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Do required minimum distribution 401(k) rules matter, and for whom? Insights from a lifecycle model[☆]

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ABSTRACT

Tax-qualified vehicles have helped U.S. private-sector workers accumulate $33Tr in retirement plans. An often-overlooked important institutional feature shaping decumulations from these plans is the "Required Minimum Distribution" (RMD) regulation requiring retirees to withdraw a minimum fraction from their retirement accounts or pay excise taxes on withdrawal shortfalls. Our calibrated lifecycle model measures the impact of RMD rules on heterogeneous households' financial behavior during their work lives and in retirement. The model shows that reforms delaying or eliminating the RMD rules have little effect on consumption profiles, but they would influence withdrawals and tax payments for households with bequest motives.

1. Introduction

Almost 10,000 Baby Boomers retire each day in the United States (US Social Security Administration 2012), and many of these individuals rely on withdrawals from employer-sponsored tax-qualified retirement plans for an important source of old age income. The decumulation phase has traditionally prompted substantial interest from the US Congress, which has imposed several rules for withdrawing tax-protected assets amounting to around $33 trillion (ICI 2023). Specifically, over the years, tax law has required older Americans to annually withdraw a stipulated minimum fraction from their tax-deferred retirement account balances, and then to pay income tax on the amount withdrawn. Moreover, if retirees withdraw too little during the taxable year, they must pay a 50% penalty tax on the under-withdrawn amounts. The motivation for this Required Minimum Distribution (RMD) policy was that contributions and investment earnings in tax-qualified employer-sponsored 401(k) plans and Individual Retirement accounts (IRA) are tax-exempt until the money is withdrawn.[1] If, however, a retirement saver were to die prior to drawing down her entire account, the remaining assets could pass to her heirs who then could stretch distributions over their own (probably longer) lifetimes, likely resulting in much lower tax revenue collected.

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[1] RMD rules apply to both traditional Individual Retirement Accounts (IRA) and most employer sponsored defined contribution plans, such as 401(k), 403(b), 503(b) and thrift savings plans; the latter may be rolled over to IRAs when the participant retires. We do not consider Roth accounts in this paper, since Roth account holders are not subject to RMD rules. For a historical discussion of RMD rules in the United States, see Warshawsky (1998) and Soled and Wolk (2000).

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In 1986, a minimum start age of 70.5 was established for mandatory withdrawals, such that the minimum fraction withdrawn from the remaining account balance rose with age to reflect the account owner's life-expectancy remaining (IRS 2015). In 2019, however, the SECURE 1.0 Act boosted the minimum start age to 72, and in 2022, the SECURE ACT 2.0 further raised it to age 73. The latter bill also phased in further increases in the RMD start age to 75 by 2033, and reduced the penalty for missed RMDs to 25% of the amount that should have been withdrawn.[2]

Whether and how Americans respond to such RMD deferrals and the tax penalties associated with noncompliance is the subject of this paper. To investigate potential effects on household decision variables, we develop and solve a realistically calibrated lifecycle model with taxable and tax-deferred retirement accounts, which allows also to evaluate the implications of alternative RMD policies for individuals and the taxes they pay. Specifically, we evaluate the impacts of raising the RMD start age on saving/consumption patterns, contribution/withdrawal paths in tax-qualified accounts, and work hours/retirement patterns. Accordingly, our research contributes to the rich literature initiated by Cocco et al. (2005) and Gomes and Michaelidis (2005) on discrete time household financial decision making using dynamic consumption and portfolio choice models (see also Gomes, 2020 and Gomes et al., 2021 for an overview). Specifically, we build on and extend prior work by Gomes et al. (2009) and Horneff et al. (2020) on tax-deferred retirement accounts by including endogenous labour supply (Gomes et al., 2008) and claiming decisions for social security benefits (Hubener et al., 2016), while undertaking a detailed consideration of the taxation of retirement plan withdrawals. We also extend existing empirical studies on the impact of RMD rules (Sabelhaus 2000; Brown et al., 2017; Mortenson et al., 2019) by providing new insights from our theoretical life cycle model. In addition, we contribute to the ongoing policy debate on the efficient decumulation of trillions in assets held in tax-qualified defined contribution retirement plans, by analyzing the economic consequences of changes in RMD policy.

