 |
| *Sample size* | | | | |
| No. of households | 759 | 180 | 390 | 189 |
| Weighted size ('000s) | 2,084.4 | 428.8 | 1,097.7 | 557.9 |

sixty-seven in 2000. The summary statistics show the clear link between education and wealth, measured both in absolute dollars and relative to final income. Annuitized wealth alone is $240,800 for the median household with less than a high school education and $375,500 for those with at least a college degree. The dispersion here is mostly due to the disparities across education categories in the level of DB pensions. The PDV of Social Security benefits varies relatively little. It is $217,000 for those who never finished high school and $248,800 for those with at least a college degree. Other financial wealth, which excludes annuitized wealth and retirement account assets, displays a high degree of dispersion, with $8,100 for the median household with less than a high school education and $328,000 for the median household with at least a college degree. These findings suggest that in evaluating 401(k) plan risk, the effect of accounting for non-401(k) assets will vary across education groups.

Table 1.4 summarizes the average wealth holdings of the different education groups, but it does not characterize the dispersion of wealth within these groups. Table 1.5 offers further detail on such distributions, showing the 20th, 40th, 60th, and 80th percentiles of the distribution of each wealth component relative to final income. Consider, for example, financial wealth. For households with high school and/or some college education but no college degree, the 20th percentile value of the ratio of financial wealth to final earnings is 0.1 while the 40th percentile value is 1.0 and the 80th percentile value is 7.4. Patterns like this emerge for each of the asset categories, with very substantial dispersion between the lowest and the highest percentiles. These tabulations suggest that one household having a higher educational attainment than another does not guarantee a higher ratio of any given financial asset class to labor income. In particular, the ratio of Social Security wealth to final earnings decreases with education. Venti and Wise (2001b) emphasize the wide range of asset accumulation within like lifetime earnings groups, at all lifetime earnings levels.

The entries in table 1.5 show the ratio of wealth components to final earnings. Final earnings vary systematically across education group, however, which makes it difficult to identify the underlying differences in wealth holdings. To facilitate such analysis, table 1.6 presents information on the wealth distribution with all entries measured in year 2000 dollars. For the median household in each education group, the results suggest a substantial amount of non-401(k) wealth already in place. The 40th percentile value of total wealth excluding retirement assets for couples in our sample with less than a high school degree is $311,800, compared with $527,700 for those with at least a high school degree and $1,007,700 for those with at least a college degree. For the 60th percentile these values are $424,900, $708,600, and $1,393,900, respectively. The households in the 60th percentile of the distribution of those with less than a high school degree correspond to those near the 30th percentile in the group with a high

**Table 1.5** **Distribution of household balance sheet items as a ratio to final earned income: HRS married households with final earnings and males aged 63–67 in 2000**

| | All education levels | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|---|
| *20th percentile* | | | | |
| Social Security | 3.0 | 3.6 | 3.2 | 2.1 |
| DB pension | 0.0 | 0.0 | 0.0 | 0.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 0.0 | 0.0 | 0.0 | 0.2 |
| IRA | 0.0 | 0.0 | 0.0 | 0.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 0.1 | 0.0 | 0.1 | 1.5 |
| Housing equity | 0.8 | 0.3 | 0.8 | 1.2 |
| Other wealth | 0.2 | 0.1 | 0.2 | 0.4 |
| SS + DB + other annuity | 4.2 | 4.5 | 4.2 | 3.5 |
| + other financial | 5.8 | 4.9 | 5.8 | 7.4 |
| Total (excl. retirement accts) | 8.1 | 6.7 | 8.1 | 10.7 |
| Total | 8.6 | 6.8 | 8.8 | 12.4 |
| *40th percentile* | | | | |
| Social Security | 4.4 | 4.9 | 4.6 | 3.4 |
| DB pension | 0.0 | 0.0 | 0.2 | 0.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 0.2 | 0.0 | 0.2 | 1.4 |
| IRA | 0.0 | 0.0 | 0.0 | 0.7 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 1.1 | 0.1 | 1.0 | 4.5 |
| Housing equity | 1.6 | 1.2 | 1.5 | 2.2 |
| Other wealth | 0.5 | 0.3 | 0.5 | 1.0 |
| SS + DB + other annuity | 5.2 | 6.3 | 6.3 | 6.1 |
| + other financial | 7.2 | 6.8 | 9.1 | 13.8 |
| Total (excl. retirement accts) | 12.6 | 8.9 | 12.3 | 19.2 |
| Total | 13.5 | 9.1 | 13.5 | 22.8 |
| *60th percentile* | | | | |
| Social Security | 5.7 | 6.7 | 5.9 | 4.9 |
| DB pension | 1.7 | 0.3 | 1.7 | 2.8 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 1.3 | 0.1 | 1.2 | 3.5 |
| IRA | 0.7 | 0.0 | 0.7 | 2.3 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 3.3 | 0.6 | 3.0 | 9.2 |
| Housing equity | 2.5 | 1.8 | 2.3 | 3.1 |
| Other wealth | 1.3 | 0.9 | 1.0 | 2.5 |
| SS + DB + other annuity | 8.8 | 8.3 | 8.6 | 9.7 |
| + other financial | 13.7 | 9.3 | 12.7 | 20.9 |
| Total (excl. retirement accts) | 18.3 | 12.9 | 17.4 | 28.3 |
| Total | 21.2 | 13.4 | 19.9 | 33.3 |

(*continued*)

**Table 1.5** (continued)

| | All education levels | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|---|
| *80th percentile* | | | | |
| Social Security | 9.2 | 9.8 | 9.4 | 7.6 |
| DB pension | 4.6 | 2.9 | 4.4 | 7.3 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 4.6 | 1.0 | 3.8 | 11.2 |
| IRA | 3.3 | 0.5 | 2.9 | 6.6 |
| 401(k) and other DC | 0.5 | 0.0 | 0.3 | 2.0 |
| Other financial wealth | 9.1 | 2.9 | 7.4 | 19.3 |
| Housing equity | 4.8 | 4.3 | 4.3 | 8.6 |
| Other wealth | 4.0 | 2.3 | 3.0 | 6.6 |
| SS + DB + other annuity | 14.0 | 11.8 | 13.2 | 17.3 |
| + other financial | 23.0 | 15.7 | 20.1 | 46.5 |
| Total (excl. retirement accts) | 32.5 | 21.2 | 26.9 | 59.0 |
| Total | 38.9 | 22.7 | 30.9 | 63.8 |

school degree and/or some college education, and to those near the 10th percentile in the group with at least a college degree.

## 1.4 Asset Market Returns and Equity Premium

Our simulation methodology is designed to calculate the 401(k) wealth at retirement for households with any given earnings profile while accounting for uncertainty in the distribution of financial market returns. We treat the other components of the household balance sheet as nonstochastic, although as we further develop the simulation algorithm that we describe here we will include a more complete analysis of the uncertainties associated with non-401(k) wealth.

We assume that households have two investment choices in their 401(k) accounts. One is an index bond, with an assured real return of 2.8 percent per year. The current term structure of yields (April 22, 2003) on U.S. Treasury Inflation Protection Securities is upward sloping. For bonds with a maturity of between five and six years, real interest rates are less than 2 percent. At a maturity of almost thirty years, the yield is between 2.7 and 2.8 percent. Since retirement saving accumulation takes place over long horizons, and to err on the side of generosity in the assumed return on bonds, we assume that investments in index bonds earn a return of 2.8 percent each year, net of inflation.

Index bonds deliver a net-of-inflation certain return only if the investor holds the bonds to maturity. Investors who sell their bonds before maturity, however, are exposed to asset price risk. If real interest rates rise between

**Table 1.6** **Distribution of household balance sheet items ($ thousands): HRS married households with final earnings and husbands aged 63–67 in 2000**

| | All education levels | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|---|
| *20th percentile* | | | | |
| Social Security | 151.2 | 138.5 | 176.4 | 136.3 |
| DB pension | 0.0 | 0.0 | 0.0 | 0.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 0.0 | 0.0 | 0.0 | 11.0 |
| IRA | 0.0 | 0.0 | 0.0 | 0.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 2.0 | –1.0 | 4.8 | 94.0 |
| Housing equity | 39.0 | 7.0 | 44.0 | 80.0 |
| Other wealth | 10.0 | 2.8 | 10.0 | 16.0 |
| SS + DB + other annuity | 199.7 | 151.2 | 214.1 | 229.3 |
| + other financial | 241.1 | 148.6 | 253.7 | 455.7 |
| Total (excl. retirement accts) | 347.5 | 202.0 | 374.7 | 675.2 |
| Total | 357.5 | 203.1 | 384.7 | 718.4 |
| *40th percentile* | | | | |
| Social Security | 216.5 | 194.2 | 224.8 | 215.4 |
| DB pension | 0.0 | 0.0 | 8.9 | 0.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 11.0 | 0.0 | 12.0 | 93.0 |
| IRA | 0.0 | 0.0 | 0.0 | 40.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 40.0 | 1.0 | 39.0 | 242.0 |
| Housing equity | 78.0 | 45.0 | 73.0 | 105.0 |
| Other wealth | 20.5 | 10.0 | 20.0 | 47.0 |
| SS + DB + other annuity | 272.3 | 217.9 | 277.4 | 320.7 |
| + other financial | 374.5 | 229.6 | 376.3 | 729.5 |
| Total (excl. retirement accts) | 536.3 | 311.8 | 527.7 | 1,007.7 |
| Total | 575.4 | 313.6 | 565.0 | 1,097.2 |
| *60th percentile* | | | | |
| Social Security | 261.1 | 235.7 | 265.1 | 284.6 |
| DB pension | 84.8 | 10.4 | 84.8 | 192.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 59.0 | 4.0 | 50.0 | 185.0 |
| IRA | 34.0 | 0.0 | 31.0 | 133.0 |
| 401(k) and other DC | 0.0 | 0.0 | 0.0 | 0.0 |
| Other financial wealth | 156.0 | 18.0 | 124.5 | 411.3 |
| Housing equity | 105.0 | 75.0 | 100.0 | 175.0 |
| Other wealth | 51.0 | 28.0 | 40.0 | 114.5 |
| SS + DB + other annuity | 353.9 | 277.0 | 358.7 | 477.4 |
| + other financial | 599.5 | 311.9 | 496.7 | 945.3 |
| Total (excl. retirement accts) | 812.5 | 424.9 | 708.6 | 1,393.9 |
| Total | 882.5 | 430.6 | 811.5 | 1,641.8 |

