How Will Persistent Low Expected Returns Shape Household Economic Behavior?

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Abstract

Many believe that global capital markets will generate lower returns in the future *versus* the past. We examine how persistently lower real returns will reshape work, retirement, saving, and investment behavior of older persons using a calibrated dynamic life cycle model. In a low return regime, workers build up less wealth in their tax-qualified 401(k) accounts versus the past, claim social security benefits later, and work more. Moreover, the better-educated are more sensitive to real interest rate changes, and the least-educated alter their behavior less. Interestingly, wealth inequality is lower in periods of persistent low expected returns.

Key words: 401(k) plan; saving; investment, Social Security claiming; retirement; tax consequences

JEL: G11, G22, D14, D91

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Despite the recent rise of inflation in the United States and other Western developed countries, it appears that persistently low *real* interest rates are likely to characterize the global economy for some time to come. For instance, governments in many European nations can now borrow at negative real rates for as far out as 50 years (Lewin, 2016; Zeng, 2017). The present paper asks how a long-term low return environment will alter household economic behaviors including work and saving patterns, social security benefit claiming ages, and retirement decumulation.

Our analysis is informed by previous research examining how rational decision makers are influenced by shocks or unanticipated surprises in the environments they confront. For instance, the influential work of Gomes and Michaelides (2005) and Cocco, Gomes, and Maenhout (2015) was extended by Love (2010) and Hubener, Maurer, and Mitchell (2016), who showed how marriage, divorce, and widowhood as well as the arrival of children can influence optimal consumption, insurance, asset allocation, and retirement patterns. Love (2007) and Gomes, Michaelides, and Polkovnichenko (2009) developed a lifecycle model which includes tax-deferred 401(k) retirement accounts. Horneff, Maurer, Mitchell, and Rogalla (2015) reported how capital market surprises alter saving and investment choices. Chai, Horneff, Maurer, and Mitchell (2011) and Gomes, Kotlikoff, and Viceira (2008) explained how labor market adjustments and endogenous claiming of social security benefits can help workers manage earnings and capital market risk in a life cycle setting. Horneff, Maurer, and Mitchell (2018) illustrated how the overall population would change behavior in response to low expected returns.

In what follows, we build and calibrate a life cycle model incorporating population heterogeneity that embeds stock market and labor market uncertainty, stochastic mortality, U.S. tax rules and minimum distribution requirements for 401(k) plans, and real-world social security benefit formulas. This calibrated lifecycle dynamic model produces realistic baseline results that agree with observed saving, work, and claiming age patterns of U.S. households. Next, we simulate anticipated changes in behavior given low real expected returns and compare outcomes with the baseline results. Our particular interest is to show how persistently low returns will alter behavior across a heterogeneous population. For instance, both men and women worker longer and claim social security benefits about a year later, and the response is most pronounced for the college-educated. Additionally, better-educated persons are more sensitive to real returns than other people, so they reduce saving in their tax-qualified retirement accounts the most. Accordingly, wealth inequality will be attenuated in a low expected return world. We also explore how results vary given a "Japanese" style economy with low expected returns and low equity risk premia, and we separately examine how results differ if an age-based investment glide path similar to Target Date funds were to be imposed. Our findings are robust to these alternative formulations.

The Lifecycle Model

To illustrate how persistent low returns are likely to influence household behavior in a life cycle setting, we build and calibrate a rational dynamic consumption and portfolio choice model for utility-maximizing individuals over the life cycle. Using this, we simulate optimal outcomes in a positive real return environment, which we term the "baseline" setting. Finally, we compare those outcomes with results in a zero return world.

Preferences. Working in discrete time, we posit that the individual's decision period starts at $t = 1$ (age of 25) and ends at $T = 76$ (age 100); accordingly, each period corresponds to one year. People have uncertain lifetimes, where the probability of surviving from year t to $t + 1$ is denoted by p_t. We represent preferences in each period by the Cobb Douglas utility function $u_t(C_t, l_t) = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho}$ which is a function of current consumption C_t and leisure time l_t (where the latter is normalized as a fraction of total available time). The parameter α measures leisure preferences, ρ denotes relative risk aversion, and β is the individual's time preference factor. The value function is derived recursively as:

$$J_t = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho} + \beta E_t(p_t J_{t+1}) \,, \qquad (1)$$

with terminal utility $J_T = \frac{(C_T l_T^{\alpha})^{1-\rho}}{1-\rho}$ and $l_t = 1$ after retirement. Survival rates p_t in the value function are taken from US Population Life Tables (Arias 2010). As discussed later, we calibrate the preference parameters in such a way that our results match empirical claiming rates reported by the U.S. Social Security Administration (2015) as well as actual wealth profiles invested in retirement plans.

