# The Trajectory of Wealth in Retirement

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**Abstract**

In this paper, we develop a measure of household resources that converts total financial, nonfinancial, and annuitized assets into an expected annual amount of wealth per person in retirement. We use this measure, which we call "annualized comprehensive wealth," to investigate spend-down behavior among a panel of older households in the Health and Retirement Study (HRS) from 1998 to 2006. Our analysis indicates that for most retired households, comprehensive wealth balances decline much more slowly than their remaining life expectancies, so that the predominate trend is for real annualized wealth actually to rise significantly with age over the course of retirement. Comparing the estimated age profiles for annualized wealth with profiles simulated from several different life cycle models, we find that a model that takes into account uncertain longevity, random medical expenses, and intended bequests lines up best with the broad patterns of rising annualized wealth in the HRS.

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# 1 Introduction

The ability to finance consumption in old age depends not only on the total amount of resources at the onset of retirement, but also, crucially, on how quickly or slowly those resources are spent after retirement. To provide a new empirical perspective on spend-down patterns, we construct a measure of the total resources available per expected year of life for a panel of retired households in the Health and Retirement Study (HRS) from 1998 to 2006. We call our measure "annualized comprehensive wealth." Our measure is *comprehensive* because in addition to net worth as it is usually defined—the sum of financial and nonfinancial assets net of debt—it also includes the value of Social Security benefits, defined-benefit pensions, and, for eligible recipients, transfer payments such as Food Stamps and Supplemental Security Income. For many retirees, these additional items constitute a sizable fraction of total resources. Our measure is an *annualized* concept in the sense that it measures the amount of wealth that is available for each expected year of remaining life and for each person in a retired household. In examining this measure of retirement wealth, we were motivated by the following reasoning. Annualized comprehensive wealth measures the constant amount that a retired household could afford to spend, in expectation, every year until they die. If the micro-data showed a strong tendency for annualized comprehensive wealth to either fall or rise substantially in retirement, we would probably want to know why.

Our paper adds to a large and growing body of research on the evolution and adequacy of retirement wealth.[1] Most directly, our paper is related to two studies that highlight the importance of precautionary saving for explaining the wealth holdings of older Americans (Palumbo, 1999; De Nardi, French, and Jones, 2006). These studies each find that wealth balances do not decline as quickly as standard life-cycle models would predict but that a slow decumulation pattern can be explained (at least partly) by the precautionary effects of uncertain out-of-pocket medical costs. The key contribution of our study is to look at a similar set of questions through the lens of annualized wealth, which we argue provides a more direct measure of the evolution of household resources. While an annualized concept of wealth is not itself an entirely new idea,[3] as far as we know, we are the first to examine

[1]The research on retirement wealth is too extensive to include more than a representative set of citations. Skinner (2007) reviews some recent work on the adequacy of household savings. A number of previous papers find that a substantial fraction of aging households are poorly positioned to finance retirement (see Bernheim, 1992; Munnell and Soto, 2005; Mitchell and Moore, 1998) and that the situation may be even worse for younger age groups (Munnell, Webb, and Delorme, 2006).[2] However, other studies generally find that observed behavior is in line with the predictions generated by stochastic life cycle models (see Engen, Gale, and Uccello, 1999, 2005; Scholz, Seshadri, and Khitatrakun, 2006). Finally, another set of papers directly examines changes in consumption at retirement (Hurd and Rohwedder, 2006; Aguiar and Hurst, 2005; Blau, 2008).

[3]For example, it closely resembles Friedman's (1957) definition of permanent income that has been central to numerous studies of household consumption. In the context of wealth adequacy, Wolff (2002) and

annualized wealth in the context of a life-cycle model.

What are the advantages of looking at annualized wealth as opposed to wealth balances alone? First, it helps us identify the direction of change in a household's ability to finance future spending in retirement. Whereas a decline in wealth balances can be consistent with either an increase or a decrease in the amount of resources available per expected remaining year of life, a decline in annualized wealth implies an unambiguous contraction. Second, annualized comprehensive wealth is a measurement concept that could help distinguish between reductions in consumption due to insufficient resources (a case in which we would expect both annualized wealth and consumption to be low) and the consequences of other motives, such as precautionary savings or intentional bequests (cases in which we would expect annualized wealth to exceed consumption). Whether annualized wealth rises or falls during retirement therefore can provide important clues that can help in sorting out the underlying causes of spending and saving behavior in retirement. Finally, because we generally lack household-level panel data on wealth and consumption changes over retirement, annualized wealth may provide a bridge between wealth balances and what those balances imply for annual consumption possibilities.[4] Developing that bridge is one of the principle motivations and contributions of the current study.

Our analysis of the HRS panel documents strongly rising patterns of annualized wealth in retirement. We find that the median value of annualized comprehensive wealth for the cohort of households aged 70 to 75 years in 1998 rises significantly in retirement, from about $32,800 per person per year in 1998 to about $42,200 per person per year in 2006—a net increase of nearly 30 percent in just eight years. At the median, comprehensive wealth therefore tends to fall much more slowly than life expectancy shortens in old age. Our regression-based estimates of the age profile from ages 65 to 90 indicate that the median surviving household tends to see its annualized comprehensive wealth climb from $25,600 per person per expected year of life at age 65 to more than $50,000 by age 90.[5]

As in other studies of household savings, we find considerable heterogeneity in the

Haveman, Holden, Wolfe, and Sherlund (2006) report ratios of annuitized retirement wealth to poverty using cross-sectional data. Haveman, Holden, Wolfe, and Romanov (2007) use Social Security data to compare annuitized wealth for a particular older cohort at two different points in time. Love, Smith, and McNair (2008) study annualized wealth in recent waves of the Health and Retirement Study.

[4]Note the distinction between consumption *possibilities* and optimal consumption. As we show later, in certain specifications of a life-cycle model, annualized wealth tracks optimal consumption fairly closely, particularly over the first half of retirement. In general, however, the two concepts are not the same. Annualized comprehensive wealth cannot directly be interpreted as a measure of welfare.

[5]Survivorship introduces complications into any study examining the evolution of wealth. As we discuss in more detail below, the panel nature of our data allow us to control, at least partly, for some sources of survivorship bias (e.g., the over-representation of longer-lived, wealthier households that can lead to bias in cross section studies). In addition, we also show how our empirical results change when we control for subjective survival expectations and for non-random attrition. Nevertheless, because survivors may always differ in important ways from non-survivors, it is not possible to eliminate all potential sources of bias.

evolution of household wealth, with annualized wealth falling for some households and rising for others. The distribution, however, is heavily tilted toward increases in annualized wealth. Indeed, we estimate that nearly one-half of older households saw their annualized comprehensive wealth rise by more than 25 percent from 1998 through 2006, while about one in eight experienced a decrease of 25 percent or more over the same time period. Further, this distribution of outcomes is surprisingly similar when we look across marital status and even household income. We also find (to varying degrees) patterns of increasing median annualized wealth across race, education, and health groups. Looking at wealth components, we find that both financial and nonfinancial wealth rose in annualized terms over the sample period.[6] Although some of the increase in nonfinancial wealth in the HRS panel seems to have been accounted for by large capital gains accruing to housing between 1998 and 2006, we find that we would estimate a net increase in annualized wealth in retirement even absent those unusual gains.

Why might households draw down their wealth balances so slowly relative to life expectancy? To consider some possible explanations, we simulate several specifications of life-cycle models of retirement consumption, adding to the simplest models some elements that have been emphasized in previous studies: uncertain longevity (Yaari, 1965; Davies, 1981; Hubbard, 1987; Hurd, 1989), random (and potentially large) out-of-pocket medical expenses (Palumbo, 1999; French and Jones, 2004; Anderson, French, and Lam, 2004), and explicit bequest motives (Kotlikoff and Summers, 1981; Hurd, 1987, 1989; Bernheim, 1991; Laitner and Juster, 1996; Dynan, Skinner, and Zeldes, 2002; De Nardi, 2004; Kopczuk and Lupton, 2007). We benchmark our different model specifications to the HRS data on a household-by-household basis and compare simulated annualized wealth trajectories with the empirical trends. We find that although models incorporating either random medical expenses or altruistic bequests can generate upward-sloping profiles of annualized wealth, the simulated profiles are generally much flatter than those evident in the HRS panel data. Rather, the strength of the overall increase in annualized comprehensive wealth seen in the HRS lines up best with model simulations that incorporate both of these saving motives, in combination with uncertain longevity. In particular, we find that the prospect of large medical expenses induces retirees to build a precautionary buffer early on, while a desire to leave a bequest leads them to maintain "excess savings" toward the end of life, and the size of these effects are not far from the patterns in the HRS.

We also find that while conventional life cycle specifications may do a good job explain-

[6] Essentially by definition, the annualized values of Social Security and DB pension wealth are virtually constant over the retirement period. We convert expected Social Security and DB pension payments into a present value and then back into an annualized value in order to account for the nonindexation of some benefits as well as the effect of survivors benefits on the expected resource stream of married couples. See Appendix 1 for more details.

ing some general tendencies of annualized wealth changes for the median household, they are less successful at matching the heterogeneity in wealth trajectories across individual households. The key contribution of our modeling approach is to investigate the behavior of annualized wealth (rather than on wealth levels) in standard specifications of stochastic life cycle models. Doing so not only allows us to connect the simulation findings to our empirical measures; it also highlights how the evolution of consumption (what we would ideally like to measure) and annualized wealth (what we are actually able to measure) are likely to differ depending on the relative importance of bequests and precautionary saving at the tail end of the life cycle.