Our results document that delaying the RMD age has little overall impact during the work life, including on workers' savings and asset allocation inside and outside tax-qualified retirement accounts. Additionally, social security claiming behavior is almost unaffected. By contrast, notable changes are observed for tax-qualified account distributions over the retirement period, depending on whether older households have a bequest motive or not. For those with no bequest motive, current and proposed RMD rules are not particularly restrictive, as optimal expected withdrawals from 401(k) plans are substantially higher than the required RMD payout pattern. By contrast, when retirees have a bequest motive, results are rather different. The RMD_{70} rule proves quite restrictive, since many individuals would prefer to make fewer withdrawals than required and use the 401(k) plans as a tax-favored tool to transfer financial wealth to the next generation. This result continues to hold when the RMD rule starts later and when the penalty tax falls to 25%. We also show that for a RMD start age of 72 or 75, the sum of lifetime tax payments is not much affected, even for those with bequest motives. We also evaluate two policy counterfactuals, one that applies RMD rules only to retirement assets in excess of $100,000 (called the 'progressive RMD' approach), and the other would completely eliminate them altogether. Both of these would result in notably lower lifetime tax payments by high-income individuals having a bequest motive. By contrast, if the RMD rules were completely eliminated but a 25% penalty tax were imposed on 401(k) assets remaining at death, comparable to a special inheritance tax, this would increase tax revenues and lead to considerable changes in household behavior.

In what follows, we develop and calibrate a discrete time lifecycle model using US data for utility-maximizing workers with endogenous work hours and retirement, consumption/saving, and portfolio choice including risky stocks and bonds held inside and outside a tax-deferred retirement plan. Our model embeds exogenous background risks, heterogeneity of income profiles and preferences, realistic rules on income taxes, and regulations regarding social security benefit claiming options. Importantly, the model also integrates real-world rules characterizing tax-qualified 401(k) accounts including pre-tax contributions, employer matches, and RMD withdrawal amounts.[3] Our results using calibrated baseline parameters agree closely with observed U.S. household saving and Social Security claiming ages. We then use our approach to generate optimal consumption/savings, work/retirement patterns, and portfolio allocations in a baseline case, and we also compare results across different RMD scenarios.

2. Life cycle model and calibration

2.1. Time budget, labor income, and retirement benefits

Our lifecycle model assumes a representative U.S. worker making annual decisions from age 24 ($t = 0$) until her maximum age of 100 ($T = 76$). This worker can allocate up to $(1 - l_t) = 0.6$ of her available time budget to paid work (assuming 100 waking hours per week and 52 weeks per year). Depending on her work effort $(1 - l_t)$ and the wage rate WR_t, her yearly before-tax labor income during work life is:

$$Y_{t+1} = (1 - l_t) \cdot WR_t. \tag{1}$$

The uncertain wage rate $WR_t = w_t \cdot P_t \cdot U_t$ consists of an age-dependent deterministic component (w_t), an uncertain permanent component $P_{t+1} = P_t \cdot N_{t+1}$ with $P_0 = 1$ and independent log-normal distributed shocks $N_t \sim LN(-0.5\sigma_P^2,\ \sigma_P^2)$, and a transitory shock $U_t \sim LN(-0.5\sigma_U^2,\ \sigma_U^2)$ assumed uncorrelated with N_t. We assume heterogeneous individuals and calibrate the deterministic components of the wage rate process and the variances of the permanent and transitory wage shocks separately for six groups, namely men and women of three educational levels: less than High School (<HS), High School graduate (HS), and at least some college (Coll+). The estimation procedure draws on data from the Panel Study of Income Dynamics (see Appendix A).

Between ages $62 \le K \le 70$, the individual can retire from work and claim social security benefits which result in the yearly retirement income $(t \ge K)$ of:

$$Y_{t+1} = PIA_K \cdot \lambda_K \tag{2}$$

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[2] The SECURE 1.0 Act required that inherited qualified retirement accounts for non-eligible designated beneficiaries be paid out over a maximum of 10 years, instead of over their life expectancies under the old law (Gradisher and Tassell-Getman 2020; Hartman 2020; US Congress 2019-2020). Eligible designated beneficiaries, including a surviving spouse, a minor child, and other individuals not more than 10 years younger than the deceased owner, can still stretch after death distributions over their own lifetimes. Several advocates have long sought to raise the RMD age to age 75 (Waddell, 2019; Kapadia and Hershberg, 2020). An approach known as a "progressive RMD" has also been discussed, which would eliminate the RMD age for retirees having retirement assets worth less than $100,000 in aggregate. Moreover, complete elimination of the RMD rules has been discussed by analysts including Berry (2020).