(*continued*)

**Table 1.6** (continued)

| | All education levels | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|---|
| *80th percentile* | | | | |
| Social Security | 311.7 | 277.0 | 309.7 | 327.4 |
| DB pension | 221.4 | 132.0 | 191.2 | 389.0 |
| Other annuity | 0.0 | 0.0 | 0.0 | 0.0 |
| Retirement accounts | 220.0 | 36.0 | 180.0 | 448.9 |
| IRA | 150.0 | 19.5 | 106.9 | 310.0 |
| 401(k) and other DC | 20.0 | 2.0 | 13.0 | 104.5 |
| Other financial wealth | 400.0 | 90.0 | 285.8 | 960.0 |
| Housing equity | 170.0 | 110.0 | 150.0 | 300.0 |
| Other wealth | 147.0 | 90.0 | 127.0 | 295.0 |
| SS + DB + other annuity | 504.4 | 364.5 | 462.0 | 660.4 |
| + other financial | 888.4 | 440.9 | 707.9 | 1,754.9 |
| Total (excl. retirement accts) | 1,212.8 | 657.6 | 1,001.0 | 2,299.5 |
| Total | 1,422.4 | 772.3 | 1,134.4 | 3,312.0 |

the time that index bonds are purchased and the time they are sold, the price of the bonds can decline, leaving the investor with a capital loss. Similarly, a decline in real interest rates would generate a capital gain. When investors do not know the precise timing of their withdrawals, as they may not when they contemplate retirement with an unknown life span, purchasing an index bond is not riskless. These bonds nevertheless seem like the least risky long-term investment available to retirement savers.

The alternative investment in our simulations is a diversified portfolio of large capitalization U.S. stocks. We assume that the uncertain real return on this portfolio is represented by the empirical distribution of returns during the 1926–2001 period. Ibbotson Associates (2003) reports the annual return time series, which has an annual average real return of 9.4 percent and a standard deviation of 20.4 percent. Figure 1.2 presents a histogram of real returns.

In an earlier simulation analysis of 401(k) wealth accumulation, Poterba, Venti, and Wise (2004) considered investments in nominal bonds and corporate stock. We consider investments in index bonds rather than corporate bonds in the current project because they are likely to provide a less risky source of long-term returns and, therefore, to provide a more natural benchmark for analyzing the risks of corporate stock from the vantage point of retirement income accumulation.

On each iteration of our simulation algorithm, we draw a sequence of thirty-five real stock returns from the empirical return distribution. The draws are done with replacement, and we assume that there is no serial correlation in returns. We then use this return sequence to calculate the real

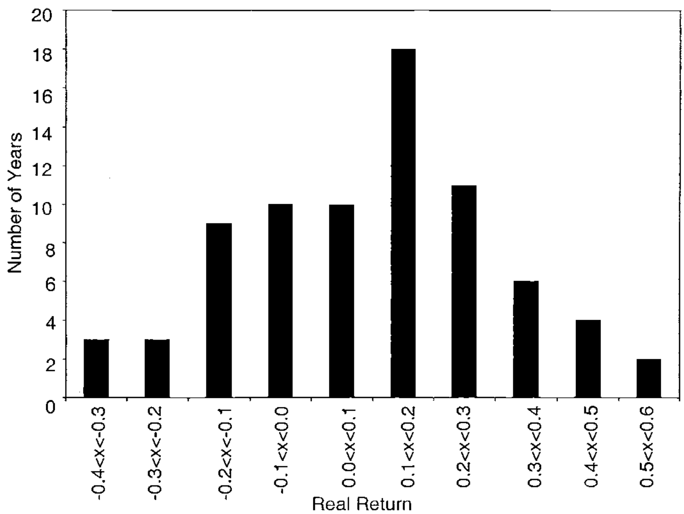


**Fig. 1.2 Empirical distribution of real S&P 500 equity returns**

value of each household's retirement account balance at age sixty-three, assuming that their contributions are determined by their earnings history. We consider the full thirty-five-year working life for each household, and we evaluate both a 100 percent equity investment case and a fifty-fifty stocks and index bonds case. Since the goal of our procedure is to generate reasonably precise estimates of the distribution of possible wealth outcomes for a given contribution history, we need to repeat our basic iteration many times. We found that with 200,000 replications, we could obtain estimates of the outcome distribution that did not vary substantially from one simulation to another. For each one of the 759 households in our sample, therefore, we simulate their 401(k) balance at age sixty-three 200,000 times. We then summarize these 200,000 outcomes either with a distribution of wealth values at retirement or by calculating the expected utility associated with this distribution of outcomes.

## 1.5 The Distribution of 401(k) Account Balances under Different Portfolio Strategies

Table 1.7 shows the distribution of 401(k) plan balances in thousands of year 2000 dollars, averaged across the 759 households in our sample. Households are stratified by education group. The first row in table 1.7 shows the results associated with a 100 percent index bond investment. Since the real bond return is certain, there is no uncertainty about the final wealth in this investment scenario. The value of 401(k) wealth varies somewhat across education categories: $172,700 for those with less than a high

**Table 1.7** **Simulated distribution of 401(k) balance at retirement in thousands of year 2000 dollars**

| Investment strategy/percentile | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| *50% riskless bonds, 50% large-cap corporate stocks* | | | |
| 1 | 54.6 | 75.5 | 83.4 |
| 5 | 162.9 | 217.9 | 233.4 |
| 10 | 188.4 | 251.3 | 267.8 |
| 20 | 225.1 | 299.2 | 316.9 |
| 30 | 256.0 | 339.7 | 358.1 |
| 40 | 286.0 | 378.8 | 397.9 |
| 50 | 317.2 | 419.7 | 439.2 |
| 60 | 352.0 | 465.1 | 485.1 |
| 70 | 393.6 | 519.3 | 539.7 |
| 80 | 448.7 | 591.2 | 611.8 |
| 90 | 538.1 | 707.9 | 728.6 |
| Mean | 345.8 | 456.9 | 475.8 |
| *100% large-cap corporate stocks* | | | |
| 1 | 15.8 | 22.8 | 26.4 |
| 5 | 127.7 | 172.0 | 185.4 |
| 10 | 171.5 | 229.6 | 244.8 |
| 20 | 246.6 | 328.2 | 345.7 |
| 30 | 321.7 | 426.6 | 445.4 |
| 40 | 404.6 | 535.1 | 554.7 |
| 50 | 502.1 | 662.6 | 682.5 |
| 60 | 623.8 | 821.7 | 841.2 |
| 70 | 787.8 | 1,035.9 | 1,053.8 |
| 80 | 1,036.2 | 1,360.8 | 1,374.7 |
| 90 | 1,517.0 | 1,989.7 | 1,992.8 |
| Mean | 730.1 | 960.9 | 972.9 |
| *50% riskless bonds, 50% large-cap stocks (risk premium reduced by 300 basis points)* | | | |
| 1 | 41.8 | 58.4 | 65.7 |
| 5 | 120.4 | 162.0 | 176.4 |
| 10 | 138.7 | 186.0 | 201.5 |
| 20 | 164.8 | 220.3 | 237.0 |
| 30 | 186.9 | 249.2 | 266.8 |
| 40 | 208.2 | 277.1 | 295.5 |
| 50 | 230.4 | 306.1 | 325.2 |
| 60 | 255.0 | 338.2 | 358.1 |
| 70 | 284.4 | 376.6 | 397.2 |
| 80 | 323.3 | 427.3 | 448.6 |
| 90 | 386.3 | 509.4 | 531.7 |
| Mean | 250.3 | 331.9 | 350.8 |

**Table 1.7** (continued)

| Investment strategy/percentile | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|
| *100% large-cap stocks (risk premium reduced by 300 basis points)* | | | |
| 1 | 10.0 | 14.8 | 17.9 |
| 5 | 70.8 | 96.8 | 107.7 |
| 10 | 93.4 | 126.8 | 139.6 |
| 20 | 131.7 | 177.3 | 192.7 |
| 30 | 169.6 | 227.1 | 244.4 |
| 40 | 211.1 | 281.4 | 300.5 |
| 50 | 259.5 | 344.8 | 365.5 |
| 60 | 319.6 | 423.3 | 445.5 |
| 70 | 400.2 | 528.4 | 552.0 |
| 80 | 521.7 | 687.0 | 711.4 |
| 90 | 755.5 | 991.9 | 1,016.2 |
| Mean | 369.4 | 487.8 | 506.6 |

school degree, $230,400 for those with high school and/or some college, and $248,200 for those with a college degree. As all three groups are assumed to have the same contribution rates out of earnings, these disparities reflect differences across groups in age-earning profiles. The assumption that all households contribute 9 percent of their earnings to their 401(k) account is a critical determinant of the overall magnitudes of the final account balances. Account balances could be scaled up or down for alternative assumptions about the contribution rate.