## 2 Data and Descriptive Statistics

We use longitudinal data from the 1998 through 2006 waves of the Health and Retirement Study (HRS). The HRS is a panel of older households that began by surveying respondents aged 51 to 61 in 1992. The HRS has reinterviewed those households every two years and has added several additional cohorts along the way. In 1998, the HRS merged with a similar survey called Aging and Health Dynamics (AHEAD), which covered households aged 70 and over in 1993. The 1998 wave of the HRS also added two additional cohorts: the War Baby cohort (aged 51 to 56 in 1998) and the Children of the Depression cohort (aged 68 to 74 that year). Thus, the 1998 wave is the first to represent the full population of U.S. households aged 51 and over—for this reason, we begin our analysis with the 1998 wave.[7]

We select households aged 65 or more in the 1998 HRS survey, and we collect information on households that survive through the 2006 wave. We focus on surviving households to mitigate the effect of survivorship bias: since we are interested in wealth profiles, non-random attrition from the sample could significantly impact the results. For example, if we included non-surviving 1998 households and lower-wealth households were more likely to drop out, we could find upward-sloping median wealth profiles just from changing sample composition, even if each individual household's profile were perfectly flat. Selecting surviving households eliminates this source of bias by holding the sample constant.

The downside of this approach, of course, is that it provides no information on the profiles of non-surviving households—which could differ from those of surviving households. To investigate this, we separately estimate the profiles of non-surviving households through their final year of observation. As we show below, we find that, while non-surviving households tend to have lower levels of wealth, the slopes of their wealth age profiles are quite

[7]We use the RAND HRS data file, which is RAND's longitudinal file of commonly used HRS variables linked by households across time. We supplement this file with our own calculations of the actuarial present values of expected flows from Social Security, defined-benefit pensions, life annuities, and transfer payments such as veterans' benefits, Food Stamps, and Supplemental Security Income. See Appendix 1 for details.

similar to the survivor group—in particular, median annualized wealth rises at similar rates regardless of survival status. We conclude that survivorship bias is not driving the tendency for annualized wealth profiles to rise in the HRS.

Table 1 reports some demographic information for our sample of 4,630 households in 2006. The average age is about 80 (for married households, we take the maximum of the spouses' ages). Nearly half are single women (many of them widowed), about 37% are married, and 14% are single men. Average annual income is about $47,000. High school is the highest degree for just over half the sample. About 10% are nonwhite and 5% Hispanic. About two-fifths report being in fair or poor health, and the average household spent about $2,500 on out-of-pocket on medical care during the prior year.[8]

For selected survey years, Table 2 provides a breakdown of the components of comprehensive wealth for the median surviving household aged 70-75 in 1998.[9] Because the median is a nonlinear statistic, median comprehensive wealth will not generally equal the sum of the component medians. To generate a table in which the components add up to the total median comprehensive wealth for a given year, we calculate mean values of a trimmed sample selected so that the mean comprehensive wealth of the trimmed sample is equal to the median of the original sample. Thus, the rows of the table can be thought of as representing the average breakdown of median comprehensive wealth in each year.

As shown in the table, just over half of median comprehensive wealth is made up of the present value of annuity-like benefits in 1998—the largest of which is Social Security. However, the share of wealth from this source declines over time as life expectancies fall. Financial wealth, in contrast, maintains a roughly constant share of about one-fifth of comprehensive wealth. Nonfinancial wealth (mostly housing) increases its share significantly, from a quarter to over a third, due in part to extraordinary capital gains over this time period. The remainder of our analysis will focus on our measure of annualized wealth.

# 3 A Measure of Annualized Wealth for Retirees

## 3.1 Definition of annualized wealth

We define annualized wealth to convert our broad measure of net wealth into an amount of annual resources available per person over their expected remaining lifetimes. Our measure of annualized wealth can be thought of as the per-person annual payout from an actuarially fair, inflation-indexed, joint fixed life annuity that a retired household could, in theory, pur-

[8]The survey actually asks about spending over the prior two years. We assume the spending was evenly divided over each of the prior two years.

[9]Choosing a single cohort helps distinguish age effects from cohort effects by holding the cohort constant.

chase with its comprehensive wealth balance (see Brown and Poterba (2000)).[10] However, as we describe below, annualized wealth is also closely related to optimal consumption in some simple life-cycle model specifications.

For each household, we define annualized wealth as

$$AW_t = a_t W_t,$$

where $W_t$ is the household's comprehensive wealth balances at age $t$, and $a_t$ is the annualizing factor that converts the balance into dollars per person per expected year of remaining life. We define $a_t$ as

$$a_t = \left[ \sum_{i=0}^{T} \left\{ \frac{\alpha S^f_{t+i} S^m_{t+i} + S^f_{t+i}(1 - S^m_{t+i}) + S^m_{t+i}(1 - S^f_{t+i})}{(1+r)^i} \right\} \right]^{-1}, \tag{1}$$

where $S^f_{t+i}$ is the probability that a female currently aged $t$ lives to age $t+i$, $S^m_{t+i}$ is the analogous probability for males, $T$ is the maximum attainable age for any person, $r$ is the real discount rate (assumed to be constant)[11], and $\alpha$ is an adjustment for household economies of scale ($\alpha \leq 2$) that may allow couples to spend less per person than single retirees.[12]

Table 3 illustrates how our annualizing factor varies with age and marital status. For a given age, couples have lower factors because they have to share resources (though with some economies of scale, as noted above). Single men have lower life expectancies, and thus higher annualizing factors (i.e., they can afford to spend more per year) than single women. As households age, life expectancies fall, causing the annualizing factors to rise.

[10] For practical purposes, Social Security is such an annuity. In general, however, we view annualized wealth as a hypothetical construct because, in the U.S. at least, prices for actual fixed life annuities are far from actuarially fair. See, for example, Mitchell, Poterba, Warshawsky, and Brown (1999).

[11] We assume a real interest rate of 2.5 percent and an inflation rate of 2 percent, in line with recent values of the inflation-indexed long-term average interest rate. According to the Federal Reserve Statistical Release H15, the average yields on TIPS with maturities longer than 10 years was 2.26 percent for the 2003–2007 period reported in the table. The average value of 10-year nominal Treasuries over the same period is 4.40 percent.

[12] In the absence of scale economies, $\alpha = 2$. See Citro and Michael (1995) and Fernándes-Villaverde and Krueger (2007) for a detailed discussion of household equivalence scales and their effect on the measurement of household resources. We adopt an equivalence scale of 1.67 for a two-person household. For comparison, the OECD scale for a two-adult household is 1.7 and the scale recommended in Citro and Michael (1995) for a two-adult household is 1.62 ($= 2^{0.7}$). In our HRS sample of older households, about 15 percent of households contain more than two members (either children living at home or other adults). Adjusting our annualizing factor for more complicated family structures would require modeling the likelihood that the additional members remain in the family unit, and would require data on any resources that might be contributed by the additional member during his or her time in the household. In the absence of such data, we ignore the effect of additional members on the equivalence scale.

### 3.2 Annualized wealth and optimal consumption in the life cycle model

Annualized wealth resembles optimal consumption from the permanent income hypothesis, but only in the simplest of life-cycle models will consumption and annualized wealth be identical. Figure 1 shows the relationship between consumption and annualized wealth in a stylized stochastic life cycle model.[13] The purpose of this figure is purely illustrative: although we set the initial wealth levels to the median levels in the HRS, no attempt is made here to match individual-level characteristics (though we will do so below).

Panel (a) of the figure shows that in the simplest life cycle model of consumption during retirement—a stripped-down version in which forward-looking, retired households are uncertain about their longevity, but not about anything else that affects their spending decisions—our measure of annualized wealth is very close to the optimal level of consumption for all ages.[14] Adding an explicit bequest motive, shown in panel (b), drives a wedge between the levels of annualized wealth and optimal consumption as households age—at least among those retirees who have "enough" resources for the bequest motive to operate strongly. But even with a relatively strong bequest motive, the growth of annualized wealth is relatively slow, on the order of about 1 percent per year from age 65 to 83.

Panel (c) shows age profiles from a simulated life cycle model that ignores any explicit bequest motive, but that includes a precautionary saving motive for retirees. In this version of the model, retirees realize random draws for (potentially large) out-of-pocket medical expenses that essentially serve as "resource shocks" with no separate utility value. As in the specification with the bequest motive, the precautionary motive can be seen to drive a wedge between the levels of annualized wealth and optimal consumption during retirement. The precautionary motive also increases the slope of the two age profiles: in panel (c), both profiles slope up from age 65 through 83, then slope down fairly steeply over the remainder of old age.

Finally, a model with both precautionary and bequest motives, shown in panel (d), generates the largest wedge between the levels and the slopes of the two profiles. The combination of the two motives leads retirees to build up relatively large buffers of resources relative to life expectancy from age 65 to about 83, then to essentially maintain the large buffer in old age even as their rates of survival drop sharply.

Note that the bequest motive and the precautionary motive in these calibrations of the life cycle model can be expected to generate a modest 1-to-2-percent upward slope

[13] The life cycle models used to generate this figure are similar to the models used below to compare to empirically estimated age-wealth profiles. Details of the models are given in Appendix 2.

[14] The difference between annualized wealth and consumption depends on the degree of relative risk aversion and on the value of assets retirees bring into retirement relative to their Social Security and DB pension benefits. The close correspondence between consumption and annualized wealth holds for moderate degrees of risk aversion; under log utility, annualized wealth is exactly equal to optimal consumption at each age.

for annualized wealth in the first stage of retirement (say, from age 65 to 83). Thus, if a downward sloping age profile for annualized wealth were prevalent in the HRS data, we would be tempted to infer that many retirees seemed to be "running out of money" early in retirement and we would want to think about why this is happening. By contrast, if a substantially upward sloping age profile were prevalent in the data, we would wonder why so many in the HRS were "saving so much money"—even relative to life cycle models calibrated to include plausible bequest motives and precautionary motives.

