10-31-2019

How Would 401(k) ‘Rothification’ Alter Saving, Retirement Security, and Inequality?

Vanya Horneff

Raimond Maurer

Olivia S. Mitchell
The Wharton School, Univ. of PA, mitchelo@wharton.upenn.edu

How Would 401(k) 'Rothification' Alter Saving, Retirement Security, and Inequality?

Abstract

The US has long incentivized retirement saving in 401(k) and similar retirement accounts by permitting workers to defer taxes on contributions, levying them instead when retirees withdraw funds in retirement. This paper develops a dynamic life cycle model to show how and whether 'Rothification' – that is, taxing 401(k) contributions rather than payouts – would alter household saving, investment, and Social Security claiming patterns. We show that these changes differ importantly for low- versus higher-paid workers. We conclude that moving to a system that taxes pension contributions instead of withdrawals will lead to later retirement ages, particularly for the better-educated. It also would reduce work hours and lifetime tax payments and increase wealth and consumption inequality. In addition, we show how these behaviors would differ in a persistently low interest rate environment versus a more "normal" historical return world.

Keywords

pension taxation, 401(k) plan, retirement, saving, Social Security claiming, retirement income, minimum distribution requirements, inequality

Disciplines

Economics

How Would 401(k) 'Rothification' Alter Saving, Retirement Security, and Inequality?

Vanya Horneff, Raimond Maurer, and Olivia S. Mitchell

October 31, 2019

PRC WP2019-20
Pension Research Council Working Paper
Pension Research Council
The Wharton School, University of Pennsylvania
3620 Locust Walk, 3302 SH-DH
Philadelphia, PA 19104-6302
Tel.: 215.573.3414 Fax: 215.573.3418
Email: prc@wharton.upenn.edu
http://www.pensionresearchcouncil.org

Acknowledgements: The authors acknowledge research support for this work from the Michigan Retirement and Disability Research Center (MRDRC), the German Investment and Asset Management Association (BVI), and the Pension Research Council/Boettner Center at The Wharton School of the University of Pennsylvania. We also thank the initiative High Performance Computing in Hessen for grating us computing time at the LOEWE-CSC and Lichtenberg Cluster; they also thank Anna Maria Maurer for helpful comments. The research reported herein was derived in whole or in part from research activities performed pursuant to a grant from the U.S. Social Security Administration (SSA) funded as part of the Retirement and Disability Research Consortium. The opinions and conclusions expressed are solely those of the authors and do not represent the opinions or policy of SSA or any agency of the Federal Government, or any of the other institutions with which the authors are affiliated. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of the contents of this report. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation or favoring by the United States Government or any agency thereof. This research is part of the NBER Aging program and the Household Portfolio workshop. All findings, interpretations, and conclusions of this paper represent the views of the author(s) and not those of the Wharton School or the Pension Research Council.

How Would 401(k) 'Rothification' Alter Saving, Retirement Security, and Inequality?

Vanya Horneff, Raimond Maurer and Olivia S. Mitchell

Abstract

The US has long incentivized retirement saving in 401(k) and similar retirement accounts by permitting workers to defer taxes on contributions, levying them instead when retirees withdraw funds in retirement. This paper develops a dynamic life cycle model to show how and whether 'Rothification' – that is, taxing 401(k) contributions rather than payouts – would alter household saving, investment, and Social Security claiming patterns. We show that these changes differ importantly for low- versus higher-paid workers. We conclude that moving to a system that taxes pension contributions instead of withdrawals will lead to later retirement ages, particularly for the better-educated. It also would reduce work hours and lifetime tax payments and increase wealth and consumption inequality. In addition, we show how these behaviors would differ in a persistently low interest rate environment versus a more "normal" historical return world.

Keywords: pension taxation, 401(k) plan, retirement, saving, Social Security claiming, retirement income, minimum distribution requirements, inequality

JEL: G11, G22, D14, D91

Vanya Horneff
Finance Department, Goethe University
Theodor-W.-Adorno-Platz 3 (Uni-PF. H 23)
Frankfurt am Main, Germany
E-Mail: vhorneff@finance.uni-frankfurt.de

Raimond Maurer
Finance Department, Goethe University
Theodor-W.-Adorno-Platz 3 (Uni-PF. H 23)
Frankfurt am Main, Germany
E-Mail: maurer@finance.uni-frankfurt.de

Olivia S. Mitchell
Wharton School, University of Pennsylvania
3620 Locust Walk, 3302 SH-DH
Philadelphia, PA 19104
E-Mail: mitchelo@wharton.upenn.edu

How Would 401(k) 'Rothification' Alter Saving, Retirement Security, and Inequality?

The US has long incentivized retirement saving by deferring taxes on workers' pension contributions until the assets are withdrawn in old age, at which point the withdrawn funds become subject to income tax. In this way, most 401(k) retirement accounts are taxed according to an "EET" regime: workers contribute out of pre-tax earnings, recognize pre-tax investment earnings in their accounts, and pay income tax on withdrawals during retirement. This policy has a large current budgetary cost: the US Treasury foregoes over $100 billion per year due to tax-deferred contributions to 401(k) and similar plans (Thornton 2017).[1] Partly because of projected federal budget shortfalls, some policymakers have recently proposed eliminating or capping tax-qualified retirement plan contributions, a practice termed 'Rothification,' named after Senator William Roth who successfully passed legislation allowing this in 1997. Specifically, the idea would be to treat all future retirement contributions to a "TEE" regime, in which workers would contribute to their pensions out of after-tax income, and then no additional tax would be levied thereafter (Schoeff 2017).

The Rothification idea has been a topic of considerable recent discussion, with former President Obama recommending a pre-tax pension contribution cap in 2015, and related proposals were offered by the Trump Administration during the 2017 tax reform debate. Though those proposals were not enacted, the topic is certain to be revisited given the amount of revenue involved. In an economy with a single tax rate and a flat benefit system, taxing benefits now versus later is unlikely to change behavior. Yet in the US economy, there are numerous nonlinearities in the tax and Social Security systems which render less obvious the ways in which such a reform might alter household behavior. Accordingly, if such a reform

[1] The Federal Government does receive some of the deferred tax revenue later when benefits are paid out, but retirees are often in a lower tax bracket than when working. Moreover the deferral of taxes tends to mean that the revenue is not 'captured' in the traditional 10-year accounting window used for revenue neutrality calculations. Hence moving the tax capture forward is politically appealing to some; see Sibaie (2017).

were to be passed in the future, it could have important implications for household behavior. Moreover, effects are likely to vary across different population subgroups.

To date, however, there has been no coherent microeconomic analysis of how Rothification could alter household consumption, saving, retirement patterns, and tax-payments. Our paper fills this gap by developing a richly detailed and state-of-the-art life cycle stochastic dynamic model with endogenous work effort, portfolio choice, consumption, saving, and Social Security claiming patterns, to evaluate such a policy's potential effects for the population overall and for different population subgroups. Of key importance is heterogeneity: that is, how outcomes will differ for workers with different lifetime earnings profiles. For instance, some have argued that "Roths may not, in fact, work out to be a better deal" for low income people (Tergesen 2017), while others argue the opposite.[2] We therefore assess how key outcomes change for a variety of worker-types differentiated by sex and education.

Additionally, it is important to recognize that converting retirement plans to Roth plans would take place against the backdrop of the new income tax structure implemented in 2018 which reduced the tax burden for most earners.[3] The tax reform therefore also changed the relative attractiveness of saving for retirement in an EET environment, since lower marginal tax rates on workers' earnings decreased the attractiveness of saving in 401(k) accounts. Our research therefore also compares how work, saving, benefit claiming behavior, and tax payments would respond in an EET versus TEE setting, for a heterogeneous set of workers.

Finally, we analyze how our results would differ if the economy were to move out of the very low interest rate environment of the last decade, and return to a more "normal" regime. We know that persistent low returns spur workers to save and invest differently and can also drive different decisions about how long to work and when to claim Social Security benefits

[2] Hallez (2017) reports that some predict that low-wage workers would save less in a TEE regime, whereas Statman (2017) concluded the opposite.

[3] This tax reform doubled the standard deduction to calculate taxable income, cut marginal tax rates, and raised tax brackets, especially for high earners. (IRS 2018)

(Horneff, Maurer, and Mitchell 2018). The quantitative easing policies of the US Federal Reserve Bank after the financial crisis have resulted in extraordinarily low real US Treasury yields over the past decade, compared to the normal historical real return of 3% (1989-2008).[4] We seek to study how appealing Rothification might be in this new low interest rate environment, compared to the traditional EET framework for the $5 trillion invested in 40(k) assets.