Labor Income, Work Patterns, and Social Security Retirement Benefits. Our model quite realistically allows individuals to select flexible work effort patterns and a retirement age: specifically, a worker can allocate up to $(1 - l_t)$ = 0.6 of his available time budget to paid work (assuming 100 waking hours per week and 52 weeks per year). Depending on his work effort, his uncertain yearly pre-tax labor income is:

$$Y_{t+1} = (1 - l_t) \cdot w_t \cdot P_{t+1} \cdot U_{t+1}. \qquad (2)$$

Here w_t is a deterministic wage rate component that depends on age, education, and sex, and whether the individual works overtime, full-time, or part-time. The variable $P_{t+1} = P_t \cdot N_{t+1}$ represents the permanent component of the wage rate with independent log-normally distributed shocks $N_t \sim LN(-0.5\sigma_P^2, \sigma_P^2)$ having a mean of one and volatility of σ_P^2. In addition, $U_t \sim LN(-0.5\sigma_U^2, \sigma_U^2)$ is a transitory shock assumed to be uncorrelated with N_t and with volatility σ_U^2. This wage rate calibration follows Horneff, Maurer, and Mitchell (2016) who estimated the deterministic component of the wage rate process w_t^i and the variances of the permanent and transitory wage shocks N_t^i and U_t^i using the 1975–2013 waves of the PSID.[1]

[1] Dollar values are given in 2013 terms.

These are estimated separately by sex and educational level, where the latter is identified as less than High School, High School graduate, or at least some college (<HS, HS, Coll+).[2]

In the U.S., a worker may decide to quit working and claim social security benefits between the ages of 62 and 70, where the benefit paid depends on his average lifetime 35 best years of earnings. If the individual claims benefits prior to (after) the system-defined Normal Retirement Age, his lifelong social security benefits are reduced (increased) according to a pre-specified set of factors. If he works beyond age 62, the model requires that he devote at least one hour per week; also, overtime work is excluded (i.e., $0.01 \leq (1 - l_t) \leq 0.4$).

Constraints During the Work Life. During his work life, an individual may use his cash on hand for consumption or for investments. Some portion A_t of the worker's pre-tax salary Y_t can be invested in a tax-qualified 401(k)-retirement plan (up to a limit of $18,000, and from age 50 onwards, an additional $6,000 catch up contributions is allowed).[3] Specifically, the plan is of the of the deferred taxation type such that contributions to the account and investment earnings are tax-exempt, while withdrawals are taxed. In addition, the worker may invest outside his retirement plan in risky stocks S_t and riskless bonds B_t. As such, his cash on hand X_t in each year is given by:

$$X_t = C_t + S_t + B_t + A_t, \tag{3}$$

where the usual constraints apply (i.e., $C_t, A_t, S_t, B_t \geq 0$). One year later, his cash on hand is given by the value of stocks (bonds) having earned an uncertain (riskless) gross return of R_{t+1} (R_f), plus income from work (after housing expenses h_t), plus withdrawals (W_t) from the 401(k) plan, minus any federal/state/city taxes and social security contributions (Tax_{t+1}):

$$X_{t+1} = S_t R_{t+1} + B_t R_f + Y_{t+1}(1 - h_t) + W_t - Tax_{t+1}\,. \tag{4}$$

[2] Details are given in Horneff, Maurer and Mitchell (2016); see Table A1, Appendix A.
[3] This approach to retirement benefit taxation is therefore similar to how conventional defined benefit and defined contribution plan payments are handled under U.S. tax law as per regulations from 2015 onward.

During his work life, the individual pays taxes (Tax_{t+1}) which reduce his cash on hand available for consumption and investments Our model builds these in using a realistic payroll tax rate of 11.65% (1.45% for Medicare, 4% city and state taxes, and 6.2% for social security taxes). Additionally, under the US tax system, individuals must also pay progressive taxes on labor income and on withdrawals from tax-qualified retirement plans (including a 10% penalty tax for withdrawals before age 60), and on returns on stocks and bonds held outside tax-qualified retirement accounts.[4] If an individual's cash on hand falls below $X_{t+1} \leq \$5{,}879$ p.a. (an amount also exempt from income taxes), we posit that he will receive subsistence support from the government at a minimum level of $5,879 for the next year.

Prior to the endogenous retirement age $t = K$, assets in the worker's tax-qualified retirement plan are invested in bonds earning a risk-free gross (pre-tax) return of R_f, and risky stocks paying an uncertain gross return of R_t. Each year, the individual decides on the relative exposure of his retirement assets in stocks ω_t^s and $(1 - \omega_t^s)$ in bonds. The total value ($F_{t+1}^{401(k)}$) of his 401(k) assets at time $t + 1$ is determined by the previous period's value minus withdrawals ($W_t \leq F_t^{401(k)}$), plus additional employee contributions (A_t), plus matching contributions (if any) from the employer (M_t) , and nontaxed returns from stocks and bonds:

$$F_{t+1}^{401(k)} = \omega_t^s \left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t \right) \mathrm{R_{t+1}} + (1 - \omega_t^s) \left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t \right) R_f, \ \ for \ \ t < K. \quad (5)$$

Subject to complex matching limits imposed by the Internal Revenue Code, employer matches are often feasible in the retirement accounts. Here we assume that the employer matches 100% of employee contributions up to 5% of the employee's yearly salary (but, as per US law, not

[4] For details, see Horneff, Maurer and Mitchell (2016).

exceeding \$265,000 or \$ 13,250 per year).[5] Accordingly, the employer matching contribution is given by:

$$M_t = \min\big(A_t, \min(0.05A_t, 13{,}250)\big). \quad (6)$$

Wealth Dynamics after Claiming. As per U.S. social security rules, the worker may claim social security benefits between age 62 and 70. The social security benefit formula uses the 35 best years of income converted into an annual Primary Insurance Amount (or the unreduced social security benefit) using a redistributive formula.[6] Also by law, a retiree's Required Minimum Distribution (RMD) amounts from his tax-qualified 401(k) account are set in accordance with the IRS Uniform Lifetime Table measures (IRS 2012a, b). Federal income taxes are calculated based on the individual's taxable income, the six (progressive) income tax brackets and the corresponding marginal tax rates for each tax bracket (Horneff et al. 2015).