### 3.3 Annualized wealth in the HRS

Table 4 reports median levels of comprehensive wealth and annualized wealth for a balanced 1998–2006 panel of households aged 70 to 75 in 1998.[15] For the median household in this cohort, comprehensive balances fall from $493,000 in 1998 to $434,000 in 2002 and to $393,000 in 2006—an average rate of decrease of 3.7 percent per year. However, because of decreases in household size and life expectancies, annualizing factors rise considerably, and thus annualized comprehensive wealth grows markedly over the 8-year period—from $32,800 per person per expected year of life in 1998 to $35,400 in 2002 and to $42,200 in 2006. This represents an average annual increase in annualized wealth of 4.3 percent per year, or nearly 30 percent, cumulatively, from 1998 through 2006. Thus, we find that while comprehensive wealth declines with age, it declines much more slowly than life expectancies shorten.

The middle section of Table 4 compares changes in the annualizing factors and annualized wealth of retirees in the cohort who were single in 1998 with those who were married in that year. While both single and married retirees in the HRS experienced significant increases in annualized comprehensive wealth between 1998 and 2006, the increases were somewhat larger for couples (4.7 percent per year, on average) than for single retirees (3.7 percent). One reason for this difference is that some spouses die during the period, leading to a jump in their households' annualizing factor (owing to the steep drop in the "overall" life expectancy) and therefore in the amount of annualized wealth that can be afforded with a given comprehensive wealth balance.

The bottom section of the table compares the trajectory of annualized wealth from 1998 to 2006 for households in the bottom 20 percent of the income distribution with those in the top 20 percent. The conclusions are similar to those above. The median retired household in both income groups experienced a significant increase in annualized comprehensive wealth

[15] As discussed above, the balanced panel has the advantage of mitigating the "classical problem" of survivorship bias that affects similar tabulations computed using cross-section data. As explained in Shorrocks (1975) and Attanasio and Hoynes (2000), the classical problem is that if wealthier individuals are more likely to survive to older ages, then cross-section data will tend to show a positive association between wealth and age, as the less wealthy individuals are "over-represented" in the younger age groups.

over the 8-year period covered by our HRS data, but the rate of increase was larger for retirees in the high-income group than in the low-income group. The quantitative difference in the slope of the age profile for annualized wealth reflected two factors: First, high-income retirees spent down their comprehensive wealth balances more slowly than did low-income retirees (0.6 percent per year, on average, vs. 5.6 percent); and second, high-income retirees experienced a slower average rate of increase in their annualizing factors between 1998 and 2006, in part because they were more likely to stay married.

Table 5 shows that, for several subgroups of income and marital status, about 45 percent of households experienced an increase in annualized wealth between 1998 and 2006 that was 25 percent or larger, while about 10 to 15 percent of households experienced a decrease in annualized wealth of at least 25 percent.

As noted above, confining the analysis to individuals who survived until 2006 reveals nothing about the possibly different trajectories for non-survivors. When we calculate changes in wealth among households who drop out before 2006, we find that they do indeed have lower levels of annualized wealth—about $24,000 per person per year at the median in 1998, compared to $33,000 among survivors—but the *trajectory* of annualized wealth is quite similar—growth of about 3.4 percent per year for non-survivors, vs. 4.3 percent per year among survivors. Moreover, the distribution of annualized wealth changes is essentially identical between the two groups.

## 4 Age-Wealth Profiles in the HRS

As a preliminary empirical look at the evolution of resources over the course of retirement, we construct nonparametric profiles of median wealth in the HRS between the ages of 65 and 90 years.[16] Although nonparametric age profiles have a number of drawbacks (in particular, they do not control for cohort effects, survivorship bias, or household characteristics) they provide a sense of the raw data patterns without imposing any structural assumptions.[17]

Figure 2 shows that median annualized financial wealth is rising in real terms for most cohorts over the panel period (despite volatility in the stock market), but the combined profile in financial wealth across cohorts is relatively flat across the entire age distribution. This suggests that households do not appear to run down their financial wealth any more or

[16] To produce these profiles, we divide the surviving 1998 sample into age bins and calculate the median value of wealth for each bin over the following eight years. We use the HRS sampling weights to compute the medians in each age group. We plot six points for each age group, corresponding to the 1998, 2000, 2002, 2004 and 2006 waves of the HRS. Arrayed by age on the horizontal axis, the series of segments trace out an empirical age profile of wealth.

[17] To conserve on space, we omit the raw profiles for the components of wealth balances (as opposed to annualized wealth). At the median, the raw profiles for median comprehensive wealth and all of its components decline markedly with age, suggesting that some degree of spend-down is occurring.

less quickly than their life expectancies are shortening. We also see within-cohort increases in annualized *nonfinancial* wealth, reflecting the strong housing market over this period. But in contrast to financial wealth, we also see an increasing age profile of nonfinancial *across* cohorts, suggesting that households may be reluctant to fully consume their housing wealth as they age. The annualized value of annuity-like wealth is, not surprisingly, roughly flat over the retirement period, with perhaps a slight decline due to non-indexation of some benefits. All told, the median value of annualized comprehensive wealth shows an upward slope across older ages, from about $30,000 per person per year at age 65 to about $45,000 per person per year by age 90.

The raw profiles provide a broad-brushed view of the trajectory of annualized wealth within and across cohorts. To see whether these patterns hold up when we control for cohort effects, year effects (such as market movements), and (at least partly) survivorship bias, we turn to regression-based age profiles of wealth. The general strategy is to pool all observed wave-to-wave growth rates in wealth and regress the growth rates on age. The coefficients can then be used to construct age profiles over the full range of ages from 65 to 90. The focus on wave-to-wave growth rates helps mitigate survivorship bias in two ways. First, because the wave-to-wave growth rates are calculated only for households who survive from one wave to the next, the slope estimates of annualized wealth will be unaffected by the "classical problem" of nonrandom attrition. At the same time, selecting wave-to-wave survivors rather than full-panel survivors mitigates the sample selection problem that arises because survivors may differ in their saving behavior (and in other ways) from non-survivors.[18] Second, we mitigate the bias further by focusing on growth rates rather than levels. As noted above, there is much less difference between survivors and nonsurvivors in growth rates than in levels. While our methods help minimize the effects of survival bias, we cannot claim to have eliminated it entirely—the fact remains that, for each age, we can only calculate a wealth change among households who survive for at least two waves.

To produce the regression-based profiles, we use a four-step procedure. First, we calculate a household-level wealth-growth factor from each wave to the next (resulting in four growth factors per household). Second, we pool all of the growth factors and estimate a median regression of the growth factors on indicators for two-year age brackets (e.g., 60-61, 62-63, etc.) and survey-year dummies.[19] Third, we use the estimated age coefficients to calculate *predicted* median growth factors for each age, and then multiply these together to

[18]Survivors are always different than nonsurvivors—for example, they tend to have more wealth—but the differential is smaller when survival is defined only to the next wave, rather than to the end of the panel.

[19]We use two-year age bins, rather than single-year age indicators, simply to smooth the age profiles a bit. The results are qualitatively the same when we use single-year age dummies. We use the survey-year dummies to remove year effects (e.g. market conditions) when creating the profiles. Rather than including household characteristics in the regression, we estimate separate profiles for different household groups, as discussed below.

construct a predicted "cumulative growth factor" across the full range of ages.[20] Finally, we connect the dots between each age's predicted cumulative growth factors to form an age profile. The resulting profile will be purely relative (e.g., an index starting from one at age 65); to convert it to level terms, we benchmark the middle of each age profile so that it passes through the median level of wealth held by 78-year-olds.

## 4.1 Profiles by Household Type

Figure 3 shows the resulting profiles of annualized comprehensive wealth, for various groups of households. Panel (a) shows that the median profile of annualized wealth for all households increases fairly steeply from about $26,000 per person per year at age 65 to about $52,000 at age 90. Panel (b) indicates an even steeper profile among married households, with single men and women experiencing much more gradual increases.[21] One should keep in mind, however, that any remaining survival bias due to differential mortality by wealth is exacerbated when selecting married couples.[22] Panel (c) shows median age profiles by income, where the income groups are defined conditional on marital status and age. We find that median annualized comprehensive wealth shows a gradual net increase for lower- and middle-income households, and a pronounced rise for upper-income households. That is, we find a rising pattern of median annualized wealth across all of the income distribution.

Panel (d) breaks households down by race and demonstrates a significantly steeper rise in annualized wealth among white households than nonwhite or Hispanic households. Panel (e) illustrates the effect of health status in 1998: healthy households show much more rapid accumulation of annualized wealth than less healthy households. However, like marital status, health status is variable over time, and thus the "healthy" profile is essentially representing households who are healthy as of the base year, rather than healthy at age 65.

Finally, panel (f) groups households by their base-year level of out-of-pocket medical expenses (where the groups are equal thirds of the expense distribution). We find that the slopes are quite similar across the groups until very old ages, when households with the highest levels of medical expenses show decreasing annualized wealth. This could indicate spend-down of resources in order to finance their medical care, or perhaps indicate increas-

[20] For example, if the predicted median growth factor for age 60-61 were 1.10 and the predicted median growth factor for age 62-63 were 1.05, then the predicted *cumulative* growth factor for age 62-63 would be $1.10 \times 1.05 = 1.155$.

[21] Since we do not observe marital status as of age 65 for all households, we identify married households based on their status in the base year of 1998. Thus the profile is best interpreted as the median among "base-year-married" households, rather than among all households married at age 65.

[22] As a simple illustration, suppose that wealthy individuals of either gender survive to the next period with probability 0.9 and that poor individuals survive with probability 0.8. Compare these differential probabilities with those of a married couple. If marriages end only in death, a wealthy married couple will survive to the next period with probability 0.81, while a poor married couple will survive only with probability 0.64.

ing pessimism about life expectancy or quality of life, which could accelerate non-medical spending as well. To get a better sense of how empirically estimated age profiles might vary with such expectations of the future, we group households by expectation using some of the forward-looking questions in the HRS.