In what follows, we first build and calibrate a structural life cycle model assuming an EET framework calibrated to US federal/state income tax and Social Security/Medicare premium structures and realistic Social Security benefit formulas including adjustments for early and delayed claiming. Importantly, the baseline model also incorporates real-world rules characterizing EET tax-qualified 401(k) accounts including the current caps on 401(k) pre-tax contributions, employer matches, penalties and taxes on early withdrawals, and Required Minimum Distribution withdrawals. We show that our results agree closely with observed consumption, saving, and Social Security claiming age behavior of U.S. households, while matching the current distribution of 401(k) wealth rather nicely.

Next, we develop results under an alternative environment where 401(k) contributions are taxed according to a TEE structure. This permits us to identify changes in behavior for the heterogeneous workers described above, under the two tax regimes (EET versus TEE). Next, we compare results with those obtained in a higher real return environment. In particular, we assess whether the lower-paid behave differently from the higher-paid in terms of savings inside and outside the tax-qualified accounts, as well as in non-pension savings accounts, and whether they would change their claiming behavior for Social Security benefits. In addition, we are interested in how Rothification would alter the distribution of retirement incomes relative to the current EET-system. For example, the gap between high and low-wage workers' take home pay

---

[4]Based on our analysis using DataStream of US Treasury rates deflated by the CPI.

is not diminished by income taxes under an EET system, whereas it is under a TEE program. Moreover, the Social Security replacement rate formula is progressive, as it provides relatively higher benefits for low-wage workers than for the higher paid. Given this, an EET scheme enhances the progressivity of overall old age income (pension account withdrawals plus Social Security benefits), whereas a TEE structure treats retirement benefits more neutrally. Accordingly, it is theoretically unclear how Rothification will alter household behavior without modeling the rich institutional details confronting real-world consumers, along with the economic environment, capital and labor market risk, and uncertain lifetimes. The paper also compares expected household tax payments over the life cycle under both the EET and TEE regimes. We conclude that taxing pension contributions instead of withdrawals leads to delayed retirement, lower lifetime tax payments, reductions in consumption, and higher wealth and consumption inequality. Retirement asset accumulation is also lower under the Rothification regime.

Related Literature

This research builds on prior work (Horneff, Maurer, and Mitchell 2018, 2019) by exploring the impact of a Rothification reform for 401(k) plans. Here we add to the literature by delving into the distributional impacts of such a reform in both a "normal" and a low return environment, while accounting for the income tax regime recently adopted. Our work is informed by a number of studies using a life cycle framework to model and evaluate how individuals respond to a range of environmental shocks. For example, the workhorse model of Cocco, Gomes, and Maenhout (2005) and Gomes and Michaelides (2005) was subsequently extended by Love (2010) and Hubener, Maurer and Mitchell (2016), who showed how family shocks due to changes in marital status and children alter optimal consumption, insurance, asset allocation, and retirement patterns. Horneff, Maurer, Mitchell, and Rogalla (2015) demonstrated how capital market surprises can influence saving and portfolio allocation patterns, and Chai, Horneff, Maurer, and Mitchell (2011) shows how flexible work patterns can help people hedge both earnings and capital market risk. In the present paper, we evaluate how people might optimally respond to a TEE versus the current EET tax regime for retirement accounts by adjusting their consumption, saving, investment, and retirement patterns. In addition we analyze these possible changes in optimal behavior if the capital market were to move away from a *persistently* low return environment to what used to be perceived as the "normal" return environment. In contrast to our life cycle model in Horneff, Maurer, and Mitchell (2016), we do not include annuity purchases but we do allow flexible work effort and endogenous claiming of Social Security benefits.[5]

The Consumer's Lifecycle Problem: Model and Calibration

In what follows, we build and calibrate a structural dynamic consumption and portfolio choice model for an individual maximizing his utility over his life cycle using a richly specified, sophisticated formulation of lifetime behavior calibrated to US federal/state income tax and Social Security/Medicare premium structures, along with realistic Social Security benefit formulas.[6] Just as importantly, the baseline model also incorporates real-world rules characterizing EET tax-qualified 401(k) accounts including the current U.S. caps on 401(k) pre-tax contributions, employer matches, penalties and taxes on early withdrawals, and Required Minimum Distribution withdrawal amounts. Results using calibrated baseline parameters agree closely with observed consumption, saving, and Social Security claiming age patterns of U.S. households. Specifically, our model generates a large peak at the earliest claiming age at 62 along with a second peak at the (system-defined) Full Retirement Age, and the model also matches the current distribution of 401(k) wealth rather nicely (Horneff et al. 2018).

---

[5] We also provide a theoretical backing for the empirical claiming age patterns identified by Shoven and Slavov (2012, 2014).

[6] In particular, we take account of Social Security PIA and AIME formulas, as well as early and delayed retirement adjustments, and full retirement ages.

Preferences. We work in discrete time and assume that the worker's decision period starts at $t = 1$ (age 25) and ends at $T = 76$ (age 100); accordingly, each period corresponds to one year. The household has an uncertain lifetime, such that the probability to survive from t until the next year $t + 1$ is denoted by p_t. Survival rates entering into the utility function are taken from the US Population Life Table (Arias 2010). Preferences are represented by a Cobb Douglas function $u_t(C_t, l_t) = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho}$ based on current consumption C_t and leisure time l_t (normalized as a fraction of total available time). The parameter α measures leisure preferences; ρ is the coefficient of relative risk aversion; and β is the time preference factor. The recursive definition of the value function is given by:

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

with terminal utility $J_T = \frac{(C_T l_T^{\alpha})^{1-\rho}}{1-\rho}$ and $l_t = 1$ after retirement. We calibrate the preference parameters so our results match empirical claiming rates reported by the US Social Security Administration and average assets in tax-qualified retirement plans. This matching procedure produces preference parameters of $\alpha = 1.2$, $\rho = 5$ and $\beta = 0.96$ (for details, see below).

Time budget, labor income, and Social Security retirement benefits. As in Horneff et al. (2016), our model allows for flexible work effort and retirement ages. The worker has the opportunity to 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, the uncertain yearly before-tax labor income is given by:

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

Here w_t is a deterministic wage rate component which depends on age, education, sex, and an indicator for whether the individual works full time, part time, or overtime. The variable $P_{t+1} = P_t \cdot N_{t+1}$ is the permanent component of wage rates with independent lognormal 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 with volatility σ_U^2 and assumed uncorrelated with N_t.

The calibration of 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 is based on 1975–2015 waves of the Panel Study of Income Dynamics (PSID). We estimate these separately by sex and educational level, where the latter groupings are less than High School, High School graduate, and at least some college (<HS, HS, Coll+); see Appendix A, Table A1.

Between ages 62 and 70, a worker may retire from work and claim Social Security benefits. The benefit formula is an overall concave piece-wise linear function of the worker's average indexed lifetime earnings. Accordingly, this provides an annual unreduced Social Security benefit – also named Primary Insurance Amount (PIA) – equal (in 2015) to 90 percent of (12 times) the first \$826 of average indexed monthly earnings, plus 32 percent of average indexed monthly earnings over \$826 and through \$4,980, plus 15 percent of average indexed monthly earnings over \$4,980 and through the cap \$9,875.[7] This value is called the Primary Insurance Amount (PIA). Should an individual claim benefits before (after) his system-defined Normal Retirement Age of 66, his lifelong Social Security benefits will be permanently reduced (increased) according to pre-specified factors. If the individual were to work beyond age 62, the model stipulates that he devote at least one hour per week; also, our model rules out overtime work in retirement (i.e. $0.01 \leq (1 - l_t) \leq 0.4$).

Wealth dynamics during the work life. During the work life, an individual has the opportunity to use current cash on hand for consumption C_t and investments. Some portion A_t of the worker's pre-tax salary Y_t (up to a limit of \$18,000 per year) can be invested into a tax-qualified 401(k)-retirement plan of the EET or TEE type. Also, from age 50 onwards, he is permitted an

[7] Following Chai et al. 2011 in the optimization the PIA is approximated using the permanent income; in the simulation of optimal life cycle we use the 35 best years of earnings to specify the PIA and adjust the corresponding permanent income state.

additional \$6,000 of 'catch-up' contributions. In addition, a worker can invest outside his retirement plan in risky stocks S_t and riskless bonds B_t. Hence, cash on hand X_t in each year can is given by:

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

In addition to the usual constraints, $C_t, A_t, S_t, B_t \geq 0$, the worker may not contribute more than $A_t \leq \$18{,}000$ in the 401(k) plan (as per US law). 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 costs h_t), plus withdrawals (W_t) from the 401(k) plan, minus any federal/state/city taxes and Social Security contributions, Tax_{t+1}, and health insurance HI_t costs:

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

We model housing costs h_t as in Love (2010). Our "baseline" financial market parameterizations assume a risk-free interest rate of 1%, and an equity risk premium of 4% with a return volatility of 18%. In subsequent simulations, we work with a higher interest rate of 3%, reflective of the more historically normal capital market returns. The annual cost of health insurance HI_t is set at \$1200. As in Lusardi, Michaud and Mitchell (2017), if a worker's cash on hand were to fall below $X_{t+1} \leq \$5{,}879$ p.a., the model posits that he receives a minimum welfare benefit of \$5,879 the next year.