[3] An working paper by Stuart and Bryant (2021) related to ours built a structural lifecycle model to investigate the impact of RMD withdrawal penalties on Individual Retirement Account (IRAs). While their model-simulated outcomes match IRA withdrawal data provided by the IRS, their setup is far less rich than ours. Unlike the present paper, that study does not allow endogenous work hours, social security claiming, portfolio decisions, shocks from risky stocks, and out-of–pocket medical expenditures. It also does not undertake heterogeneity analysis, while we model six different income profiles (by sex and education), preferences (bequest/no bequest), and three exogenous shocks (to stocks, medical expenditures, and labor income).

Old age retirement benefits depend on the retiree's Primary Insurance Amount (PIA) and an adjustment factor for early or delayed claiming. Thus, the $PIA = \min[0.9AIME;\, 9,666 + 0.32(AIME - 10,740);\, 26,954 + 0.15(AIME - 64,764);\, 36,500]$ in 2018 was a piecewise linear function of (12 times) the worker's average indexed lifetime earnings (AIME).[4] If a worker claims benefits at the system-defined Normal Retirement Age of 66, the PIA replaces 90% of the first \$10,740 of average lifetime earnings, plus 32% of earnings between \$10,740 through \$64,764, plus 15% of earnings over \$64,764 up to the cap (\$128,400). An adjustment factor permanently decreases (increases) benefits if an individual claims benefits before or after the Normal Retirement Age of 66. More specifically, the factors we use are: $\lambda_{62} = 0.75$; $\lambda_{63} = 0.8$; $\lambda_{64} = 0.867$; $\lambda_{65} = 0.933$; $\lambda_{66} = 1.0$; $\lambda_{67} = 1.081$; $\lambda_{68} = 1.16$; $\lambda_{69} = 1.24$; $\lambda_{70} = 1.32$.

2.2. Wealth dynamics and budget constraint

The individual can use current cash on hand for consumption C_t, investments in risky stocks $S_t \geq 0$ represented by a diversified index fund, riskless bonds $B_t \geq 0$, and contributions $A_t \geq 0$ to an employer sponsored tax-deferred qualified 401(k) plan. We assume that all workers have access to such retirement plans which are taxed according to an EET-regime: that is, workers can deduct contributions to retirement accounts from taxable income up to a yearly limit,[5] earn pre-tax investment earnings in their accounts, and pay income tax on withdrawals during retirement (when the marginal tax rate is usually lower than during the work life). After retirement at age K, no further contributions may be made into 401(k) plans $A_t = 0$ $(t \geq K)$. Hence, cash on hand X_t in each year is given by:

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

One year later, cash on hand is the value of stocks (bonds) having earned an uncertain (riskless) gross return of R_{t+1} (R_f), plus income from work after age-dependent housing costs h_t (as in Love, 2010), plus withdrawals (W_t) from the retirement plan, minus taxes (Tax_{t+1}):

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

Our financial market parameterizations assume a risk-free rate of 1% and lognormal distributed stock returns, $\ln(\mathrm{R_t}) \sim N(0.05; 0.18)$, with a mean of 5% and a return volatility of 18%. As in Lusardi et al. (2017), individuals whose cash on hand falls below $X_{t+1} \leq \$5,879$ receive subsistence support from the government making up the difference.

Individuals must pay three kinds of taxes: payroll, federal income, and penalty taxes for non-compliant RMD withdrawals from 401(k) accounts. Payroll taxes are proportional to the worker's annual earnings, amounting to 11.65% until retirement (the sum of 1.45% Medicare, 4% city/state tax,[6] and 6.2% social security contributions to a cap). After retirement, social security and Medicare contributions are usually no longer paid. In addition, both workers and retirees pay federal income taxes that depend on taxable income and corresponding progressive marginal tax rates for each of the seven tax brackets (in 2018). Own contributions into a 401(k) plan reduce the worker's taxable income (see Appendix B), while withdrawals from 401(k) plans increase it. A penalty tax of 10% is payable on withdrawals from 401(k) accounts prior to age 59½ $(t = 36)$, and for the base case, a penalty of 50% (25%) applies if withdrawals from the RMD start age are less than required under the rules we are analyzing. Inherited assets are exempt from estate taxes.[7]