### 4.2 Profiles by Household Expectation

Figure 4 breaks down estimated profiles by expectations over mortality, bequests, and nursing home stays. Finally, we estimate the age profile of an alternative concept of annualized wealth that excludes expected medical costs over the household's remaining lifetime.

Panel (a) shows that households who are more optimistic about their life expectancies than the age- and gender-specific Social Security life tables have significantly steeper increases in annualized wealth, particularly at older ages. Thus, one motive for building up wealth relative to life expectancies is to provide resources for more years than expected by the standard tables.[23]

As shown in panel (b), the slope of the age profile also correlates with bequest expectations, especially at later ages.[24] Households reporting low probability of a bequest display quite flat profiles, while those with medium and high probabilities show much steeper patterns, particularly after age 75 or so. Thus, another potential explanation for rising profiles is an explicit bequest motive.[25]

Panel (c) breaks out households by their reported probability of entering a nursing home in the next 5 years, capturing some expectation about the likelihood of significant future medical expenses. We find rising profiles across all categories of nursing-home expectations, but significantly steeper rises for middle- and high-probability households than low-probability households. Thus, an additional possible explanation for rising profiles is precautionary savings arising from uncertain future medical expenses.

Panel (d) examines the effect of expected medical costs on annualized wealth. To the extent that medical costs represent an exogenous shock to household resources, it may be of interest to track the evolution of annualized wealth *net* of expected annualized medical costs. We calculate each household's expected future medical costs by regressing log out-of-pocket expenses on age, education, race, financial wealth, and year dummies. We estimate

[23]We arbitrarily categorize households as "optimistic" if the ratio of their own survival probability to that implied by the life table is greater than 120%. Similiarly, we categorize households as "pessimistic" if the ratio is less than 80%.

[24]The question asks households for their subjective probability that they will leave a bequest of at least $100,000. We arbitrarily categorize households as "high" if they report a probability of at least 80%, and "low" if the reported probability is less than 20%.

[25]Note, however, that the question is phrased as a bequest *expectation* rather than a bequest *motive*. There is a conceptual difference due to accidental bequests: a household that is self-insuring against outliving its resources may acknowledge the possibility of leaving an unplanned bequest (i.e., dying early) even if it places little value on doing so.

separate regressions for married couples, single males, and single females, and then use the coefficients to compute predicted present value medical costs for each household. As shown in the figure, subtracting the annualized value of expected medical costs has remarkably little effect on the trajectory of annualized wealth—because annual expected costs are generally small (about $700 at the median). Moreover, we find essentially no correlation between changes in annualized wealth and medical expenses.

### 4.3 The effect of capital gains on the estimated age profiles

How should we interpret the build-up in wealth relative to life expectancy at the end of the life cycle? One question is whether the upward-sloping age profiles are simply the consequence of unexpected capital gains on housing or corporate equity over the 1998-2006 sample period.[26] To test the sensitivity of our results to these changes in capital gains, we re-estimate the regression-based age profiles using a counterfactual HRS dataset that holds each household's level of corporate equity and net housing wealth fixed over the sample years, letting the other components of comprehensive wealth follow their reported trajectories in the HRS. To remove capital gains from equities, we replace each household's reported holdings of corporate equity in each wave with its (household-specific) average value over the eight-year period. To remove the effects of the dramatic run-up in house prices, we replace each *non-moving* household's reported housing wealth in the five waves with the level it reported in 1998 (thereby assuming no change in housing wealth over our sample period).[27]

Perhaps surprisingly, we find that these adjustments to the reported measures of comprehensive wealth in the HRS do not materially change our result that median annualized wealth rises with age across all three income groups. The profiles continue to slope up for two reasons: first, other forms of financial and nonfinancial wealth (such as deposits, money market funds, mutual funds, vehicles, and business equity) increased notably in annualized terms across waves of the HRS. But more importantly, we find a rising slope of wealth *across* cohorts, reflecting different starting levels of wealth by age *as of the base year of 1998*. Thus, we conclude that the upward sloping age profile for annualized comprehensive wealth over retirement is not being driven by the effects of unanticipated capital gains on corporate equity or housing over our sample period.

[26] Equity prices gyrated markedly over the sample period. The change in the Wilshire 5000 stock price index between 1998 and 2000 was 7.6 percent, between 2000 and 2002 was -31.5 percent, between 2002 and 2004 was 43.5 percent, and between 2004 and 2006 was 19.1 percent. Housing prices, in contrast, climbed steadily and substantially. On a seasonally adjusted basis, the cumulative change in the national purchase-only house price index produced by the Office of Federal Housing Enterprise Oversight (OFHEO) between 1998 and 2006 was 72.9 percent.

[27] We do not change the housing wealth of movers, because these wealth changes may not be due to capital gains—that is, these households may have either downsized or upsized their housing consumption.

# 5 Age-Wealth Profiles in a Life Cycle Model of Consumption

To shed more light on how we might interpret rising age profiles of annualized wealth, we compare the empirical profiles to those generated by fairly standard specifications of the life cycle model of consumption. Our model is similar to those used in other studies;[28] our contribution is to focus on profiles of *annualized* wealth and compare the simulated paths to our empirically estimated profiles. A simple specification of the life cycle model—one that allows for uncertainty only in survival and in which the discount rate is equal to the interest rate—would predict a *downward*-sloping trajectory of annualized wealth at older ages, due to the effects of survival discounting. That is, model households place increasing weight on current consumption relative to future consumption as they age and their survival probabilities fall, leading to an acceleration of wealth drawdown and a consequent decline in the growth rate of annualized wealth toward the end of the life cycle.

To see whether the life cycle framework can generate the upward-sloping annualized wealth patterns seen in the data, we consider four variations of the standard lifecycle model. Starting with a baseline specification that introduces uncertainty only through survival, we layer on, sequentially, a bequest motive, medical expense uncertainty, and a combination of all of the above. The model specifications, described in detail in Appendix 2, adapt the cash-on-hand framework of Carroll (1997) and others to allow for household composition changes (see, e.g., Cubeddo and Ríos-Rull (2005)) and bequests.

The value of this exercise is twofold. First, because the focus of our paper is on annualized wealth, we want to understand how annualized wealth behaves in standard life cycle model specifications, and how well the models fit the data from this perspective. Second, the exercise allows us to parse the relative contributions of uncertain lifetimes, bequests and precautionary saving in explaining the empirical trajectory of annualized wealth. Thus, while others have shown that wealth patterns in the data are broadly consistent with various specifications of a life cycle model, we try to identify the features and parameterization that best explain the age profile of annualized wealth in the HRS.

## 5.1 Simulations

To see how well our standard life cycle model fits the HRS data, we present two benchmarking exercises. The first simulates household annualized wealth starting from an initial distribution that matches aggregate characteristics of HRS households aged 65-70, and

[28] See, for example, Cagetti (2003); Carroll (1992, 1997) and Carroll and Samwick (1998) for models of precautionary saving in response to uncertain income, Palumbo (1999); Rust and Phelan (1997); French and Jones (2004); Anderson, French, and Lam (2004) and Davis (2006) for studies of the effect of uncertain medical expenses, and Kotlikoff and Summers (1981); Hurd (1987, 1989); Bernheim (1991); Laitner and Juster (1996); Dynan, Skinner, and Zeldes (2002); De Nardi (2004) and Kopczuk and Lupton (2007) for models incorporating explicit bequest motives.

the second simulates annualized wealth growth rates household-by-household for our full sample. To the extent that older households in the HRS entered retirement with similar distributions of wealth, income, and marital status as younger HRS households, the first simulation exercise tests the model's ability to predict the evolution of annualized wealth over the course of retirement. The second exercise, which benchmarks the model to households of all ages in retirement, provides a measure of how well the model predicts the growth of annualized wealth for each household in our sample.

The first simulation exercise begins with an initial distribution of wealth, income, education, and marital status for respondents aged 65-70. From an empirical distribution of 8,105 households, we randomly draw (with replacement) 20,000 observations to form an initial distribution of characteristics for the simulations. Starting from the initial distribution, we then simulate the 20,000 life histories, allowing for fluctuations in net retirement income, as well as for transitions from marriage to widowhood.

For each of our four specifications, Table 6 compares the median growth rates in the HRS with those from our simulated life histories. The first column shows that the baseline specification produces consistently negative growth rates, reflecting the discounting effect of declining survival probabilities. As shown in the remaining columns of the table, a combination of bequests and uncertain medical costs can generate upward-sloping trajectories of annualized wealth, but the age patterns and magnitudes do not always agree with the patterns in the HRS. For example, while medical expenses and bequests each generate positive growth rates of annualized wealth for all age groups combined, they affect older and younger households differently. Medical expense risk increases the growth of annualized wealth for younger households, who retain savings as a buffer against the consequences of a shock to permanent income, consequences which are larger the more years of future income that are at stake. Bequests, in contrast, tend to have the largest effect on the growth rates of older households, whose stocks of intended bequests grow large in relation to life expectancy. Although the fit of the model is far from perfect, it does modestly well at matching the median annualized wealth patterns in the HRS, and it does so with a common parameterization of risk aversion and impatience.

The second simulation experiment uses each household's actual income net of medical costs, marital status, ages, education, and cash on hand in each year to predict a household-specific growth rate of annualized wealth, taking as given a household-specific bequest parameter.[29] Our procedure for selecting household-specific bequest parameters

[29] We pool the entire sample and estimate the growth of annualized wealth for all of our households in multiple years. As an alternative estimation procedure, we also experimented with using each household's actual income and medical expense fluctuations (in addition to information about changes in marital status) over the 1998-2006 sample period to compute an average simulated growth rate of annualized wealth. Using the expected path of income for each household type, we calculated the permanent shocks as the average annual percentage deviations of the actual income path from the predicted path and the transitory shocks

assumes that each household correctly projects the likelihood that they will leave a bequest of at least $100,000.[30] For each household bequest probability, we search over a vector of bequest parameters to find the one that generates the closest fit between the empirical probability and the simulated fraction of bequests over $100,000. One advantage of this matching procedure is that it adjusts for the tendency for wealthier households to leave large accidental bequests. As noted above, the HRS question does not distinguish between accidental and intentional bequests—it simply asks about the probability of leaving a sizable inheritance. According to our procedure, a wealthy household expecting to leave a $100,000 bequest with a 50% probability will receive a smaller bequest parameter than a poorer household reporting the same probability.