Taxation and evolution of retirement plans: During the work life and retirement, households must pay various taxes (Tax_{t+1}) which reduce cash on hand available for consumption and investment. The amount and timing of these tax payments over the life cycle differ significantly in the case of an EET versus TEE system.

First, workers must pay payroll taxes PT_{t+1}^{tax} amounting to 11.65%, which is the sum of 1.45% Medicare, 4% city and state tax and 6.2% Social Security tax (up to a cap of 118,500 per year). Payroll taxes are not directly affected by retirement accounts. Second, the individual must also pay a progressive federal income tax IT_{t+1}^{tax} based on his taxable income Y_{t+1}^{tax}, seven income tax brackets, and the corresponding marginal tax rates for each tax bracket (for details, see Appendix B). Taxable income is a complex function of labor earnings, income from investments, and contributions into as well as withdrawals from 401(k) plans. Under both regimes for tax-qualified retirement accounts that we consider, investment earnings on assets are not counted as part of taxable earnings, yet the treatment of contributions (including employer matching contributions) and withdrawals differs between the two tax regimes. In the EET setup, contributions to the retirement account are tax-exempt (E) up to a limit, while withdrawals are part of taxable income (T). Technically, this means that employer matching contributions are not part of taxable income, while own contributions can be subtracted from taxable income. In the TEE case, contributions (including matching employer contributions) are taxed, but withdrawal are tax exempt. Technically, this means that own contributions cannot be deducted from taxable income, and employer matching contributions are added to taxable income. To sidestep liquidity problems due to back tax payments, we assume that employer contributions are taxed directly at the source, based on the worker's personal income tax rate. This generates a tax burden of M_t^{tax}, which reduces the contribution into the TEE account as well as the income tax amount.[8]

Finally, in line with US regulation, the individual must also pay *penalty* tax of 10% on early withdrawals from 401(k) accounts prior to age 59 ½ ($t = 36$). This rules applies for both the TEE and EET regime:

EET
$$Tax_t = PT_t^{tax} + IT_t^{tax} + penalty_t \tag{5}$$

TEE
$$Tax_t = PT_t^{tax} + (IT_t^{tax} - M_t^{tax}) + penalty_t$$

[8] Actual Roth-401(k) regulation requires that employer contributions are taxed according to the EET regime, which requires a separate account for own versus employer contributions. This would require an additional state variable in our models, greatly increasing the computational burden required to solve the models, so we do not follow that approach here.

Next, we describe the development of the tax-qualified retirement account in the life-cycle model. Prior to the endogenous retirement age $t = K$, the worker's assets in his tax-qualified retirement plan are invested in bonds earning a risk-free gross (pre-tax) return of $R_{f,}$ as well as risky stocks paying an uncertain gross return of R_t. The total value ($F_{t+1}^{401(k)}$) of the 401(k) assets at time $t+1$ is therefore determined by the previous period's value minus any withdrawals ($W_t \leq F_t^{401(k)}$), plus additional own contributions (A_t), plus any employer match (M_t), and returns on stocks and bonds. To avoid substantial tax penalties from age 70.5 onwards, retirees must take Required Minimum Distributions from 401(k) plans which are based on life expectancy data from the IRS Uniform Lifetime Table (IRS 2015b). In the TEE regime, the employer match is reduced by the tax pre-payment M_t^{tax}. The variable ω_t^s denotes the relative exposure of overall assets allocated to stocks. Overall, the wealth dynamics of the EET or TEE retirement account evolves as follows:

EET $$F_{t+1}^{401(k)} = \omega_t^s\left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t\right)R_{t+1} + (1-\omega_t^s)\left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t\right)R_f \quad \text{and} \tag{6}$$

TEE $$F_{t+1}^{401(k)} = \omega_t^s\left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t - M_t^{tax}\right)R_{t+1} + (1-\omega_t^s)\left(F_t^{401(k)} - \mathrm{W_t} + A_t + M_t - M_t^{tax}\right)R_f.$$

To be considered as a safe harbor 401(k) plan and therefore avoid complex non-discrimination testing, we assume that the employers match 100% of employee contributions up to 5% of yearly labor income.[9] Due to regulation, the matching rate can only applied to a maximum compensation of \$265,000, so the maximum employer contribution is \$13,250. The matching contribution is then given by:

$$M_t = \min(A_t, 0.05Y_t, \$13{,}250). \tag{7}$$

[9] See Willson (2019) for 401(k) safe harbor plans. Love (2007) reports a modal value of 6% for matching rates of US defined contribution plans.

Wealth dynamics during retirement. The worker can retire and claim Social Security benefits between age 62 and 70. After selecting his endogenous retirement age, K, the individual may still elect to save outside the tax-qualified retirement plan in stocks and bonds, as follows:

$$X_t = C_t + S_t + B_t. \tag{8}$$

His cash on hand for the next period evolves as follows:

$$X_{t+1} = S_t R_{t+1} + B_t R_f + Y_{t+1}(1 - h_t) + W_t - Tax_{t+1}. \tag{9}$$

Old age retirement benefits provided by Social Security are determined by the worker's Primary Insurance Amount (PIA), which in turn depend on his average lifetime earnings as described above. Social Security payments (Y_{t+1}) in retirement ($t \geq K$) are given by:

$$Y_{t+1} = PIA_K \cdot \lambda_K \cdot \ \varepsilon_{t+1} \,. \tag{10}$$

Here, λ_K is the mandated adjustment factor for claiming before or after the system-defined Full Retirement Age, which in our model is assumed to be age 66.[10] The variable ε_t is a transitory shock ε_t ~LN$(-0.5\sigma_\varepsilon^2, \sigma_\varepsilon^2)$, which reflects out-of-pocket medical and other expenditure shocks in retirement (as in Love 2010). During retirement, benefits payments from Social Security are partially taxed by the individual federal income tax rate as well as the 4% city and state and 1.45% Medicare taxes.[11]

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

$$\begin{aligned} F_{t+1}^{401(k)} &= \omega_t^s\Big(F_t^{401(k)} - \mathrm{W_t}\Big)\mathrm{R_{t+1}} \\ &\qquad + (1 - \omega_t^s)\Big(F_t^{401(k)} - \mathrm{W_t}\Big)R_f, \qquad for\ \ t < \ K. \end{aligned} \tag{10}$$

[10] 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_c).

[11] For Social Security tax rules see US SSA (nd_d). Up to 85% of Social Security benefits may be subject to income tax for higher-income households, yet due to generous exemptions, most households receive their Social Security benefits tax-free (see Horneff, Maurer, and Mitchell 2016). From age 65 onward, benefits are not taxed by Social Security or Medicare Part A (hospital insurance). Nevertheless, most elderly enroll in Medicare Part B (medical insurance), Part C (advantage plans), and Part D (drug prescription), and pay premiums. To simplify calculations, we assume that these premiums equal 1.45% of benefits.

Under US law, plan participants must take retirement account payouts from age 70 onwards, according to the Required Minimum Distribution rules (m) specified by the Internal Revenue Service (IRS 2015b). Accordingly, withdrawals from the retirement account must take into account the following constraints: $F_t^{401(k)} m \leq W_t < F_t^{401(k)}$.

Calibration of preference parameters and model solution. We posit that households maximize the value function (1) subject to the constraints and calibrations set out above, by optimally selecting their consumption, work effort, claiming age for Social Security benefits, investments and withdrawals from tax-qualified 401(k)-plans, and investments in as well as redemptions of stocks and bonds. As this optimization problem cannot be solved analytically, it requires a numerical procedure using dynamic stochastic programming. Accordingly, to generate optimal policy functions, in each period t we discretize the space in four dimensions 30(X)×20($F^{401(k)}$)×8(P)×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 with <HS, HS, and Coll+). We then aggregate the subgroups to obtain national mean values using weights from the National Center on Education Statistics (2016). Specifically, the weights are 50.7% female (61% with Coll+, 28% with HS, and 11% with <HS), and 49.3% male (57% with Coll+, 30% HS, and 13% <HS).