2.3. Tax deferred retirement accounts and RMD rules

The worker's assets in the tax-qualified retirement plan are invested in a portfolio of risky stocks and bonds. Letting $\omega_t^s \geq 0$ be the relative exposure to equity, this portfolio generates a gross portfolio return of $R_{t+1}^{401(k)} = \omega_t^s R_{t+1} + (1 - \omega_t^s) R_f$. In addition to the benefits from deferred taxation, we assume that employers match 100% of employee contributions up to 5% of yearly labor income, so that the 401(k) plan is able to avoid complex nondiscrimination testing.[8] Due to tax regulation (as of 2018), the matching rate is only applied to a maximum compensation of \$275,000, so the overall matching contribution is given by $M_t = \min(A_t, 0.05Y_t, \$13,750)$. After retirement, no additional own contributions are possible $(A_t,\ M_t = 0)$. Prior to the endogenous retirement age $t = K$, the total value (F_{t+1}) of retirement assets at time $t + 1$ is determined by the previous period's value minus any withdrawals $(W_t \leq F_{t+1})$, plus additional own contributions (A_t), plus any employer match (M_t), and returns on stocks and bonds.

From a given starting age onwards (RMD_{age}), plan participants must take payouts from the retirement account each year, defined as a certain fraction (m_t) of the account value according to the Required Minimum Distribution rules. This required fraction is increasing with age and is calculated as one divided by the distribution period specified in the IRS Uniform Lifetime Table (IRS 2018).[9] For the starting age RMD_{age}, we consider three cases: age 70 (the RMD start age prior to 2019); age 72 (consistent with the SECURE 1.0 Act); and age 75 (as per the SECURE 2.0 Act). Withdrawals below the RMD threshold requires the payment of a penalty tax PT of 50% (or 25%, depending on the setting) on the under-withdrawn amount, taken directly from the 401(k) account. Depending on the setting, PT = 50%, 25%, or 0%. The dynamics for the retirement account evolve as follows:

$$F_{t+1} = \begin{cases} (F_t - \mathrm{W_t} + A_t + M_t) R_{t+1}^{401(k)} & for\ t < K \\ (F_t - \mathrm{W_t}) R_{t+1}^{401(k)}, & for\ K \leq t < RMD_{age} \\ (F_t - \mathrm{W_t}) R_{t+1}^{401(k)} - max(PT(m_t F_t - W_t), 0), & for\ t \geq RMD_{age} \end{cases} \tag{5}$$

Additionally, we consider the progressive RMD case, where the RMD_{age} rises to 75 but the withdrawal rule applies only to those with tax-qualified retirement accounts worth over \$100,000. Finally, we consider a case where the RMD rule is eliminated and the 25% penalty tax is due only on assets remaining in the retirement account at the time of death.

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[4] Following Chai et al. (2011), we approximate the PIA using permanent income in the optimization. In the simulation of optimal life cycles, we use the 35 best years of earnings to generate the PIA and adjust the corresponding permanent income state. Throughout the paper we use parameters for institutional rules (taxes, social security, 401(k) limits) from 2018; these increase with inflation each year (US SSA nd_a and b) so our model focuses on real rather than nominal values.

[5] Our model uses a yearly own contribution limit of \$18,500 (plus 'catch-up' contributions of \$ 6,000 for those over age 50 until retirement.

[6] State and local taxes vary widely across the states (e.g. 0% Texas; 13.3% California) and municipalities, so our parameter is an average that we add to the payroll tax for simplicity's sake.

[7] U.S. law does not require the filing of estate tax returns for gross assets of less than \$11.58 million for deceased persons (in 2020). Eligible designated beneficiaries do not pay estate tax on inherited IRA assets and can defer payment of income tax for at least 10 years.

[8] See Willson (2019) for a discussion of 401(k) safe harbor plans. Love (2007) reports a value of 100% matching to 6% in US defined contribution plans.

[9] If an individual remains employed at the same firm at which she has her retirement plan, she need not take an RMD until she stops working. The uniform table changed in 2022 (with slightly lower withdrawal rates) but these are not modeled here, as we focus our analysis on the impact of alternative RMD rules.