The next two panels of table 1.7 show the distribution of 401(k) balances when half, and then when all, of the 401(k) account is invested in corporate stock. The table shows the value for every tenth percentile of the distribution. For households with a high school education, simulated 401(k) wealth is $299,200 at the 20th percentile, and $591,200 at the 80th percentile when the 401(k) account is invested 50 percent in corporate stock.

Panel A of figure 1.3 shows the ratio of 401(k) wealth to final earnings for households with a high school or some college education, for the all-index bond, the mixed, and the all-stock portfolio strategies. Over most of the distribution of possible stock returns, the ratio of wealth to final earnings is higher when the portfolio is half in corporate stock than when it is completely in index bonds. The figure shows that if a household holds the all-equity portfolio, the chance is slightly greater than 10 percent that the wealth outcome at retirement will fall below the outcome for the index bond portfolio. The scale of panel A of figure 1.3 illustrates why we focus on dollar amounts of the simulation in our tables and analysis. Some households' earnings decline before retirement, resulting in very low final earnings and correspondingly very high ratios of 401(k) balances and other wealth components to final earnings. The mean of such a distribu-

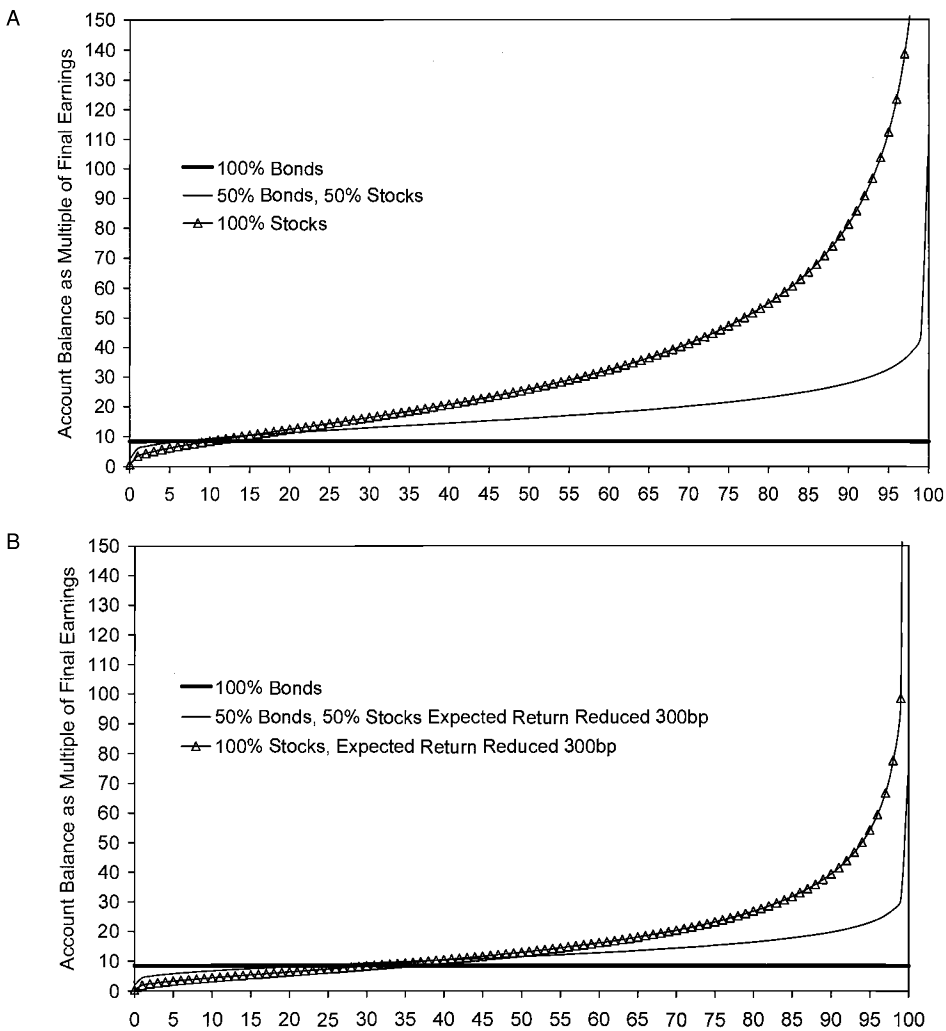


**Fig. 1.3** ***A,*** **Cumulative density functions of 401(k) wealth relative to final earnings for households with high school or some college education;** ***B,*** **cumulative density functions of 401(k) wealth relative to final earnings for households with high school or some college education, stock return reduced by 300 basis points**

tion is very sensitive to these extreme values. To highlight this issue, panel A of figure 1.4 shows the same data as in panel A of figure 1.3, but with dollar amounts instead of ratios to final earnings.

One potential difficulty with our simulation procedure is that the historical period over which we measure equity returns may have been abnormal. Mehra and Prescott (2003) discuss this possibility along with other poten-

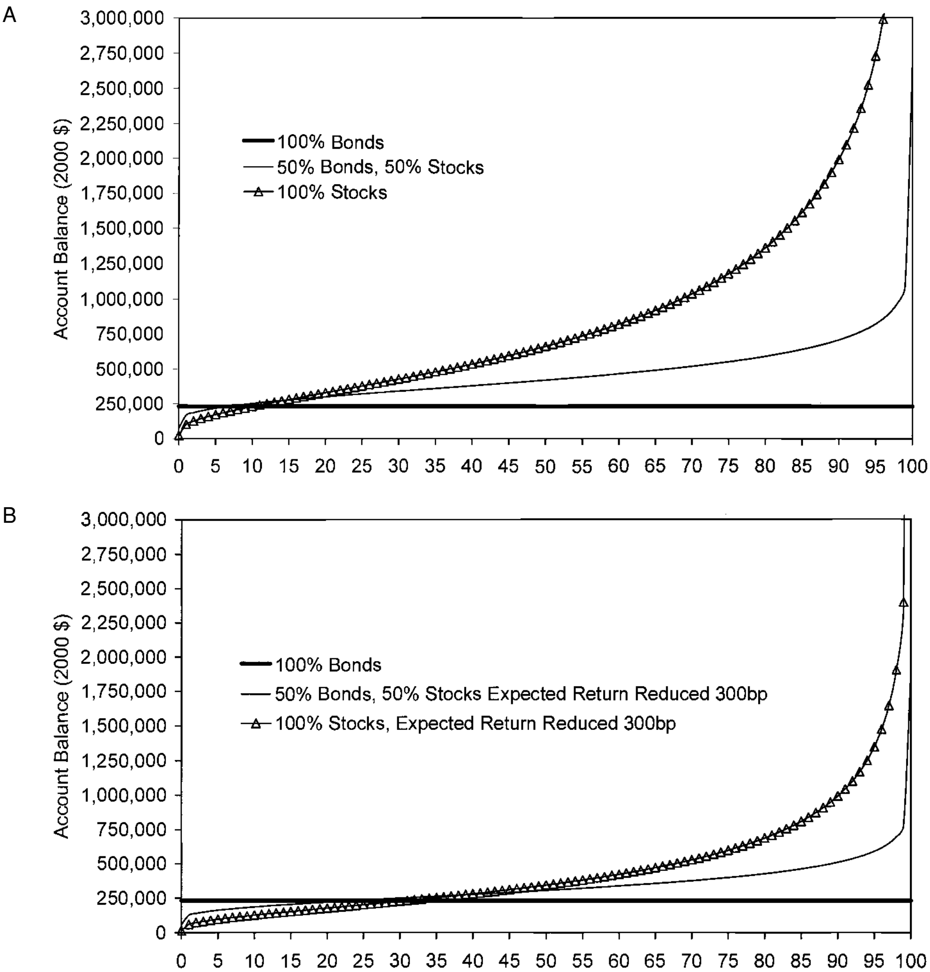


**Fig. 1.4** ***A*, cumulative density functions of 401(k) wealth for households with high school or some college education; *B*, cumulative density functions of 401(k) wealth for households with high school or some college education, stock return reduced by 300 basis points**

tial explanations for the "equity premium puzzle." To allow for the possibility that the historical distribution of equity returns may overstate the prospective returns on stocks, we also consider a reduced equity return scenario, in which we reduce the expected return on corporate stock by 300 basis points, while leaving the dispersion of returns the same as in the base case. The results of this modification, for both half and all of the 401(k) account invested in corporate stock, are shown in the lower two panels of table 1.7 and in panel B of figures 1.3 and 1.4. The results indicate that with a lower equity return, the index bond investment strategy looks more attractive relative to the equity investment strategy. Even with the reduced equity return, however, there is still a relatively low probability that the all-index bonds strategy will outperform a fifty-fifty mix of index bonds and corporate stock. With the reduced equity return, the retirement wealth in the all index bonds case for a household with high school and/or some college education falls at around the 22nd percentile of the outcome distribution for the fifty-fifty mix of index bonds and stocks. It falls at around the 31st percentile in the outcome distribution with only stock investment, which attests to the greater volatility, as well as the greater average return, from holding all stocks rather than a fifty-fifty mix. Similar patterns emerge in the retirement wealth distributions for the other educational groups.