After retirement at the endogenous age K, the individual has the opportunity to save outside the tax-qualified retirement plan in stocks and bonds:

$$X_t = C_t + S_t + B_t. \quad (7)$$

We model housing costs h_t as in Love (2010). Accordingly, cash on hand for the next period evolves as follows:

$$X_{t+1} = S_t R_{t+1} + B_t R_f + Y_{t+1}(1 - h_t) + W_t - Tax_{t+1}. \quad (8)$$

Social security old age retirement benefits are determined by the individual's Primary Insurance Amount (PIA), which is determined by his 35 best years of earnings and his claiming age.[7] Social security payments (Y_{t+1}) in retirement ($t \geq K$) are given by:

$$Y_{t+1} = PIA_K \cdot \lambda_K \cdot \varepsilon_{t+1} . \quad (9)$$

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[5] Love (2007) reported that US pension contribution matching rates range between 1% and 10% with a modal value of 6%.

[6] For more on the Social Security formula see https://www.ssa.gov/oact/cola/piaformula.html.

[7] The benefit formula is a piece-wise linear function of the Average Indexed Monthly Earnings providing (as of 2013) a replacement rate of 90% up to a first bend point (\$791), 32% between the first and the second bend point \$4768), and 15% above that. See US SSA (nd).

Here λ_K is the adjustment factor for claiming prior to or after the government-set Normal Retirement Age, which in this exercise is set at age 66.[8] The variable ε_t is a transitory shock $\varepsilon_t \sim \mathrm{LN}(-0.5\sigma_\varepsilon^2, \sigma_\varepsilon^2)$ reflecting out-of-pocket medical and other expenditure shocks during retirement (as in Love 2010). Benefit payments from social security are partially subject to tax at the individual's federal income tax rate, as well as a 1.45% Medicare and 4% city and state tax.[9]

We model the retiree's 401(k) plan payouts as follows:

$$F_{t+1}^{401(k)} = \omega_t^s\left(F_t^{401(k)} - \mathrm{W_t}\right)\mathrm{R_{t+1}} + (1-\omega_t^s)\left(F_t^{401(k)} - \mathrm{W_t}\right)R_f, \quad for\ t < K. \tag{10}$$

Under US law, plan participants must take retirement account payouts from age 70 onwards according to the Required Minimum Distribution (RMD) rules (*m*) specified by the Internal Revenue Service (IRS 2012b). Accordingly, to avoid substantial penalty taxes withdrawals from the retirement account, the retiree must take into account the following constraint: $F_t^{401(k)} m \leq W_t < F_t^{401(k)}$. All of these rich institutional factors are taken into account in generating our model outcomes.

Optimal Behavior Under the Baseline

We first simulate our model under what had been considered to be "normal" interest rate conditions, to illustrate baseline optimal patterns of consumption, saving, work, social security claiming, portfolio allocations outside inside and outside the tax-qualified accounts, and withdrawals from the tax-qualified 401(k) plans. This baseline calibration assumes a risk-

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[8] The factors we use are 0.75 (claiming age 62), 0.8 (claiming age 63), 0.867 (claiming age 64), 0.933 (claiming age 65), 1.00 (claiming age 66), 1.08 (claiming age 67), 1.16 (claiming age 68), 1.24 (claiming age 69), and 1.32 (claiming age 70). See US SSA (nd,). The Normal Retirement Age will move to age 67 in the near future.

[9] For tax rules for Social Security, see US SSA (nd). Based on the combined income up to 85% of Social Security can be taxed for households with high income additional to Social Security benefits. Yet because of quite generous exemptions, many households receive their Social Security benefits tax-free (see Horneff, Maurer, and Mitchell 2016).

free interest rate of 1%, and an expected risk premium on stocks (over the risk-free rate) of 5% with a volatility of 18%. When simulating other return environments, we vary these assumptions and then assess how behavioral outcomes compare.

We posit that households maximize the value function (1) under the budget restrictions given above. Since this optimization problem cannot be solved analytically, we apply a numerical procedure using dynamic stochastic programming. To generate optimal policy functions, in each period t we discretize the space in four dimensions $30(X)\times 20(F^{401(k)})\times 10(P)\times 9(K)$, with X being cash on hand, $F^{401(k)}$ assets held in the 401(k) retirement plan, P permanent income, and K the claiming age. Next, we simulate 100,000 independent life cycles based on optimal feedback controls for each of the six population subgroups of interest (male/female in three education groups of <HS/HS/Coll+). Using weights from the National Center on Education Statistics (2012) we aggregate the subgroups to obtain national mean values. The population is comprised of 50.7% females (of whom 62% have Coll+, 30% have HS, and 8% have <HS education), and 49.3% males (of whom 60% have Coll+, 30% have HS, and 10% <HS education).