We calibrate preference parameters (assumed to unique for the six subgroup) in such a way that our model results match empirical claiming rates reported by the US Social Security Administration and average assets in 401(k) plans. Our baseline calibration assumes a risk-free interest rate of 1%, and also that people have access to tax qualified 401(k) retirement accounts under the EET regime. Specifically, we calibrate our model to data from the Employee Benefit Research Institute (2017) which reports 401(k) account balances for 7.3 million plan participants in five age groups (20-29, 30-39, 40-49, 50-59, and 60-69) in 2015. To generate 401(k) simulated balances and claiming rates, we first solve the life cycle model where the individual has access to traditional EET 401(k) plans under the tax-regime in 2015 (i.e. before the reform in 2018); we then generate 100,000 lifecycles using optimal feedback controls for each of the six subgroups (male/female with <HS, HS, and Coll+). These six subgroups are aggregated to obtain national median values, using National Center on Education Statistics (2016) weights. Finally, to compare our results to the EBRI (2017) data, we construct average account levels for each of five age subgroups. Repeating this procedure for alternative preference parameter sets, we find that a coefficient of relative risk aversion ρ of 5, a time discount rate β of 0.96, and a leisure parameter α of 1.2 are the parameters that most closely match simulated model outcomes and empirical evidence on both 401(k) balances and claiming rates of Social Security Benefits.[12]

Figure 1 (top) presents claiming rates generated by our life cycle model (dark bars) versus empirical claiming rates (light bars) reported by the US Social Security Administration for the year 2015 for nondisabled males and females. Here we see that our model closely tracks the empirically-observed early claiming age peak at age 62, as well as the second peak at the Full Retirement Age (66). The lower Panel of Figure 1 displays simulated versus empirical evidence on 401(k) assets by age groups. Again, our simulated outcomes are remarkably close to the empirically-observed 401(k) account values, implying that our model accords well with real-world data.

Figure 1 here

What Would Rothification Do?

We next illustrate how switching from traditional EET to a TEE tax regime for retirement savings would affect claiming ages, assets held inside and outside tax-qualified retirement plans, consumption, hours of work, asset and consumption inequality, and tax

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

payments over the life cycle. In addition, we study how the results would differ, if the very low interest rate environment of the last decade ($r = 1\%$) were to be replaced by a more historically "normal" return regime ($r = 3\%$).

Asset accumulation patterns. Table 1 offers an accounting of how the tax regime change alters asset allocation patterns in the 401(k) accounts versus non tax-qualified assets. Here we focus on lifecycle asset accumulation patterns under the EET/TEE regimes, as well as the low/high expected return scenarios. Most strikingly, we see that assets in 401(k) plans (Panel A) are lower under the Rothification regime, particularly in later life, compared to the higher levels under the EET regime. This shortfall is greater in the higher return regime, such that tax qualified assets are always larger in the EET environment. By contrast, non-qualified assets are markedly lower in the EET world from age 60 onward, by about half as of the Full Retirement Age (i.e., the mid-60s). Yet in terms of consumption opportunities, the value of retirement plan assets in the EET regime is not directly comparable with that in the TEE regime. This is because withdrawals of EET assets must be taxed before they can used for consumption, while withdrawals from TEE assets are tax free.

Table 1 here

Impacts on consumption and work hours. Table 2 evaluates the effects of moving from an EET to a TEE regime on consumption patterns and work hours, for low and high interest rates ($r =$ 1% and 3%). In the low interest rate regime, EET lifetime consumption is below that in the TEE world from age 40 onward. Panel B also reveals that people work about three more hours per week in the TEE scenario during the Social Security claiming window (age 62-69). If the real return were instead $r = 3\%$, average consumption under TEE would be lower for all age groups, compared to the EET case. In addition, during the work life, work effort would be about two hours per week lower under TEE. Nevertheless, in the Social Security benefit claiming window, people work about three hours more per week under the TEE regime. Overall, Rothification reduces work over the lifetime but pushes out retirement claiming, compared to the EET tax environment.

Table 2 here

Impact on claiming ages. Table 3 shows how Social Security benefit claiming ages would change by sex across tax regimes and under the low versus high interest rate scenarios. In both tax regimes men and women's average retirement ages are later when interest rates are low ($r = 1\%$). This is because delaying Social Security is similar to buying a deferred annuity.[13] Hence it is more attractive to draw down one's 401(k) account to delay Social Security claiming, compared to keeping the money in the retirement account and earning (uncertain) investment returns.

Overall, the TEE regime's lower marginal tax rate on 401(k) payouts induces workers to defer Social Security claiming more than under the EET regime. This may be explained as follows: some workers with sufficient retirement plan assets want to retire, but they find it attractive to wait to claim Social Security so as to boost these via the delayed claiming factors (6-8% increase per year of delayed claiming). Meanwhile, financing consumption during this no-work phase requires them to withdraw from their 401(k) assets. Under an EET regime, workers must pay income taxes on their pension withdrawals; thus the attraction of earning higher Social Security benefits by delaying claiming must be weighed against the disadvantage of paying high income taxes on withdrawals. If the tax burden on withdrawals is heavier than the advantage of receiving higher Social Security benefits, it is rational to claim earlier. This tradeoff must also take into account the fact that only a portion of Social Security benefits are included in taxable income (up to 50% could be tax-free). Accordingly, the net-of-tax gain from delaying Social Security claiming is relatively small in the EET scenario. The effect is stronger when interest rates are high, because workers build more assets in their 401(k) accounts.

Such complex tax considerations are irrelevant under the TEE regime, because pension withdrawals are not counted as part of taxable income. Therefore, given their financial resources to finance consumption until claiming, in the TEE scenario workers base their

[13] Naturally, the price of the annuity varies with the market return. For instance, the implied interest rate to price an annuity comparable to Social Security in the private market would range between 2 and 5%, depending on the retiree's age and sex. See Hubener et al. (2016), Shoven and Slavov (2014), and Maurer et al 2017.

decisions to delay claiming only on delayed retirement credit earned by deferring Social Security. Moreover, this effect is stronger under a high versus a low interest rate regime.

Table 3 here

The average claiming age changes do obscure some interesting differences across population subgroups, as can be seen in Figure 2. Specifically, claiming behavior of the least-educated high school dropouts is relatively similar in the EET and TEE regimes, primarily because this group saves and accumulates fewer assets than the better-educated. Moreover, the changes in claiming ages for this group are small under both interest rate environments. For example, women (men) without a high school degree work only 0.5 (3) month more under the TEE regime in a low interest rate environment, while Coll+ men and women defer claiming benefits by more than a year under both interest rate environments. The impact is strongest for college-educated females who work 16 months longer given a high real rate, in the TEE versus EET setup. Accordingly, more educated and wealthier workers are predicted to work substantially longer under Rothification, with a much smaller impact on the less-educated.

Figure 2 here

Impacts on tax payments over the life cycle. Next, in Figure 3 we plot the average tax payments per individual over the life cycle under the EET and TEE regimes. The figure includes payroll taxes, income taxes, and penalty taxes for early withdrawals for the overall population comprised by our six subgroups. Both scenarios assume a low and persistent interest rate of 1%. As anticipated, tax payments under EET are lower during the first 25 years of the worklife, since 401(k) contributions are not part of taxable income; by contrast, under the TEE regime, workers must pay taxes on both own and employer matching contributions. Yet the situation changes around age 50 when tax payments rise in the EET regime, and the difference is particularly marked between ages 62 and 70. Thereafter, tax payments in both the EET and TEE scenarios are relatively low.

The explanation is that, in both tax regimes, workers begin curtailing their work hours after age 50 and finance their consumption by 401(k) withdrawals. From age 60 onward, 401(k) withdrawals are not subject to the 10% penalty tax in both tax regimes, but withdrawals from EET accounts are part of taxable income which results in higher tax payments – in contrast to the TEE world. The difference in tax payment is particularly large between ages 62 and 70. For example, at age 65, the annual EET tax payment averages \$8,000, or about twice as large as in the Roth regime. This result is driven by individuals who have relatively large accumulations in their 401(k) plans and use these assets to (partially) retire from work, delay claiming Social Security benefits, and spend retirement assets to cover consumption until claiming. From age 70 onwards, most of the 401(k) assets are spent so people withdraw only small amounts from their retirement plans. Hence, retirees in the EET world pay only slightly more taxes than those in the TEE world.