Evaluating the absolute magnitude of retirement assets as reported in table 1.7 is complicated by the fact that assets in the 401(k) account are measured on a pretax basis. Withdrawal of these assets would trigger income tax liability for the beneficiary. Simple corrections for this, such as multiplying by $(1 - t)$ where $t$ is a plausible estimate of the marginal tax rate on ordinary income, are not sufficient, because if the assets remain in the 401(k) account for many years after the head of household turns sixty-five, the effective tax burden may be relatively low. Poterba (2004) presents illustrative calculations on the conversion between balances in taxable and tax-deferred accounts.

## 1.6 Certainty Equivalent Measures of the Cost of Uncertain Returns

Table 1.7 and panels A and B of figure 1.4 are examples of the use of the entire distribution of retirement wealth outcomes to describe the effects of different portfolio strategies. They present information on how different portfolio strategies will affect the average level of retirement wealth, as well as its dispersion. The fraction of retirement wealth outcomes in the all-stock or fifty-fifty stock/index cases that fall below the outcome in the all-index-bond case provides some insight on the risks associated with the various strategies. Results similar to these are a key component of "outcomes-based" financial planning software that enables clients to determine the probability of reaching retirement wealth goals. These software programs are based on Monte Carlo simulations of future wealth accumulations, and their results provide a picture of the risk associated with different investment strategies. Presumably, different investors with different tolerances for risk would prefer different investment strategies.

Results that portray the "picture" of retirement wealth risks provide no a priori way to describe how households or groups of households might evaluate these two distributions and thereby decide which portfolio strategy to pursue. At the heart of this difficulty is the question of how households evaluate small probabilities of low retirement plan balances. The picture approach does not attempt to evaluate the cost to a household of a retirement wealth outcome below the all-bonds level.

The last part of our analysis is directed to this issue. We compute the expected utility generated by the distribution of retirement resources for each portfolio strategy, using a standard household utility function. We then convert this expected utility to a certainty equivalent wealth measure to value the potential outcomes of different portfolio strategies. Table 1.8 presents these results assuming that the 401(k) balance is the household's only wealth. By excluding other wealth and assuming that the household is dependent on 401(k) wealth only, these calculations exaggerate the true level of risk faced by the household. Since household consumption risk during retirement is tempered by the existence of non-401(k) wealth, we relax this counterfactual assumption below.

The values in the first panel in table 1.8 are based on linear utility ($\alpha = 0$) and are thus the expected values of each investment choice represented

**Table 1.8 Certainty equivalent wealth in thousands of year 2000 dollars for different portfolio allocation rules and expected stock returns, assuming no wealth other than 401(k)**

| Investment strategy/risk aversion (alpha) | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|
| *alpha = 0* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 345.8 | 456.9 | 475.8 |
| 100% stocks | 730.1 | 960.9 | 972.9 |
| 50% bonds, 50% equity return reduced 300bp | 250.3 | 331.9 | 350.8 |
| 100% stocks, equity return reduced 300bp | 369.4 | 487.8 | 506.6 |
| *alpha = 1* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 317.8 | 420.7 | 440.4 |
| 100% stocks | 506.2 | 669.3 | 690.3 |
| 50% bonds, 50% equity return reduced 300bp | 230.9 | 306.9 | 326.2 |
| 100% stocks, equity return reduced 300bp | 262.7 | 349.6 | 370.8 |
| *alpha = 2* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 292.3 | 387.7 | 408.0 |
| 100% stocks | 355.5 | 473.3 | 498.0 |
| 50% bonds, 50% equity return reduced 300bp | 213.2 | 284.1 | 303.5 |
| 100% stocks, equity return reduced 300bp | 190.1 | 255.5 | 276.6 |
| *alpha = 4* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 248.1 | 330.4 | 351.4 |
| 100% stocks | 186.1 | 252.8 | 276.4 |
| 50% bonds, 50% equity return reduced 300bp | 182.4 | 244.3 | 263.8 |
| 100% stocks, equity return reduced 300bp | 106.0 | 146.0 | 164.0 |

in table 1.7. The second panel shows that for a household with no wealth outside the retirement account, and whose preferences over wealth are given by $U(W) = \log W$, which implies $\alpha = 1$ the certainty equivalent value of a portfolio invested in the large-cap equity portfolio is nearly three times as great as the value of the all-index-bond portfolio for a household with a high school education. For a fifty-fifty index bond and stock portfolio, the certainty equivalent is between 80 and 85 percent larger than the value of the all-index bond investment strategy. As risk aversion rises, the certainty equivalent value for the stock portfolio declines relative to the value of the index bond portfolio. When the household has a relative risk aversion of two, for example, the certainty equivalent of the all stock investment declines to about twice that of the all index bond portfolio, while the certainty equivalent of the fifty-fifty portfolio falls to around 70 percent of the value of the index bond investment. At a risk aversion of four, the certainty equivalent of an all-stock portfolio allocation is only slightly greater than that of an all-index bond allocation, but the value of a fifty-fifty portfolio remains considerably larger in certainty equivalent terms.

Figure 1.5 shows the cumulative distribution of the *utility values* of the wealth outcomes in the simulated distribution for four different levels of risk aversion. These are transformed values of the constant relative risk aversion utility function in equation (2) for each of the simulated outcomes. The utility values are scaled using a linear transformation, such that zero is the worst empirical outcome and one is the best outcome for each value of $\alpha$. When $\alpha = 0$, so that the household is risk neutral, the plot of the cumulative distribution function (CDF) for utility levels is the same as the cumulative distribution of the values of wealth at retirement. The 90th percentile outcome is less than 10 percent of the level of the best possible outcome, reflecting the very long upper tail of the empirical distribution. The cumulative density function for the risk-neutral household is convex. As risk aversion increases, the distribution of utility diverges more and more from the distribution of wealth, and it becomes clear that raising risk aversion puts more weight on the negative outcomes in the left tail of the potential retirement wealth distribution. The second derivative of the CDF rises as risk aversion increases. When $\alpha = 4$, the CDF is highly concave, as the low retirement wealth outcomes generate very low utility outcomes. As a result, by the 5th percentile of the utility outcome distribution, household utility is already 99 percent of the level of the best utility outcome.

Panels A and B of figure 1.6 show the distribution of certainty equivalent wealth values, measured in dollars at age sixty-three, for different levels of risk aversion and for each of our investment strategies. We restrict attention in these figures to households with a high school education. The three sets of figures differ in the assumptions that they make about the household's non-401(k) wealth at retirement.

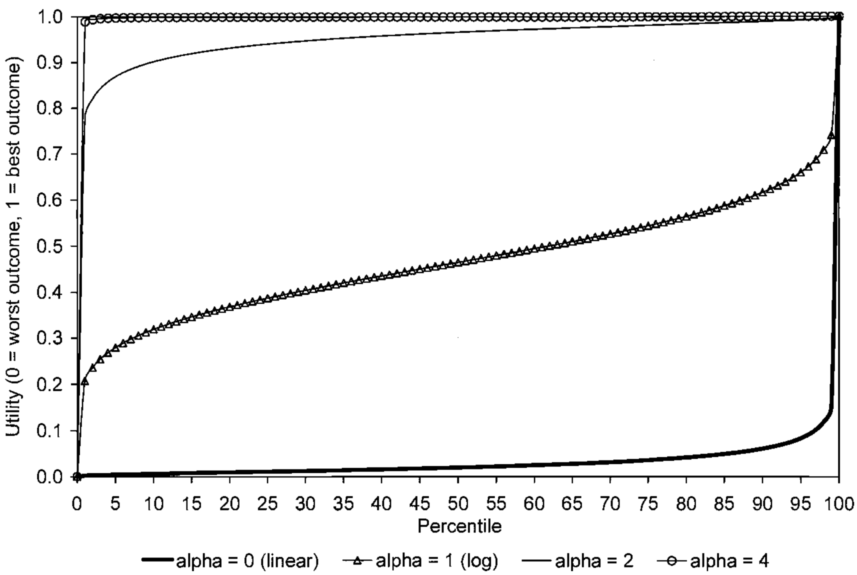


**Fig. 1.5 Cumulative density functions of different utility functions for households with high school or some college education**

*Notes:* This figure shows the cumulative distribution of the utility values of the wealth outcomes in the simulated distribution for four different levels of risk aversion. The scale of the utility values depends on the risk aversion parameter. In this figure, all utility values are scaled so that 0 is the worst outcome, and 1 is the best outcome, for a given alpha. The Von-Neumann Morgenstern (VNM) utility function over which expected utility is calculated is unique up to an affine transformation. The linear transformation necessary to put each utility value on a 0–1 scale is therefore a legitimate transformation that preserves the VNM function's properties. Furthermore, since the actual utility magnitudes of outcomes across different alphas are not comparable, the scale on which we represent the distribution of outcomes can be arbitrary as long as the VNM ordering is preserved.