Baseline Results. For each of the six subgroups of interest, we select a unique set of values of the preference parameters so the model produces national 401(k) wealth profiles and social security claiming patterns compatible with historical evidence. After solving the model several times, we find that a coefficient of relative risk aversion ρ of 5, a time discount rate β of 0.96 and a leisure preference parameter of $\alpha = 0.9$ are the parameters that closely match simulated model outcomes to empirical evidence.[10]

This is evident from Panel A of Figure 1 which indicates that the social security claiming patterns generated by our baseline model align well with empirical claiming rates reported by

[10] Interestingly, these parameters are also in line with those used in prior work on life-cycle portfolio choice; see, for instance, Brown (2001).

the US Social Security Administration (2015).[11] In particular, the model produces a substantial peak at the earliest claiming age of 62, mirroring the data where around 45% of workers claim benefits at that early age. Also in line with the evidence, a smaller second peak can be seen at the (system-defined) Full Retirement Age of 66, where about 15% of workers claim benefits for the first time.

Figure 1 here

In addition, our model closely tracks EBRI (2017) data on average 401(k) account balances (in year 2015) for 7.5 million plan participants in five age groups (20-29, 30-39, 40-49, 50-59, and 60-69). Panel B of Figure 1 compares our simulated and the empirical data for the five age groups, and it reveals that our simulated outcomes are remarkably close to the empirically-observed 401(k) account values.

Overall, then, our model generates results that agree closely with observed saving and social security claiming behavior of U.S. households during what we call the "baseline" economic environment, before the advent of persistent low expected returns.

How Persistent Low Returns Will Drive Behavioral Change

To determine how optimal economic behavior would differ in alternative interest rate environments, we compare outcomes for real risk-free interest rates of 0% and 2%, with a particular focus on the lowest and the highest expected return: in this case, the equity risk premium remains at 5% as in the baseline scenario. In addition, we analyze a situation a real risk-free 0% interest rate and an equity risk premium of only 2%. The latter scenario is comparable to the capital market situation characterizing Japan over the past 30 years. Table 1 shows how social security claiming patterns would respond by gender and age, average claiming ages, and average hours of work.

[11] This model therefore provides a theoretical backing for the empirical claiming patterns shown by Shoven and Slavov (2012, 2014).

Table 1 here

A first finding is that optimal social security claiming ages and hours of work increase when the risk-free rate is lower. This is not surprising, inasmuch as individuals earn less on their savings in a 0% environment and hence would need to withdraw more of their assets if they claimed early. Specifically, when the long term interest rate is 0% instead of 2%, average claiming ages rise by about one year later and average work hours are five percent higher, for both men and women. Moreover, substantially fewer women and men claim at age 62 in the low-return world: only 35.5% (24.2) of the females (males) do so when the real return is 0%, versus 46.1% (37.2%) at a 2% real return. This supports Shoven and Slavov's (2012) and Cahill, Giandrea, and Quinn's (2015) surmise that delayed claiming is more appealing in a low versus a high return environment. In the capital market scenario with a real interest rate of 0% and an equity premium of only 2%, behavior changes even more in the same direction. Men and women claim 1.5 years later on average, compared to the high return case. In addition, during the work life, individuals devote per week more than 3 hours more on the job, compared to the high return case.

Figure 2 provides additional insight into the heterogeneous impact of low versus high returns. Specifically, the most-educated defer claiming more when returns are 0% versus 2%; a similar conclusion applies to both men and women. By contrast, the least-educated (particularly women) change claiming behavior very little.

Figure 2 here

Next, we report how optimal wealth accumulation patterns vary with the interest rate regime, both inside and outside 401(k) plans. Table 2 shows that workers build up far less wealth in their retirement plans in a low versus a higher expected return environment. For instance, if the safe yield is only 0%, middle-aged women (age 45-54) optimally accumulate an average of about $145,000 in their 401(k) plans. By contrast, in the 2% yield scenario, they average 20% more, or $168,400 at the same point in their life cycle. Middle-aged men accumulate $176,100 in the zero-rate environment, and 20% more ($206,700) in the 2% interest rate scenario. In other words, the gain from saving in pretax plans is lower in a low return environment, depressing the tax advantage of saving in 401(k) plans. The Table also shows that the impact of a lower interest rate on assets in non-qualified accounts is relatively small. The reason is that such accounts tend to be held for precautionary reasons, to smooth consumption in case of income shocks or capital market shocks.

Table 2 here

In the worst-case "Japanese" capital market scenario, middle-aged (age 45-54) men as well as women accumulate 40% less in their tax-qualified retirement accounts compared to the more favorable baseline situation where the interest rate was 2% and the equity risk premium 5%. The "Japanese" economic environment has a larger percentage impact boosting assets held outside retirement accounts, by 53% for middle-aged women and 39% for similar-aged men. Nevertheless, these nonpension accounts remain small compared to the 401(k) asset holdings.

Figure 3 shows how 401(k) asset values diverge by gender and education under the low- versus the high-expected return scenarios. When returns are low, the optimal value of tax-qualified retirement savings proves to be substantially smaller for both men and women, and for all three age and education groups. Additionally, saving reductions are most notable for the best-educated individuals. Conversely, in a higher return world, the college-educated save 30-40% more, with 15% less for high-school dropouts. Accordingly, wealth inequality is diminished in times of low real expected returns.

Figure 3 here

Thus far, our analysis has assumed that households optimize their asset allocation inside their 401(k) plans (i.e. the portfolio weights in stocks and bonds are endogenous). Yet a large majority of 401(k) retirement plans today automatically default workers' contributions into target-date investment strategies that follow an age-based allocation rule, entailing higher equity shares early in life and lower ones nearing and into retirement (Vanguard 2017).

