Are Americans Saving "Optimally" for Retirement?

John Karl Scholz
Department of Economics, the Institute for Research on Poverty, and NBER
University of Wisconsin – Madison
1180 Observatory Drive
Madison, Wisconsin 53706-1393
jkscholz@facstaff.wisc.edu

Ananth Seshadri
Department of Economics
University of Wisconsin – Madison
1180 Observatory Drive
Madison, Wisconsin 53706-1393
aseshadr@ssc.wisc.edu

Surachai Khitatrakun
Department of Economics
University of Wisconsin – Madison
1180 Observatory Drive
Madison, Wisconsin 53706-1393

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Abstract:

This paper examines the degree to which Americans are saving optimally for retirement. Our standard for assessing optimality comes from a life-cycle model that incorporates uncertain lifetimes, uninsurable earnings and medical expenses, progressive taxation, government transfers, and pension and social security benefit functions derived from rich household data. We solve every household's decision problem from death to starting age and then use the decisions rules in conjunction with earnings histories to make predictions on wealth in 1992. Ours is the first study to compare, household by household, life-cycle model predictions of wealth with Health and Retirement Study data. Our results are striking – we find that the model is capable of accounting for more than 80 percent of the 1992 cross-sectional variation in wealth. Fewer than 20 percent of households have less wealth than their optimal targets, and of those who are undersaving, their wealth deficit is generally small.

There is considerable skepticism in public policy discussions and in the financial press that Americans are preparing adequately for retirement. A quotation from the Wall Street Journal captures a popular view:

> A long time ago, New England was known for its thrifty Yankees. But that was before the baby boomers came along. These days, many New Englanders in their 30s and 40s, and indeed their counterparts all over America, have a different style: they are spending heavily and have sunk knee-deep in debt. ... A recent study sponsored by Merrill Lynch & Co. showed that the average middle-aged American had about $2,600 in net financial assets. Another survey by the financial-services giant showed that boomers earning $100,000 will need $653,000 in today's dollars by age 65 to retire in comfort – but were saving only 31 percent of the amount needed. In other words, saving rate will have to triple. Experts say the failure to build a nest egg will come to haunt the baby boomers, forcing them to drastically lower standards of living in their later years or to work for longer, perhaps into their '70s.[1]

We examine the degree to which households are optimally preparing for retirement by constructing a stochastic life-cycle model that captures the key features of a household's consumption decisions. We use data on the entire history of earnings realizations that the household received, which allows us to make household-specific comparisons, and solve each household's life-cycle problem to predict optimal wealth at given ages. We then compare these predictions to observed data.

Our approach is related to Hubbard, Skinner and Zeldes (1995).[2] They solve the life-cycle problem from death to first working age for representative household types using a dynamic,

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[1] "Binge Buyers: Many Baby Boomer Save Little, May Run Into Trouble Later On: They Don't Build Nest Eggs Nearly Rapidly Enough for an Easy Retirement," Bernard Wysocki Jr., 6/5/95, A1 Wall Street Journal. Also, see Wolff (2002) who concludes "retirement wealth accumulation needs to be improved for the vast majority of households."

[2] Also see Engen, Gale, and Uccello (1999) for a similar analysis to Hubbard, Skinner, and Zeldes (1995). Moore and Mitchell (1998); Gustman and Steinmeier (1999a); and Kotlikoff, Spivak, and Summers (1982) examine saving adequacy by comparing data to financial planning rules of thumb. Banks, Blundell, and Tanner (1998); Bernheim,

stochastic life-cycle model. They then obtain a *distribution* of optimal wealth-earnings ratios by Monte Carlo simulation (of earnings draws) which, when combined with the model, allows them to calculate the consumption choices of a set of representative households. They compare the distribution of simulated optimal ratios to the distribution of actual ratios computed from the Panel Study of Income Dynamics (PSID). They find, once they account for asset tests associated with income transfer programs, that actual wealth-to-earnings distributions from the PSID closely match the simulated optimal distributions.

But papers that derive optimal distributions of wealth (or wealth-income ratios) do not answer the issue posed in this paper: are Americans saving optimally for retirement? In the Hubbard *et al.* paper, for example, each household in the PSID has an optimal wealth income ratio given any specific life-cycle model and history of earnings realizations. So the fact that actual and simulated wealth-to-earnings *distributions* are similar does not ensure that each household is achieving its target.

Our approach has a number of distinctive features. We calculate household-specific optimal wealth targets, using data from the Health and Retirement Study (HRS). Households' expectations about earnings come from 40 years of earnings realizations drawn from restricted-access social security earnings records: these realizations are also a fundamental input to calculating optimal wealth. Our life-cycle model incorporates uncertainty about earnings, mortality, and health.[3] Households form realistic expectations about social security, which

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Skinner and Weinberg (2001); and Hamermesh (1984) make inferences about adequacy from consumption changes around retirement. See Hurd and Rohwedder (2003) for comments on the difficulties of interpreting consumption changes around retirement.

[3] The literature on life-cycle models is vast. See, for example, Deaton (1991) and Aiyagari (1994) who emphasize precautionary savings behavior; Carroll (1997), who analyzes buffer-stock behavior; Laibson, Repetto and Tobacman (1998) who look at self-control problems; and Palumbo (1999), who examines end of life uncertainty in medical expenses in a life-cycle model.

depend on lifetime income, and about pension benefits, which depend on income in the final year of work. We incorporate a stylized, time-varying income transfer system, which Hubbard *et al.* (1995) emphasize as being an important factor affecting wealth accumulation in the context of the life-cycle model. We also incorporate a stylized, time-varying progressive income tax. Finally, we incorporate detailed HRS data on family structure and age of retirement (treating both as exogenous and known from the beginning of working life) in calculating optimal life-cycle consumption profiles.

We find that over 80 percent of HRS households have accumulated more wealth than their optimal targets. These targets indicate the amounts of private saving household need to solve their life-cycle planning problem, given social security and defined benefit pension expectations and realizations. For those not meeting their targets, the magnitudes of the deficits are typically small. In addition the cross-sectional distribution of wealth in 1992 closely matches the predictions of our life-cycle model.

I. The Health and Retirement Study

The HRS is a national panel study with an initial sample (in 1992) of 12,652 persons and 7,702 households.[4] It oversamples blacks, Hispanics and residents of Florida. The baseline 1992 study consisted of in-home, face-to-face interviews of the 1931-1941 birth cohort, and their spouses, if married. Follow-up interviews were given by telephone in 1994, 1996, 1998, 2000, and 2002. For the analyses in this paper we exclude 379 married household where one spouse did not participate in the 1992 HRS, 93 households that failed to ever have at least one year of

[4]An overview of the HRS is given in a Supplementary issue of the Journal of Human Resources, 1995 (volume 30). There, 22 authors discuss and assess the data quality of many dimensions of the initial wave of the HRS. Subsequently careful work with the HRS related to this paper includes Gustman, Mitchell, Samwick and Steinmeier

full-time work, and 908 households where the highest earner began working fulltime prior to 1951.[5] Our resulting sample has 6,322 households.

The survey covers a wide range of topics, including batteries of questions on health and cognitive conditions and status; retirement plans and perspectives; attitudes, preferences, expectations and subjective probabilities; family structure and transfers; employment status and job history; job demands and requirements; disability; demographic background; housing; income and net worth; and health insurance and pension plans.

Subjective Assessments of Retirement Preparation

A substantial number of Americans are concerned about their standard of living in retirement. Table 1 shows responses by heads of households to a question that asks if they worry about "not having enough income to get by" in retirement (the specific questions are given in the notes to the table). Twenty-three percent of the not-retired heads and 34 percent of the retired heads "worry a lot" about not having enough income to get by. More than 45 percent of the heads worry a lot or somewhat about not having enough income for retirement.

There is substantial variation in the concern people have about retirement income across lifetime earnings percentiles. Fifty-nine percent of households in the lowest 20 percentiles of the lifetime earnings distribution worry a lot or somewhat about not having enough income to get by in retirement. Over forty percent of those in the middle deciles (40-60 percentile) of the lifetime earnings distribution worry a lot or somewhat. But these worries are not exclusive to low- and middle-income households. Over a quarter of those in the top decile of the lifetime earnings

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(1998), Moore and Mitchell (1998), Gustman and Steinmeier (1999a) and Gustman and Steinmeier (1999b).

[5] We drop the first two groups because large amounts of crucial data needed for the analysis are missing. We drop households where the highest earner started working before 1951 for computational reasons. Our procedures to

distribution report worrying a lot or somewhat about not having enough income to get by. When we focus on the narrower category of worrying a lot, thirteen percent of households in the top quintile worry a lot compared to 43 percent of households in the bottom quintile.

The subjective responses suggest that Americans worry about their financial security in retirement. But a more rigorous standard for assessing retirement preparation is needed to help interpret the subjective evidence. We turn to this in the following sections.

Wealth Measures in the HRS

Households typically maintain living standards in retirement by drawing on their own (private) saving, employer-provided pensions, and social security wealth. To study the degree to which households optimally accumulate wealth, therefore, we need accurate measures of these wealth components.

Net worth (private saving) is a comprehensive measure that includes housing assets less liabilities, business assets less liabilities, checking and saving accounts, stocks, bonds, mutual funds, retirement accounts including defined contribution pensions, certificates of deposits, the cash value of whole life insurance, and other assets, less credit card debt and other liabilities. It excludes defined benefit pension wealth, social security wealth, consumer durables, and future earnings. The concept of wealth is similar (and in many cases identical) to those used by other studies of wealth and saving adequacy.

We use the "Pension Present Value Database" that Bob Peticolis and Tom Steinmeier have kindly made available on the HRS Web Site to calculate the value of defined benefit pensions

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impute missing and top-coded data are considerably more complicated when initial values of the earnings process are missing. Details for the earnings imputations are given in Appendix I.

and, as described below, estimate household's expectations of future pension benefits.[6] The program makes present value calculations of HRS pensions for wave 1 (1992) respondents for nine different scenarios, corresponding to the Social Security Administration's low, intermediate and high long-term projections for interest rates, wage growth rates and inflation rates.[7] We use the intermediate values when calculating DB pension wealth.

HRS Earnings Data

Restricted access social security earnings data are central for the analysis. These provide a direct measure of earnings realizations and lifetime income, and, as described below, they are used to estimate household's expectations of future earnings. They also allow us to accurately simulate social security benefits for the respondent and spouse or, if higher, the couple.[8]

Two issues arise in using earnings information. First, social security earnings records are not available for 22.8 percent of the respondents included in the simulation (we have 10,523 respondents in 6,322 households). Second, the social security earnings records are top-coded (households earn more than the social security taxable wage cap) for 16 percent of earnings observations between 1951 and 1979 (we also have access to uncensored W-2 earnings records from 1980-1991, so censoring is not an issue beginning in 1980).

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[6]See http://www.umich.edu/~hrswww/center/rescont2.html. The programs use detailed plan descriptions along with information on employee earnings. We use self-reported defined-benefit pension information for households not included in the Peticolis and Steinmeier file. The assumptions used in the program to calculate the value of defined contribution (DC) pensions – particularly the assumption that contributions were a constant fraction of income during years worked with a given employer – are likely inappropriate. Consequently, we follow others in the literature (for example, Engen *et al.*, 1999, page 159) and use self-reported information to calculate DC pension wealth.

[7] The intermediate Social Security Administration assumptions are 6.3 percent for interest rates, 5 percent for wage growth, and 4 percent for inflation.

[8] Appendix II provides details of the social security calculations.

We impute earnings histories for those individuals with missing or top-coded earnings records assuming the individual log-earnings process

$$y^*_{i,0} = x'_{i,0}\beta_0 + \varepsilon_{i,0}$$

$$y^*_{i,t} = \rho y^*_{i,t-1} + x'_{i,t}\beta + \varepsilon_{i,t}, \; t \in \{1,2,...,T\} \qquad (1)$$

$$\varepsilon_{i,t} = \alpha_i + u_{i,t}$$

where $y^*_{i,t}$ is the log of observed earnings of the individual *i* at time *t* in 1992-dollars, $x_{i,t}$ is the vector of *i*'s characteristics at time *t*, and the error term $\varepsilon_{i,t}$ includes a household-specific component α_i, which is constant over time, and an unanticipated white noise component, $u_{i,t}$. We employ random-effect assumptions with homoskedastic errors to estimate equation (1).

We estimate the model separately for four groups: men without college, men with some college, women without college, and women with some college. Details of the empirical earnings model and coefficient estimates are given in Appendix I. In the same Appendix we also describe how we use the model of individual earnings to impute earnings for individuals who refuse to release their social security earnings histories to the HRS,[9] and how we use a Gibbs sampling procedure to estimate earnings for individuals in years when their social security earnings records are top-coded. The Gibbs procedure is conceptually appealing as it allows us to use information from the entire sequence of individual earnings to impute top-coded earnings.

Table 2 provides descriptive statistics for the HRS sample. Mean (median) earnings in 1991 of HRS households are \$35,263 (\$28,298), though note that 13 percent are not in the paid labor force when interviewed in 1992. The mean (median) present discounted value of lifetime household earnings is $1,691,104 ($1,516,931).[10] Retirement consumption will be financed out of pension wealth (mean is $105,919, median is $17,371); social security wealth (mean is $97,150, median is $106,714); and non-pension net worth (mean is $250,513, median is $107,000). These descriptive means and medians are similar to other work published with the HRS.

Our empirical procedures result in social security replacement rates that are somewhat lower than those discussed in Engen *et al.* (1999). The replacement rate is defined as equaling annual social security benefits divided by the average of the final five years of earned income (prior to retirement), multiplied by 100. The median for our sample of married couples is 38.4 percent. Those with less than a high school degree have a median of 43.7 percent. Those with a high school degree or some college have a median rate of 39.3 percent. College graduates have a median rate of 31.6 percent, while those with more than a college degree have a median rate of 29.8 percent. Engen *et al.* cite figures from Grad (1990) who reports that an average replacement rate for couples was roughly 55 percent in 1982. Social security has become less generous since 1982. Because we use social security earnings records and a close approximation to the social security benefit rules, our measure compared to those in Grad (1990) show how replacement rates have changed over time.