Panel A of figure 1.6 shows that an all-stock portfolio is preferred to an all-index bond portfolio by investors with risk aversion (α) below approximately 4.25. This is not surprising, since the empirical distribution of historical stock returns has a much higher mean than the index bond portfolio. Thus, only a small number of 401(k) wealth outcomes under the partial- or full-equity strategies fall below the value of the index bond portfolio. The variability of returns on corporate stock does not create enough low utility outcomes to lead households with modest risk aversion to choose index bonds over a portfolio with some equity exposure. A fifty-fifty mixture of stock and index bonds is preferred to an all-bond portfolio by investors at all levels of risk aversion shown in the figure. The value of α that would make a household indifferent between the all-index-bonds portfolio strategy and each of the equity exposure strategies can be found at the intersections of the various curves. A value of α greater than eight is

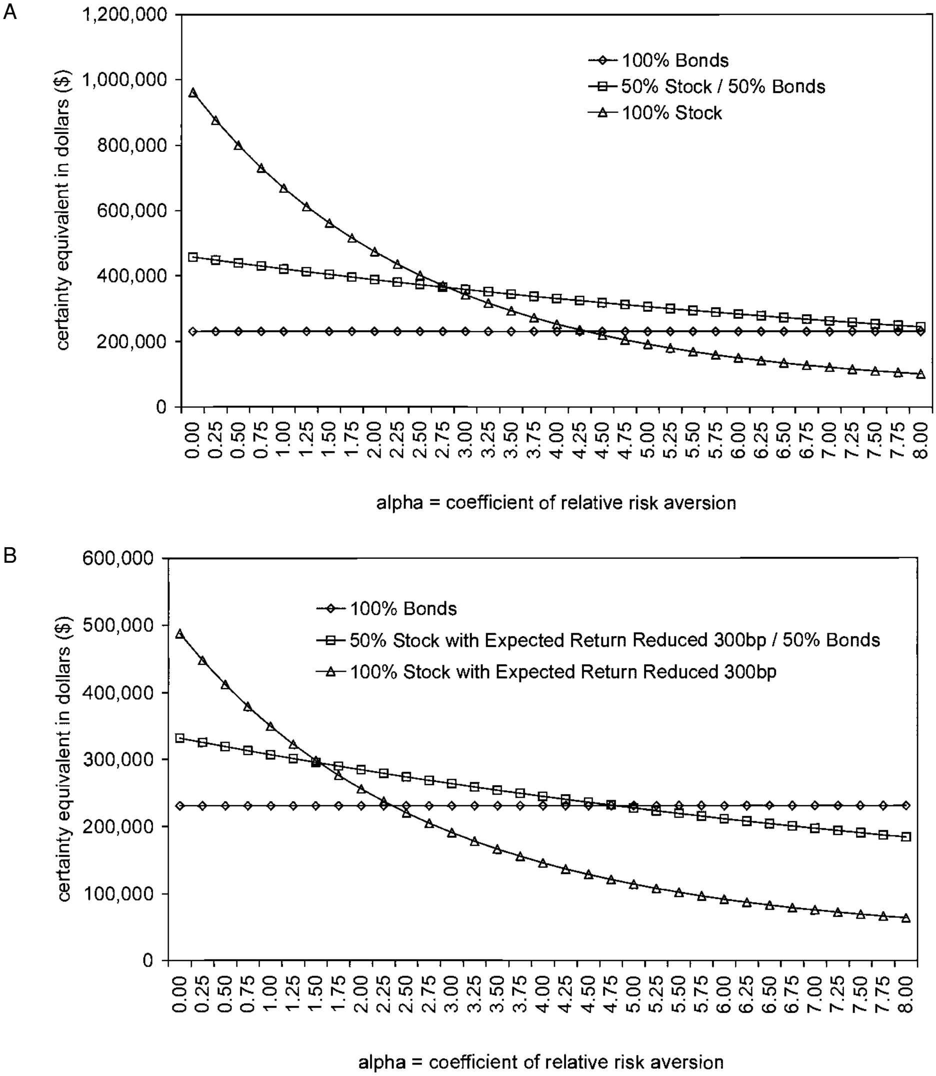


**Fig. 1.6** ***A*, Certainty equivalents and risk aversion for households with high school or some college education, baseline equity returns, and no wealth other than 401(k); *B*, certainty equivalents and risk aversion for households with high school or some college education, reduced equity premiums, and no wealth other than 401(k)**

needed for a household to prefer all index bonds to a fifty-fifty index bond–stock mix. For $\alpha > 2.75$, a household prefers the fifty-fifty mix to an all-stock portfolio.

Panel B of figure 1.6 shows that the certainty equivalent of the 50 percent and 100 percent equity allocations declines if the expected return on corporate stock is assumed to be 300 basis points lower than historical returns. The effects are most pronounced at high levels of risk aversion. For $\alpha = 4$, for example, the certainty equivalent of an all-stock allocation falls substantially *below* that of the all-index-bond portfolio when the expected equity return is 6.4 percent, while it is just under 10 percent higher than the certainty equivalent of the bond portfolio with an average equity return of 9.4 percent, the historical mean. Even with $\alpha = 2$, however, the expected utility of following the all-stock investment strategy exceeds that of the all-index-bond strategy when the expected equity return is 6.4 percent. When we reduce the average return by 300 basis points, the levels of $\alpha$ for which stocks and the fifty-fifty mix are preferred to the index bond portfolio are lower. Investors with $\alpha < 2.25$ prefer the all-stock portfolio strategy over all index bonds in this case, and those with $\alpha < 4.5$ prefer the fifty-fifty mix to the all-index-bond portfolio even when the expected return on stocks is reduced.

The results in table 1.8 and both panels of figure 1.6 assume that the 401(k) balance is the only wealth that the household accumulates to provide for retirement support. A sequence of stock market returns that delivers a very low retirement wealth is therefore very costly in terms of household utility. Yet the summary statistics in our earlier tables show that essentially all households have Social Security wealth and a large fraction of households have other wealth as well. To explore the importance of these other sources of retirement income, we repeated our stochastic simulations, taking account of other wealth. In table 1.9 and panels A and B of figure 1.7, we assume that each household holds non-401(k) wealth at retirement equal to the present discounted value of their Social Security wealth, DB plan wealth, and income annuity wealth. In table 1.10 and panels A and B of figure 1.8, each simulation household receives non-401(k) wealth at retirement equal to its total net worth—including Social Security wealth, DB wealth, and income annuity wealth—but excluding the value of retirement account assets that they report.

Table 1.9 thus presents findings like those in table 1.8, but from simulations that account for the presence of Social Security, DB wealth, and other income annuities, in addition to simulated 401(k) wealth. The first row of each panel in table 1.9 shows that for a couple with a high school education, the index bond portfolio generates the utility level associated with \$230,400. This is identical to the index bond portfolio certainty equivalents in table 1.8, and it is independent of $\alpha$, as there is no uncertainty associated with this simulated investment strategy. Comparing the other results in table 1.9 with those in table 1.8 shows that the certainty equivalent from holding a risky stock portfolio is larger when the household has other sources of financial support than when it does not. For example, households with a high school education and with log utility ($\alpha = 1$) have certainty equivalent wealth equal to \$669,300 for the stock portfolio in table

**Table 1.9 Certainty equivalent wealth in thousands of year 2000 dollars for different portfolio allocation rules and expected stock returns, assuming non-401(k) wealth = Social Security + defined benefit + other annuities**

| Investment strategy/risk aversion (alpha) | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|
| *alpha = 0* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 345.8 | 456.9 | 475.8 |
| 100% stocks | 730.1 | 960.9 | 972.9 |
| 50% bonds, 50% equity return reduced 300bp | 250.3 | 331.9 | 350.8 |
| 100% stocks, equity return reduced 300bp | 369.4 | 487.8 | 506.6 |
| *alpha = 1* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 328.7 | 435.1 | 455.7 |
| 100% stocks | 562.0 | 743.6 | 772.9 |
| 50% bonds, 50% equity return reduced 300bp | 239.9 | 318.6 | 338.4 |
| 100% stocks, equity return reduced 300bp | 301.5 | 400.8 | 425.5 |
| *alpha = 2* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 313.4 | 415.5 | 437.5 |
| 100% stocks | 454.0 | 603.9 | 641.4 |
| 50% bonds, 50% equity return reduced 300bp | 230.4 | 306.6 | 327.1 |
| 100% stocks, equity return reduced 300bp | 256.3 | 342.6 | 370.0 |
| *alpha = 4* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 287.2 | 381.9 | 406.0 |
| 100% stocks | 330.1 | 443.3 | 485.6 |
| 50% bonds, 50% equity return reduced 300bp | 214.0 | 285.7 | 307.1 |
| 100% stocks, equity return reduced 300bp | 200.8 | 270.9 | 299.5 |

1.8, where we assume no non-401(k) wealth. But the certainty equivalent of the 401(k) account rises to $743,600 when Social Security, DB pension wealth, and other income annuity wealth are included as non-401(k) wealth as in table 1.9.