Moreover, the regulatory environment has encouraged this practice, in that the 2006 Pension Protection Act permitted plan sponsors to include Target Date Funds (TDFs) as qualified default investment alternatives in participant-directed plans. Accordingly, we investigate how sensitive our results are to a default 401(k) allocation that follows an age-related portfolio rule; while there are many variants in the market, generally speaking the percentage of 401(k) assets invested in equities follows a (120 – age)/100 rule. This we implement in Table 3.[12]

Table 3 here

To illustrate the key differences in outcomes when the real interest rates drops from 2% to 0%, we report average differences in social security claiming ages (in years) and average percentage differences in 401(k) assets for the two investment strategies. Both females and males claim slightly later if the 401(k) plan were to be invested according to a Target Date (age-based) rule versus optimal endogenous equity weights. This is accompanied by a larger drop in 401(k) assets for the Target Date portfolio, compared to the endogenous asset allocation case. This is due to the fact that the worker's exposure to bonds is higher under the Target Date approach versus the optimal asset allocation, particularly for older workers and for retirees. Nevertheless, as these differences are small in magnitude, we conclude the two investment approaches do not materially change economic behaviors in the context of persistently low interest rates.

Conclusions

Over $8 trillion of bonds currently trade at negative rates around the world, compared to none in 2014 (Slok, 2018). Despite this new global reality, relatively little research has focused on the profound impacts of persistent low returns on life cycle work, saving, investment, and social security claiming behavior.

[12] We thank David Richardson for this suggestion.

Our contribution in this paper is therefore to develop and calibrate a richly-detailed life cycle model that enables us to explore the potential impacts of this new economic environment across heterogeneous population subgroups. To this end, we model realistic tax, social security, and minimum distribution rules, as well as uncertain income, stock returns, medical spending, and mortality. We then use this model to assess how key outcomes change. The baseline simulation which assumes a 1% expected real return generates wealth and claiming patterns quite consistent with the evidence, including a peak claiming rate at the earliest feasible age of 62, and asset accumulation patterns comparable to actual data.

By contrast, a zero expected return induces workers to claim social security benefits later and increase work effort. Moreover, people save less, particularly in their tax-qualified accounts, and they draw down their 401(k) assets sooner. Results prove to be similar for men and women, yet the best-educated subgroup optimally changes behavior more, compared to the least-educated. Overall, the changes reduce observed wealth inequality. Sensitivity analyses allowing for age-based investment profiles akin to Target Date funds shows that results are robust. We also compare our results to those generated by a “Japanese” style economy with low expected returns and low equity premia, and again findings are comparable.

We leave for future work a discussion of the potential macroeconomic consequences of reduced saving and earlier claiming patterns. Nevertheless, our life cycle model which embodies richly detailed tax and social security claiming rules is clearly an invaluable tool to help assess how households will react to the “new normal” financial market conditions.

References

Arias, E. (2010). United States Life Tables, 2005. *National Vital Statistics Reports* 58(10), US National Center for Health Statistics: Hyattsville, Maryland.

Brown, J. R. (2001). Private Pensions, Mortality Risk, and the Decision to Annuitize. *Journal of Public Economics* 82(1): 29-62

Cahill, K., M. Giandrea, and J. Quinn. (2015). Evolving Patterns of Work and Retirement. In *The Handbook of Aging and the Social Sciences*, 8th ed. L. George and K. Ferraro, Eds. London UK: Academic Press: 271-291.

Chai, J., W. Horneff, R. Maurer, and O. S. Mitchell. (2011). Optimal Portfolio Choice over the Life Cycle with Flexible Work, Endogenous Retirement, and Lifetime Payouts. *Review of Finance* 15(4): 875-907.

Cocco, J., F. Gomes, and P. Maenhout. (2005). Consumption and Portfolio Choice over the Life Cycle. *Review of Financial Studies* 18(2): 491-533.

Employee Benefit Research Institute. (EBRI 2017). What Does Consistent Participation in 401(k) Plans Generate? Changes in 401(k) Plan Account Balances, 2010–2015. *EBRI Issue BRIEF No.439, Oct. 2017.*

Gomes, F. J., L. J. Kotlikoff, and L. M. Viceira. (2008). Optimal Life-Cycle Investing with Flexible Labor Supply: A Welfare Analysis of Life-Cycle Funds. *American Economic Review: Papers & Proceedings* 98(2): 297-303.

Gomes, F. J., and A. Michaelides. 2005. Optimal Life-Cycle Asset Allocation: Understanding the Empirical Evidence. *The Journal of Finance* 60(2):869-904.

Gomes, F., A. Michaelides, and V. Polkovnichenko (2009). Optimal Savings with Taxable and Tax-Deferred Accounts. *Review of Economic Dynamics* 12(4): 718-735.

Horneff, V., R. Maurer, and O. S. Mitchell. (2018). "How Low Returns Alter Optimal Life Cycle Saving, Investment, and Retirement Behavior." In R. Clark, R. Maurer, and O. S. Mitchell, eds. *How Persistent Low Returns Will Shape Saving and Retirement*. (2018). Oxford: Oxford University Press. *Forthcoming*.

Horneff, V., R. Maurer, O.S. Mitchell, and R. Rogalla. (2015). Optimal Life Cycle Portfolio Choice with Variable Annuities Offering Liquidity and Investment Downside Protection. *Insurance: Mathematics and Economics* 63(1): 91-107.