Figure 3 here

Table 4 shows numerical values of average lifetime tax payments per individual for the two tax regimes and interest rate scenarios under consideration. In all scenarios, we find that average tax payments are higher under the EET system until workers attain age 49. For example, assuming $r = 1\%$, workers pay about \$11,000 more in taxes under the TEE system up to that age. Yet between ages 50-69, workers in the EET regime pay \$26,000 more than in the TEE world. Over the complete life cycle, tax payments average 6% (\$24,000) more in the EET world when the interest rate is low; the difference increases to about 10% (\$42,000) if the real rate is 3%. Overall, we conclude that tax payments are higher in the short run in the TEE regime, but lower in the long run.

Table 4 here

Impact on Inequality

Last, we evaluate how a TEE versus an EET tax regime for retirement savings affects asset and consumption inequality. For the three population subgroups and the ETT versus TEE tax regimes, Table 5 reports average wealth inside and outside tax-qualified accounts as of age 62, as well as average income and average consumption between ages 25-62. Panel A depicts results for the low and Panel B for the high interest rate scenario.

Table 5 here

Following Lusardi, Michaud, and Mitchell (2017), we measure relative wealth, income, and consumption inequality in terms of the ratio of college graduates to high school dropouts as of age 62. The higher is this ratio, the greater the inequality along this dimension. Regardless of the interest rate environment, we see that inequality measured in this way is greater under the TEE regime for all four metrics. For example, under the EET regime, a Coll+ individual receives 3.73 times the income of the <HS group in the low interest regime; this differential rises to 3.81 under the TEE tax setup. If the interest rate is higher, income inequality rises further. Additionally, consumption inequality is larger under the TEE regime, and inequality of assets outside tax qualified accounts rises by over 100 percentage points, for both interest rate scenarios. In contrast, 401(k) assets are less unequal under the TEE regime, though it must be recalled that asset levels in 401(k) accounts cannot be directly compared across the two tax regimes, since 401(k) assets are subject to tax on withdrawal and under the TEE regime, such assets are not taxed. Furthermore, the marginal tax rate for <HS who have only about $14,000 in their 401(k) accounts is far lower than for their Coll+ counterparts who have over $210,000 in their 401(k) accounts. Given that fact, overall higher asset inequality is greater under the TEE regime.

Conclusions

This paper evaluates whether adopting a different tax treatment of retirement plan contributions would materially change Social Security benefit claiming ages and work hours, consumption, and asset allocation of workers looking ahead to retirement. We also assess whether the lower-paid would behave differently from the higher-paid, in terms of change in claiming, saving inside and outside the Roth accounts, and non-pension saving. Rothification also alters the distribution of retirement incomes relative to the current EET-system. For example, the gap between high and low-wage workers' take home pay is not diminished by income taxes under an EET system, whereas it is under a TEE program. Moreover, the Social Security replacement rate formula is progressive, as it provides relatively higher benefits for low-wage workers than for the higher paid. Given these realities, an EET scheme enhances the progressivity of overall old age income (pension account withdrawals plus Social Security benefits), whereas a TEE structure treats pension benefits more neutrally. Accordingly, it is theoretically impossible to predict how Rothification will alter household behavior without taking into account the rich institutional details confronting real-world consumers, along with the economic environment, capital and labor market risk, and uncertain lifetimes.

Our structural model is a richly specified, sophisticated formulation of lifetime behavior calibrated to US federal/state income tax and Social Security/Medicare premium structures, along with realistic Social Security benefit formulas. We account for PIA and AIME formulas, early and delayed retirement adjustments under Social Security, and real-world rules characterizing tax-qualified DC accounts including the current caps on pre-tax contributions, employer matches, penalties and taxes on early withdrawals, and Required Minimum Distribution withdrawals. This lifecycle model of work, saving, consumption, and retirement behavior provides several lessons for those interested in an alternative tax regime for pension plans. Overall, we show that that taxing pension contributions instead of withdrawals leads to later retirement ages, especially for the better-educated. It also reduces lifetime work hours, and increases wealth and consumption inequality. While there is some sensitivity to market returns, our overall conclusions remain robust to the alternative assumptions explored here. Finally, lifetime tax payments are lower by 6-10% under the Rothification tax regime.

References

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

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

Carroll, C. D. and A. A. Samwick. (1997). The Nature of Precautionary Wealth. *Journal of Monetary Economics.* 40(1): 41-71.

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. 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.

Hallez, E. (2017). How a GOP Roth Plan Could Impact Retirement Savings. *Ignites.com*. https://www.ignites.com/c/1781243/209413?referrer_module=SearchSubFromIG&highlight=How%20a%20GOP%20Roth%20Plan%20Could%20Impact%20Retirement%20Savings

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. 119-131.

Horneff, V., R. Maurer, and O.S. Mitchell. (2019). How Will Persistent Low Expected Returns Shape Household Economic Behavior? *Journal of Pension Economics and Finance* 18, 612-622.

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 2015a). *Form 1040 (Tax Tables): Federal Tax Rates, Personal Exemptions, and Standard Deductions*. Downloaded 09/13/2018. https://www.irs.com/articles/2015-federal-tax-rates-personal-exemptions-and-standard-deductions

Internal Revenue Service (IRS 2015b). *Retirement Plan and IRA Required Minimum Distributions FAQs*. https://www.irs.gov/pub/irs-prior/p590b--2015.pdf

Internal Revenue Service (IRS 2018). *Form 1040 (Tax Tables): Federal Tax Rates, Personal Exemptions, and Standard Deductions*. Downloaded 08/26/2019. https://www.irs.com/articles/2018-federal-tax-rates-personal-exemptions-and-standard-deductions

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.

Lusardi, A.M., O.S. Mitchell, and P.C. Michaud (2017). "Optimal Financial Literacy and Wealth Inequality." *Journal of Political Economy*. 125(2): 431-477.

Maurer, R., O.S. Mitchell, R. Rogalla, and T. Schimetschek (2017). Optimal Social Security Claing Behavior Under Lump Sum Incentives: Theory and Evidence. NBER Working Paper 23073.

National Center on Education Statistics. (2016). *Digest of Education Statistics* 52nd Edition, Table 104.30. https://nces.ed.gov/pubs2017/2017094.pdf (download 09.13.2018).

Schoeff, M. (2017). Promises by Congress to Protect Retirement-savings Incentives Don't Ease Advocates. Jul 12. *InvestmentNews.com*. https://www.investmentnews.com/article/20170712/FREE/170719976/promises-by-congress-to-protect-retirement-savings-incentives-dont

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.

Sibaie, A. (2017). What Rothification Means for Tax Reform. The Tax Foundation. Washington, D.C. https://taxfoundation.org/what-rothification-means-for-tax-reform/

Statman, M. (2017). Critically, 'Rothification' of 401(k)'s not Harmful to Lower Incomes. *TheHill.com*.

Tergesen, Ann. (2017). How a $2,400 Cap on 401(k) Deductions Would Affect Your Savings. Oct. 29. https://www.wsj.com/articles/how-a-2-400-cap-on-401-k-deductions-would-affect-your-savings-1509313100?mg=prod/accounts-wsj

Thornton, Nick. (2017). Asset Managers' Profits Threatened by Rothification. benefitspro.com, September.http://www.benefitspro.com/2017/09/07/asset-managers-profits-threatened-by-rothification?t=retirement&slreturn=1508873159&page=3&page_all=1

US Department of Labor (US DOL). (2016). *Economic News Release Table A-4. Employment Status of the Civilian Population 25 Years and Over by Educational Attainment*. Washington, DC.

US Department of Labor (US DOL). (2006). *Fact Sheet: Default Investment Alternatives under Participant-Directed Individual Account Plans*. Washington, DC. https://www.dol.gov/ebsa/newsroom/fsdefaultoptionproposalrevision.html

US Department of Labor (US DOL). (nd). *Fact Sheet: Regulation Relating to Qualified Default Investment Alternatives in Participant-Directed Individual Account Plans.* Washington, DC. https://www.dol.gov/ebsa/newsroom/fsqdia.html

US Social Security Administration (US SSA). (nd_a). *Primary Insurance Amount*. Washington, DC. https://www.ssa.gov/oact/cola/bendpoints.html

US Social Security Administration (US SSA). (nd_b). *Fact Sheet: Benefit Formula Bend Points*. Washington, DC. https://www.ssa.gov/oact/cola/piaformula.html

US Social Security Administration (US SSA). (nd_c). *Incentivizing Delayed Claiming of Social Security Retirement Benefits Before Reaching the Full Retirement Age*. Washington, DC https://www.ssa.gov/policy/docs/ssb/v74n4/v74n4p21.html

US Social Security Administration (US SSA). (nd_d). *Benefits Planner: Income Taxes and Your Social Security Benefit.* Washington, DC. https://www.ssa.gov/planners/taxes.html

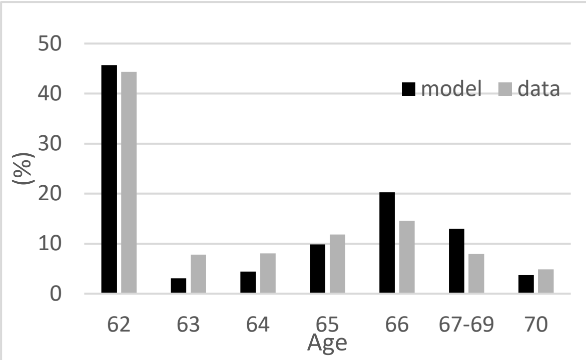
US Social Security Administration. (2014). *Annual Statistical Supplement to the Social Security Bulletin*. Washington, DC. www.ssa.gov/policy/docs/statcomps/supplement/2014.