Figure 1, which shows the median levels of pension wealth, social security wealth, and non-pension net worth in each lifetime income decile, highlights the critical role played by social

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[9] We repeated our central empirical analyses dropping individuals who refused to release their social security records and generated nearly identical results to those reported in the paper. Brief details are given in the sensitivity analysis section, 4.5.

[10] When calculating present discounted values of earnings, social security or DB pension wealth, we discount the constant-dollar sum of earnings (social security, or pensions) by a real interest rate measure (prior to 1992, we use the difference between the CPI-W and the 3-month Treasury bill rate; for 1992 and after we use 4 percent).

security in enhancing retirement income, particularly for households with low levels of lifetime income. Social security exceeds the combined value of pension and non-pension net worth in the bottom three deciles of the lifetime income distribution. Private net worth significantly exceeds the value of social security in the top two deciles of the lifetime income distribution. The metaphor of the "three-legged stool," where retirement income security is supported by the three legs of social security, employer-provided pensions, and private wealth accumulation, appears to only apply for households in the top 70 percent of the lifetime income distribution due to the lack of employer-provided pension coverage of low-income workers.

II. A Model of Optimal Wealth Accumulation

Consider a simple life-cycle model, augmented to incorporate uncertain lifetimes, uninsurable earnings, uninsurable medical expenses, and borrowing constraints. The unit of analysis is a household. Households can be married or single.[11] Individuals within a household live up to a maximum age D. Between ages 0 and $S-1$ individuals are children and therefore make no consumption decisions. Adults start working at age S, have exogenous labor supply (and total labor income equals earnings), and potentially give birth to n children at ages B_1, B_2, ..., B_n. Earnings depend on age (which affects work experience) and a random shock that may be correlated across time. Every period adults decide how much to consume and how much to save for the future.

Beginning at age $R+1$ households retire and face a probability of death in each remaining year of life. During this period, they start receiving health shocks that are allowed to be correlated across ages. Retired households receive income from social security, defined benefit plans (if they have one) and assets. Social security receipts depend on total earnings during the pre-retirement period, while defined benefit pension receipts are a function of a household's last earnings receipt before retirement.

2.1. Household's maximization problem

A household derives utility $U(c)$ from period-by-period consumption in equivalent units, where $g(A_j, K_j)$ is a function that adjusts consumption for the number of adults A_j and kids K_j in a household at age j. Let c_j and a_j represent consumption and assets at age j. With probability p_j the individual survives into the next period, so an individual survives until age j with probability $\prod_{k=S}^{j-1} p_k$, where $\prod_{k=S}^{j-1} p_k = 1$ if $j-1 < R$. At age D, $p_D = 0$. Let the discount factor on future utilities be β. Then expected lifetime utility is

$$E\left[\sum_{j=S}^{D} \beta^{j-S} U\left(c_j / g(A_j, K_j)\right)\right]$$

The expectation operator E denotes the expectation over future earnings uncertainty, uncertainty in health expenditures and length of life.

Consumption and assets are chosen to maximize expected utility subject to the constraints,

$$y_j = e_j + ra_j + T,\ j \in \{S, ..., R-1\},$$

$$y_j = SS\left(\sum_{j=S}^{R} e_j\right) + DB\left(e_R\right) + ra_j + T,\ j \in \{R, ..., D\},$$

$$c_j + a_{j+1} = y_j + a_j - \tau\left(y_j\right), j \in \{S, ..., R-1\}$$

$$c_j + a_{j+1} + m_j = y_j + a_j - \tau\left(y_j\right), j \in \{R, ..., D\}\text{ , and}$$

[11] We do not model marriage or divorce. If a household is married, they become single only if a spouse dies. Single households remain single forever.

$$a_{j+1} \geq 0.$$[12]

e_j denotes labor earnings at age j, and $\tau(\cdot)$ is a tax function that depicts total tax payments as a function of taxable income, y_j. T denotes means-tested transfers. $SS(\cdot)$ are social security receipts, which are a function of aggregate lifetime income, and $DB(\cdot)$ are defined benefit receipts, which are a function of earnings received at the last working age. Medical expenditures are denoted by m_j and the interest rate is denoted by r.

2.2. Recursive Formulation of the Life-Cycle Problem

The life-cycle problem may be solved backwards from age D, given the terminal condition at that age. There are two sources of uncertainty in retirement – death and medical expenses. We start by describing the problem for retired married households. The problem for the single households is dealt with in a similar fashion.

2.2.1. The Retired Household's Problem[13]

A retired household between the ages R and D obtains income from social security, defined benefits, and pre-retirement assets.[14] The dynamic programming problem at age j for a married household with both members alive at the beginning of age j is given by

[12] The last constraint will never be violated even if it were not imposed exogenously since it is a direct implication of the non-negativity restriction on consumption. The intuition is the following: for the problem to be well-specified, the household should not be allowed to die with debt, regardless of the stochastic sequence of earnings (and medical) shocks. Since earnings shocks in every period can get arbitrarily close to zero, the household should be in a position to repay debt even in this eventuality – failing this, consumption goes to zero and marginal utility of consumption goes to infinity, which is clearly non-optimal (since the utility function satisfies the Inada condition). Consequently, the household will maintain a non-negative asset position in every age. The same logic applies in retirement, with the exception that rather than earnings uncertainty, the individual now faces uncertainty in medical expenses and life-span.

[13] To define a household's retirement date for those already retired, we use the actual retirement date for the person in the household who contributed the largest share of lifetime household earnings. For those not retired, we use the expected retirement date of the person who is expected to contribute the largest share of lifetime household earnings.

$$V(e_R,E_R,a,j,m,3)=\max_{c,a'}\begin{Bmatrix} U(c/g(2,0))+ \\ \beta p_{hj}p_{wj}\int V(e_R,E_R,a',j+1,m',3)d\Omega_{jm}(m'|m)+ \\ \beta p_{hj}(1-p_{wj})\int V(e_R,E_R,a',j+1,m',1)d\Omega_{js}(m'|\frac{m}{2})+ \\ \beta p_{wj}(1-p_{hj})\int V(e_R,E_R,a',j+1,m',2)d\Omega_{js}(m'|\frac{m}{2}) \end{Bmatrix}, \quad (2)$$

subject to

$$y=SS(E_R)+DB(e_R)+ra+T(e_R,E_R,a,j),$$

$$c+a'+m=y+a-\tau(y), \quad (3)$$

In equation (2), $V(e_R,E_R,a,j,m,3)$ denotes the present discounted value of utility from age j until the date of death, $V(e_R,E_R,a',j+1,m',3)$ denotes the corresponding value at the following year; β is the discount factor on future utilities; and, as noted before, p_{hj} and p_{wj} denote the probability of survival between ages j and $j+1$ for the husband and the wife respectively. Medical expenses are drawn from the Markov processes $\Omega_{jm}(m'|m)$ and $\Omega_{js}(m'|m)$. Notice that these distributions are allowed to be different depending upon whether the household is married or single. Total earnings up to the current period are denoted by E_R while the last earnings draw, at the age of retirement is e_R. Note that E_R and e_R do not change once the individual is retired. Finally, the integers in the last argument of the value function signify that only the husband survives (1), only the wife survives (2), or both the husband and wife are alive (3) at the beginning of the period.

[14] To simplify notation, age *j* variables will be expressed without any subscripts or superscripts, and age $j-1$ variables and age $j+1$ variables will be represented with subscript "-1" and superscript "'", respectively.

2.2.2. The problem at the age of retirement

Age R represents the last working age for the individual. At this age, the individual knows that in the next period he or she will cease working and begin receiving income from social security and defined benefit pensions. The corresponding dynamic programming problem is

$$V(e_R, E_R, a, j, m, 3) = \max_{c,a'} \begin{Bmatrix} U(c/g(2,0)) + \\ \beta p_{hj} p_{wj} \int V(e_R, E_R, a', j+1, m', 3) d\Omega_{jm}(m' \mid m) + \\ \beta p_{hj}(1-p_{wj}) \int V(e_R, E_R, a', j+1, m', 1) d\Omega_{js}(m' \mid \frac{m}{2}) + \\ \beta p_{wj}(1-p_{hj}) \int V(e_R, E_R, a', j+1, m', 2) d\Omega_{js}(m' \mid \frac{m}{2}) \end{Bmatrix}, \tag{4}$$

subject to

$$y = e_R + ra + T(e_R, E_{R-1}, a, R),$$

$$c + a' + m = y + a - \tau(y),$$

and

$$E_R = E_{R-1} + e_R.$$

The last earnings draw is e_R. This draw will determine the household's defined benefit pension receipts in retirement. Further, this earnings draw together with total earnings to date, E_{R-1}, determine total lifetime earnings, E_R. Lifetime social security receipts will depend on E_R. Finally, the household realizes that they will start receiving medical shocks beginning in the next period from the distribution $\Omega^*_{Rm}(m')$ or $\Omega^*_{Rs}(m')$, depending on whether both spouses survive into the next period or just one. These distributions are assumed to be the stationary distributions associated with the corresponding Markov chains.

2.2.3. The Working Households's Problem

Between ages S and R, the individual receives an exogenous earnings draw e. Given earnings and savings from previous period, the individual decides how much to consume and save. The decision problem reads

$$V(e,E_{-1},a,j)=\max_{c,a'}\left\{U\left(c/g(A_j,K_j)\right)+\beta\int_{e'}V(e',E,a',j+1)d\Phi_j\left(e'|e\right)\right\}, \tag{5}$$

subject to

$$y=e+ra+T(e,E_{-1},a,j),$$

$$c+a'=y+a-\tau\left(y\right),$$

and

$$E=E_{-1}+e.$$

Note that during working years, earnings draws for the next period come from the distribution Φ conditional on the individual's age and current earnings draw. The solution to this problem yields the decision rule as a function of the individual state: denote this decision rule $a'=G(e,E_{-1},a,j)$. We assume that each household begins life with zero assets. Given the observed earnings history of a household, we recover the optimal level of assets at every age using the decision rules.

III. Calibration and Estimation of Exogenous Processes

In this section we specify functional forms and parameter values that we use for the numerical simulations.

Preferences: The utility function for consumption of final goods is assumed to be CRRA:

$$U(c)=\begin{cases}\dfrac{c^{1-\gamma}}{1-\gamma}, & \text{if } \gamma\neq 1\\ \log c, & \text{if } \gamma=1\end{cases}$$

Following Hubbard, Skinner, and Zeldes (1995); Engen, Gale, and Uccello (1999); and Davis, Kubler, and Willen (2002), the discount factor is set as, $\beta = 0.97$, and the coefficient of relative risk aversion (the reciprocal of the intertemporal elasticity of substitution) is set as, $\gamma = 3$. We describe sensitivity analysis on these key parameters below.

Equivalence Scale: This is obtained from Citro and Michael (1995) and takes the form $g(A_j, K_j) = (A_j + 0.7K_j)^{0.7}$.

Survival Probabilities: These are calculated based on the 1992 life tables of the Center for Disease Control and Prevention, U.S. Department of Health and Human Services (http://www.cdc.gov/nchs/data/lifetables/life92_2.pdf).

Rate of Return: We assume an annualized real rate of return of 4 percent. This is the average (rounded to the nearest percentage point) of the average real stock market return between 1947 and 1996 (7.6 percent) and the average real return on 3-month Treasury bills (0.8 percent).

Taxes: We model an exogenous, time-varying, progressive income tax that takes the form

$$\tau(y) = a_0\left(y - \left(y^{-a_1} + a_2\right)^{-1/a_1}\right).$$

Parameters are estimated by Gouveia and Strauss (1994, 1999), and characterize U.S. effective, average household income taxes between 1966 and 1989.[15] We use the 1966 parameters for years before 1966 and the 1989 parameters for 1990 and 1991.

[15] Estimated parameters, for example, in 1989 are $a_0 = 0.258$, $a_1 = 0.768$ and $a_2 = 0.031$. In the framework, $a_1 = -1$ corresponds to a lump sum tax with $\tau(y) = -a_0 a_2$, while when $a_1 \to 0$, the tax system converges to a proportional tax system with $\tau(y) = a_0 y$. For $a_1 > 0$ we have a progressive tax system.

Transfers: The government redistributes according to an income maintenance program following Hubbard, Skinner and Zeldes (1995). The transfer that an individual receives while working is given by

$$T = \max\left\{0, \underline{c} - \left[e + (1+r)a\right]\right\},$$

while the transfer that he or she will receive upon retiring is

$$T = \max\left\{0, \underline{c} - \left[SS(E_R) + DB(e_R) + (1+r)a\right].\right\}$$

This transfer function guarantees a pre-tax income of $\underline{c}$, which we set based on parameters drawn from Moffitt (2002).[16] Subsistence benefits ($\underline{c}$) increased sharply to $9,887 in 1974 from $5,992 in 1968 (all in 1992 dollars) for a one-parent family with two children. Benefits have trended down from their 1974 peak – in 1992 the consumption floor was $8,159 for a family of three.

Social Security and Defined Benefit Functions: By making use of the social security earnings records, we calculate a close approximation of each household's social security entitlement. Households in the model understand social security rules and develop expectations of social security benefits that are consistent with their earnings expectations. Details on social security in the model are given in the first section of Appendix II.

Defined benefit pension expectations are formed based on an empirical pension function that depends in a nonlinear way on union status, years of service in the pension-covered job, and

[16] Moffitt (2002, http://www.econ.jhu.edu/People/Moffitt/DataSets.html) provides a consistent series for average benefits received by a family of four. We use his "modified real benefit sum" variable, which roughly accounts for the cash value of food stamp, AFDC, and Medicaid guarantees. We weight state-level benefits by population to calculate an average national income floor. We use 1960 values for years prior to 1960 and use the equivalence scale described above to adjust benefits for families with different configurations of adults and children. We confirm that the equivalence scale adjustments closely match average benefit patterns for families with different

expectations about earnings in the last year of work. We estimate the function with HRS data. Details are given in the second section of Appendix II.