Horneff, V., R. Maurer, and O.S. Mitchell. (2016). Putting the Pension Back in 401(k) Plans: Optimal versus Default Longevity Income Annuities. *NBER Working Paper* 22717

Hubener, A., R. Maurer, and O. S. Mitchell. (2016). How Family Status and Social Security Claiming Options Shape Optimal Life Cycle Portfolios. *Review of Financial Studies* 29(4): 937-978.

Internal Revenue Service (IRS 2012a). Form 1040 (Tax Tables): Tax Tables and Tax Rate Schedules. Downloaded 03/12/2013. www.irs.gov/pub/irs-pdf/i1040tt.pdf.

Internal Revenue Service (IRS 2012b). Retirement Plan and IRA Required Minimum Distributions FAQs. https://www.irs.gov/Retirement-Plans/Retirement-Plans-FAQs-regarding-Required-Minimum-Distributions.

Lewin, J. (2016). Swiss Bond Yields Now Negative Out to 50 Years. *FT.com*, July 5. https://www.ft.com/content/2ae4237a-2d3e-33dd-b9e0-120c4a93a29c

Love, D.A. (2007). What Can Life-Cycle Models Tell Us about 401(k) Contributions and Participation? *Journal of Pension Economics and Finance* 6 (2): 147-185.

Love, D.A. (2010). The Effects of Marital Status and Children on Savings and Portfolio Choice. *Review of Financial Studies* 23(1): 385-432.

Shoven, J.B., and S. N. Slavov. (2014). Does it Pay to Delay Social Security? *Journal of Pension Economics and Finance* 13 (2): 121-144.

Shoven, J.B., and S. N. Slavov. (2012). The Decision to Delay Social Security Benefits: Theory and Evidence, NBER Working Paper 17866.

Slok T. (2018). $8trn Bubble Still There. *Deutsche Bank Research Presentation*. June.

US Social Security Administration (US SSA nd). *Fact Sheet: Benefit Formula Bend Points*. https://www.ssa.gov/oact/cola/bendpoints.html

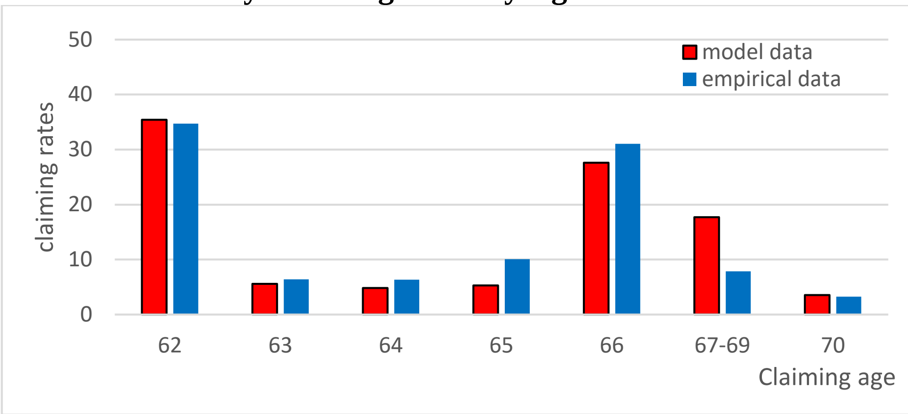
US Social Security Administration. (2015). *Annual Statistical Supplement to the Social Security Bulletin, 2015* (Table 6.B 5).

Vanguard. (2017). *How America Saves 2017*. https://pressroom.vanguard.com/nonindexed/How-America-Saves-2017.pdf

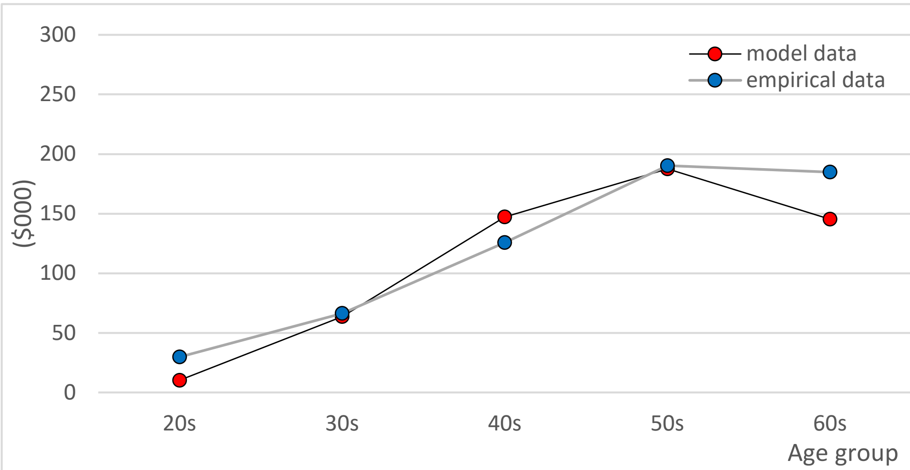
Zeng, M. (2017). US 10-Year Note Yield Hits Low for the Month. *WallStreetJournal.com.* March 31. https://www.wsj.com/articles/u-s-bonds-rebound-from-earlier-losses-1490108750?tesla=y

Figure 1: Social Security Claiming Patterns and 401(k) Account Values in a "Normal" Return Environment: Model versus Data