Including another nonstochastic wealth component for non-401(k) wealth raises the certainty equivalent of the 401(k) account still further, as shown in table 1.10, where all nonretirement account assets reported in the HRS are included in the utility evaluation for each household. For the household with a high school education and log utility, the all-stock portfolio now has a certainty equivalent of $779,600. Therefore, relative to the all-index-bond case, where the certainty equivalent is $230,400, the all-stock investment generates a certainty equivalent that is 2.9 times greater if there is no wealth; 3.2 times greater than the case with Social Security, DB, and other annuity wealth; and 3.4 times greater than if non-401(k) wealth consists of all HRS wealth excluding retirement accounts. This in-

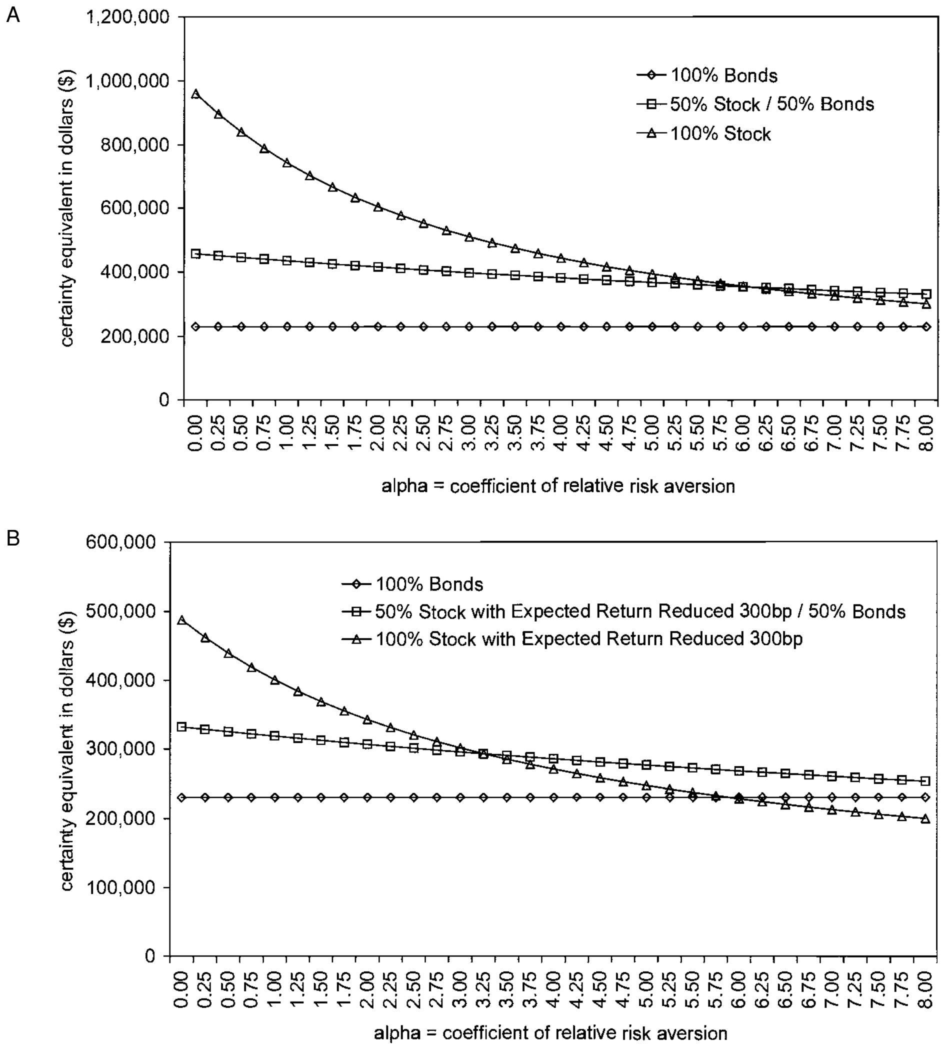


**Fig. 1.7** ***A*, Certainty equivalents and risk aversion for households with high school or some college education, baseline equity returns, and SS + DB + annuity wealth; *B*, certainty equivalents and risk aversion for households with high school or some college education, reduced equity premiums, and SS + DB + annuity wealth**

crease in certainty equivalent wealth with larger levels of nonstochastic wealth is a feature of the constant relative risk aversion utility function.

At higher levels of risk aversion, the assumptions that we make about non-401(k) wealth are more important than at lower risk aversion values. The all-stock strategy has a certainty equivalent of $252,800 for $\alpha = 4$ when we assume households have no non-401(k) wealth, as in table 1.8.

**Table 1.10** **Certainty equivalent wealth in thousands of year 2000 dollars for different portfolio allocation rules and expected stock returns, assuming non-401(k) wealth = all HRS wealth excluding retirement accounts**

| Investment strategy/risk aversion (alpha) | Less than high school degree | High school and/or some college | College and/or postgraduate |
|---|---|---|---|
| *alpha = 0* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 345.9 | 456.8 | 475.8 |
| 100% stocks | 730.6 | 960.9 | 973.1 |
| 50% bonds, 50% equity return reduced 300bp | 250.4 | 331.9 | 350.9 |
| 100% stocks, equity return reduced 300bp | 369.6 | 487.8 | 506.7 |
| *alpha = 1* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 331.7 | 440.8 | 464.2 |
| 100% stocks | 580.5 | 779.6 | 831.2 |
| 50% bonds, 50% equity return reduced 300bp | 241.9 | 322.6 | 344.2 |
| 100% stocks, equity return reduced 300bp | 311.7 | 420.3 | 455.6 |
| *alpha = 2* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 319.0 | 426.2 | 453.5 |
| 100% stocks | 483.2 | 660.9 | 734.1 |
| 50% bonds, 50% equity return reduced 300bp | 234.3 | 314.0 | 337.9 |
| 100% stocks, equity return reduced 300bp | 272.3 | 373.5 | 418.3 |
| *alpha = 4* | | | |
| 100% riskless bonds | 172.7 | 230.4 | 248.2 |
| 50% bonds, 50% stocks | 297.0 | 400.7 | 434.4 |
| 100% stocks | 368.5 | 517.6 | 609.8 |
| 50% bonds, 50% equity return reduced 300bp | 220.9 | 298.8 | 326.7 |
| 100% stocks, equity return reduced 300bp | 222.4 | 312.3 | 366.6 |

This is only 10 percent higher than the certainty equivalent of the all-index-bond strategy, $230,400. However, the certainty equivalent of the all-stock strategy rises to $443,300 in table 1.9 and $517,600 in table 1.10. These values are 1.9 times and 2.2 times the values with the all index bond portfolio.

## 1.7 Conclusions and Directions for Further Work

This paper presents new evidence on the valuation of risky retirement saving assets when investors have a choice between investing in corporate stocks and index bonds. We find that the historical return distribution for equities leads investors to earn higher expected utility, in most cases, if they invest primarily in stocks rather than in index bonds. We have explored the robustness of this finding to reducing the expected return on corporate stocks by 300 basis points per year. While this shifts the distribution of re-

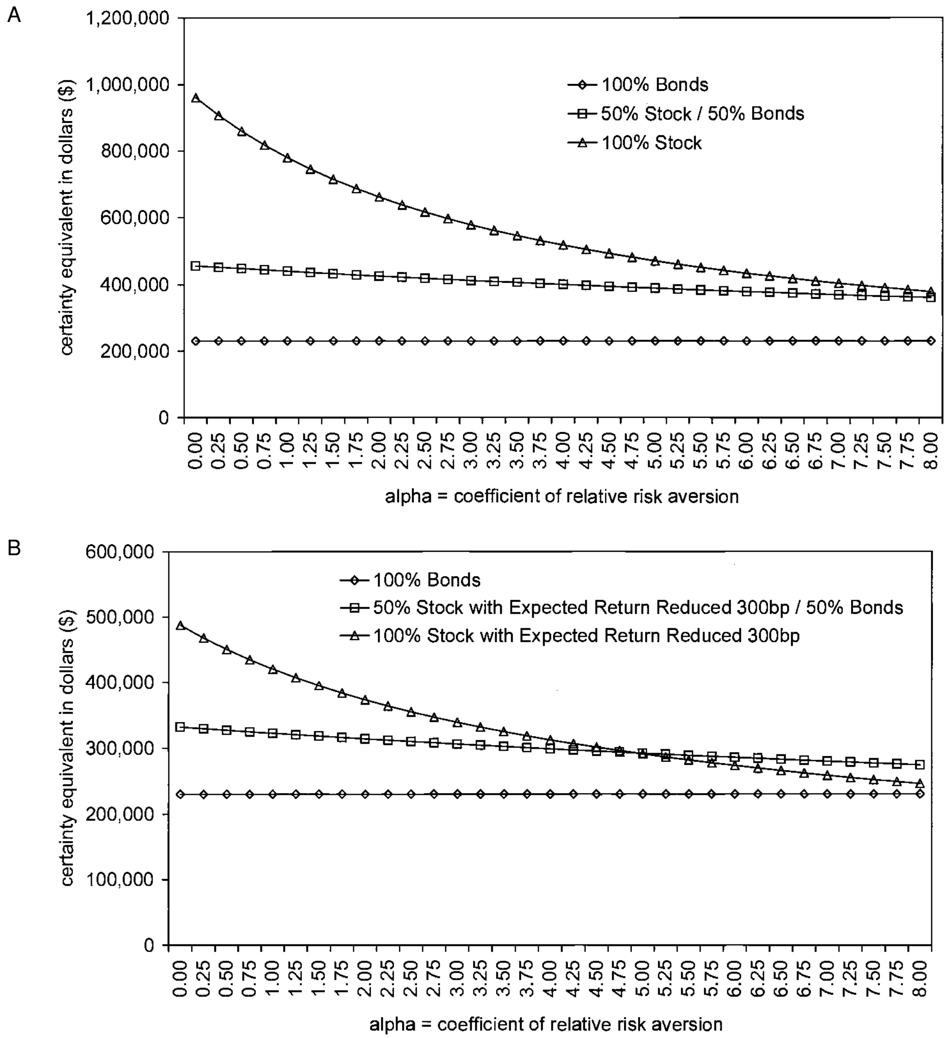


**Fig. 1.8** ***A*, Certainty equivalents and risk aversion for households with high school or some college education, baseline equity returns, and all non-401(k) wealth; *B*, certainty equivalents and risk aversion for households with high school or some college education, reduced equity premiums, and all non-401(k) wealth**

tirement balances to lower values and reduces the expected utility of holding stocks, we still find that only highly risk-averse investors would choose not to hold corporate stocks.