Table 7 shows the results for the household-by-household simulation.[31] As in the first simulation exercise, the baseline model generates negative growth rates of annualized wealth. Comparing the last three columns of the table, we can see that a model that includes both a bequest motive and uncertain medical expenses produces results that are more in line with the HRS than those produced by models with a bequest motive or medical costs in isolation. Further, when the bequest parameter is calibrated according to each household's stated probability of leaving a bequest, we see a smaller effect of bequests on the median growth rate of annualized wealth among older households. Intuitively, households with substantial resources in retirement reporting only a medium-sized probability of leaving a bequest will need only a small bequest parameter to rationalize their stated expectations.

## 6 Conclusion

By examining the trajectory of annualized comprehensive wealth—a measure of total resources per person per expected remaining year of retirement—our analysis brings some saving patterns into relief that would otherwise be difficult to discern. Our primary empirical finding from the HRS is that annualized comprehensive wealth tends to *rise* with age in retirement, reflecting the tendency for wealth balances to decrease more slowly than remaining life expectancies shorten. We find this pattern of increasing annualized wealth over retirement for most types of households and for the major components of comprehensive wealth. In addition, we estimate that a much larger share of retirees experience a

as the difference between each year's deviation from predicted growth and the permanent shock. The fit was not improved by such an exercise—the volatility in reported household income net of medical costs generated noisy estimates of annualized growth—so we report the results from the more straightforward procedure that uses pooled household information for each year.

[30] The HRS asks respondents: "[W]hat are the chances that you [and your] [you/husband/wife/partner] will leave an inheritance totaling $100,000 or more?"

[31] The HRS data column shows different values than those in the previous table because this is a different, randomly-selected sample of 5,000 observations. Not surprisingly, the samples disagree most for the oldest (and therefore most sparsely represented) households in the data.

considerable increase in annualized comprehensive wealth over the six years covered by our HRS sample (1998 to 2006) than experience a significant decline.

It is reasonably well known that retirees in the bottom quintile of the income distribution (conditional on their age and marital status) rely almost exclusively on DB pension benefits, Social Security benefits, and other government transfers to finance spending. Although these sources do not constitute a high level of comprehensive wealth, their annuity-like payout scheme means that they can finance a more or less constant path of outlays through retirement. While annuity-like benefits are also an important source of wealth for retirees in the middle- and upper-income groups, these retirees also tend to have significant financial and nonfinancial wealth. A new finding from our analysis is that, for the median retiree in the middle- and upper-income groups, annualized comprehensive wealth tends to rise over retirement. One might have expected wealth balances to fall roughly in line with declining longevity in retirement—after all, this is the trajectory that would be predicted by the simplest life cycle model of consumption.

To gauge what factors might lie behind the tendency for annualized comprehensive wealth to rise in retirement, we compare the empirical age profiles of annualized wealth from the HRS data with simulated profiles from life cycle models that are extended to include uncertainty about longevity, precautionary saving in light of uncertain medical expenses, and an explicit motive for retirees with greater resources to leave bequests. Within the class of models we consider, specifications that include all three of these factors seem to line up best with the rate of increase of annualized comprehensive wealth in the HRS data. In this case, saving in retirement (relative to the simplest life cycle benchmark) provides insurance against the possibility of financing consumption into advanced ages, is available to help finance possibly very large medical expenditures, and it increases the size of intended (as well as unanticipated) bequests. Quantitatively, the simulated age profiles for annualized wealth match up fairly well with the estimated profiles, although the models are unable to match the heterogeneity of annualized wealth patterns across individual households.

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# Appendix 1: Present Value Calculations for Comprehensive Wealth

In this appendix, we discuss our method for computing present values of annuitized streams of payments in the HRS. See Love, Smith, and McNair (2008) for additional details.

### Defined-benefit pensions

The HRS includes questions about current pension benefits (for retirees) and expected future pension benefits (for workers). Since our sample selects households whose older member is at least 65, we are primarily (but not exclusively) using data on retirees. Households are asked about the current (or expected) pension amount (and start date, if they have not yet begun), cost-of-living adjustments (COLAs), and survivors' benefits.[32] In the case of working households, we use the expected pension at retirement; this serves to include the value of benefits not yet accrued. For DB plans with COLAs (about 40 percent of the reported plans), we discount using a real interest rate. For plans without COLAs, we discount using a nominal rate.

We define the actuarial present value of pension wealth as the annual pension benefit multiplied by the sum of discounted annual survival probabilities, with an extra term accounting for any payments made to the spouse after the death of the respondent.[33] We compute present values for each plan held by the respondent and spouse and sum them to arrive at our calculation of household-level pension wealth. Some current workers report that they expect to receive lump-sum payouts from their DB plans upon retirement; in this case, we discount the lump sum back to the current age, again using life-table survival probabilities.

The survival probabilities are based on the one-year age- and sex-specific conditional death probabilities in the Social Security Administration's 2002 Period Life Table (SSA, 2006). Period life tables provide a snapshot of the mortality conditions prevailing in a single year, rather than the expected mortality experience of a given cohort over time. For young cohorts (e.g., children born in 2002), one might expect actual longevity to be significantly greater than shown in the 2002 period life table, since longevity generally improves over time. However, since our sample is of older households in 2006, we conclude that the 2002 period table is a reasonable estimate of our sample's expected mortality experience.[34]

[32]We use self-reported pension data to calculate pension wealth. Because most of the sample is currently receiving benefits, we are less concerned about households' misunderstanding or ignorance of pension formulas.

[33]Bernheim (1987) argues that actuarial discounting is inappropriate for risk-averse individuals facing imperfect annuity markets, because such individuals would attach additional value to the otherwise unavailable insurance product. He suggests straight discounting (ignoring the probability of death) instead. However, he points out that his analysis rests on the premise that individuals place no value on the death-contingent value of assets (i.e., that there are no bequest motives). We treat the household as a unit, and explicitly value the death-contingent component of each individual's assets (e.g., survivors' benefits and life insurance). Thus we use the actuarial present value of DB and Social Security benefits. Note that we are only computing the amount of wealth, and not the utility value of that wealth. Similarly, we make no adjustment in the PV calculation for the utility value of risk (e.g., longevity risk or the risk of a large medical-expense shock.)

[34]Note that these are average survival for the population. Thus, to the extent that, for example, lower-wealth respondents face lower survival probabilities than higher-wealth respondents, our calculations will

**Social Security benefits**

The present value of Social Security benefits is computed in a similar manner, with the main differences being that Social Security benefits are always indexed for inflation and that survivors' benefits entitle retirement-age widows or widowers to 100% of the spouse's benefits if these exceed their own benefit amount.[35]

**Annuities and welfare benefits**

The present value of annuity wealth is calculated in the same way as pensions, where we make similar adjustments for COLAs and survivor benefits. Our measure of expected welfare payments includes veteran's benefits, food stamps, Supplemental Security Income (SSI), and other welfare. In this calculation, we assume that individuals who are currently receiving these payments will continue to receive the same inflation-indexed welfare payments as long as they live. Moreover, we apply SSI as a floor to our calculation of annualized wealth—that is, we assume that current nonrecipients will begin to receive SSI if their resources fall sufficiently low in the future.[36] Since welfare benefits are typically indexed to inflation, we discount this stream of expected welfare payments using the real interest rate and the relevant conditional survival probabilities.

**Annualized values of annuity-type wealth**

Note that the annual benefits from annuity-type sources such as pensions, annuities, and Social Security are not, in general, equivalent to the annualized present values of these sources of wealth. For example, because DB benefits are not typically adjusted for inflation, the real value of benefits will decline over time relative to their annualized present value. (The annualized present value in period $t$ of a declining real stream of payments will always be less than or equal to the real value of a single payment from that stream in period $t$, with equality only in the final period.) Moreover, the annualized present value takes account of any benefit changes expected to occur as a result of spousal deaths. For annuity payments, like Social Security, that pay out in real terms, annualized wealth will be identical to the benefit stream for a single-member household. We convert annuity-type benefit streams into a present value and then back into an annuity in order to account for the effects of non-indexation of benefits and survivors benefits on the resource stream of married couples.

tend to overstate the pension wealth of the lower-wealth groups and to understate the pension wealth of the higher-wealth groups. However, we do not expect this to be a large effect because differential mortality seems to be evident primarily at very old ages (see Anderson, French, and Lam (2004) and Attanasio and Hoynes (2000)), where heavy discounting is already being applied for most retirees.

[35] Again, since the vast majority of the sample is already receiving benefits, we are less concerned about households' ignorance of Social Security formulas. Moreover, annual notifications of accrued benefits from the Social Security Administration help alleviate such concerns even among individuals who are still working.

[36] In practice, the SSI floor binds in very few cases in our sample.