2.4. Preferences

The individual derives utility from a composite good consisting of consumption C_t and leisure time l_t (normalized as a fraction of total available time), modelled by the time-separable power utility function $u_t(C_t, l_t) = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho}$. After retirement, she enjoys full leisure ($l_t = 1$). The parameter α measures leisure preferences; ρ is the coefficient of relative risk aversion; and β the time preference factor. In addition, she receives utility from bequeathing financial wealth to her heirs after she dies, from both her tax-qualified and regular saving accounts $Q_t = F_t + S_t + B_t$. The parameter $b \geq 0$ measures the strength of the bequest motive.[10] The recursive definition of the value function of this dynamic optimization problem is given by:

$$J_t = \frac{(C_t l_t^{\alpha})^{1-\rho}}{1-\rho} + \beta E_t\left(p_t J_{t+1} + (1-p_t) b \frac{\left(\frac{Q_{t+1}}{b}\right)^{1-\rho}}{1-\rho} \right), \tag{6}$$

with terminal utility $J_T = \frac{(C_T)^{1-\rho}}{1-\rho} + \beta E_T \frac{b(\frac{Q_{t+1}}{b})^{1-\rho}}{1-\rho}$. Age-specific annual survival probabilities p_t ($p_0 = 1$ and $p_T = 0$) for males and females are taken from US population life tables (Arias 2010).

For the baseline analysis, we use the following preference parameters: relative risk aversion $\rho = 5$, time discount rate $\beta = 0.96$, leisure $\alpha = 1.5$, and bequest $b = 3$. These parameters closely match simulated model outcomes as well as empirical evidence on both average assets in tax-qualified retirement accounts and social security claiming ages (see Appendix C).[11] In some cases considered below (specifically for the RMD_{72} rule), we compare households with and without bequest motives, which we do by solving solve the life cycle model for the six household subgroups without a bequest motive (setting $b = 0$) and retaining the other preference parameters.[12]

We posit that individuals in each of the six subgroups (male/female, with education levels <HS, HS, and Coll+) maximize the value function (6) subject to the constraints and calibrations set out above, by optimally choosing their eight control variables each year: consumption, work hours, social security claiming age, contributions/withdrawals from tax-qualified 401(k)-plans, 401(k) equity exposures, and investments in stocks and bonds in non-tax-qualified accounts. To solve the individual optimization problem, we use dynamic stochastic programming techniques with respect to five state variables: cash on hand X_t, 401(k) assets F_t, permanent income P_t, claiming age K_t, and time t (see Appendix D).

3. How restrictive are the RMD rules?

In this section we concentrate on the RMD start age at 72 currently in effect, to explore whether, and for whom, RMDs are a binding constraint restricting optimal withdrawal behavior. On the one hand, as noted by Brown et al. (2017), RMD rules only constrain qualified account holders who would prefer to withdraw less from their account balances than the rules prescribe. Such individuals could include those having a bequest motive or who experienced a large growth in retirement assets due to very high stock returns. On the other hand, retirement accounts are designed to support old-age consumption, and lifetime utility maximizing retirees may wish to take more than the required RMD amounts. Moreover, Mortenson et al. (2019) noted that the actual RMD schedule is modest, since the implied remaining life expectancy figures are below those from actual mortality tables. For example, according to the IRS uniform table, the remaining life expectancy or distribution period at age 75 is set at 22.9 years, generating an RMD of 1/22.9 = 4.4% of the retiree's account balance. Yet life expectancy remaining according to US population tables (used in the utility function) is much lower, around 13 years for females and 11 years for males, which translates into withdrawal rates of 7.7% and 9.1%, respectively. An additional factor supporting higher than required withdrawals is the implied low risk-free interest rate of 1% versus the subjective discount factor of 4% used in the utility function.

3.1. Expected lifecycle profiles, optimal and required minimum distributions

To investigate the restrictiveness of the RMD_{72} rules on a quantitative basis, the first row of Fig. 1 reports overall population expected life profiles for consumption, income from work or social security in retirement, cash on hand, and assets held inside tax-qualified 401(k) accounts. The second row provides insight into expected withdrawals when RMD_{72} rules become effective. That is, we trace the expected optimal withdrawals predicted by the lifecycle model and withdrawals required by the RMD_{72} rule. Individuals lacking a bequest motive are depicted on the left side, and those with a bequest on the right side.