Earnings Process: The basic unit of analysis for our life-cycle model is the household. We aggregate individual earnings histories into household earnings histories. Earnings expectations are a central influence on life-cycle consumption decisions both directly and through their effects of expected pension and social security receipts.

The household model of log earnings is

$$\log e_j = \alpha^i + \beta_1 AGE_j + \beta_2 AGE_j^2 + u_j\,,$$

$$u_j = \rho u_{j-1} + \varepsilon_j\,,$$

where e_j is the observed earnings of the household *i* at age *j* in 1992-dollars, α^i is the household specific constant, AGE_j is age of the head of the household, u_j is an AR(1) error term of the earnings equation, and ε_j is a zero-mean i.i.d., normally distributed error term. The estimated parameters are α^i, β_1, β_2, ρ, and σ_ε^2.

We divide households into 6 groups according to marital status, education, and number of earners in the household resulting in 6 sets of household-group-specific parameters.[17] Estimates (excluding the household-specific effect) are given in Appendix Table 4.[18]

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numbers of adults and children using data from the Green Book (1983, pp. 259-260, 301-302; 1988, pp. 410-412, 789).

[17] The 6 groups are (1) single without a college degree; (2) single with a college degree or more; (3) married, head without a college degree, one earner; (4) married, head without a college degree, two earners; (5) married, head with a college degree, one earner; and (6) married, head with a college degree, two earners. A respondent is an earner if his or her lifetime earnings are positive and contribute at least 20 percent of the lifetime earnings of the household.

[18] Given the model assumption, *predicted* earnings are given by

$$\hat{e}_j = \exp(\alpha^i + \beta_1 AGE_j + \beta_2 AGE_j^2 + \rho^{(j-l)} u_l + \sigma_\varepsilon^2/2)$$

where the period *s* disturbance is calculated as

$$u_l = \log(e_l) - \alpha^i - \beta_1 AGE_l - \beta_2 AGE_l^2$$

Out of Pocket Medical Expenses: The specification for the household age-medical expense profiles is given by

$$m_t = \beta_0 + \beta_1 AGE_t + \beta_2 AGE_t^2 + u_t,$$

$$u_t = \rho u_{t-1} + \varepsilon_t,\ \ \varepsilon_t \sim N(0, \sigma_\varepsilon^2),$$

where m_t is the log of the household's out-of-pocket medical expenses at time t (the medical expenses are assumed to be $1 if the self-report is zero), AGE_t is age of the household head at time t, u_t is an AR(1) error term and ε_t is white-noise. The parameters to be estimated are β_0, β_1, β_2, ρ, and σ_ε.

We estimate the medical-expense specification for 4 groups of households: (i) single without a college degree, (ii) single with a college degree, (iii) married without a college degree, and (iv) married with a college degree, using the 1998 and 2000 waves of the HRS.[19] The age and education characteristics correspond to that of the head of household. We assume that the medical expenses are incurred only after retirement. Results are given in the third section of Appendix II. To facilitate exposition, we denote the distribution from which a retired individual will draw next period's (age $j+1$) medical expenses m', conditional on the current earnings draw being m at age j, by $\Omega_j\left(m'\middle|m\right)$.

The household *expected* earnings profile is $\{\overline{e}_j\}_{j=S}^{R}$, where S is the first year that the head of the household started working full time, R is the head's last year of work. The head of household is defined throughout the paper as the person in the household with the largest share of lifetime earnings.

[19] New cohorts were added to the HRS in 1998 so the later years give us a broader range of ages to estimate age-medical expense profiles. These new cohorts were not matched to their social security earnings records so they cannot be used for our baseline analysis.

3.1 Model solution

We solve the dynamic programming problem by linear interpolation on the value function. Recall that the state space is composed of six variables for retired households: earnings drawn at j=R, e_R; cumulative earnings at the time of retirement, E_R; assets, a; age, i; medical expenses, m; and the number of household members alive, n (to simplify computation, we assume there is no mortality risk and out-of-pocket medical expenses for working households). We begin by "discretizing" the state space. The grid for earnings is constructed using the procedure discussed in Tauchen (1986). The grid for assets is chosen to be denser at lower levels of assets and progressively coarser so as to account for non-linearities in the decision rules for assets induced by the borrowing constraint. We start at age D and compute the value function $V(e_R, E_R, a, D, m, n)$ associated with all possible states in the discretized set. (The problem at this stage is trivial, since the individual will simply consume all income). We move backwards to the previous period and solve for the value function and the decision rule for assets. If optimal assets do not lie on the grid, we linearly interpolate between the points on the grid that lie on either side. In this fashion we go all the way to the starting age S and consequently recover the decision rules $a' = G(e, E_{-1}, a, j)$ for all $j = S...R$ and $a' = G(e, E_{-1}, a, j, m, n)$ for all $j = R+1...D$.

To summarize, for each household in our sample we compute optimal decision rules for consumption (and hence asset accumulation) from the oldest possible age (D) to the beginning of their working life (S). These decision rules differ for each household, since each faces stochastic draws from different earnings distributions (recall that α_i is household-specific). Household-specific earnings expectations also influence directly expectations about social security and pension benefits. Other characteristics also differ across households: for example, birth years of children affect the “adult equivalents” in a household at any given age. Consequently, it is not sufficient to solve the life-cycle problem for just a few household types.

Once optimal decision rules are solved for each household, we simulate optimal consumption (and therefore wealth) each period for each household using data on the observed realizations of earnings. Specifically, we start at age *S*, the first working age, where the household is assumed to start off with zero assets. Earnings-to-date are also zero at *S*. Given observed earnings at age *S*, $\hat{e}_S$, wealth (saving) is given by $a_{S+1} = A(\hat{e}_S, 0, 0, S, 0, n)$. In the next period, the household receives an observed earnings draw $\hat{e}_{S+1}$, so aggregate earnings are given by $\hat{E}_S = \hat{e}_S$. Consequently, wealth is given by $a_{S+1} = A(\hat{e}_{S+1}, \hat{E}_S, a_S, S+1, 0, n)$. We move forward in this fashion until we reach the age at which wealth data are available for that particular household.

IV. Model Predictions and Their Correspondence to HRS Data

In this section we compare the optimal wealth levels for each household to their actual wealth holdings. We start by providing information on optimal wealth from the simulation model. We then present detailed information on the degree to which HRS households are meeting their specific targets. The third subsection examines correlations between household characteristics and the degree to which households are and are not meeting their targets. We then compare our results to wealth predictions that would arise from a naïve behavioral model, where households save an age-varying and income-varying fraction of their annual earnings. The section concludes with sensitivity analyses on key model parameters.

4.1 Optimal wealth accumulation in the HRS

Table 3 summarizes the distribution of optimal net worth holdings. These targets include resources that could be accumulated in real and financial assets, the current value of defined contribution pensions (including 401(k)s), and housing net worth (for now, we assume households are willing to reduce housing in retirement to maintain consumption standards).

Like the results of Hubbard, Skinner, and Zeldes (1995), low-skilled households will optimally accumulate negligible amounts of wealth outside of social security. The optimal wealth target for the median households in the 10^{th} percentile of the lifetime income distribution is $2,941 (including housing wealth). Means-tested transfer programs including AFDC (during the period being studied), food stamps, SSI, and other forms of assistance have income and asset tests. Households receiving transfers or who may draw benefits after a negative earnings shock may optimally accumulate fewer assets than they would in the absence of a safety net, since assets above a threshold will make households ineligible for transfers.[20]

Optimal wealth targets are $69,777 for the median household and are $253,631 for the median household in the highest decile of the lifetime income distribution. The targets increase monotonically with lifetime income and with educational attainment.

There are two reasons why the optimal wealth targets in Table 3 may *overstate* the wealth needed to equate the discounted marginal utility of consumption across time. First, our model makes no allowance for the possibility that work or other expenses (such as mortgage payments) may fall in retirement. Second, if consumption and leisure are substitutes or if households spend

[20] Empirical work on the effects of asset tests and asset accumulation comes to mixed conclusions. Gruber and Yelowitz (1999) find significant negative effects of Medicaid on asset accumulation, but Hurst and Ziliak (2001) find only very small effects of AFDC and food stamp asset limits.

more time in food preparation in retirement we will expect consumption expenditures to fall (see, for example, Hurd and Rohwedder, 2003; and Aguiar and Hurst, 2003).

There are two reasons why the optimal wealth targets in Table 3 may *understate* needed retirement wealth. First, social security may be fiscally unsustainable, which could lead to future reductions in social security benefits, though we think it is unlikely that these benefit reductions will affect significantly households in the HRS.[21] Second, high lifetime-income households may have operative bequest motives. Dynan, Skinner, and Zeldes (2003), for example, argue that bequest intentions are the best way to reconcile wealth-income patterns in several nationally representative datasets.

Weighing the possible biases in our optimal wealth targets, the targets given in Table 3 will likely *overstate* the wealth needed for households to maintain their own living standards in retirement (if there are no planned bequests or *inter-vivos* transfers). Our assumptions about social security are likely to be accurate for HRS households. At the same time, we think it is likely that some expenses will fall in retirement and consumption and leisure may be substitutes.

In other studies, wealth targets are commonly given in the form of wealth-earnings ratios. In the second column of Table 3 we show targets as a ratio of average income earned in the last five years that the household worked in the 1992 HRS. Optimal wealth-earnings ratios are 2.4 at the median, and median ratios range from 1.2 to 4.0 across the educational attainment distribution and from 0.6 to 3.9 across deciles of the lifetime income distribution.

A central feature of our work that distinguishes it from earlier papers is that we can compare optimal levels of wealth with actual wealth for each household in the HRS.

[21] Later in the paper we will report sensitivity analysis for a simulation where social security is 25 percent less generous than the current system.

4.2 Are households preparing optimally for retirement?

Figure 2 gives a scatterplot of optimal net worth against actual net worth, for HRS households with optimal and actual wealth between $0 and $1,000,000. The curved line gives a cubic spline of the median values of observed and optimal net worth.[22] The Figure is striking, in that households appear to cluster just below the 45 degree line. The scatterplot gives suggestive visual evidence that most households appear to be saving adequately for retirement.

A second striking aspect of Figure 2 is that it illustrates how a well-specified life-cycle model can closely account for variation in cross-sectional household wealth accumulation. A simple goodness of fit measure – $R^2 = 1 - \left(\frac{\sum_{i=1}^{N} (a_i - o_i)^2}{\sum_{i=1}^{N} (a_i - \bar{a})^2} \right)$, where a_i is the actual wealth of household *i* and o_i is the household's optimal target – shows the model overall explains 83 percent of the cross-household variation in wealth.

Table 4 shows the fraction of HRS households with wealth deficits, broken out by educational attainment and lifetime earnings deciles. Overall 18.6 percent of the HRS sample has deficits (their wealth is less than the optimal target). The likelihood of having a deficit falls sharply with lifetime income. While by this measure, nearly one in five HRS households is saving too little, the median magnitude (conditional on having a deficit) is very small, averaging $5,714. While some households are approaching retirement with significant wealth deficits, Table 4 provides additional evidence that HRS households overwhelmingly are prepared well for retirement.

[22] The median band is smoothed by dividing households into 30 groups based on observed net work. We use Stata's "connect(s) bands(30)" option for the Figure.

The last four columns of Table 4 help put the magnitude of the wealth deficits in perspective. Column 3 repeats the optimal net worth (excluding DB pensions and excluding social security wealth) targets shown in the previous table. Comparing columns 2 and 3, median deficits for households who have deficits are generally small relative to the optimal targets. The Table also shows that across all but the highest lifetime income decile, the median optimal wealth targets are less than the median value of social security entitlements. More generally, for lower income households, retirement security is provided by private wealth accumulation and social security. DB pensions only play an important role for households in the top parts of the educational attainment and lifetime income distributions.

To this point we have only presented figures for the median household in the population or the median household within education or lifetime income deciles. Figure 3 graphs percentiles – 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} – of the *distribution* of the difference between actual and optimal wealth targets by lifetime income deciles. If our model perfectly characterized household behavior, this difference would be $0 for all households. We see all households from the 25^{th} percentile of the distribution and above are meeting or exceeding their wealth target. Households in the 10^{th} percentile of the "actual minus optimal" wealth distribution have wealth shortfalls, but the magnitudes are very small. Figure 3 provides additional evidence against the idea that most HRS households are preparing poorly for retirement.

There is some question about the degree to which the elderly are willing to reduce housing equity to sustain consumption in retirement. Venti and Wise (2001), for example, write "... these results suggest that in considering whether families have saved enough to maintain their pre-retirement standard of living after retirement, housing equity should not be counted on to support general non-housing consumption." This conclusion is controversial. Hurd (2003) shows the elderly households in the AHEAD data (the Study of Assets and Health Dynamics Among the Oldest Old) decumulate housing wealth as they age. Engen, Gale, and Uccello (1999) make a forceful case for including at least a significant portion of housing wealth when measuring resources households can draw on to maintain living standards in retirement.[23]

To explore the consequences of altering the treatment of housing in our calculations, we also examine the distribution of wealth deficits excluding half of housing from the resources available to meet the wealth target. Excluding half of housing equity, 57.9 percent of all households meet or exceed their wealth targets. The 25th percentile of the saving surplus distribution (net worth minus optimal targets) has a deficit of $10,296. The 10th percentile of the distribution has a deficit of $40,371. The full distribution is given in Figure 4.

4.3 Characteristics correlated with over- and under-saving

The left two columns of Table 5 show the results from a probit regression of the probability that an HRS household failed to meet their optimal wealth target, again assuming that households can eventually draw on all housing wealth to support living standards in retirement. Recall from Table 4 that the probability of failing to meet the target was 35 percent in the lowest lifetime income decile and was 6 percent in the highest. It is striking, therefore, that lifetime income does not have a strong, statistically significant effect once we condition on other covariates. The only factor that is strongly correlated with having a wealth deficit is being single

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[23] Engen, Gale, and Uccello (1999) make four points. First, existing work suggesting the elderly do not decumulate is flawed, since housing should be the last asset to tap since it is illiquid and tax-preferred, and because some evidence is based on cohorts that were considerably less mobile than the HRS cohort. Second, households have vigorously extract equity from houses in the 1980s and 1990s. Third, tax consequences of selling households have fallen in recent years. Fourth, housing provides consumption services and thus represents wealth. Conceptually and from a policy perspective, it makes little sense to ignore one important source of wealth when considering the economic well-being of households in retirement.