Data on asset allocation in retirement accounts are broadly consistent with the expected utility results that emerge from our simulations. Bergstresser and Poterba (2004) report that of the 51.1 million households in the 2001 Survey of Consumer Finances with some assets in a tax-deferred account, just over 20 percent (10.4 million) hold only bonds. The overall allocation between stocks and bonds in tax-deferred accounts is similar to that in DB plans, which are managed by professional investment managers. One important difference is that there is a higher concentration of company stock in DC plan accounts.

One of our goals is to compare two alternative approaches to evaluating the riskiness of portfolio strategies for retirement wealth accumulation. First, we presented pictures of the distribution of wealth outcomes for different investment allocation rules. This approach is closely related to the techniques used by many financial planners, who show clients the set of outcomes that they might achieve under a given set of assumptions about future returns and investment strategy. It is also the approach that we, and others, have used in past studies that considered the returns to different investment strategies. Feldstein and Ranguelova (2001) use a related approach to summarize the potential returns associated with different investment strategies in a partially privatized Social Security system. Second, we tried to synthesize the information in the distribution of wealth outcomes by computing an expected utility measure corresponding to each distribution. This approach allows for the possibility that the marginal utility of wealth declines with wealth, so that a given increment to wealth is more valuable when wealth is at a low level than when it is high.

Both the picture and the parametric utility function approaches are useful. The picture provides the information that any household that is considering retirement saving needs to evaluate the various investment strategies. It could be used, and sometimes is used, by financial planners who are trying to elicit a household's preferences with respect to risk. The planner can show the household several distributions of potential wealth outcomes and then ask which of these outcome distributions is preferred. In such a setting, different households would be expected to reach different conclusions about which strategy to pursue. This would reflect heterogeneity in their risk preferences.

The parametric utility function approach starts from the premise that a household's relative risk aversion can be characterized by a single parameter. Conditional on this parameter, it is straightforward to characterize the optimal portfolio strategy for the household. This approach assumes away the problems associated with eliciting a household's preferences with regard to risk, and it requires strong parametric assumptions about the form of the household's utility function. When it is reasonable to maintain these assumptions, however, the parametric utility function approach delivers simple rankings of different portfolio strategies.

The parametric utility function approach can potentially provide some guidance on the extent to which observed portfolio choices can be reconciled with the optimizing choices of households that are trying to maximize their expected utility. Any analysis of such choices requires data on assets held outside retirement accounts as well as inside these accounts, since there are important asset location issues that combine tax planning with investment choices in both taxable and tax-deferred accounts. If we are prepared to assume that past returns will characterize future returns on various asset classes, we can make estimates of how risk averse a household would have to be to forego any investment in corporate stock, or to hold only one quarter of its overall portfolio in stock. From these calculations, one could implicitly evaluate the fraction of households in the overall population that would need to have risk aversion above a given level in order to rationalize observed portfolio holdings.

The findings in this paper suggest a number of promising directions for future work. One is to develop a richer stochastic structure for the determination of 401(k) balances as well as the other components of the household balance sheet. The states of nature in which DC plan balances are low are likely to be states of nature in which other wealth balances are also low—for example, because aggregate stock market returns have been low. To the extent that fluctuations in real interest rates affect 401(k) values, and that such movements also affect the present discounted value of Social Security benefits and DB pension benefits, virtually all of the balance sheet components may exhibit some covariance.

It should also be possible to extend our framework to consider other assets that could be held in the retirement account. There is particular interest in the role of employer stock in 401(k) plans, as indicated in Mitchell and Utkus (2003), Munnell and Sunden (2002), and Poterba (2003). While we have focused on index bonds as a low-risk investment strategy for 401(k) investors, we could also consider investments in corporate bonds, which expose investors to inflation risk. Our earlier work on portfolio holdings in 401(k) plans, Poterba, Venti, and Wise (2001), considered the risk of investment portfolios with nominal bonds and corporate stock.

A second natural direction for further work concerns the comparison between the risks associated with DB and DC pension arrangements. Samwick and Skinner (2004) use data from the Survey of Consumer Finances (SCF) to compare the risks of the two types of retirement schemes from the standpoint of retirement income security. The SCF includes detailed information on the structure of pension arrangements for survey respondents, through the Pension Provider Survey, but it does not include data on the earnings history for survey participants. Yet the risks associated with DB plans depend significantly on the pattern of job changes, job loss, and retirement decisions for individual workers, as documented in a series of papers by Kotlikoff and Wise and reviewed in Kotlikoff and Wise (1989). The HRS data, linked with SSA earnings records, make it possible to assess these risk sources in DB plans. We are currently developing an algorithm to evaluate DB plan risk.

Finally, further work can explore the extent to which simple utility functions, such as power functions of wealth, provide an adequate description of the criterion that individuals use to evaluate their choices in the face of asset price risk. There is a long tradition, illustrated by many studies that are cited in surveys by Rabin (1998) and Starmer (2000), of finding inconsistencies with standard expected utility analysis. Kahneman and Tversky (1979) is a seminal example. Even within the framework of parametric CRRA utility functions, there is little consensus on the "correct" value of the relative risk aversion coefficient. We are concerned more generally that choices predicted by the CRRA function may be a poor guide to actual behavior when the distribution of wealth outcomes includes values near zero. We hope to gain a better understanding of individual preferences over uncertain levels of future retirement assets by developing a set of survey questions designed to elicit respondent preferences over alternative wealth outcomes. We hope to include these questions on household surveys like the HRS. Kapteyn and Teppa (2002) have had some success in using a similar approach to explain household portfolio choices as a function of risk preference, as revealed by a set of survey questions. Ultimately, we aim to improve our ability to judge how individuals rank the distributions associated with different asset allocation and saving strategies.

## Appendix

**Table 1A.1 Household sample counts**

| | HRS 2000[a] | SS earnings only | Final earnings only | Couples with final earnings | Couples with final earnings and male aged 63–67 |
|---|---|---|---|---|---|
| | | | *Unweighted observations* | | |
| Total | 6,195 | 4,233 | 3,749 | 2,275 | 759 |
| Couples | 3,838 | 2,446 | 2,275 | 0 | 0 |
| Singles | 2,357 | 1,787 | 1,474 | 0 | 0 |
| At least one person working | 3,269 | 2,194 | 2,096 | 1,413 | 459 |
| Couples, two people working | 899 | 592 | 581 | 581 | 166 |
| Receives DB pension | 2,293 | 1,609 | 1,430 | 1,027 | 373 |
| Expects DB pension | 478 | 370 | 364 | 270 | 72 |
| Receives Social Security | 3,681 | 2,550 | 2,203 | 1,411 | 575 |
| Has IRA | 2,531 | 1,737 | 1,618 | 1,192 | 417 |
| Has DC | 1,333 | 884 | 862 | 629 | 216 |
| | | | *Weighted observations (millions of households)* | | |
| Total | 16.7 | 11.6 | 10.4 | 6.4 | 2.1 |
| Couples | 10.4 | 6.8 | 6.4 | 6.4 | 2.1 |
| Singles | 6.4 | 4.8 | 4.0 | 0.0 | 0.0 |
| At least one person working | 9.0 | 6.2 | 5.9 | 4.0 | 1.3 |
| Couples, two people working | 2.6 | 1.8 | 1.7 | 1.7 | 0.5 |
| Receives DB pension | 6.3 | 4.5 | 4.0 | 2.8 | 1.0 |
| Expects DB pension | 1.4 | 1.1 | 1.0 | 0.8 | 0.2 |
| Receives Social Security | 9.7 | 6.9 | 6.0 | 3.9 | 1.6 |
| Has IRA | 7.5 | 5.2 | 4.9 | 3.6 | 1.2 |
| Has DC | 3.8 | 2.6 | 2.5 | 1.9 | 0.6 |

[a]Accounting for household splits and excluding households with missing birthdays. Each HRS household is defined uniquely by its household identifier (HHID) and wave 5 subhousehold identifier (GSUBHH).