# Appendix 2: Description of the Life Cycle Model Used in the Simulations

## 6.1 The model

The life-cycle model augments the cash-on-hand framework of Carroll (1997) to allow for household composition (see, e.g., Cubeddo and Ríos-Rull (2005)) and bequests. We will describe only the final specification since the others involve "turning off" select features. In each period $t$, households choose an amount of consumption $C_t$ that maximizes their expected discounted utility from their current ages to a maximum age of 120, subject to a budget constraint that represents a transition equation for cash on hand $X_t$—the sum of wealth and current income—and a non-negativity constraint for wealth at each age.[37] Since we are interested in matching the behavior of retired households in the HRS, we confine our solution to ages of 65 and older.[38]

Households differ by age, sex, marital status, and education. Spouses may be of different ages but they are assumed to share the same education level. In defining the value functions, it will be helpful to index a married couple with $m$, a single male with $g$, and a single female with $g^*$. In each period $t$, a household of a particular type is constrained to consume no more than the sum of saving from the previous period, $R(X_{t-1} - C_{t-1})$, and income net of medical costs, $Y_t$.[39] The value function for a single (male) is given by:

$$V_{t,g}(X_t) = \max_{C_t} \left\{ u_g(C_t) + \beta p_{g,t} \mathbf{E}_t V_g(X_{t+1}) + \beta(1 - p_{g,t}) \mathbf{E}_t B(X_{t+1}) \right\}, \tag{A-1}$$

where

$$X_{t+1} = R(X_t - C_t) + Y_{t+1} \tag{A-2}$$
$$X_t \geq C_t, \tag{A-3}$$

where $u_g(.)$ is the period utility function, $\beta$ is the discount factor, $p_{g,t}$ is the conditional survival probability, and $B(.)$ is a bequest function. Period utility for a household of type $i \in \{m, g, g^*\}$ is iso-elastic and depends on household economies of scale:

$$u_i(C_t) = \frac{1}{1-\rho} \left( \frac{C_t}{n_i} \right)^{1-\rho}, \tag{A-4}$$

[37] A complete treatment of the life cycle from the beginning of working life would introduce potentially interesting sources of heterogeneity in wealth and retirement income, but this type of heterogeneity is not the focus of our analysis. For our purposes, little is lost by starting our model at retirement, and we gain transparency and simplicity since we can show how different factors affect consumption patterns *independent of initial retirement wealth.*

[38] Our modeling exercise differs from Scholz, Seshadri, and Khitatrakun (2006), which compares observed wealth levels in the HRS with predicted levels using household-specific lifetime earnings.

[39] The formulation of income net of medical costs is a simplification of the process used in other work on medical expenses, such as Hubbard, Skinner, and Zeldes (1995); Palumbo (1999); French and Jones (2004). In contrast to these studies, we do not model social insurance, and we do not allow income net of medical costs to become negative (as would be the case if households paid medical expenses in excess of their retirement income). The simplification avoids non-convexities in the value function, which allows for considerably faster computations.

where $n_i$ is a scale adjustment, $\rho$ is the coefficient of relative risk aversion and $1/\rho$ is the elasticity of intertemporal substitution. When operative, the bequest motive is captured by the iso-elastic function:

$$B(X_t) = \frac{b}{1-\rho}\left(\frac{X_t}{b}\right)^{1-\rho}, \tag{A-5}$$

where $b$ determines the intensity of the bequest motive.

Married couples face a slightly different problem. Spouses typically face different survival probabilities, and the longer-lived spouse has more incentive to save than the shorter-lived one. We follow Cubeddo and Ríos-Rull (2005) and assume that the household solves a joint maximization problem with (in our case) equal decision weights on the husband's and wife's utilities and with current household consumption constrained to be split equally between the spouses.[40] The married couple's value function is given by:

$$\begin{aligned} V_{t,m}(X_t) = \max_{C_t}\{&u_m(C_t) + \beta p_{g,t}p_{g^*,t}\mathbf{E}_t V_{t+1,m}(X_{t+1}) + \beta(1-p_{g,t})(1-p_{g^*,t})\mathbf{E}_t B(X_{t+1}) \\ &+\frac{1}{2}\beta p_{g,t}(1-p_{g^*,t})\mathbf{E}_t V_{t+1,g}(X_{t+1}) + \frac{1}{2}\beta p_{g^*,t}(1-p_{g,t})\mathbf{E}_t V_{t+1,g^*}(X_{t+1})\}, \end{aligned} \tag{A-6}$$

subject to equations (A-2)-(A-3). The three terms in the first line of the value function represent (1) the sum of each spouse's weighted utility from consuming $C_t$ as a couple, (2) the expected value of remaining married in the next period, and (3) the expected value of bequeathing remaining cash on hand in the event that both members die in the next period. The two expressions in the second line correspond to the weighted utilities of the husband and wife, respectively.

We solve the model by first normalizing the variables by permanent income $P_t$ and then using the normalized value functions to obtain consumption decision rules for each point in the state space.[41] In practice, we approximate the value functions by considering 200 endogenously chosen cash-on-hand values and by numerically computing the expectation integrals with 10-point Gauss-Hermite quadrature for each of the transitory and permanent shock distributions. By interpolating the resulting consumption decision rules, we can simulate household consumption decisions for different ages, education levels, marital status, income, and cash on hand.

## 6.2 Income process

The process for income net of medical costs follows Carroll (1997). Income $Y_t$ is the product of a transitory shock $\Theta_t$, a permanent shock $N_t$, and a growth factor $G_t$ that captures

[40] The standard consumption Euler condition applies at the household level but not necessarily at the individual level.

[41] See Carroll (2007) for an excellent introduction to solving models of this type. We apply Carroll's (2006) method of endogenous gridpoints, which dramatically reduces computational time by working with end-of-period saving rather than beginning-of-period cash on hand.

changes in trend income over time and in response to changes in marital status:

$$\begin{aligned} Y_t &= P_t \Theta_t && \text{(A-7)} \\ P_t &= G_t P_t N_t, && \text{(A-8)} \end{aligned}$$

where $\log(N_t) \sim \mathcal{N}(-\frac{\sigma_n^2}{2}, \sigma_n^2)$ and $\log(\Theta_t) \sim \mathcal{N}(-\frac{\sigma_\theta^2}{2}, \sigma_\theta^2)$.

We estimate separate income age profiles and covariance structures using the 1998-2006 waves of the HRS. We define non-asset income in retirement as the sum of Social Security benefits, pension benefits, private annuities, and any welfare payments, averaged over the 8-year period and measured in 2006 dollars. (We average income over the sample period because our focus is on medical cost risk and large fluctuations in annuitized retirement income are likely to reflect measurement error rather than true volatility.) From this measure of income, we then subtract annual out-of-pocket medical costs to arrive at our measure of income net of medical costs. Because we estimate the income profiles using the natural logarithm of net income, we restrict our sample to households with non-negative values of net income. The restriction eliminates between 2 and 3 percent of the sample—presumably those experiencing catastrophically large medical costs.[42]

We follow a two-step process in estimating the net-income process in the model. First, for each education group, we regress the natural logarithm of net retirement income on age, marital status dummies for single male and single female, and a set of 5-year birth-year controls. The coefficient estimates from this first step allow us to construct average growth rates for permanent income by education and marital status. In the second step of the process, we estimate the covariance process of net retirement income by following the variance decomposition procedure in Carroll and Samwick (1997).[43] The coefficient estimates (not shown) imply a slightly declining age profile of net retirement income for high school and college graduates, and a slightly upward sloping pattern for dropouts. The age pattern is consistent with the means testing for Medicaid—lower-income households (dropouts) are less likely to pay for large out-of-pocket expenses than high-income households. The estimated variances show considerable volatility in both transitory and permanent components. The estimates reflect the large size of out-of-pocket expenses relative to income in retirement. We estimate permanent variances (standard errors in parentheses) of 0.0368 (0.0015), 0.0263 (0.0006), and 0.0335 (0.0007) for household heads with less than high school, high school, and college educations, respectively. The estimated transitory variances for the three education categories are: 0.0729 (0.0048), 0.0583 (0.0018), and 0.0815 (0.0022).

[42] Allowing for negative net income, however, would rule out efficient numerical optimization techniques by introducing nonconvexities in the value function. While these nonconvexities can generate interesting economic behavior, they are not the focus of this section of the paper, which is to see whether the most standard life-cycle models are capable of producing the upward-sloping annualized wealth profiles observed in the data.

[43] Let $r_t^d$ denote the difference between the unexplained part of net-income in period $t+d$ and that in period $t$. Using the fact that $Var(r_t^d) = d\sigma_N^2 + 2\sigma_\Theta^2$, we can obtain parameter estimates by regressing $Var(r_t^d)$ on a set of $d$'s and a vector of 2's, adjusting for the two-year spacing of the HRS waves.

## Tables and Figures

Table 1: Household Characteristics in 2006

| Variable | Mean |
|---|---|
| Age (years) | 80.5 |
| Married (%) | 36.8 |
| Single Male (%) | 13.6 |
| Single Female (%) | 49.6 |
| Income (thous. $2006) | 46.6 |
| HS is Highest Degree (%) | 54.2 |
| College Degree (%) | 18.0 |
| Nonwhite (%) | 10.5 |
| Hispanic (%) | 5.0 |
| Fair or Poor Health (%) | 41.4 |
| OOP Medical Expense (thous. $2006) | 2.5 |

Sample size is 4,630 households. Means calculated using HRS sample weights.

Table 2: Components of Comprehensive Wealth: Surviving Households Aged 70-75 in 1998*

| | *Wealth (th. 2006 $)* | | | *Share of CW (%)* | | |
|---|---|---|---|---|---|---|
| | 1998 | 2002 | 2006 | 1998 | 2002 | 2006 |
| Financial | 98 | 92 | 82 | 20 | 21 | 21 |
| Stocks[1] | 43 | 40 | 30 | 9 | 9 | 8 |
| Other[2] | 55 | 52 | 52 | 11 | 12 | 13 |
| Nonfinancial | 130 | 134 | 142 | 26 | 31 | 36 |
| Housing | 97 | 106 | 117 | 20 | 24 | 30 |
| Other[3] | 34 | 28 | 25 | 7 | 7 | 6 |
| Annuity-like benefits | 264 | 207 | 169 | 54 | 48 | 43 |
| Social Security | 177 | 139 | 115 | 36 | 32 | 29 |
| DB Pensions | 72 | 55 | 41 | 15 | 13 | 10 |
| Other[4] | 15 | 13 | 13 | 3 | 3 | 3 |
| Comprehensive Wealth | 493 | 434 | 393 | 100 | 100 | 100 |

*For each year, the rows report means from a trimmed sample selected so that the trimmed mean comprehensive wealth (CW) is equal to the nontrimmed median; thus, the components sum to median CW. Calculations use HRS sample weights. Sample size is 1,360 in 2006.