A . Social Security Claiming Rates by Age

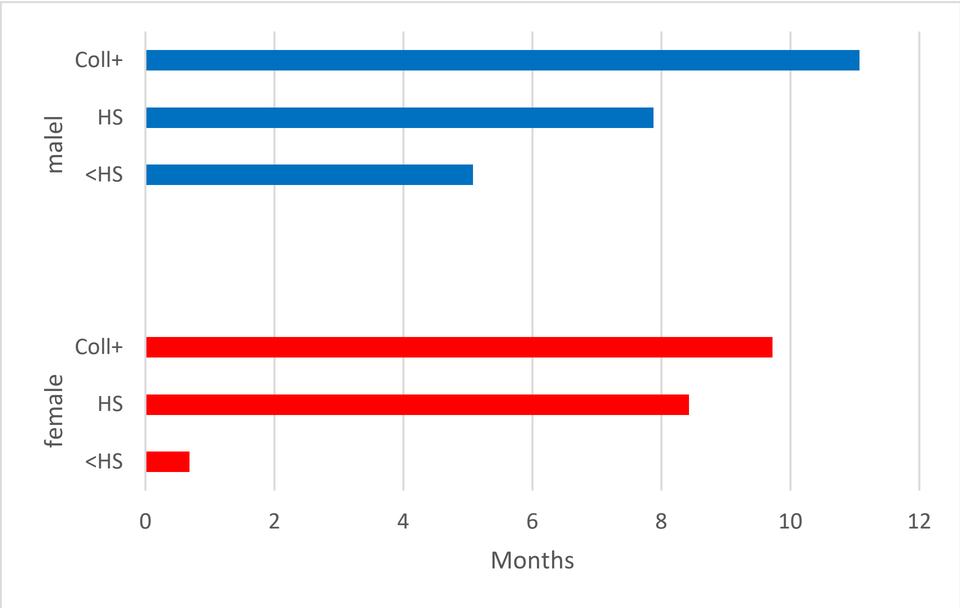


B. Average 401(k) Account Values by Age



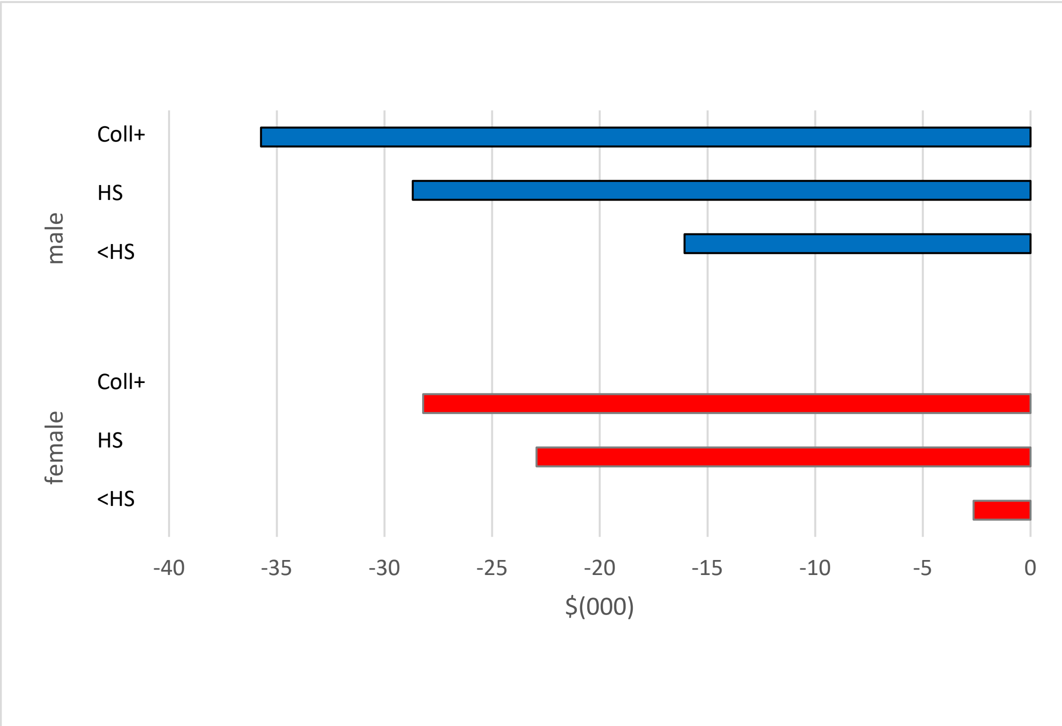
Notes: Panel A compares endogenous social security claiming rates at ages 62-70 generated by our life cycle model versus retirement (and disability) empirical claiming rates by age from Social Security Administration (2015). Expected values are calculated from 100,000 simulated lifecycles based on optimal feedback controls for each of the six subgroups of interest. Results for the female (male) population use income by education levels for men (62% +Coll; 30% HS; 8% <HS) and women (60% +Coll; 30% HS; 10%<HS). Baseline calibration parameters are: risk aversion $\rho = 5$; time preference $\beta = 0.96$; and leisure preference α=0.9. Social security benefits are based on average permanent incomes and the 2013 value of bendpoints; minimum required withdrawals from 401(k) plans are based on life expectancy using the IRS-Uniform Lifetime Table in 2013; tax rules for 401(k) plans are as in Horneff (2015). The risk premium for stock returns is 5% and return volatility 18%; the risk-free rate in the Baseline is 1%. Panel B compares simulated 401(k) account balances by age (averages for ages 20-29, 30-39, 40-49, 50-59, and 60-69) with empirical data from EBRI (2017). Source: Authors' calculations.