– married households are 27.2 percentage points less likely to have a deficit than single households.

In additional regressions estimated separately for a sample of single households and for a sample of married households, no covariates are correlated with saving less than the optimal target for single households. The only covariate correlated with married couples having a wealth deficit is an indicator variable for Hispanic ethnicity. Hispanic couples are 2.9 percentage points less likely than white couples to have deficits. These results suggest under-saving is approximately randomly distributed though the population – it is not a phenomenon disproportionately affecting poor households or households with low levels of education. Moreover, the strong income gradient shown in Table 4 is purely a composition effect – single households are much more likely than married households to not meet their wealth targets. Since single households are more likely to have lower incomes than married households, they are disproportionately represented in the lower deciles of the lifetime earnings distribution.

The last two columns of Table 5 show the results of a median regression on "saving adequacy," defined as the difference between actual net worth (excluding DB pensions and social security wealth) and optimal net worth. These results reveal a sharply increasing, positive relationship between wealth accumulation and lifetime income starting in the middle lifetime income decile. There is also a strong positive relationship between wealth and educational attainment, being self employed, married, and social security wealth. Households headed by men and Black households have lower wealth than white, female-headed households.

4.4 Alternative, "naïve" models

In the conclusion of their paper on variation in retirement wealth, Bernheim, Skinner, and Weinberg (2001) write, "… the empirical patterns in this paper are more easily explained if one steps outside the framework of rational, far-sighted optimization. If, for example, households follow heuristic rules of thumb to determine saving prior to retirement…" Indeed, naïve or rule-of-thumb models of consumption have had an important place in the consumption literature at least since the Keynesian consumption function.

The exceptionally rich data we have on household earnings contain a great deal of information. Health shocks prior to retirement, unemployment, changes in labor demand and supply, among other things, will be reflected in the 40-year series of earnings we have for most households. Given the rich earnings data, it is natural to ask how much of the variation in HRS wealth can be explained by applying simple, rule of thumb saving behavior to the household-specific earnings trajectories. In doing this analysis, we continue to assume a 4 percent real interest rate as we have done in the baseline life-cycle simulations.

The simplest model we examined assumes that households save a constant fraction of their income, independent of their income or age. We iteratively sought the saving rate that maximized the goodness of fit measure, R^2. The fit-maximizing saving rate is 6.9 percent and the model explains 7.1 percent of the 1992 cross-sectional distribution of wealth in the HRS. A naïve model with age-varying and income-varying saving rates, in this case drawn from the parameters estimated in Dynan, Skinner, and Zeldes (2003, Table 3), explains 11.4 percent of the variation in retirement wealth. It is clear that the life-cycle model presented in this paper, which explains 83 percent of the cross-sectional variation in wealth, does a vastly better job matching the cross-sectional distribution of wealth in the 1992 HRS than the rule of thumb models we examine.

One objection that can be raised to the comparison of the life-cycle and rule of thumb models is that the life-cycle model involves many more parameters than the rule of thumb models. With more parameters, model fit should improve. In particular, our baseline life-cycle model has a household-specific intercept, α_i, of the household age-earnings profiles, in effect adding 6,322 parameters to the model. We think this is a sensible way to model earning expectations – households presumably have a reasonable understanding of where in the ability distribution they lie, given observable characteristics such as educational attainment and age. Nevertheless, we also consider an alternative, more parsimonious version of the baseline model where we assume that all households possess identical α's. To do this we re-estimate the AR(1) process (assuming identical α's) and simulate the optimal decision rules. We find that the model can account for 43.6 percent of the observed variation in 1992 wealth. Thus, even the life-cycle model with relatively few parameters can do a fairly good job matching the 1992 cross-sectional distribution of wealth in the HRS.

4.5 Sensitivity analysis

There are three model parameters that we specify exogenously before solving the model – the discount factor, the coefficient of relative risk aversion, and the real interest rate. In this subsection we analyze the sensitivity of the results to our choices of β, γ, and r. Table 6 shows the results. As expected, increases in β and r increase the incentive to save more in the future. In the life-cycle model this raises the optimal (or "target") level of wealth. When matching these targets to the observed HRS data, more households are failing to save adequately for retirement.

For example, raising the real interest rate to 7 percent from 4 percent increases the fraction of households with wealth less than the optimal to 39 percent from 18 percent. An increase in γ has a similar effect because, as households get more risk averse, precautionary saving increases. This increases the optimal (or target) level of wealth accumulation and consequently under-saving. Nevertheless, the degree of under-saving is not all that high – assuming that $\gamma = 5$, for example, increases the fraction of households with wealth less than the optimal to 33 percent from 18 percent in the baseline results. Finally, when social security benefits are cut by 25 percent for all households, we find that 36.1 percent of households under-save, almost twice as many as in the baseline model.

Our sensitivity analysis leads us to conclude that within the range of values considered, most households in the HRS appear to have saved adequately for retirement. Moreover, within a reasonably broad range of parameter values, the model can explain at least 67 percent of the cross-sectional variation in wealth in the 1992 HRS. These results do not depend at all on the inclusion of households in the sample with fully-imputed earnings histories. When we drop households who did not allow the HRS to have access to their social security earnings records using our baseline parameters, the results are nearly identical. 18.4 percent of households accumulate less wealth than their optimal targets. Conditional on having a deficit, the median shortfall is $5,028. And the model accounts for 84 percent of the cross-sectional distribution of wealth in this restricted subsample.

V. Conclusions

In this paper we develop a rigorous approach for assessing the degree to which a representative sample of households nearing retirement have prepared financially for that event.

We find strikingly little evidence that HRS households have under-saved. And because consumption requirements likely fall when households reach retirement (if for no other reason than work expenses fall), our standard may overstate required wealth. We also note that our primary data come from 1992, well before the exceptionally strong stock market performance of the 1990s. Because 81 percent of households meet or exceed their wealth targets (and most of those who are below miss by a relatively small amount), we are skeptical that the consumption changes around retirement documented by Bernheim, Skinner, and Weinberg (2001) are due to inadequate retirement wealth accumulation.

We also find it striking how much of the variation in observed wealth accumulation can be explained by our life-cycle model. We explain over 85 percent of the variation in wealth for married households, and over 70 percent for single households who never married. And the results presented reflect no tweaking or prior fitting of the model. If we had found major deviations from the model and behavior, it would be difficult to determine whether Americans were preparing poorly for retirement, or we had constructed a lousy behavioral benchmark. The fact that our predictions and data closely align suggests two things. First, as mentioned above, Americans are saving enough to maintain living standards in retirement. And second, the life-cycle model provides a very good representation of behavior related to retirement wealth accumulation. Of course, we still admit the possibility that Americans are preparing poorly for retirement and our underlying behavioral model is lousy, and the errors coincidentally offset.

While the specific measures of undersaving and model fit clearly depend on parameter values, our main two results – the life-cycle model is capable of closely matching the cross-sectional distribution of wealth in the HRS and that most HRS households are saving more than their optimal targets (and of those households saving too little, the magnitude of undersaving is very small) – are not affected significantly by parameter choices that are within the range commonly found in the related literature. We also find the life-cycle model does a much better job matching the cross-sectional distribution of wealth in 1992 than a naïve model where households save an income- and age-varying fraction of income.

Turning to the question posed in the title of the paper: are Americans saving optimally for retirement? The HRS covers a specific cohort of Americans – households age 51 to 61 in 1992. Consequently, we need to be careful in generalizing our results for the HRS cohort to younger households. This is particularly true if the generosity of social security is reduced in the future. Moreover, saving too much has efficiency costs in the sense that, absent preferences about intergenerational transfers or charitable contributions, reallocating consumption across time could increase lifetime utility. Because we cannot determine whether systematic oversaving of HRS households reflects bequest motives, expectations of future reductions in social security, other failures in our characterization of the economic environment, or reflects non-optimal behavior on the part of HRS households, we cannot definitively answer the question posed in the paper title. But the paper provides new, strong support for the life-cycle model as a good characterization of the process governing retirement wealth accumulation. And more importantly, it adds considerably to our confidence that Americans are preparing well for retirement.

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Appendix I: Imputing Earnings in the HRS

We have two problems that we address with the earnings data. For 77 per cent of the 1992 HRS sample, we have access to individual's Social Security earnings records from 1951 to 1991. The Social Security earning records report wage, salary, and self-employment income up to the earnings maximum (the earnings thresholds where social security taxes are no longer taken from income). For 92 per cent of the respondents with Social Security earnings records, we also have W2 earnings records from 1980 to 1991. These W2 records provide complete earnings information for wage and salary earners and the self-employed. The first difficulty is that 16 percent of positive Social Security earnings records are top-coded, and 41 percent of respondents with Social Security earnings records have at least one top-coded observation.

Our second problem is that 23 percent of observations refused to grant access to Social Security earnings records. For these households we have self-reported earnings information for their current job (or the most recent job if not employed) and as many as 3 previous jobs. We need to estimate their earning profiles based on their self-reported earnings information.

The goal is to use all available information to impute top-coded and missing earning observations, and as a result obtain complete individual earning histories. For the imputation, we proceed in two steps. First, based on the Social Security and W2 records, we estimate a dynamic panel Tobit model to obtain individual earning processes. Then, conditional on all available earning information, we use the estimates to impute the top-coded and missing observations.

Estimation

We start by describing our approach to estimating earnings for individuals with top-coded earnings. The model is arguably better than a simple cross-sectional earnings model in that it allows for some relationship between earnings across periods. As a result, it allows us to predict earnings more accurately. This is crucial as a goal of this exercise is to obtain reliable imputed values for the top-coded and missing earnings observations.

For simplicity, suppose that we have earnings records of N individuals from time $t = 0$ to T, where 0 is the first period that these individuals started working fulltime. Assume for the moment that earnings are positive each time period.[24] Denote the logarithmic value of individual i's actual (latent) and observed (to the researcher) earnings as $y^*_{i,t}$ and $y_{i,t}$, respectively. The relationship between the observed and actual (latent) earnings can be described as

$$y_{i,t} = \begin{cases} y^*_{i,t} & if\ y^*_{i,t} < y^{tc}_t \\ y^{tc}_t & if\ y^*_{i,t} \geq y^{tc}_t \end{cases}$$

where y^{tc}_t is the logarithmic value of the Social Security maximum taxable earnings at time t.

The individual log-earnings process is specified as

$$y^*_{i,0} = x'_{i,0}\beta_0 + \varepsilon_{i,0}$$

[24] Generalizing this to the case where earnings series begins after time 0 and the case where some earnings observations are zero are straightforward but detail-oriented, so we omit the discussion. We did treat these cases in practice, however.

$$y^*_{i,t} = \rho y^*_{i,t-1} + x'_{i,t}\beta + \varepsilon_{i,t},\ t \in \{1,2,...,T\}$$
$$\varepsilon_{i,t} = \alpha_i + u_{i,t} \qquad (6)$$

where $x_{i,t}$ is the vector of i's characteristics at time t, and the error term $\varepsilon_{i,t}$ includes an individual-specific component α_i, which is constant over time and "known" to the individual before time 0, and the unanticipated white noise component, $u_{i,t}$. Notice that parameters β_0 and β are allowed to be different. In the following analysis, we employ "random-effect" assumptions with homoskedastic errors

(A1) $\alpha_i \mid \underline{x}_i \sim iid\, N(0,\sigma^2_\alpha)$

(A2) $u_{i,t} \mid \underline{x}_i \sim iid\, N(0,\sigma^2_u)\ \ \forall t$

(A3) $E[u_{i,t} \mid \underline{x}_i,\alpha_i] = 0, E[u^2_{i,t} \mid \underline{x}_i,\alpha_i] = \sigma^2_u, E[u_{i,t}u_{i,k} \mid \underline{x}_i,\alpha_i] = 0,\ \ \forall t \in \{0,1,..,T\}, t \neq k$

These three assumptions imply that

$$\varepsilon_i = (\varepsilon_{i,0},\varepsilon_{i,1},...,\varepsilon_{i,T})' \sim N(0,\Sigma) \qquad (7)$$

where

$$\Sigma = \begin{bmatrix} \sigma^2_{0,0} & \sigma_{0,1} & \cdots & \sigma_{0,T} \\ \sigma_{1,0} & \sigma^2_{1,1} & \cdots & \sigma_{1,T} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{T,0} & \sigma_{T,1} & \cdots & \sigma^2_{T,T} \end{bmatrix}$$

with $\sigma^2_{j,k} = \sigma^2_\alpha + \sigma^2_u$ for $j = k$, and $\sigma^2_{j,k} = \sigma^2_\alpha$ otherwise. Our goal here is to obtain consistent estimates of the true parameters $\theta^* = (\beta,\beta_0,\rho,\sigma^2_\alpha,\sigma^2_u)$. We do this by maximum likelihood.

To construct the likelihood function for each individual's earnings series, notice that we can always write the joint distribution function of each pair of random variables $(y_{i,t}, y^*_{i,t})$ as $g(y_{i,t}, y^*_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}, y_{i,t-2}, y^*_{i,t-2},....., y_{i,0}, y^*_{i,0}; \underline{x}_i, \theta)$. From the AR(1) assumption on earnings made in (6), we can write

(A4) $g(y_{i,t}, y^*_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}, y_{i,t-2}, y^*_{i,t-2},....., y_{i,0}, y^*_{i,0}; \underline{x}_i, \theta) = g(y_{i,t}, y^*_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta)$

In other words, of all information about the past realized and observed earnings, only information from the previous period matters. As a special case, the conditional likelihood of the pair $(y_{i,0}, y^*_{i,0})$ is $g_0(y_{i,0}, y^*_{i,0} \mid \underline{x}_i, \theta)$ because there is no information about earnings before period 0.