US Social Security Administration. (2015). *Annual Statistical Supplement to the Social Security Bulletin, 2015* (Table 6.B5). Washington, DC.

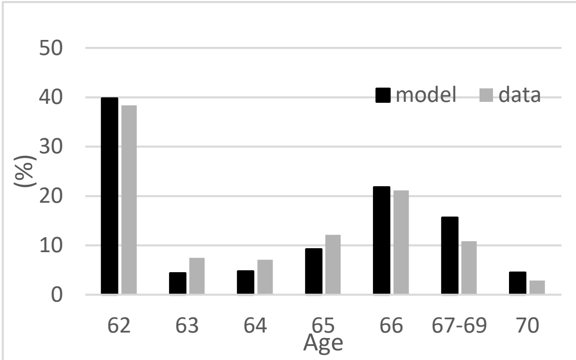
Willson, Nicolle (2019). Safe Harbor 401(k): The 2019 Guide for Business Owners. https://www.guideline.com/blog/safe-harbor-401k-plan/

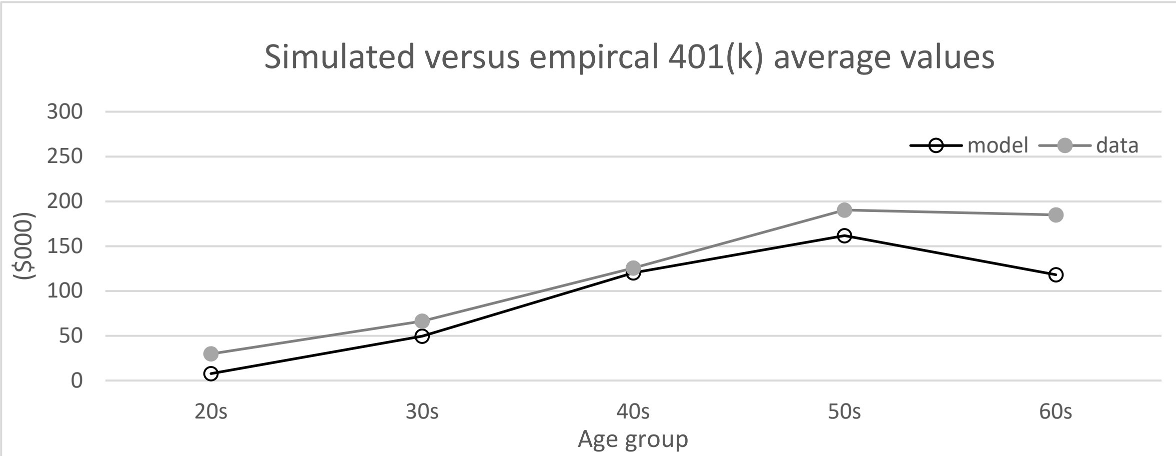
Figure 1: Social Security Claiming Patterns for Males and Females, and 401(k) Asset Values *(model vs data)*

A: Female



B: Male

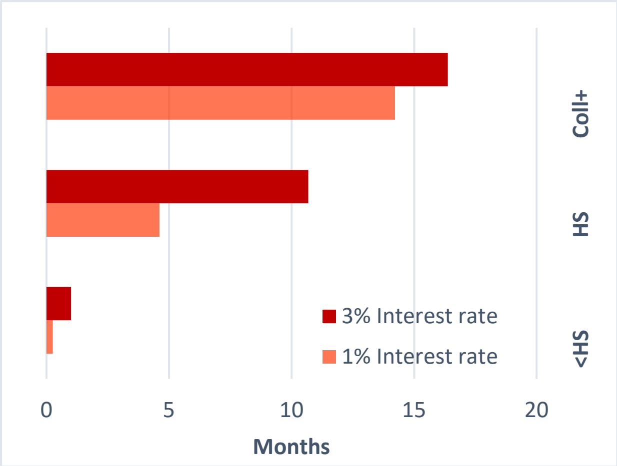


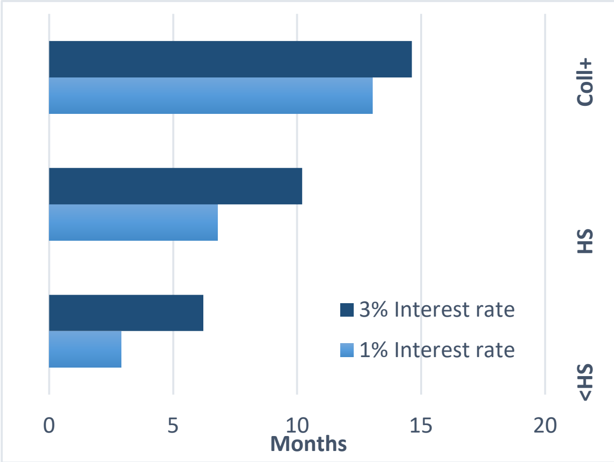


Notes: The top two panels compare claiming rates generated by our life cycle models and empirical claiming rates reported by the US Social Security Administration for the year 2015 (without disability). Expected values are calculated from 100,000 simulated lifecycles based on optimal feedback controls. Results for the entire female (male) population are computed using income profile for three education levels: 61% +Coll; 28% HS; 11% <HS (57% +Coll; 30% HS; 13%<HS). Parameters used for the baseline calibration are as follows: risk aversion $\rho = 5$; time preference $\beta = 0.96$; leisure preference $\alpha = 1.2$; endogenous retirement age 62-70. Social Security benefits are based on average permanent income and the bend points in place in 2015; minimum required withdrawals from 401(k) plans are based on life expectancy using the IRS-Uniform Lifetime Table in 2015; tax rules for 401(k) plans are as of 2015 and described in Appendix B. The risk premium for stocks returns is 5% and return volatility 18%; the risk free rate in the baseline case is 1%. The lower panel compares empirical 401(k) account balances across the US population. Empirical account balance data are taken from the Employee Benefit Research Institute (2017); age groups referred to as 20s, 30s, 40s, 50s, and 60s denote average values for persons age 20-29, 30-39, 40-49, 50-59, and 60-69. Source: Authors' calculations

Figure 2: Average Claiming Age Differences by Education: TEE (Roth) vs EET Tax Regimes, and Low vs High Return Scenarios

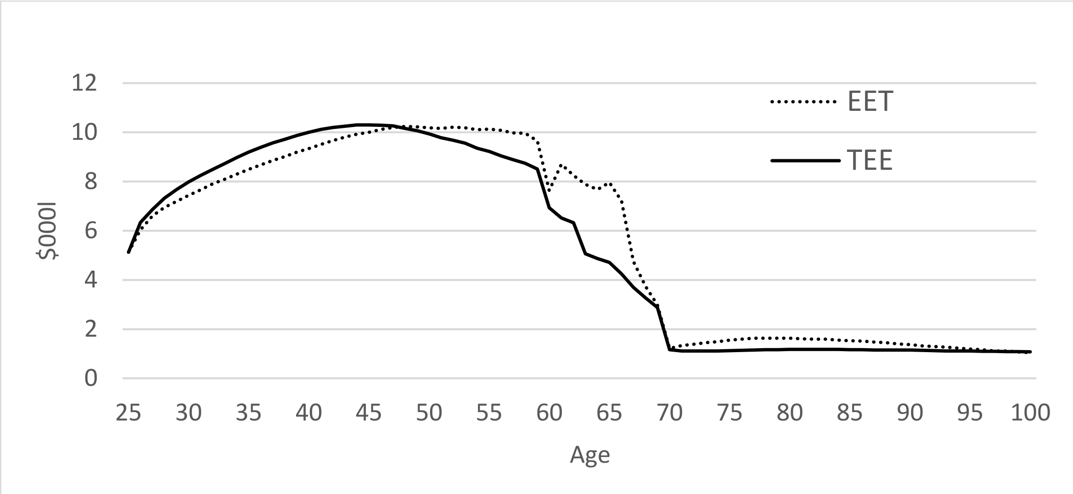
A: Female **B: Male**





Notes: We report the average claiming age difference for EET vs TEE for r=1% and 3% by sex and education groups <HS, HS, +Coll, derived from 100,000 simulated lifecycles based on optimal feedback controls from the life cycle model. Preference parameters are as follows: risk aversion $\rho = 5$; time preference $\beta = 0.96$; leisure preference $\alpha = 1.2$. The endogenous retirement age is between age 62-70.The assumed risk premium for stock returns is 5% and return volatility 18%. Tax bracket are based on 2018 regulations (as described in Appendix B). Source: Authors'