Figure 2: Average Increase in Social Security Claiming Ages (in Months) by Gender and Education for Expected Real Interest Rates of 0% instead of 2%



Notes: This Figure reports the average claiming age *difference* for an interest rate level of 0% instead of 2%, by sex and three education groups (<HS, HS, +Coll), derived from 100,000 simulated lifecycles using optimal feedback controls in our life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. Other parameters are in Figure 1. Source: Authors' calculations.

Figure 3: Average Decline in 401(k) Assets by Gender and Education for Expected Real Interest Rates of 0% instead of 2%



Notes: This Figure reports the average *difference* in 401(k) assets (over the lifecycle) for an interest rate level of 0% instead of 2%, by sex and three education groups (<HS, HS, +Coll), derived from 100,000 simulated lifecycles using optimal feedback controls in our life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. Other parameters are as in Figure 1. Source: Authors' calculations.

Table 1: Optimal Social Security Claiming Ages and Work Hours by Gender for Different Capital Market Scenarios

	Females			*Males*		
	Japanese Scenario	0% Interest Rate	2% Interest Rate	Japanese Scenario	0% Interest Rate	2% Interest Rate
Panel A: Percent Claiming by Age						
Age 62	31.6	35.5	46.1	19.4	24.2	37.2
Age 63	2.2	4.2	5.0	2.9	5.3	6.1
Age 64	2.2	3.6	3.1	4.6	5.4	5.7
Age 65	4.4	4.6	3.7	5.9	7.2	5.6
Age 66	16.8	23.1	26.6	20.0	29.8	32.5
Age 67	8.2	8.6	5.0	12.2	10.6	4.5
Age 68	14.4	10.3	5.2	23.1	9.4	2.8
Age 69	10.8	6.1	2.1	5.3	4.6	2.0
Age 70	9.5	4.0	3.2	6.6	3.4	3.6
Panel B: Average Claiming Ages						
	65.7	65.0	64.3	66.0	65.3	64.5
Panel C: Average Weekly Hours of Work						
	35.2	33.4	32.0	41.8	39.8	38.2

Notes: This Table reports claiming ages and weekly hours of work by age and gender, under three interest rate scenarios. Expected values are derived from 100,000 simulated lifecycles using optimal feedback controls in our life cycle model. The risk premium for stock returns is 5% and return volatility 18% in the 0% and 2% interest rate scenario. In the Japanese scenario, the interest rate is 0% and the risk premium for stocks is 2%. Other parameters are as in Figure 1. Source: Authors' calculations.

Table 2: Optimal Lifecycle Asset Accumulation Patterns by Gender for Different Capital Market Scenarios

	Females			*Males*		
	Japanese Scenario	0% Interest Rate	2% Interest Rate	Japanese Scenario	0% Interest Rate	2% Interest Rate
Panel A: 401(k) Assets ($000)						
Age 25-34	19.4	25.0	28.5	19.1	24.4	27.5
Age 35-44	65.5	92.3	107.9	77.5	103.9	120.8
Age 45-54	93.2	145.0	168.4	119.1	176.1	206.7
Age 55-64	79.2	129.6	163.8	93.7	158.1	207.7
Age 65-74	39.8	94.4	140.2	37.1	105.8	167.1
Age 75-84	14.0	55.3	95.9	10.5	54.2	106.5
Age 85-94	1.7	17.7	39.4	1.0	14.7	39.5
Panel B: Non-Qualified Assets ($000)						
Age 25-34	3.7	3.7	3.9	5.0	5.1	5.0
Age 35-44	12.8	9.4	8.5	15.9	15.0	12.4
Age 45-54	20.7	12.3	13.6	25.0	20.5	18.0
Age 55-64	16.7	15.5	18.2	23.0	24.0	23.3
Age 65-74	13.1	12.6	12.5	20.0	18.3	17.8
Age 75-84	7.2	7.2	7.8	12.3	11.5	12.2
Age 85-94	5.8	6.0	6.1	8.4	8.4	8.3

Notes: This Table reports expected assets in tax-qualified 401(k) plans and non-qualified assets by age and gender, under three interest rate scenarios. Expected values are derived from 100,000 simulated lifecycles using optimal feedback controls in our life cycle model. The risk premium for stock returns is 5% and return volatility 18%. In the "Japanese" scenario, the interest rate is 0% and the risk premium for stocks is 2%. Other parameters are as in Figure 1. Source: Authors' calculations.

Table 3: Impact of Endogenous versus Target Date Investments of 401(k) Assets on Claiming and Wealth Accumulation: Expected Real Interest Rates of 0% instead of 2%

	Females		*Males*	
	Claiming Age Change	401(k) Asset Change	Claiming Age Change	401(k) Asset Change
Target Date	+1.1	-18%	+1.0	-22%
Endogenous	+0.8	-15%	+0.9	-20%

Notes: This Table reports the average *difference* in 401(k) assets and average *difference* in Social Security claiming ages over the lifecycle for an interest rate level of 0% instead of 2% used in the base case. For the row labeled life Target Date, the equity weights of 401(k) assets are determined according to an age-based (120-age)/100 rule. For the row labeled Endogenous, the equity weights in 401(k) assets are derived from optimal feedback controls in the life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. Other parameters are as in Figure 1. Source: Authors' calculations.