Applying Bayes' rules to the density $g(\ )$, we have

$$g(y_{i,t}, y^*_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta) = h(y^*_{i,t} \mid y_{i,t}, y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta) q(y_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta) \qquad (8)$$

where the density for the observed log-earnings conditional on the past information is a conventional Tobit likelihood function

$$q(y_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta) = [f(y_{i,t} \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta)]^{1\{y^*_{i,t} < y^{tc}_t\}} [\Pr(y^*_{i,t} \geq y^{tc}_t \mid y_{i,t-1}, y^*_{i,t-1}; \underline{x}_i, \theta)]^{1\{y^*_{i,t} \geq y^{tc}_t\}}$$

and the conditional density $h(\ )$ for non-censored observations is the probability *mass* function

$$h(y_{i,t}^* \mid y_{i,t} < y_t^{tc}, y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta) = \begin{cases} 1 & if\ y_{i,t}^* = y_{i,t} \\ 0 & if\ y_{i,t}^* \neq y_{i,t} \end{cases}$$

and the conditional density is simply $h(y_{i,t}^* \mid y_{i,t} = y_t^{tc}, y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta)$ for censored observations.

Similarly, we can write $g_0(y_{i,0}, y_{i,0}^* \mid \underline{x}_i, \theta) = h_0(y_{i,0}^* \mid y_{i,0}; \underline{x}_i, \theta) q_0(y_{i,0} \mid \underline{x}_i, \theta)$ where the conditional density $h_0(\ )$ for non-censored observations is the probability *mass* function $h_0(y_{i,0}^* \mid \underline{x}_i, \theta) = \begin{cases} 1 & if\ y_{i,0}^* = y_{i,0} \\ 0 & if\ y_{i,0}^* \neq y_{i,0} \end{cases}$ and the conditional density is $h_0(y_{i,0}^* \mid y_{i,0} = y_0^{tc}; \underline{x}_i, \theta)$ for censored observations. In addition, the density for the time-0 observed log-earnings conditional on past information is $q_0(y_{i,0} \mid \underline{x}_i, \theta) = [f(y_{i,0} \mid \underline{x}_i, \theta)]^{1\{y_{i,0}^* < y_0^{tc}\}} [\Pr(y_{i,0}^* \geq y_0^{tc} \mid \underline{x}_i, \theta)]^{1\{y_{i,0}^* \geq y_0^{tc}\}}$.

From (6) and (7), it is apparent that the functions $f(y_{i,0} \mid \underline{x}_i, \theta)$ and $f(y_{i,t} \mid y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta)$, $t > 0$, are normal probability distribution functions and $\Pr(y_{i,0}^* \geq y_0^{tc} \mid \underline{x}_i, \theta)$ and $\Pr(y_{i,t}^* \geq y_t^{tc} \mid y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta)$, $t > 0$, are normal cumulative distribution functions. For expositional convenience, define

$$\begin{aligned} h^{tc}(0; \underline{x}_i, \theta) &\equiv h_0(y_{i,0}^* \mid y_{i,0} = y_0^{tc}; \underline{x}_i, \theta) \\ h^{tc}(t; \underline{x}_i, \theta) &\equiv h(y_{i,t}^* \mid y_{i,t} = y_t^{tc}, y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta), \quad t > 0 \\ q(0; \underline{x}_i, \theta) &\equiv q_0(y_{i,0}; \underline{x}_i, \theta) \\ q(t; \underline{x}_i, \theta) &\equiv q(y_{i,t} \mid y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta), \quad t > 0 \end{aligned}$$

The likelihood function for *i*'s series of observed log-earnings is

$$\begin{aligned} & L_i(y_{i,T}, y_{i,T-1}, \ldots, y_{i,1}, y_{i,0}; \underline{x}_i, \theta) \\ &= \int_{y_{i,T}^*}^{\infty} \cdots \int_{y_{i,0}^*}^{\infty} \left\{ \prod_{t=0}^{T} q(t; \underline{x}_i, \theta) \right\} \cdot \left\{ h(y_{i,0}^*; \underline{x}_i, \theta) \prod_{t=1}^{T} h(y_{i,t}^* \mid y_{i,t}, y_{i,t-1}, y_{i,t-1}^*; \underline{x}_i, \theta) \right\} dy_{i,0}^* \cdots dy_{i,T}^* \qquad (9) \\ &= \int_{y_{i,c_n}^*}^{\infty} \cdots \int_{y_{i,c_1}^*}^{\infty} \left\{ \prod_{t=0}^{T} q(t; \underline{x}_i, \theta) \right\} \cdot \left\{ \prod_{k=c_1}^{c_n} h^{tc}(k; \underline{x}_i, \theta) \right\} dy_{i,c_1}^* \cdots dy_{i,c_n}^* \quad = E_{y_{i,c_1}^*, \ldots, y_{i,c_n}^*} \left[\prod_{t=0}^{T} q(t; \underline{x}_i, \theta) \right] \end{aligned}$$

where c_1, c_2, ..., c_n are the periods where the observed log-earnings are censored, i.e. equal to their corresponding top-coded limits. Notice that, since we do not observe $y_{i,t}^*$ when it is censored, we integrate out $y_{i,t}^*$ for censored observations. Unfortunately, the integration does not yield any analytical solution, nor is direct numerical evaluation of the integral computationally feasible in this case. As an alternative, Chang (2002) proposes using a GHK (probit) simulator to deal with the computational burden of the integration.[25] The estimation results are given below.

[25] The GHK simulator gives a numerical approximation of a probit probability of interest. The GHK simulator is a popular choice of probit simulators due to its relative accuracy; see Geweke, Keane and Runkle (1994) for details.

Appendix Table A1: Estimation Results of Individual Earning Processes §

Variables	Sample Male without College	Male with College	Female without College	Female with College
Initial Observation [t = 0]				
Constant	5.585*** (0.051)	3.858*** (0.326)	7.270*** (0.150)	4.954*** (0.427)
Race (white = 1, 0 otherwise)	0.304*** (0.025)	0.323*** (0.086)	0.132*** (0.037)	-0.013 (0.035)
Years of Schooling / Professional Post-Graduate Degree Dummy §	0.042*** (0.001)	-0.116** (0.059)	0.023*** (0.008)	0.041 (0.273)
No High School Dummy / Post-Graduate Degree Dummy §	-0.007*** (0.002)	-0.120*** (0.034)	-0.174*** (0.045)	0.122 (0.088)
Marital Status in 1992 HRS	0.113*** (0.018)	0.030 (0.019)	-0.034 (0.025)	0.108 (0.128)
Two-Earner Household Dummy	-0.071 (0.048)	-0.087 (0.067)	0.175*** (0.032)	0.143 (0.093)
Age	0.165*** (0.003)	0.294*** (0.021)	0.062*** (0.009)	0.231*** (0.028)
0.01 x Age^2	-0.189*** (0.004)	-0.336*** (0.033)	-0.066*** (0.013)	-0.284*** (0.042)
Subsequent Observations [t > 0]				
Constant	2.618*** (0.053)	2.120*** (0.069)	3.252*** (0.075)	2.932*** (0.169)
Race (white = 1, 0 otherwise)	0.114*** (0.006)	0.048** (0.019)	0.038** (0.019)	-0.025 (0.024)
Years of Schooling / Professional Post-Graduate Degree Dummy §	0.019*** (0.002)	0.043*** (0.009)	0.029*** (0.004)	0.066* (0.034)
No High School Dummy / Post-Graduate Degree Dummy §	-0.028*** (0.008)	-0.009 (0.007)	-0.070*** (0.020)	0.097*** (0.021)
Marital Status in 1992 HRS	0.140*** (0.014)	0.123*** (0.026)	-0.128*** (0.017)	-0.123*** (0.031)
Two-Earner Household Dummy	-0.082*** (0.009)	-0.106*** (0.014)	0.210*** (0.014)	0.171*** (0.027)
Age	0.037*** (0.001)	0.034*** (0.005)	0.019*** (0.002)	0.014** (0.006)
0.01 x Age^2	-0.045*** (0.001)	-0.040*** (0.005)	-0.013*** (0.003)	-0.010 (0.006)
Earnings at the Previous Period	0.633*** (0.005)	0.730*** (0.014)	0.565*** (0.008)	0.667*** (0.027)
Variance of the Individual-Specific Effect (σ_α^2)	0.027*** (0.001)	0.013*** (0.002)	0.047*** (0.003)	0.028*** (0.007)
Variance of the Gross Error Term (σ_ε^2)	0.214*** (0.004)	0.227*** (0.010)	0.258*** (0.006)	0.239*** (0.014)
Number of Individual-Year Observations	92,889	21,479	48,625	8,747
Number of Respondents	3,095	724	2,670	452

§ The dependent variable is the respondents' natural-log-earnings. For samples with at most high school, the education variables are (i) Years of Schooling, and (ii) No High School Dummy. For samples with at least a bachelor degree, the education variables are (i) Professional Post-Graduate Degree (MBA, J.D., M.D., or Ph.D.) Dummy, and (ii) Post-Graduate Degree Dummy. Standard errors are in parentheses. *, **, and *** denote statistically significant at the 10%, 5% and 1% levels, respectively.

Imputation

The idea is to impute top-coded and missing earnings observations with their conditional expectations where the conditioning variables include both individual's characteristics and observed earnings. The conditional expectations are calculated numerically based on the dynamic earnings model (6) and the distributional assumption (7). The imputation scheme is similar for top-coded and missing observations; therefore, we only discuss the scheme for top-coded observations here.[26]

To be concrete, notice that (6) implies that

$$E[y_0^* \mid \underline{y},\underline{x},\theta] = x_0'\beta_0 + E[\varepsilon_0 \mid \underline{y},\underline{x},\theta]$$
$$E[y_t^* \mid \underline{y},\underline{x},\theta] = \rho E[y_{t-1}^* \mid \underline{y},\underline{x},\theta] + x_t'\beta + E[\varepsilon_t \mid \underline{y},\underline{x},\theta],\ t \in \{1,2,...,T\} \qquad (10)$$

where $\underline{y} = (y_0, y_1,..., y_T)$ is the series of individual *i*'s observed earnings (the individual subscript *i* is omitted throughout this subsection). By construction, given information about individual's characteristics and observed earnings, $E[y_t^* \mid \underline{y},\underline{x},\theta]$ is on average the best guess for y_t^*. In other words, for top-coded observations, equations (6) suggest the imputed values

$$y_t^{imp} = E[y_t^* \mid y_t = y_t^{tc}; \underline{y},\underline{x},\theta]$$

which requires knowledge of $E[\varepsilon_t \mid y_t = y_t^{tc}; \underline{y},\underline{x},\theta]$ for every period *t* in which $y_t = y_t^{tc}$. The analytical form of $E[\varepsilon_t \mid y_t = y_t^{tc}; \underline{y},\underline{x},\theta]$ is not available in our case; therefore, we calculate this object numerically using the Gibbs sampling procedure.[27]

To facilitate the discussion about details of the procedure, denote $\underline{\varepsilon}_{<t} = (\varepsilon_0, \varepsilon_1,..., \varepsilon_{t-1})'$, $\underline{\varepsilon}_{>t} = (\varepsilon_{t+1}, \varepsilon_{t+2},..., \varepsilon_T)'$ and $\underline{\varepsilon}_{-t} = (\varepsilon_0, \varepsilon_1,..., \varepsilon_{t-1}, \varepsilon_{t+1},..., \varepsilon_T)'$ for any vector $\underline{\varepsilon} = (\varepsilon_0, \varepsilon_1,..., \varepsilon_T)'$. Here, we want to simulate *R* sets of $\underline{\varepsilon}$ that are consistent with the observed $\underline{y}$ and $\underline{x}$ given θ. The Gibbs sampling procedure does this in 2 steps for each round of simulation.

1. In the r^{th} round of simulation, *r* = 1,2, ... ,*R*, generate a "random" initial value $\underline{\varepsilon}_0^{(r)} = (\varepsilon_{0,0}^{(r)}, \varepsilon_{1,0}^{(r)},..., \varepsilon_{t,0}^{(r)},..., \varepsilon_{T,0}^{(r)})$ which satisfies (6) given $\underline{y}$, $\underline{x}$ and θ.
   Notice that $\varepsilon_{t,0}^{(r)}$ is not identified when $y_t = y_t^{tc}$. In this case, $\varepsilon_{t,0}^{(r)}$ is chosen randomly under the restriction that $y_{t,0}^{*(r)} \equiv (y_t^* \mid \underline{\varepsilon}_{<t} = \underline{\varepsilon}_{<t,0}^{(r)}, \varepsilon_t = \varepsilon_{t,0}^{(r)}; \underline{x},\theta) \geq y_t^{tc}$. If $y_{t-1} < y_{t-1}^{tc}$ and $y_t < y_t^{tc}$, $\varepsilon_{t,0}^{(r)}$ is defined by (6), i.e. it is actually not random.
2. Start with *m* = 1, draw a random number $\varepsilon_{t,m}^{(r)}$ from *t* = 0, ..., *T* from the distribution of $\varepsilon_t \mid \underline{\varepsilon}_{-t}; \underline{x},\theta$ such that $y_{t,m}^{*(r)} = (y_t^* \mid \underline{\varepsilon}_{>t} = \underline{\varepsilon}_{>t,m-1}^{(r)}, \varepsilon_{<t} = \varepsilon_{<t,m}^{(r)}, \varepsilon_t = \varepsilon_{t,m}^{(r)}; \underline{x},\theta) = y_t$ if $y_t < y_t^{tc}$,

[26] We can think of a missing earning observation as an observation with top-coded value being 0, which is equivalent to saying that we know nothing about earnings in that period (as opposed to the case where we observe top-coded earnings and know that the actual earnings is at least as large as the top-coded earnings).