Figure 3: Average Annual Tax Payments per Individual: EET vs TEE (Roth) Tax Regimes



Notes: The table reports average annual tax payments (sum of income taxes, payroll taxes, and penalty tax for early withdrawals) over the life cycle per individual for EET versus TEE taxation based on low interest rates (1%). Values are based on 100,000 simulated lifecycles for each of the six subgroups (male / female and three education groups) using optimal feedback controls from the life cycle model. Results for the entire population are computed using the following weights for the three education levels: females (61% +Coll; 28% HS; 11% <HS) and males (57% +Coll; 30% HS; 13%<HS); the weights for females is 51% and for males 49%. Further notes on parameters see Figure 2.

Table 1: Lifecycle Asset Accumulation Patterns under EET versus TEE Tax Regimes, and Low versus High Expected Return Scenarios

	r=1 %		*r=3 %*	
	EET	TEE	EET	TEE
Panel A: 401(k) Assets ($000)				
Age 30-39	54.8	46.6	61.5	51.5
Age 40-49	130.6	110.2	149.5	114
Age 50-59	174.7	147.3	201.7	148.8
Age 60-69	127.1	91.1	162.9	105.3
Age 70-79	87.6	67.1	128.6	94.9
Age 80-89	43.6	34.3	75.5	58
Age 90-99	8.8	6.6	18.9	14.7
Panel B: Non-Qualified Assets ($000)				
Age 30-39	6.3	5.6	7.2	5.7
Age 40-49	8.9	8.2	7.9	6.9
Age 50-59	8.1	8.6	6.4	7.9
Age 60-69	16.7	31.5	16.6	30.5
Age 70-79	10.9	16.2	11.9	11.7
Age 80-89	7.7	8.7	8.5	6.8
Age 90-99	5.4	6	5.7	5.4

Notes: The two panels show expected assets by age in tax-qualified 401(k) plans and non-qualified assets for low and high interest rate (1% and 3%), and different tax regimes. Expected values are based on 100,000 simulated lifecycles using optimal feedback controls from the life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. For other parameters, see Figure 1. Source: Authors' calculations.

Table 2: Life Cycle Consumption and Working Hours under EET versus TEE Tax Regimes, and Low versus High Expected Return Scenarios

	r=1 %		*r=3 %*	
	EET	TEE	EET	TEE
Panel A: Consumption ($000)				
Age 30-39	24.0	23.7	24.3	21.3
Age 40-49	27.8	28.0	28.5	24.9
Age 50-59	29.5	30.2	30.2	27.0
Age 60-69	27.9	29.1	29.5	26.6
Age 70-79	24.8	25.2	27.3	24.0
Age 80-89	23.4	23.9	26.4	23.9
Age 90-99	20.8	21.8	22.9	22.1
Panel B: Av. Work Hours per Week				
Age 25-61	33.8	33.9	33.2	31.6
Age 62- 69	8.8	11.6	6.7	9.4
Age 25-69	29.4	29.9	28.5	27.6

Notes: The two panels report average consumption and weekly work hours for low and high r (1% and 3%), and different tax regimes. Expected values are based on 100,000 simulated lifecycles using optimal feedback controls from the life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. For other parameters, see Figure 1. Source: Authors' calculations.

Table 3: Social Security Claiming Patterns (in %) for Females and Males under EET versus TEE Tax Regimes, and Low versus High Expected Return Scenarios

	Female				*Male*			
	r=1 %		*r=3 %*		*r=1 %*		*r=3 %*	
Age	EET	TEE	EET	TEE	EET	TEE	EET	TEE
62	42.5	37.8	49.1	37.3	34.6	29.4	36.9	28.6
63	3.1	3.1	4.9	4.4	4.3	4	6.2	4.1
64	3.9	2.8	5.6	4.3	4.6	3	7.8	3.1
65	6.7	4	7.7	6.0	7.9	3.8	10.4	7.1
66	**16**	**7.3**	**13.6**	**8.0**	**19.8**	**14.1**	**17.3**	**15.5**
67	8	7.5	5.5	11.4	9.3	10	6.9	12.2
68	7.5	11.4	7	9.1	8.4	11	7.6	12.7
69	7.2	11	4.2	10.2	5.8	12.3	3.7	8.3
70	4.9	15.1	2.3	9.3	5.3	12.3	3.2	8.3
Av. Claim Age (years)	64.7	65.5	64.1	65.2	65.0	65.8	64.5	65.6

Notes: We report the average claiming age for low and high r (1% and 3%) by sex, for the two different tax regimes (EET vs TEE) derived from 100,000 simulated lifecycles based on optimal feedback controls from the life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. For other parameters, see Figure 1. Source: Authors' calculations.

Table 4: Sum of Average Life-Time Tax Payments per Individual: EET vs TEE (Roth) Tax Regimes, and Low versus High Expected Return Scenarios

	r = 1 %		r = 3 %	
	EET	TEE	EET	TEE
Age 25-49	214.6	225.4	213.9	222.7
Age 50-69	167.4	141.2	165.8	133.4
Age 70-100	43.4	35.2	54.5	36.3
Age 25-100	**425.4**	**401.8**	**434.2**	**392.4**

Notes: The table reports average life-time tax payments (sum of income taxes, payroll taxes, and penalty tax for early withdrawals) per individual for EET versus TEE taxation and for low and high interest rates (1% and 3%). Values are based on 100,000 simulated lifecycles for each of the six subgroups (male / female and three education groups) using optimal feedback controls from the life cycle model. Results for the entire population are computed using the following weights for the three education levels: females (61% +Coll; 28% HS; 11% <HS) and males (57% +Coll; 30% HS; 13%<HS); the weights for females is 51% and for males 49%. Further notes on parameters see Figure 2.

Table 5: Asset and Consumption Inequality by Education under EET versus TEE Tax Regimes, and Low versus High Expected Return Scenarios

	EET				TEE			
	Ave. Cash on Hand @62	Pre-tax Ave. 401(k) Assets @62	Pre-tax Ave. Income Age 25-62	Ave. Consumption Age 25-62	Ave. Cash on Hand @62	Ave. 401(k) Assets @62	Pre-tax Ave. Income Age 25-62	Ave. Consumption Age 25-62
Panel A: r= 1%								
<HS	$19,291	$16,677	$13,940	$11,983	$21,021	$13,039	$13,856	$11,874
HS	$35,027	$67,193	$28,913	$19,540	$41,311	$50,139	$28,781	$19,395
Coll+	$58,061	$210,349	$52,016	$32,416	$84,833	$158,400	$52,815	$32,911
Ratio (Coll+/<HS)	*301%*	*1,261%*	*373%*	***271%***	*404%*	*1,215%*	*381%*	***277%***
Panel B: r=3%								
<HS	$21,075	$28,443	$15,177	$12,878	$23,536	$21,969	$15,118	$12,808
HS	$35,849	$90,032	$28,364	$20,080	$45,039	$67,241	$28,696	$20,143
Coll+	$57,616	$250,887	$49,173	$32,830	$89,490	$183,962	$50,693	$33,631
Ratio (Coll+/<HS)	*273%*	*882%*	*324%*	***255%***	*380%*	*837%*	*335%*	***263%***

Notes: The table reports average cash on hand, 401(k) plan assets, and average annual pre-tax earnings by educational group, for low and high r (1% and 3%) and different tax regimes. Expected values are based on 100,000 simulated lifecycles using optimal feedback controls from the life cycle model. The assumed risk premium for stock returns is 5% and return volatility 18%. For other parameters, see Figure 1. Source: Authors' calculations.