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## Comment Robert J. Willis

The extent to which individuals are willing to trade off the risk of low retirement wealth against the expectation of higher wealth is a critical question both for individual retirement planning and for public policies toward 401(k) plans or for Social Security reforms that endeavor to raise expected returns through the creation of individual accounts that may be invested in equities. The high historical returns of stocks relative to alternative instruments, at least in the United States during the past century, have given rise to a large literature on the "equity premium puzzle" (Mehra and Prescott 2003), so named because the excess returns on risky assets appear to be larger than would be demanded by investors with plausible degrees of risk aversion. An early study of the implications of high equity returns for retirement saving and pension wealth by MaCurdy and Shoven (1992) found that an all-stock portfolio would have dominated an all-bond portfolio for every career that ended in retirement over the period 1926–89. This striking result implies that a portfolio held all in stocks would dominate alternative portfolios no matter how risk averse the household. Putting their money where their mouth is, MaCurdy and Shoven reported that their own pension contributions were 100 percent in stocks—a great place to have been in the early 1990s! The puzzle, of course, is why anyone holds bonds in their retirement portfolio.

I shall refer to this aspect of the equity premium puzzle as the "retirement portfolio puzzle" and organize much of my discussion of the Poterba, Rauh, Venti, and Wise (PRVW) paper around the question of whether their work helps resolve the puzzle. In fairness, I should point out that this is not an explicit goal of their paper. Indeed, the paper is really not so much an exercise in positive economics as it is an exploration of the normative or prescriptive implications of alternative portfolio strategies that may be relevant for private policies of firms and their workers who participate in 401(k) plans and for public policies concerning the regulation of these savings vehicles. Still, it seems to me that one's confidence in basing advice on a model that is contradicted by behavior is undermined if one cannot understand why actual behavior diverges from the optimal behavior implied by the model.

PRVW present new evidence on the riskiness of retirement portfolios by simulating the probability distribution of 401(k) balances generated by alternative contribution strategies for hypothetical households over their working life cycles. They compare the performance of making 401(k) contributions all in stocks, all in riskless index bonds, or in a fifty-fifty mix of stocks and bonds. Their methodology allows for a much richer set of pos-

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sible sample paths of returns implied by the historical data than in MaCurdy and Shoven's analysis. Specifically, PRVW treat the observed distribution of historical returns, illustrated by the histogram in figure 1.2 of their paper, as an estimate of the probability distribution of future returns. Each simulated life-cycle portfolio containing stocks is based on a vector of thirty-five independent draws from this distribution and estimates of the distribution of retirement wealth are based on 300,000 replications. In general, like MaCurdy and Shoven, they find that expected wealth is a sharply increasing function of the fraction of the portfolio held in stocks. For example, their table 1.6 shows that a high school graduate household contributing 9 percent of earnings to a 401(k) for thirty-five years would have expected 401(k) wealth at retirement of $234,000 under the all-bond strategy, $465,000 under the fifty-fifty strategy, and $936,000 under the all-stock strategy. There is, however, about a 5 percent chance that the 100 percent stock portfolio will be worth less at retirement than a portfolio containing bonds. Thus, unlike MaCurdy and Shoven, PRVW find that retirement wealth generated by a stock-only strategy does not dominate a bond portfolio, implying that a sufficiently risk-averse household would prefer a less risky strategy.

This finding motivates PRVW to calculate the certainty equivalent value of terminal wealth for households with varying degrees of risk aversion, under the assumption that households have constant relative risk aversion (CRRA) utility functions. They find that households with risk aversion coefficients over 4.5 would prefer an all-bond to an all-stock portfolio and that those with a coefficient over 2.75 would prefer a fifty-fifty portfolio to an all-stock portfolio. Survey evidence on the distribution of risk tolerance (the reciprocal of the coefficient of relative risk aversion) among fifty-one- to sixty-one-year-olds in the HRS by Barsky and others (1997, note 18) indicates that about three-quarters of the sample have a risk tolerance less than 0.25 and about 90 percent less than 0.5. This distribution, in combination with the PRVW results, suggests that only 10 percent of households would be better off with a 401(k) plan containing 100 percent stocks and only a quarter would optimally choose a contribution strategy with at least 50 percent stocks. These figures can be compared with the portfolio choices of TIAA-CREF participants reported by MaCurdy and Shoven (1992): only about 3 percent chose 100 percent stocks, about half chose a fifty-fifty contribution rate, and most of the rest chose a still more conservative strategy. During the bull market of the 1990s, however, there was a sharp increase in the fraction of contributions going to stocks by TIAA-CREF participants with, for example, a rise in those choosing 100 percent stocks from 3 percent in 1989 to 25 percent in 1998 (Ameriks and Zeldes 2001).

Does the PRVW analysis help resolve the retirement portfolio puzzle? The evidence just discussed suggests that it might. According to their findings, it appears that there is a small chance that a 401(k) portfolio containing significant amounts of stock will do worse than a safe portfolio and that this risk is sufficient to cause a large fraction of households with empirically plausible levels of risk aversion to be better off with a conservative investment strategy even at considerable sacrifice to the expected value of their portfolios. However, PRVW extend their analysis in two directions, one weakening this conclusion and the other potentially strengthening it.

The retirement portfolio puzzle reappears when PRVW consider the safety net created by retirement resources outside the 401(k) plan. Giving a representative household the present value of median Social Security and DB pension plan annuities dramatically increases the threshold of risk aversion below which a household would maximize expected utility by holding a 100 percent stock portfolio. Another factor working in this direction that PRVW do not consider is variable labor supply. If a household's 401(k) portfolio turns out badly near the planned time of retirement, the option to continue working cushions this event. Looking forward, households with flexible work options should be willing to bear greater risk in their 401(k) plans. This effect would be smaller, the less likely such options are to be available because of employer inflexibility, chance of disabling illness, and so on.

A major attraction of the 100 percent stock strategy is, of course, the (puzzlingly) high historical returns on stocks relative to safe assets. A key question for a long-term investor is whether these historical returns will hold far into the future. PRVW examine the sensitivity of their results to the possibility that future returns will average 300 basis points less than the historical average, by simulating portfolios with an average rate of return reduced from 9.7 percent to 6.7 percent. They report that a reduction of this magnitude in the expected rate of return has a substantial effect, especially for households with high levels of risk aversion. While lower expected returns on stocks would help rationalize why people do not hold all stock 401(k) portfolios, clearly they cannot explain the failure of large numbers of households to hold such portfolios in the past unless we assume that ex ante expectations were systematically much lower than the historical average.

Another way to interpret uncertainty about future returns is to suggest that stock returns are riskier than implied by the historical data used by PRVW. Their procedure treats these returns, as depicted in the histogram in figure 1.2, as if it is an exact estimate of the distribution of returns. An alternative view is that the expected return calculated from historical data is estimated with error and that the investors should take this error into account when choosing their investment strategy. For example, Brennan (1998, p. 300) finds that the variance of an investor's prior distribution of the mean market return is $(0.0243)^2$ if he forms his estimate based on sixty-nine years of data and $(0.0452)^2$ if only the past twenty years are used.

Intuitively, it would seem that increased uncertainty about the mean rate of return on stocks would increase the riskiness of stocks, leading risk-averse investors to choose a smaller fraction of stocks in their portfolio. This conclusion is correct for investors with CRRA utility with $\alpha > 1$ who decide on fixed contribution rates and hold their wealth until retirement, as is assumed in the PRVW model. However, if investors are able to trade continuously and returns follow a diffusion process (i.e., a continuous time random walk), finance researchers have established "an important and surprising result: the variance of the instantaneous rate of return on the risky asset that is used to determine the optimal portfolio is unaffected by the uncertainty about the mean of the process" (Brennan 1998, p. 297). The intuition for this counterintuitive result is that the optimal balance at any given time depends only on the instantaneous expected return since the loss due to uncertainty about this parameter is second order and disappears as the trading horizon goes to zero. Uncertainty does have an effect on portfolio decisions, as Brennan (1998) shows, if the investor revises his estimate of the expected rate of return in light of the observed pattern of returns. For risk-averse investors with $\alpha > 1$, the potential for learning creates a negative hedging demand for stock that may even be strong enough to reduce the demand for stocks to zero (Kézdi and Willis 2003). On the other hand, Brennan's model suggests that the run-up of the stock market during the 1990s would lead investors to revise their subjective expected rate of return upward, causing them to increase the fraction of stocks in their monthly allocations. This is consistent with trends in behavior, noted earlier, of TIAA-CREF participants reported by Ameriks and Zeldes (2001).

This discussion suggests that a useful extension of the PRVW analysis might be to consider alternatives to the assumption that households follow a fixed contribution rule for thirty-five years in order to assess the riskiness of 401(k) portfolios that allow for dynamic optimization and learning. For example, it would be possible to use the distribution of historical returns to simulate how Bayesian updating of expectations would influence optimal portfolio choice and the implied distribution of 401(k) wealth. Another avenue for future research is to explore how households' subjective expectations of stock returns, their degree of subjective uncertainty about these returns, and changes in expectations over time are related to the distribution of expected returns that a rational agent derives from examination of historical returns. Beginning with its 2002 wave, the HRS has added questions on subjective probabilities of stock market gains that will facilitate research on this topic. For instance, Kézdi and Willis (2003) find very substantial heterogeneity in expectations that is significantly related to actual stock holdings. They also find that households who generally appear to have imprecise views about probabilities tend to be less likely to hold stocks.

An increase in our ability to resolve puzzles about the actual functioning of equity markets and behavior of individual households is, in my view, an important component in developing sound public policies to help increase the well being of older Americans. The line of research presented by PRVW is a significant step toward this goal, but more remains to be done.

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