[27] Briefly, Gibbs sampling is a procedure to draw a set of numbers randomly from a (valid) joint distribution. Then, the random draws are used to estimate properties of any marginal distribution of interest, which is difficult to derive analytically from the joint distribution. The procedure relies upon the law of large numbers, i.e. that moments of a distribution can be estimated consistently from a set of random draws from that distribution.

and $y^{*(r)}_{t,m} = (y^*_t \mid \underline{\varepsilon}_{>t} = \underline{\varepsilon}^{(r)}_{>t,m-1}, \varepsilon_{<t} = \varepsilon^{(r)}_{<t,m}, \varepsilon_t = \varepsilon^{(r)}_{t,m}; \underline{x}, \theta) \geq y^{tc}_t$ if $y_t = y^{tc}_t$. (This is equivalent to drawing $\varepsilon^{(r)}_{t,m}$ from $\varepsilon_t \mid \underline{\varepsilon}_{-t}; \underline{y}, \underline{x}, \theta$.) Then, continue from $m = 2$ to $m = M$.

With $\underline{\varepsilon}^{(r)}_M$, $r = 1,2, \ldots ,R$, an estimate of $E[\varepsilon_t \mid \underline{y}, \underline{x}, \theta]$ is

$$\hat{E}[\varepsilon_t \mid \underline{y}, \underline{x}, \theta] = \frac{1}{R}\sum_{r=1}^{R} \varepsilon^{(r)}_{t,M} \tag{11}$$

Given the estimate $\hat{E}[\varepsilon_t \mid \underline{y}, \underline{x}, \theta]$, we calculate the imputed value of earnings as

$$\begin{aligned} y^{imp}_0 &= x'_0 \beta_0 + \hat{E}[\varepsilon_0 \mid \underline{y}, \underline{x}, \theta] \\ y^{imp}_t &= \rho y^{imp}_{t-1} + x'_t \beta + \hat{E}[\varepsilon_t \mid \underline{y}, \underline{x}, \theta],\ t \in \{1,2,\ldots,T\} \end{aligned} \tag{12}$$

Notice that, by construction, $y^{imp}_0 = \frac{1}{R}\sum_{r=1}^{R} y^{*(r)}_{0,M}$ and $y^{imp}_t = \frac{1}{R}\sum_{r=1}^{R} y^{*(r)}_{t,M}$, $t \in \{1,2,\ldots,T\}$, and that $y^{imp}_t = y_t$ if $y_t < y^{tc}_t$ and $y^{imp}_t \geq y_t$ if $y_t = y^{tc}_t$.

The remaining parts of this subsection (i) construct the functional form for the conditional distribution of $\varepsilon_t \mid \underline{\varepsilon}_{-t}; \underline{x}, \theta$, and (ii) show how to draw a random number $\varepsilon^{(r)}_{t,m}$ from this conditional distribution to satisfy (6) given $\underline{y}$, $\underline{x}$ and θ. More notation is required. For any matrix Σ, denote $\Sigma_{t,t}$ as the element of Σ on the t^{th} row and t^{th} column, $\Sigma_{t,-t}$ as the t^{th} row of Σ with the element $\Sigma_{t,t}$ removed, $\Sigma_{-t,t}$ as the t^{th} column of Σ with the element $\Sigma_{t,t}$ removed, and $\Sigma_{-t,-t}$ as the matrix Σ with the t^{th} row and t^{th} column removed.

Recall the property of a joint-normal vector that

$$\begin{aligned} &\underline{\varepsilon} \sim N(E[\underline{\varepsilon}], \Sigma) \quad \Rightarrow \quad \varepsilon_t \mid \underline{\varepsilon}_{-t} \sim N(\mu_{t|-t}, \Sigma_{t|-t}) \\ &\mu_{t|-t} = E[\varepsilon_t] + \Sigma_{t,-t}\Sigma^{-1}_{-t,-t}\{\underline{\varepsilon}_{-t} - E[\underline{\varepsilon}_{-t}]\},\ \Sigma_{t|-t} = \Sigma_{t,t} - \Sigma_{t,-t}\Sigma^{-1}_{-t,-t}\Sigma_{-t,t} \end{aligned} \tag{13}$$

[28]

Recall from (7) that $E[\underline{\varepsilon}_i] = 0$ and $\Sigma = (1-\rho)\sigma^2_\varepsilon I_{T+1} + \rho\sigma^2_\varepsilon 1_{T+1}$, where 1_{T+1} is a $(T+1)$ x $(T+1)$ matrix whose elements are all 1. Thus, $\mu_{t|-t} = \Sigma_{t,-t}\Sigma^{-1}_{-t,-t}\underline{\varepsilon}_{-t}$, and $\Sigma_{t,-t}\Sigma^{-1}_{-t,-t} = \Sigma_{s,-s}\Sigma^{-1}_{-s,-s}$ and $\Sigma_{t|-t} = \Sigma_{s|-s}$ for any $t = 0, \ldots, T$ and $s = 0, \ldots, T$.

Recall that we draw a value for $\varepsilon^{(r)}_{t,m}$ randomly from the conditional distribution $\varepsilon_t \mid \underline{\varepsilon}_{-t}$ such that, given $\underline{\varepsilon}^{(r)}_{>t,m-1}, \varepsilon^{(r)}_{<t,m}, \varepsilon^{(r)}_{t,m}, \underline{x}, \theta$,

$$\begin{aligned} y^{*(r)}_{t,m} &= y_t \qquad \text{if } y_t < y^{tc}_t \\ y^{*(r)}_{t,m} &\in [y^{tc}_t, \infty) \quad \text{if } y_t = y^{tc}_t \end{aligned} \tag{14}$$

In practice, it is more convenient to work with the standard-normal transformation of $\varepsilon_t \mid \underline{\varepsilon}_{-t}$

$$z_{t|-t} \equiv \frac{(\varepsilon_t \mid \underline{\varepsilon}_{-t}) - \mu_{t|-t}}{\sigma_{t|-t}} \sim N(0,1), \quad \sigma_{t|-t} = \sqrt{\Sigma_{t|-t}} \tag{15}$$

[28] See, for example, Goldberger (1991, pages 196-197).

From (6), $\varepsilon_0 \mid \underline{\varepsilon}_{-0} = (y_0^* \mid \underline{\varepsilon}_{-0}) - x_0'\beta_0$ and $\varepsilon_t \mid \underline{\varepsilon}_{-t} = (y_t^* - \rho y_{t-1}^* \mid \underline{\varepsilon}_{-t}) - x_t'\beta,\ t \in \{1,2,...,T\}$.
Also, since $(y_t^* \mid \underline{\varepsilon}_{-t}; \underline{x}, \theta) = (y_t^* \mid \underline{\varepsilon}_{<t}; \underline{x}, \theta)$, $(y_{t-1}^* \mid \underline{\varepsilon}_{>t} = \underline{\varepsilon}_{>t,m-1}^{(r)}, \underline{\varepsilon}_{<t} = \underline{\varepsilon}_{<t,m}^{(r)}; \underline{x}, \theta) = y_{t-1,m}^{*(r)}$.

Thus, with the transformation (15), drawing $\varepsilon_{t,m}^{(r)}$ from (13) to satisfy (14) is equivalent to drawing $z_{t|-t,m}^{(r)}$ such that

$$z_{0|-0,m}^{(r)} = \begin{cases} \{y_0 - x_0'\beta_0 - \mu_{0|-0,m}^{(r)}\}/\sigma_{0|-0} & \text{if } y_0 < y_0^{tc} \\ \Phi^{-1}\left(\xi_{0,m}^{(r)} + (1-\xi_{0,m}^{(r)})\Phi(\{y_0^{tc} - x_0'\beta_0 - \mu_{0|-0,m}^{(r)}\}/\sigma_{0|-0})\right) & \text{if } y_0 = y_0^{tc} \end{cases}$$

for $t = 0$, and

$$z_{t|-t,m}^{(r)} = \begin{cases} \{y_t - \rho y_{t-1,m}^{*(r)} - x_t'\beta - \mu_{t|-t,m}^{(r)}\}/\sigma_{t|-t} & \text{if } y_t < y_t^{tc} \\ \Phi^{-1}\left(\xi_{t,m}^{(r)} + (1-\xi_{t,m}^{(r)})\Phi(\{y_t^{tc} - \rho y_{t-1,m}^{*(r)} - x_t'\beta - \mu_{t|-t,m}^{(r)}\}/\sigma_{t|-t})\right) & \text{if } y_t = y_t^{tc} \end{cases}$$

for $t > 0$,[29] with

$$y_{0,m}^{*(r)} = x_0'\beta_0 + (\sigma_{0|-0} z_{0|-0,m}^{(r)} + \mu_{0|-0,m}^{(r)})$$
$$y_{t,m}^{*(r)} = \rho y_{t-1,m}^{*(r)} + x_t'\beta + (\sigma_{t|-t} z_{t|-t,m}^{(r)} + \mu_{t|-t,m}^{(r)}),\ t \in \{1,2,...,T\}$$

where $\mu_{t|-t,m}^{(r)} = \Sigma_{t,-t}\Sigma_{-t,-t}^{-1}\begin{pmatrix} \underline{\varepsilon}_{<t,m}^{(r)} \\ \underline{\varepsilon}_{>t,m-1}^{(r)} \end{pmatrix}$, $\varepsilon_{t,m}^{(r)} = \sigma_{t|-t} z_{t|-t,m}^{(r)} + \mu_{t|-t,m}^{(r)}$, $\sigma_{t|-t} = \sqrt{\Sigma_{t|-t}}$ and $\Sigma_{t|-t} = \Sigma_{t,t} - \Sigma_{t,-t}\Sigma_{-t,-t}^{-1}\Sigma_{-t,t}$, and $\xi_{t,m}^{(r)}$ is a random draw from a [0,1] uniform distribution. Notice that $y_{t,m}^{*(r)} = y_t$ if $y_t < y_t^{tc}$ and $y_{t,m}^{*(r)} \geq y_t$ if $y_t = y_t^{tc}$ by construction.

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[29] To see how this works, note first that for $\varepsilon \sim N(\mu, \sigma^2)$, $f(\varepsilon) = (2\pi\sigma^2)^{-1/2}\exp(-0.5\{\varepsilon-\mu\}/\sigma)$. Define $z \equiv \{\varepsilon-\mu\}/\sigma$. It follows that $F(\varepsilon) = \Phi(z(\varepsilon))$, where Φ is the standard normal cumulative density function. Thus,

$$\Phi(z(\varepsilon^{(r)})) = F(\varepsilon^{(r)}) = \xi_t^{(r)} + (1-\xi_t^{(r)})F(\varepsilon^{tc}) = \xi_t^{(r)} + (1-\xi_t^{(r)})\Phi(z(\varepsilon^{tc}))$$

In other words, drawing $\varepsilon^{(r)}$ from a truncated distribution of $(\varepsilon|\varepsilon \geq \varepsilon^{tc})$ is equivalent to drawing $z^{(r)} = z(\varepsilon^{(r)})$ from a truncated distribution of $(z|z \geq z^{tc})$ and then transforming $z^{(r)}$ back to $\varepsilon^{(r)}$.

Appendix II: Underlying Model Processes

A1. Social Security function

From the expected earnings profiles, we can calculate the *lifetime* summation of household earnings up to the year of retirement as $E_R \equiv \sum_{j=S}^{R} e_j$, where e_j denotes the household earnings at age j in a common base-year unit, and S and R denote the first and the last working ages, respectively.[30] Denote $\overline{\phi}^h$ and $\overline{\phi}^w$ as the fractions of E_R that are contributed by the husband and wife of the household, respectively.[31] Based on E_R, $\overline{\phi}^h$ and $\overline{\phi}^w$, we can approximate the household annual social security benefits as follows.

(a) Calculate *Individual* PIA[32]

Individual i's annual indexed monthly earnings (AIME) can be approximated as

$$AIME^i \approx \overline{\phi}^i \, E_R / L^i \tag{16}$$

with

$$L^i = 12 \times \max\{R^i - 22, 40\}$$

where $i = h$ (husband) or w (wife), and L^i is the number of months of i's covered period.[33] Without loss of generality, we set $L^w = 40$ for single-male households and $L^h = 40$ for single-female households.

Individual PIA can be calculated as

$$\begin{aligned} PIA^i = {} & 0.90 \times \min\{AIME^i, b_0\} + 0.32 \times \min\{\max\{AIME^i - b_0, 0\}, b_1 - b_0\} \\ & + 0.15 \times \max\{AIME^i - b_1, 0\} \end{aligned} \tag{17}$$

where b_0 and b_1 are the bend points. For the 1992 formula, b_0 = \$387 and b_1 = \$2,333.

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[30] As opposed to a *discounted* present value of earnings, the summation is a straightforward summation of earnings in a common base-year currency unit which is the concept employed by the social security administration (SSA).

[31] The terminologies "husband" and "wife" are not literal. In particular, we call a single male respondent "husband" and a single female respondent "wife." Without this simplification, we need separate treatments for married and single households. Under this generalization, $\overline{\phi}_i^h$ = 1 and $\overline{\phi}_i^w$ = 0 for single-male households, and $\overline{\phi}_i^h$ = 0 and $\overline{\phi}_i^w$ = 1 for single-female households.

[32] Social security benefits derived from the calculations in this section are not precise because the calculated AIME may be smaller than the actual AIME and, conditional on AIME being correctly calculated, the calculated household benefits may be larger than the actual ones. For the former, the reasons are (i) we do not exclude 5 years of lowest earnings from calculation, (ii) we use base-year (i.e. real) values of earnings after age 60 instead of nominal values, (iii) we do not take into account earnings in retirement if respondents work beyond their household retirement dates. For the latter, the reason is that we assume both husband and wife of a married household are eligible for collecting benefits at the household retirement date. If one of them is not eligible at the retirement date, the approximation will overstate the benefits. Nevertheless, by virtue of having complete earnings histories for most individuals, our calculations are considerably more accurate than those in other life-cycle simulation models of wealth accumulation.

[33] Without the lower bound of 40 years in the max operator (max{R_i – 22, 40}), AIME would be too high for households whose members retire before age 62. In addition, notice that we use the *household* retirement date (R_i) rather than the *individual* retirement date.