Online Appendix A: Wage rate estimation

We calibrated the wage rate process using the Panel Study of Income Dynamics (PSID) 1975-2015 from age 25 to 69. During the work life, each individual's labor income profile has deterministic, permanent, and transitory components with uncorrelated and normally distributed shocks according to $ln(N_t) \sim N(-0.5\sigma_n^2,\ \sigma_n^2)$ and $ln(U_t) \sim N(-0.5\sigma_u^2,\ \sigma_u^2)$. The wage rate values are expressed in $2015. These are estimated separately by sex and by educational level. The educational groupings are: less than High School (<HS), High School graduate (HS), and those with at least some college (Coll+). Extreme observations below $5 per hour and above the 99th percentile are dropped.

We use a second order polynomial in age and dummies for employment status. The regression function is:

$$\ln(w_{i,y}) = \beta_1 * age_{i,y} + \beta_2 * age_{i,y}^2 + \ \beta_5 * ES_{i,y} + \beta_{waves} * wave\ dummies, \quad \text{(A1)}$$

where $\log(w_{i,y})$ is the natural log of wage at time *y* for individual *i*, *age* is the age of the individual divided by 100, *ES* is the individual's employment status, and wave dummies control for year-specific shocks. For employment status, we include three groups depending on work hours per week as follows: part-time worker (≤ 20 hours), full-time worker (< 20 & ≤ 40 hours) and overtime worker (< 40 hours). OLS regression results for the wage rate process equations are provided in Table A1.

To estimate the variances of the permanent and transitory components, we follow Carroll and Samwick (1997) and Hubener at al. (2016). We calculate the difference of the observed log wage and the regression result, and we take the difference of these differences across different lengths of time *d*. For individual *i,* the residual is:

$$r_{i,d} = \sum_{s=0}^{d-1}(N_{t+s}) \ + U_{i,t+d} - U_{i,t}. \quad \text{(A2)}$$

We then regress the $v_{id} = \overline{r_{i,d}^2}$ on the lengths of time *d* between waves and a constant:

$$v_{id} = \beta_1 \cdot d + \beta_2 \cdot 2 + e_{id}, \quad \text{(A3)}$$

where the variance of the permanent factor $\sigma_N^2 = \beta_1$ and the $\sigma_U^2 = \beta_2$ represents the variance of the transitory shocks.

Table A1: Regression results for wage rates

Coefficient	Male <HS	Male HS	Male +Coll	Female <HS	Female HS	Female +Coll
Age/100	3.161***	5.972***	9.092***	1.256***	2.767***	4.731***
	(0.108)	(0.049)	(0.070)	(0.110)	(0.046)	(0.072)
Age²/10000	-3.329***	-6.416***	-9.351***	-1.339***	-2.915***	-4.960***
	(0.130)	(0.062)	(0.089)	(0.131)	(0.059)	(0.094)
Part-time work	-0.109***	-0.153***	-0.0826***	-0.0858***	-0.129***	-0.0847***
	(0.020)	(0.009)	(0.011)	(0.006)	(0.003)	(0.004)
Over-time work	0.00412	0.0506***	0.0949***	0.0158***	0.0748***	0.106***
	(0.004)	(0.002)	(0.002)	(0.006)	(0.002)	(0.003)
Constant	1.807***	1.435***	1.151***	2.051***	2.015***	1.938***
	(0.042)	(0.012)	(0.015)	(0.037)	(0.011)	(0.017)
Observations	48,762	327,305	293,386	31,788	290,597	225,211
R-squared	0.069	0.102	0.147	0.032	0.044	0.092
Permanent	0.009***	0.013***	0.019***	0.008***	0.013***	0.019***
	(0.001)	(0.0002)	(0.0003)	(0.0001)	(0.0002)	(0.001)
Transitory	0.028***	0.031**	0.041***	0.023***	0.028***	0.038***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Observations	28,359	175,247	140,984	20,863	176,304	123,145
R-squared	0.214	0.283	0.307	0.146	0.255	0.264

Notes: Regression results for the natural logarithm of wage rates (in $2015) are based in on information in the Panel Study of Income Dynamics (PSID) for persons age 25-69 in waves 1975-2015. Independent variables include age and age-squared, and dummies for part time work (≤20 hours per week) and overtime work (≥ 40 hours per week). Robust standard errors in parentheses. Source: Authors' calculations.

Online Appendix B: Modeling retirement accounts

We embed a US-type progressive tax system in our model to explore the impact of having access to a qualified (tax-sheltered) pension account of the EET versus the TEE (Roth) type.[14] (All values are in $2015 and relevant amounts are inflation adjusted yearly). Here the worker must pay taxes on labor income and on capital gains from investments in bonds and stocks. During the working life, he invests A_t in a tax-qualified pension account which reduces his taxable income; contributions can be made to an annual maximum amount D_t=$18,000 (and from age 50 an additional $6,000 catch up is feasible). Correspondingly, withdrawals W_t from the tax-qualified account increase taxable income. Finally, the worker's taxable income is reduced by a general standardized deduction GD. For a single person, this deduction was in 2015 $6,300 (in 2018 $12,000) per year. Consequently, taxable income during the working age is given by:

$$\begin{aligned} &\text{EET} \quad Y_{t+1}^{tax} = \max\big[\max\big(S_t \cdot (R_{t+1} - 1) + B_t \cdot \big(R_f - 1\big);\ 0\big) + \\ &\qquad Y_{t+1}(1 - h_t) + W_t - \min(A_t; D_t + catch\ up) - GD; 0\big], \text{ and} \\ &\text{TEE} \quad Y_{t+1}^{tax} = \max\big[\max\big(S_t \cdot (R_{t+1} - 1) + B_t \cdot \big(R_f - 1\big);\ 0\big) + M_t + \\ &\qquad Y_{t+1}(1 - h_t) - GD; 0\big]. \end{aligned} \tag{B1}$$

For Social Security (Y_{t+1}) taxation, we use the following rules: when the retiree's *combined income*[15] is between $25,000 and $34,000 (over $34,000), 50% (85%) of benefits are taxed. After retirement, we set A_t= 0, i.e. no further contributions in 401(k) retirement plans are possible.

In line with US rules for federal income taxes, our progressive tax system has seven income tax brackets (IRS 2015a). These brackets $i = 1, \dots, 7$ are defined by a lower and an upper bound of taxable income $Y_{t+1}^{tax} \in [lb_i, ub_i]$ and determine a marginal tax rate r_i^{tax}. In 2018, the marginal taxes rates for a single household were 10% from $0 to $9,225, 12% from $9,225 to $38,700, 22% from $38,701 to $82,500, 24% from $82,501 to $157,500, 32% from $157,500 to $200,000 35% from $200,001 to $500,000 and 37% above $500,000 (see IRS 2018). Based on these tax brackets, the dollar amount of taxes payable is given by:[16]

[14] That is, contributions and investment earnings in the account are tax exempt (E), while payouts are taxed (T).
[15] Combined income is sum of adjusted gross income, nontaxable interest, and half of his Social Security benefits (US SSA nd_c).
[16] Here we assume that capital gains are taxed at the same rate as labor income, so we abstract from the possibility that long-term investments may be taxed at a lower rate.

$$
\begin{aligned}
IT_{t+1}^{tax} = {} & (Y_{t+1}^{tax} - lb_7) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_7\}} \cdot r_7^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_6) \cdot 1_{\{lb_7 > Y_{t+1}^{tax} \geq lb_7\}} + (ub_6 - lb_6) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_7\}} \right) \cdot r_6^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_5) \cdot 1_{\{lb_6 > Y_{t+1}^{tax} \geq lb_5\}} + (ub_5 - lb_5) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_6\}} \right) \cdot r_5^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_4) \cdot 1_{\{lb_5 > Y_{t+1}^{tax} \geq lb_4\}} + (ub_4 - lb_4) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_5\}} \right) \cdot r_4^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_3) \cdot 1_{\{lb_4 > Y_{t+1}^{tax} \geq lb_3\}} + (ub_3 - lb_3) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_4\}} \right) \cdot r_3^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_2) \cdot 1_{\{lb_3 > Y_{t+1}^{tax} \geq lb_2\}} + (ub_2 - lb_2) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_3\}} \right) \cdot r_2^{tax} \\
& + \left((Y_{t+1}^{tax} - lb_1) \cdot 1_{\{lb_2 > Y_{t+1}^{tax} \geq lb_1\}} + (ub_1 - lb_1) \cdot 1_{\{Y_{t+1}^{tax} \geq lb_2\}} \right) \cdot r_1^{tax}
\end{aligned}
\tag{B2}
$$

where, for $A \subseteq X$, the indicator function $1_A \rightarrow \{0, 1\}$ is defined as:

$$
1_A(x) = \begin{cases} 1 \mid x \in A \\ 0 \mid x \notin A \, . \end{cases}
\tag{B3}
$$