[1]Shares held directly and through mutual funds, trusts, and retirement accounts.

[2]Liquid assets, bonds, and non-stock assets held in trusts and retirement accounts.

[3]Vehicles and businesses.

[4]Life annuities and government transfers.

Table 3: Sample Annualized Factors for Singles and Couples

| | Annualizing factor | | | Annualized value of $500,000 | | |
|---|---|---|---|---|---|---|
| Age of head | Couple | Single female | Single male | Couple | Single female | Single male |
| 67 | .043 | .076 | .089 | $21,400 | $38,000 | $44,500 |
| 77 | .063 | .117 | .141 | $31,500 | $58,500 | $70,500 |
| 87 | .096 | .221 | .272 | $48,000 | $110,500 | $136,000 |

Table 4: Evolution of Median Wealth: Surviving Households Aged 70-75 in 1998*

| | 1998 | 2002 | 2006 | Annual % Change, 1998–2006 |
|---|---|---|---|---|
| Comp. Wealth (th. 2006 $) | 493 | 434 | 393 | -3.7 |
| Annualizing Factor (%) | 6.0 | 8.0 | 12.3 | 12.9 |
| Ann. Wealth (th. 2006 $) | 32.8 | 35.4 | 42.2 | 4.3 |
| | | | | |
| *By Marital Status in 1998* | | | | |
| Comp. Wealth (th. 2006 $) | | | | |
| Single | 292 | 266 | 245 | -2.9 |
| Married | 660 | 580 | 530 | -3.6 |
| Annualizing Factor (%) | | | | |
| Single | 9.6 | 11.7 | 14.7 | 7.3 |
| Married | 5.3 | 6.5 | 8.2 | 7.6 |
| Ann. Wealth (th. 2006 $) | | | | |
| Single in 1998 | 28.3 | 29.9 | 35.1 | 3.7 |
| Married in 1998 | 35.5 | 39.4 | 46.8 | 4.7 |
| | | | | |
| *By Income in 1998* | | | | |
| Comp. Wealth (th. 2006 $) | | | | |
| Bottom 20% | 234 | 197 | 166 | -5.6 |
| Top 20% | 1077 | 1047 | 1039 | -0.6 |
| Annualizing Factor (%) | | | | |
| Bottom 20% | 5.8 | 9.6 | 12.3 | 13.4 |
| Top 20% | 5.8 | 7.2 | 10.4 | 10.2 |
| Ann. Wealth (th. 2006 $) | | | | |
| Bottom 20% | 14.3 | 15.6 | 16.6 | 2.5 |
| Top 20% | 76.1 | 80.8 | 99.9 | 4.6 |

*Sample size is 1,360 in 2006. Income categories are defined conditional on age and marital status in 1998.

Table 5: Distribution of Changes in Annualized Wealth from 1998 to 2006: Surviving Households Aged 70-75 in 1998

| | Percent of Households with a Change in Annualized Wealth that is: | | | | |
|---|---|---|---|---|---|
| Classification | <-25% | -25% to -10% | -10% to 10% | 10% to 25% | >25% |
| Full Sample | 12 | 10 | 19 | 14 | 45 |
| Single in 1998 | 15 | 11 | 20 | 12 | 43 |
| Married in 1998 | 11 | 9 | 19 | 15 | 46 |
| Bottom 20% of Income in 1998 | 13 | 9 | 22 | 15 | 41 |
| Top 20% of Income in 1998 | 15 | 9 | 14 | 15 | 46 |

*Sample size is 1,360 in 2006. Income categories are defined conditional on age and marital status in 1998.

Table 6: Simulated AW Growth Rates by Age and Marital Status*

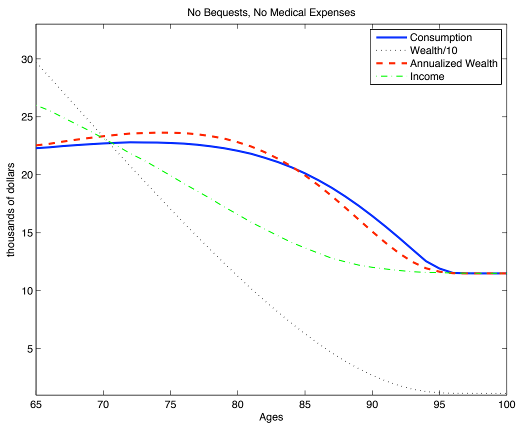
| Age category | HRS Data | Baseline | Baseline + bequests | Baseline + Med Costs | Med Costs + Bequests |
|---|---|---|---|---|---|
| Entire sample | | | | | |
| $<70$ | 1.00 | 0.03 | 0.95 | 1.98 | 2.23 |
| 71-80 | 2.37 | -0.42 | 1.31 | 1.74 | 2.25 |
| 81+ | 2.75 | -1.65 | 1.98 | -0.49 | 1.69 |
| All | 2.05 | -0.69 | 1.48 | 1.44 | 2.21 |
| Married couples | | | | | |
| $<70$ | 0.64 | -0.55 | 0.05 | 1.26 | 1.42 |
| 71-80 | 1.97 | -1.04 | 0.03 | 0.65 | 1.00 |
| 81+ | 2.11 | -1.64 | 0.31 | -1.23 | 0.04 |
| All | 1.54 | -1.25 | 0.06 | 0.37 | 0.85 |
| Singles | | | | | |
| $<70$ | 1.48 | 0.71 | 2.10 | 2.92 | 3.28 |
| 71-80 | 2.84 | -0.07 | 2.03 | 2.34 | 3.03 |
| 81+ | 3.16 | -1.64 | 2.15 | -0.41 | 1.87 |
| All | 2.58 | -0.46 | 2.10 | 1.86 | 2.81 |

*The table shows the median percentage growth rates of annualized wealth for the HRS data and each of four different model specifications. Each specification is solved for a CRRA parameter $\rho = 3$, a discount factor $\beta = 0.98$, survival probabilities according to the SSA life tables, and an initial simulated distribution of cash-on-hand, income, demographics, and education that is sampled 20,000 times from the HRS distribution of respondents aged 65-70. The second column, the "baseline" specification, includes no bequest motive and no medical costs. The third column adds to the baseline a bequest motive with parameter $b = 3$. The fourth column adds to the baseline the uncertain medical costs described in the text. The last column includes both the bequest motive and the uncertain medical costs.

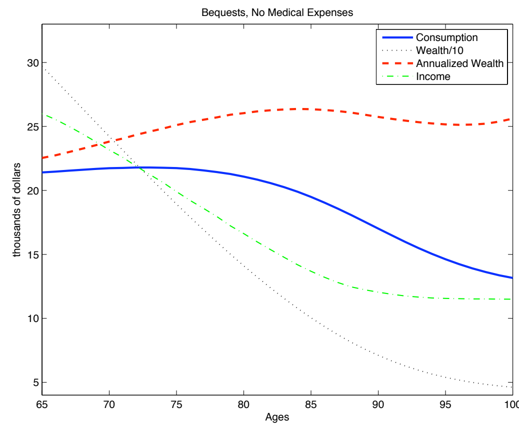
Table 7: Simulated AW Growth Rates by Age and Marital Status, Matched at the Household Level*

| Age category | HRS Data | Baseline | Baseline + bequests | Baseline + Med Costs | Med Costs + Bequests |
|---|---|---|---|---|---|
| Entire sample | | | | | |
| $< 70$ | 1.54 | 0.02 | 1.56 | 0.62 | 1.78 |
| 71-80 | 2.41 | -0.48 | 1.11 | 0.57 | 1.67 |
| 81+ | 3.46 | -1.57 | -0.01 | 0.58 | 1.62 |
| All | 2.41 | -0.66 | 0.90 | 0.58 | 1.68 |
| Married couples | | | | | |
| $< 70$ | 1.46 | -0.31 | 1.25 | 0.30 | 1.46 |
| 71-80 | 2.07 | -0.86 | 0.69 | 0.16 | 1.19 |
| 81+ | 2.93 | -3.09 | -1.57 | -0.86 | 0.04 |
| All | 1.92 | -1.02 | 0.53 | 0.03 | 1.09 |
| Singles | | | | | |
| $< 70$ | 1.61 | 0.54 | 2.05 | 1.10 | 2.29 |
| 71-80 | 2.74 | -0.01 | 1.62 | 1.09 | 2.26 |
| 81+ | 3.68 | -0.82 | 0.77 | 1.30 | 2.40 |
| All | 2.91 | -0.29 | 1.29 | 1.16 | 2.31 |

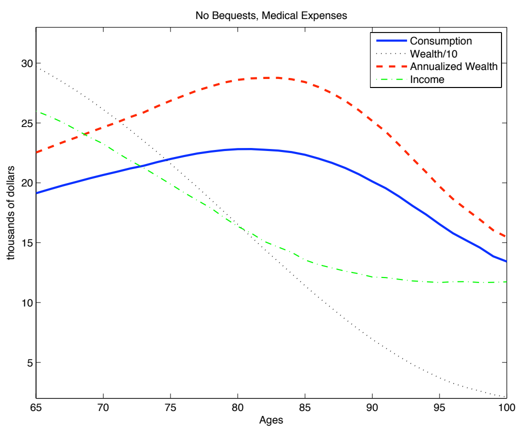
*The table shows the median percentage growth rates of annualized wealth for the HRS data and each of four different model specifications. Each specification is solved for a CRRA parameter $\rho = 3$, a discount factor $\beta = 0.98$, survival probabilities according to the SSA 2004 period life tables, and an initial distribution of cash-on-hand, income, demographics, and education for 5,000 randomly-selected households in the 1998-2006 waves of the HRS. The second column, the "baseline" specification, includes no bequest motive and no medical costs. The third column adds to the baseline a bequest motive with bequest parameters matched at the household level, in accordance with the households' stated probability of leaving an inheritance larger than $100,000 (see text for details). The fourth column adds to the baseline the uncertain medical costs described in the text. The last column includes both the bequest motive and the uncertain medical costs.