(b) Calculate *Household* Annual Social Security Benefits

First, the *individual* monthly social security benefits are calculated as

$$ssb^i = \max\{d^i_{own} PIA^i, d^i_{spouse} PIA^{i\text{'s spouse}}, ssx^i\} \quad (18)$$

where *i's spouse* = *h* (*w*) if *i* = *w* (*h*), d^i_{own} is the fraction of *i*'s PIA that *i* would get if *i* collected benefits based on *i*'s PIA, d^i_{spouse} is the fraction of PIA of *i*'s spouse that *i* would get if *i* collected benefits based on PIA of *i*'s spouse, and ssx^i is the monthly benefits that *i* would get if *i* collected benefits based on PIA of *i*'s ex-spouse.[34] Without loss of generality, for single-male households, $d^h_{spouse} = d^w_{own} = d^w_{spouse} = ssx^w = 0$, and $d^w_{spouse} = d^h_{own} = d^h_{spouse} = ssx^h = 0$ for single-female households. In addition, we set $ssx^h = ssx^w = 0$ for married households because we do not have any information to determine ssx^i. Similarly, $ssx^i = 0$ for any single households without information to determine their ex-spouses' PIA.

Finally, household *i*'s *annual* social security benefits can be approximated as

$$ss_i = 12 \times (ssb^h_i + ssb^w_i) \quad (19)$$

which, for a married household, is the benefits the household would get when both the husband and wife survive. When one of the spouses in a married household dies, the *annual* social security benefits of the surviving spouse is

$$ss^{survive}_i = 12 \times \max\{d^h_{own} PIA^h, d^w_{own} PIA^w\} \quad (20)$$

In other words, we approximate the surviving spouse's benefits to be the higher of the husband's and wife's benefits that they would be able to collect based on their own earning histories (which determine their PIAs) and the household retirement date (which determines the factors *d*). This approximates the actual guideline of the Social Security Administration.

A2. Defined Benefit pension:

The annual defined benefit (DB) pension benefit is estimated as

$$\begin{aligned} db = {} & DB^h\{\beta^h_0 + \beta^h_1 UNION^h + \beta^h_2 YRSV^h + (\gamma^h_0 + \gamma^h_1 UNION^h + \gamma^h_2 YRSV^h\}\phi^h_R e_R\} + \\ & DB^w\{\beta^w_0 + \beta^w_1 UNION^w + \beta^w_2 YRSV^w + (\gamma^w_0 + \gamma^w_1 UNION^w + \gamma^w_2 YRSV^w\}\phi^w_R e_R\} \\ & + \beta^b_0 DB^h DB^w + \xi \end{aligned} \quad (0.11)$$

where the superscripts *h* and *w* indicate "husband" and "wife," respectively. DB^i is a binary variable equal to 1 if *i* has a DB pension. $UNION^i$ is a binary variable equal to 1 if *i* belongs to a union at the DB job. $YRSSV^i$ is the number of years that *i* stays in the DB job up to *i*'s retirement date. e_R is the household earnings in the last period of work, and ϕ^h_R and ϕ^w_R indicate the fractions of e_R that belong to the husband and wife, respectively, with $\phi^h_R + \phi^w_R = 1$ by

[34] To recover the ex-spouse's PIA, we first compute the benefit amount that a single respondent would get based on her own earning history. Then, we compare the amount to the reported amount of social security benefits in the first wave that the respondent reported collecting the benefits. If the reported benefit amount is higher, we assume that the single collected benefits based on her ex-spouse's records and the reported amount is used to recover her ex-spouse's PIA.

construction. ξ is an error term that is assumed to be distributed as $N(0,\sigma_\xi^2)$.[35] Finally, the parameters to be estimated are $\beta_0^b,\beta_0^h,\beta_1^h,\beta_2^h,\beta_0^w,\beta_1^w,\beta_2^w,\gamma_0^h,\gamma_1^h,\gamma_2^h,\gamma_0^w,\gamma_1^w,\gamma_2^w$ and σ_ξ^2.

db is calculated by assuming that the household receives annual DB pension benefits that are constant in real terms from the first period of retirement until none of the recipients survive. In particular, let *dbwealth* be the observed present discounted value of *db*.

$$dbwealth = \sum_{j=R+1}^{D} \pi_j \frac{db}{\delta_j} \quad \Rightarrow \quad db = dbwealth \Big/ \sum_{j=R+1}^{D} \frac{\pi_j}{\delta_j}$$

where δ_j is the discount rate that converts pension benefits at age *j* into an equivalent value of 1992 dollars (i.e. having δ_j 1992-dollars at age *j* is as good as having one 1992-dollar in 1992), and π_j is the probability that the household will survive at age *j* conditional on surviving in the year that *dbwealth* was reported, *R* is the last period of work, and *D* is a terminal age where household will not live beyond this age. The estimation results are given in the Table below.

Appendix Table A2: Coefficient Estimates for Annual DB Pension Benefits

Variable	Coefficient Estimates	Standard Errors
Husband's Estimate of Constant	1,914.9***	(701.7)
Husband's Estimate of Union Status	-483.943	(613.2)
Husband's Estimate of Years In Service	47.9	(30.0)
Husband's Estimate of His Last-Period Earnings	-0.028	(0.024)
Husband's Estimate of His Last-Period Earnings Interacting with Union Status	0.008	(0.022)
Husband's Estimate of His Last-Period Earnings Interacting with Years In Service	0.004***	(0.001)
Wife's Estimate of Constant	-245.366	(540.1)
Wife's Estimate of Union Status	1,108.1***	(334.0)
Wife's Estimate of Years In Service	66.6***	(22.6)
Wife's Estimate of Her Last-Period Earnings	0.013	(0.033)
Wife's Estimate of Her Last-Period Earnings Interacting with Union Status	0.003	(0.022)
Wife's Estimate of Her Last-Period Earnings Interacting with Years In Service	0.004***	(0.001)
Estimate of Constant if Both Husband And Wife Has A Pension	-168.864	(420.7)
R^2	0.572	
N	2,203	

[35] The specification is estimated with ordinary least squares using the White formula for the standard error.

A3. Medical Expenses

We construct households' annual medical expenses based on the (HRS imputed) answers to the four medical expense questions asked in 1998 and 2000 HRS. The four questions are:

> E10. About how much did you pay out-of-pocket for [nursing home/hospital/ nursing home and hospital] bills [since R's LAST IW MONTH, YEAR/in the last two years]?
>
> E18a. About how much did you pay out-of-pocket for [doctor/outpatient surgery/dental/doctor and outpatient surgery/doctor and dental/outpatient surgery and dental/doctor, outpatient surgery, and dental] bills [since R's LAST IW MONTH, YEAR/in the last two years]?
>
> E21a. On the average, about how much have you paid out-of-pocket per month for these prescriptions [since R's LAST IW MONTH, YEAR/in the last two years]?
>
> E24a. About how much did you pay out-of-pocket for [in-home medical care/special facilities or services/in-home medical care, special facilities or services] [since R's LAST IW MONTH, YEAR/in the last two years]?

We construct the households' annual medical expenses as one-half of E10 + E18a + 24*E21a + E24a. The 1996 and 1997 household annual medical expenses are calculated from the information from the 1998 HRS and, similarly, the 1998 and 1999 household annual medical expenses are calculated from the information from the 2000 HRS. The sample included is all households (HRS, AHEAD, CODA, and WB) that participated in and retained marital statuses between the 1998 and 2000 HRS. The estimation results are given in the Table below.

Appendix Table A3: Coefficient Estimates for the AR(1) Annual Medical Expenses

Group	Coefficient Estimates					R^2	*N*
	Group Constant	*Age*	$0.01*Age^2$	$\hat{\rho}$	$\hat{\sigma}$		
Single, Non-College	0.020 (0.018)	0.123*** (0.004)	-0.075*** (0.005)	0.869	1.436	0.214	20,096
Single, College	0.111*** (0.038)	0.139*** (0.007)	-0.084*** (0.009)	0.869	1.183	0.335	3,200
Married, Non-College	0.051*** (0.013)	0.174*** (0.003)	-0.115*** (0.004)	0.869	0.948	0.519	18,228
Married, College	0.026 (0.017)	0.185*** (0.004)	-0.121*** (0.005)	0.871	0.696	0.693	5,824

Note: The numbers of households for these groups are 10048, 1600, 9114, and 2912 respectively. *, **, and *** denote statistically significant at the 10%, 5% and 1% levels, respectively.

A4. Estimates of Household Earnings Expectations.

We construct household earnings as the summation of individual earnings for all adults in the household. The estimates for the model of household earnings described in the text are

Appendix Table A4: Coefficient Estimates for the Household AR(1) Earnings Profiles

Group	Coefficient Estimates					R^2	N
	Group Constant	*Age*	0.01*Age^2	$\hat{\rho}$	$\hat{\sigma}$		
Single, Non-College	4.758 (0.022)	0.231 (0.003)	-0.259 (0.004)	0.58	0.46	0.065	43,339
Single, College	3.787 (0.042)	0.293 (0.007)	-0.316 (0.009)	0.68	0.38	0.175	8,677
Married, Non-College, One-Earner	6.753 (0.018)	0.173 (0.002)	-0.195 (0.003)	0.62	0.32	0.138	65,472
Married, Non-College, Two-Earner	5.157 (0.038)	0.264 (0.006)	-0.282 (0.007)	0.70	0.31	0.283	15,779
Married, College, One-Earner	6.741 (0.019)	0.173 (0.003)	-0.187 (0.004)	0.67	0.28	0.183	56,482
Married, College, Two-Earner	5.003 (0.038)	0.259 (0.007)	-0.269 (0.009)	0.76	0.29	0.254	14,626

Note: The numbers of households for these groups are 1873, 351, 2076, 512, 1821 and 519 respectively.

Table 1: Percentage of People Expressing Worry about Not Having Enough Income to "Get By" in Retirement (or who were "Bothered," for those already retired)

	Not Retired (Head)	Retired (Head)
Worry a Lot	22.9%	33.6%
Worry Somewhat	22.6	16.0
Worry a Little	19.4	15.4
Do Not Worry	15.1	21.7
Will Never Retire Completely	12.7	8.3
Inappropriate, Not Applicable, or Do Not Know	7.3	5.1
Number of Households	4,428	1,894

Notes: The specific question (K12e) for people completely retired reads "Now for things that some people say are bad about retirement. Please tell me if during your retirement they have bothered you a lot, somewhat, a little or not at all: Not having enough income to get by." The specific question (K22e) for people not fully retired reads "Now for things that worry some people about retirement. Please tell me if they worry you a lot, somewhat, a little, or not at all: Not having enough income to get by." The responses are weighted by the 1992 HRS household analysis weights.

Table 2: Descriptive Statistics for the Health and Retirement Study (dollar amounts are in 1992 dollars)

Variable	Mean	Median	Standard Deviation
1991 Earnings	$35,263	$28,298	$35,264
Present Discounted Value of Lifetime Earnings	$1,691,104	$1,516,931	$1,193,969
Defined Benefit Pension Wealth	$105,919	$17,371	$191,328
Social Security Wealth	$106,714	$97,150	$65,140
Non-Pension Net Worth	$250,513	$107,000	$541,164
Mean Age	55.7		4.7
Mean Ed (years)	12.7		3.4
Fraction Male	0.70		0.46
Fraction Black	0.11		0.31
Fraction Hispanic	0.06		0.25
Fraction Couple	0.66		0.48
Did Not Complete H.S.	0.22		0.41
High School Graduate	0.55		0.50
College Graduate	0.12		0.33
Post College Education	0.10		0.30
Fraction Self Employed	0.15		0.35
Fraction Retired	0.29		0.45

Source: Author's calculations from the 1992 HRS. The table is weighted by the 1992 HRS household analysis weights.

Table 3: Optimal Net Worth (excluding DB Pensions) and Optimal Wealth-to-Earnings Ratios for HRS Households (dollar amounts in 1992 dollars)

Group	Median Optimal Wealth Target	Median Optimal Wealth-to-Income Ratios (Income is the average of the last 5 working years)
All Households	$69,777	2.4
No High School Diploma	$22,524	1.2
High School Diploma	$70,383	2.5
College Degree	$137,528	3.1
Post College Education	$178,924	4.0
Lowest Lifetime Income Decile	$2,941	0.6
2nd Income Decile	$15,368	1.4
3rd Income Decile	$30,059	1.9
4th Income Decile	$48,200	2.1
Middle Income Decile	$60,513	2.2
6th Income Decile	$83,399	2.6
7th Income Decile	$89,488	2.4
8th Income Decile	$106,724	2.5
9th Income Decile	$140,853	2.7
Highest Lifetime Income Decile	$253,631	3.9

Notes: Authors' calculations from the life-cycle model described in the text. Calculations use the 1992 HRS household analysis weights.

Table 4: Percentage of Population Failing to Meet Optimal Wealth Targets and Magnitude of Wealth Deficit (all dollar amounts are in 1992 dollars)

Group	Percentage Failing to Meet Optimal Target	Median Deficit (conditional on deficit)	Optimal Net Worth Target	Median Net Worth	Median Social Security Wealth	Median DB Pension Wealth
All Households	18.6%	$5,714	$69,777	$107,000	$97,150	$17,371
No High School Diploma	20.9%	$2,982	$22,524	$40,000	$71,774	$0
High School Diploma	19.1%	$5,315	$70,383	$106,000	$97,086	$21,290
College Degree	14.7%	$13,696	$137,528	$217,314	$127,167	$60,752
Post College Education	16.1%	$21,579	$178,924	$263,500	$126,691	$152,639
Lowest Lifetime Income Decile	34.6%	$2,885	$2,941	$5,288	$25,667	$0
2nd Income Decile	33.6%	$3,904	$15,368	$26,050	$41,346	$0
3rd Income Decile	26.0%	$6,599	$30,059	$48,000	$56,951	$0
4th Income Decile	24.5%	$5,500	$48,200	$80,938	$76,426	$18,428
Middle Income Decile	18.1%	$9,477	$60,513	$92,828	$95,527	$27,994
6th Income Decile	13.0%	$4,997	$83,399	$123,000	$116,054	$44,418
7th Income Decile	12.2%	$13,415	$89,488	$138,000	$133,596	$55,100
8th Income Decile	6.7%	$7,688	$106,724	$170,000	$150.893	$76,165
9th Income Decile	7.7%	$4,312	$140,853	$229,000	$163,372	$107,655
Highest Lifetime Income Decile	6.4%	$29,062	$253,631	$395,889	$200,747	$123,192

Notes: Authors' calculations as described in the text.

Table 5: Correlates of the Probability that Households Accumulate Too Little Wealth and the Median Wealth Surplus

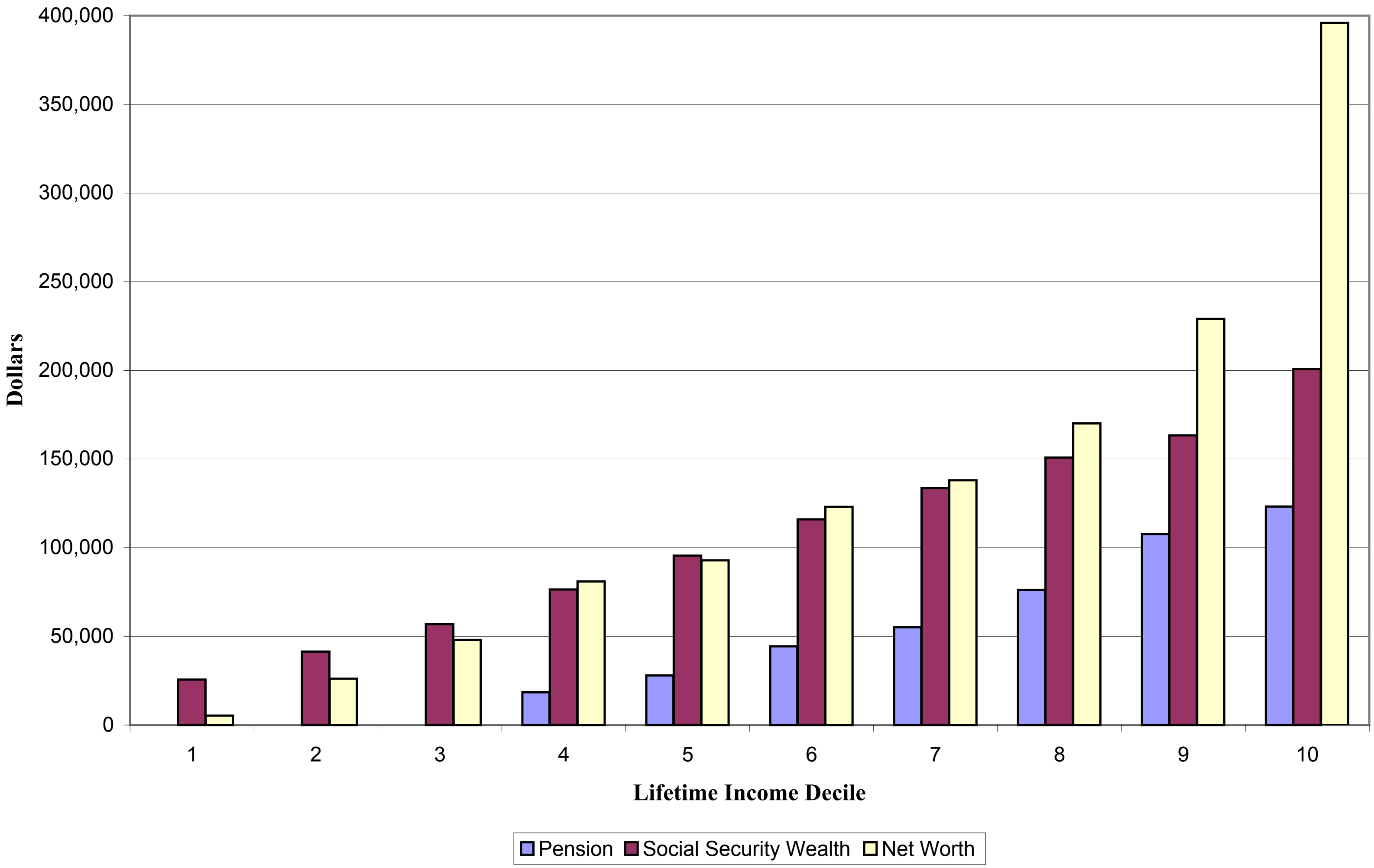
	Probit Regression on Having a Wealth Deficit		Median Regression of "Saving Adequacy" (Actual-Optimal Net Worth)	
	dF/dx [§]	Standard Error	Coefficient Estimates	Standard Error
2nd Lifetime Income Decile	.016	.018	-961.5	715.6
3rd Lifetime Income Decile	-.005	.019	10.3	954.3
4th Lifetime Income Decile	.015	.023	-1,424.4	1,170.1
5th Lifetime Income Decile	-.006	.024	3,413.2*	1,747.6
6th Lifetime Income Decile	-.021	.025	9,776.8***	2,199.3
7th Lifetime Income Decile	-.017	.028	14,740.3***	3,145.3
8th Lifetime Income Decile	-.061**	.025	25,459.2***	2,659.9
9th Lifetime Income Decile	-.046	.029	31,660.3***	5,295.4
10th Lifetime Inc. Decile	-.043	.034	75,810.3***	9,283.9
Retired	.001	.011	655.5	418.9
Has Pension	-.003	.011	-729.9	816.6
Social Security Wealth	-9.41e-08	1.88e-07	0.064***	.016
Age	-.002	.001	149.3*	78.5
Male	-.007	.012	-1,642.0**	709.4
Black	-.006	.012	-1,938.3***	502.8
Hispanic	-.028	.015	-1,005.7	698.6
Married	-.272***	.017	7,938***	916.7
High School Degree	.004	.012	1,672.5***	560.6
College Degree	-.009	.018	8,505.6***	2,672.4
Graduate Degree	-.000	.020	13,783.1***	3,976.8
Self Employed	-.012	.014	27,420.5***	7,637.0
Constant			-10,166.6**	4,157.0

[§] For dummy variables, dF/dx is a discrete change. The mean probability of a deficit in the sample is .185. The pseudo R2 for the probit regression is .1562 and sample size is 6,271.
Standard errors are bootstrapped in the median regression. The pseudo R2 for the median regression is .0918 and the sample size is 6,271.
*, **, *** denotes significance at the 10 percent, 5 percent, and 1 percent levels, respectively.

Table 6: Sensitivity Analysis

Parameter Value	Percentage Failing to Meet Optimal Target	Measure of fit: R^2 (in %)
Baseline: $\beta = 0.97$, $\gamma = 3$, $r = 4\%$	18.6	83
$\beta = 1.0$	27.6	86
$\beta = 0.93$	14.8	79
$r = 5\%$	24.5	77
$r = 7\%$	39.1	67
$\gamma = 1.5$	12.7	87
$\gamma = 5$	33.2	78

Figure 1: Median Pension Wealth, Social Security Wealth, and Non-Pension Net Worth by Lifetime Income Decile, (1992 dollars)



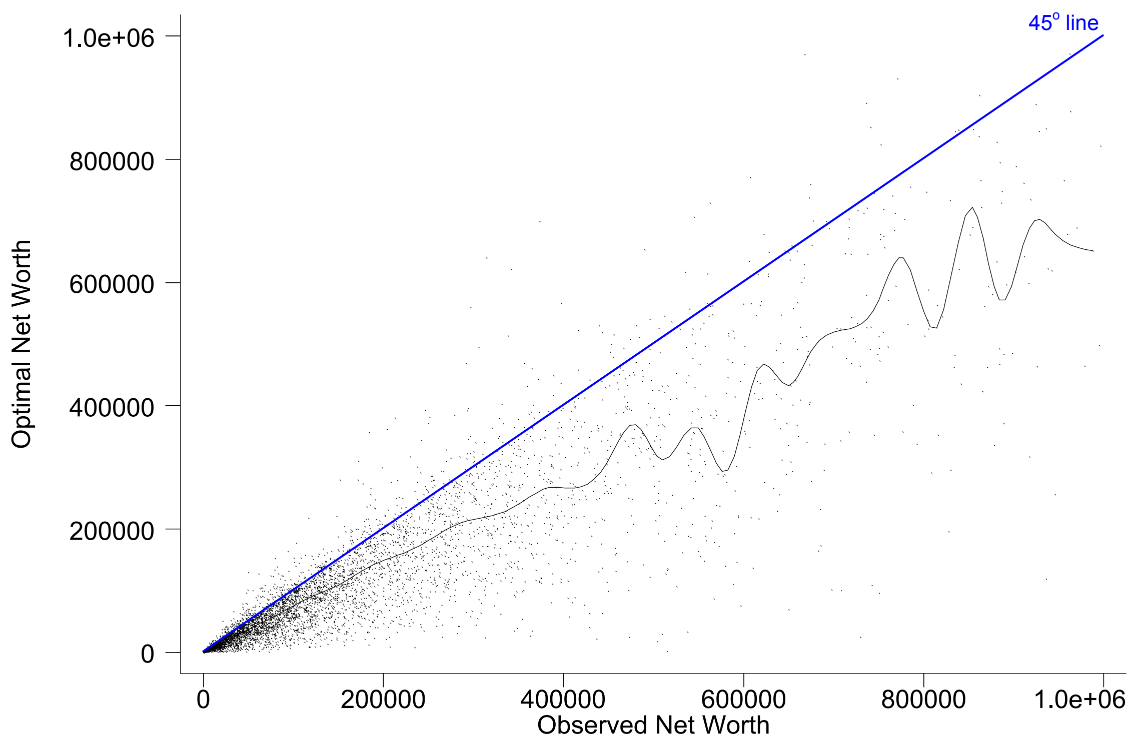


Figure 2: Scatterplot of Optimal and Actual Wealth

Figure 3: Distribution of "Saving Adequacy"
Observed Minus Simulated Non-DB-Pension Net Worth (All Households)

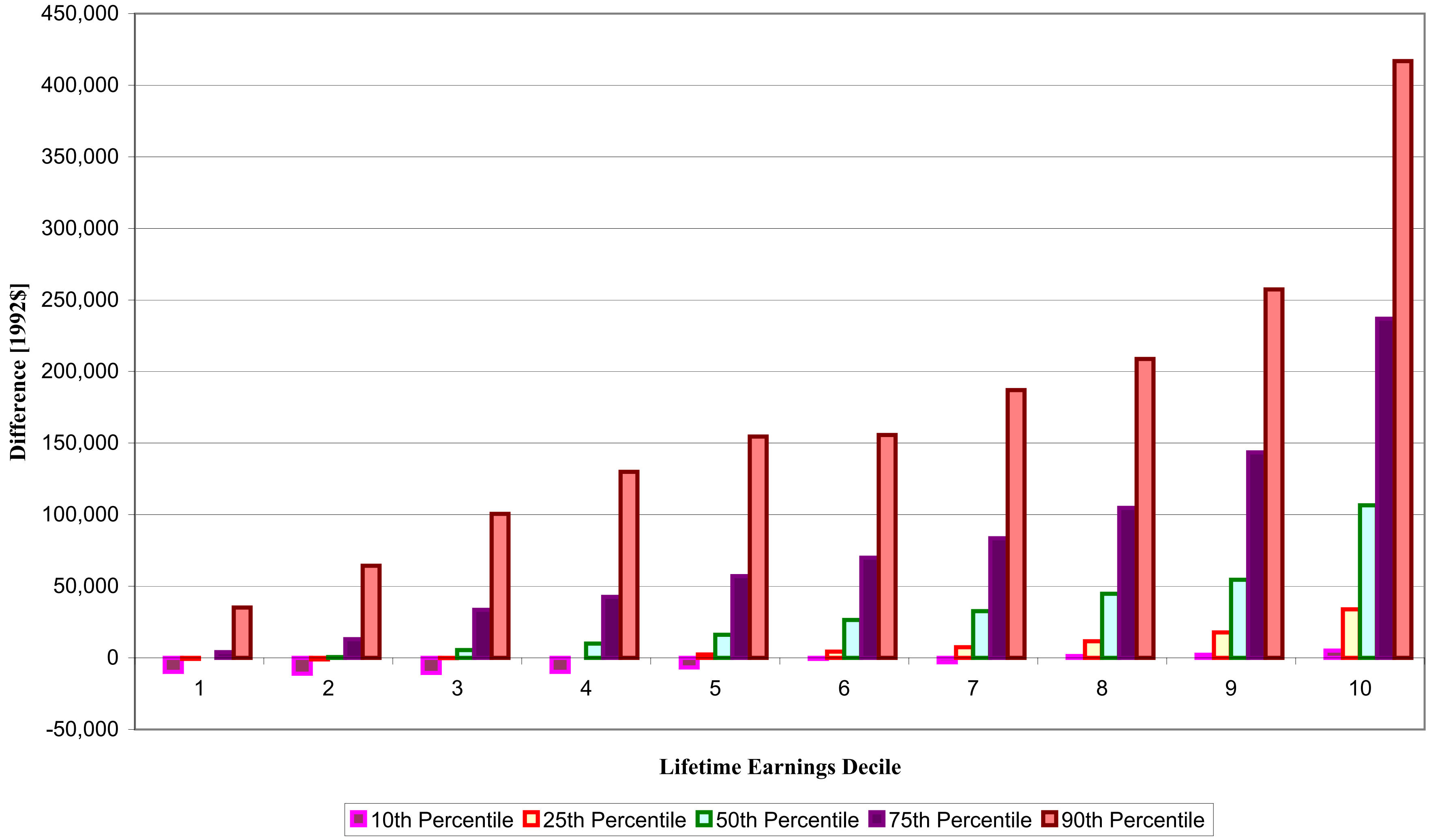


Figure 4: Distribution of "Saving Adequacy" (Observed Minus Simulated Non-DB-Pension Net Worth), Excluding Half of First-Home Housing Wealth