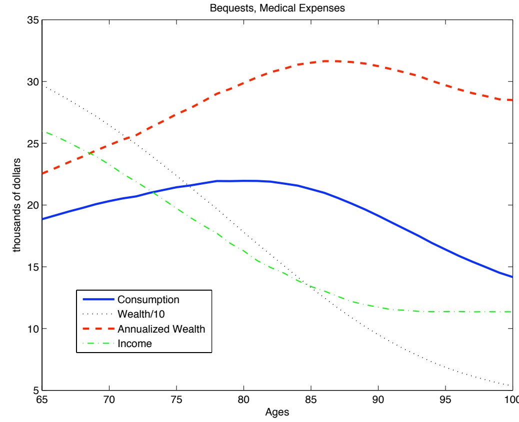

(a) Simplest model




(b) Model with bequest motive

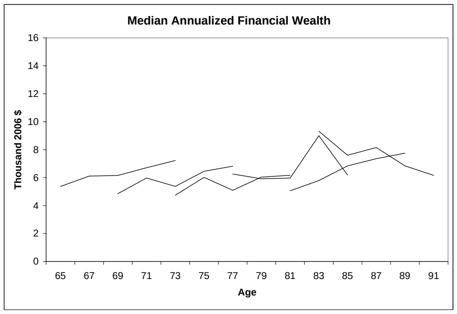



(c) Model with precautionary motive

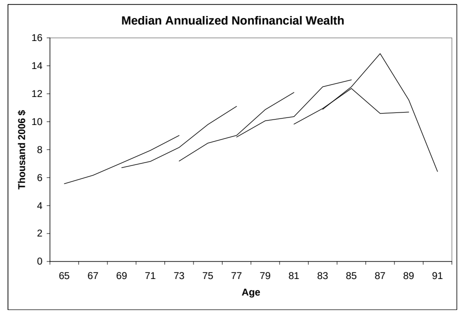



(d) Model with bequest and precautionary motives

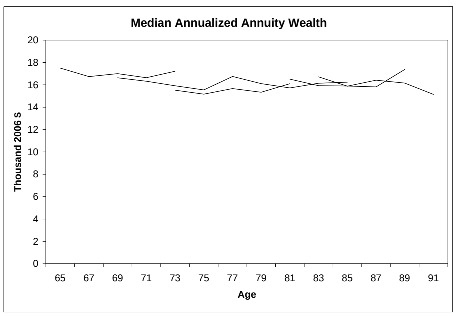
Figure 1: Age Profiles of Annualized Wealth and Optimal of the Life Cycle Model of Spending in Retirement



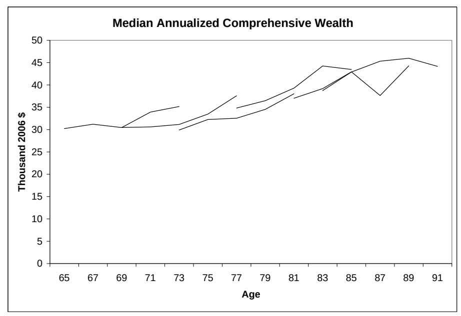

(a) Median Annualized Financial Wealth




(b) Median Annualized Nonfinancial Wealth

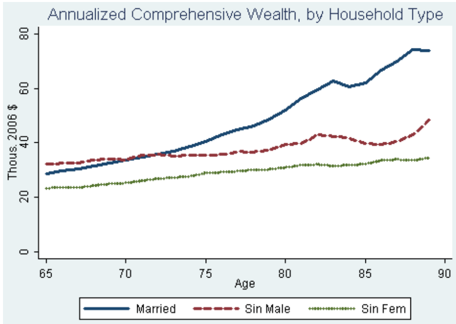



(c) Median Annualized Annuity Wealth

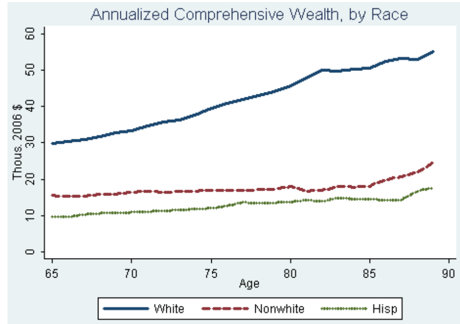



(d) Median Annualized Comprehensive Wealth

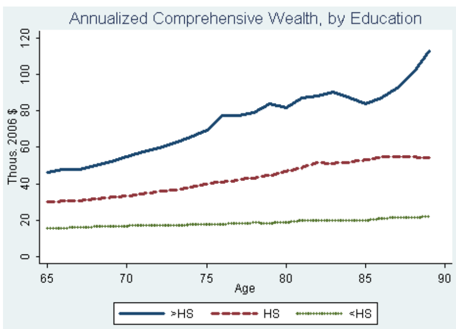
Figure 2: Nonparametric Age Profiles of Median Annualized Wealth



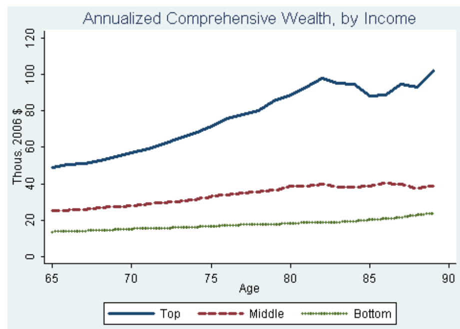

(a) Median ACW, by Marital Status in 1998



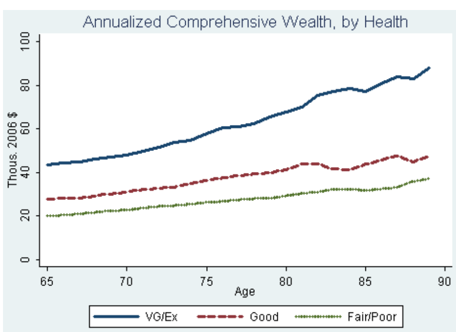

(b) Median ACW, by Race



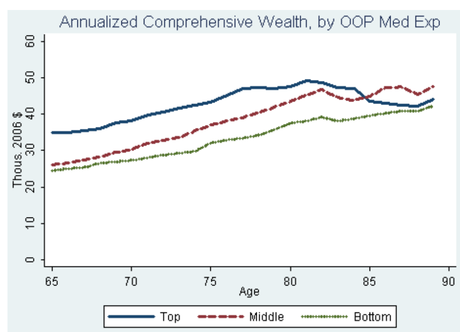

(c) Median ACW, by Education




(d) Median ACW, by Income in 1998

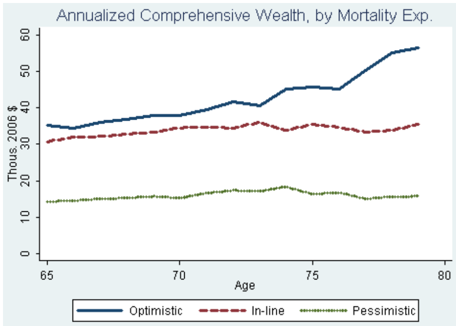



(e) Median ACW, by Health in 1998

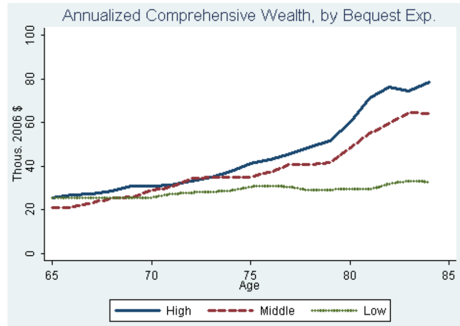



(f) Median ACW, by OOP Medical Expenses in 1998

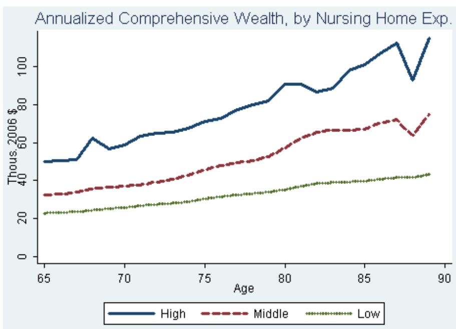
Figure 3: Regression-based Age Profiles of Median Annualized Comprehensive Wealth, for Subgroups



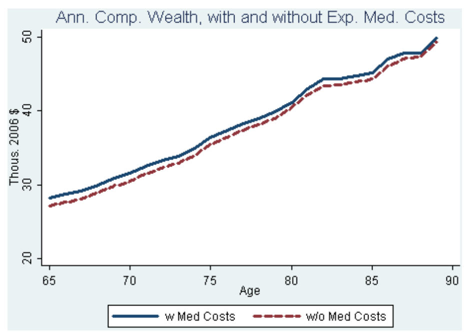

(a) Median ACW, by Mortality Expectation in 1998




(b) Median ACW, by Bequest Expectation in 1998




(c) Median ACW, by Nursing Home Expectation in 1998




(d) Median ACW, with and without Expected Medical Costs

Figure 4: Regression-based Age Profiles of Median Annualized Comprehensive Wealth, by Expectation Group