Expected life cycle profiles: The life cycle profiles shown in the top row are similar to those reported in previous studies using similar lifecycle models (e.g. Chai et al., 2011; Hubener et al., 2016). Pre-tax incomes rise over the first 25 years of workers' lives and then gradually decline until retirement (left side, panel A). This is explained by the hump-shaped earnings pattern, the reduction of working hours in later life (less overtime, more part-time work), and people's tendency to retire starting from age 62 onwards when social security benefits can be claimed. During their work lives, people save part of their salaries in tax-qualified 401(k) plans and the assets grow to age 60 (including investment returns). Thereafter, when the 10% penalty tax for early withdrawals no longer applies, individuals begin withdrawing substantial amounts from their 401(k) accounts.[13] These withdrawals are used to finance consumption during periods of part-time work or, after full retirement, to compensate for the fact that social security benefits fall below pre-retirement labor income.[14]

The model predicts also that consumption follows a hump-shaped pattern, rising over the work life and then declining between ages 62–70. In this window, people leave work completely, claim their social security benefits, and substitute consumption expenditures for more leisure time. The dotted line displays the average cash on hand. Some of the assets finance current consumption, while the remainder is held in liquid investments (stock/bonds)

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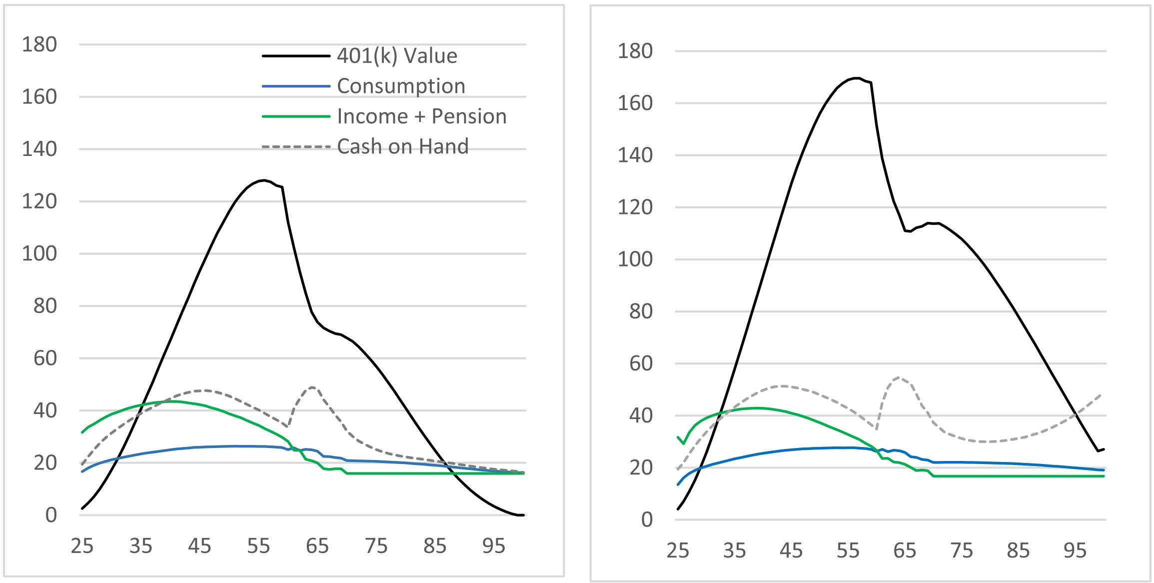
[10] See Ameriks et al. (2011) and Kraft et al. (2022) on this formulation of the bequest function. To reduce the number of preference parameters that must be calibrated, we refrain from introducing a threshold value above which inheritances are a luxury good.

[11] The coefficient of relative risk aversion is in line with prior work on life cycle models with an endogenous asset allocation among risky stocks and bonds For example, to match a lifecycle model to data, Love (2010) estimated $\rho = 6$, Inkmann et al. (2011) used $\rho = 6.5$, and in Catherine (2022) the estimated coefficient of relative risk aversion ranged from 6 to 7 (depending on the model).

[12] A recalibration of the other preference parameters (α, β, ρ) for households without a bequest motive was not undertaken, due to the high computational effort involved. In addition, in the data we use on claiming behavior (SSA) and 401(k) assets (EBRI), we are unable to differentiate households with and without bequest motives.

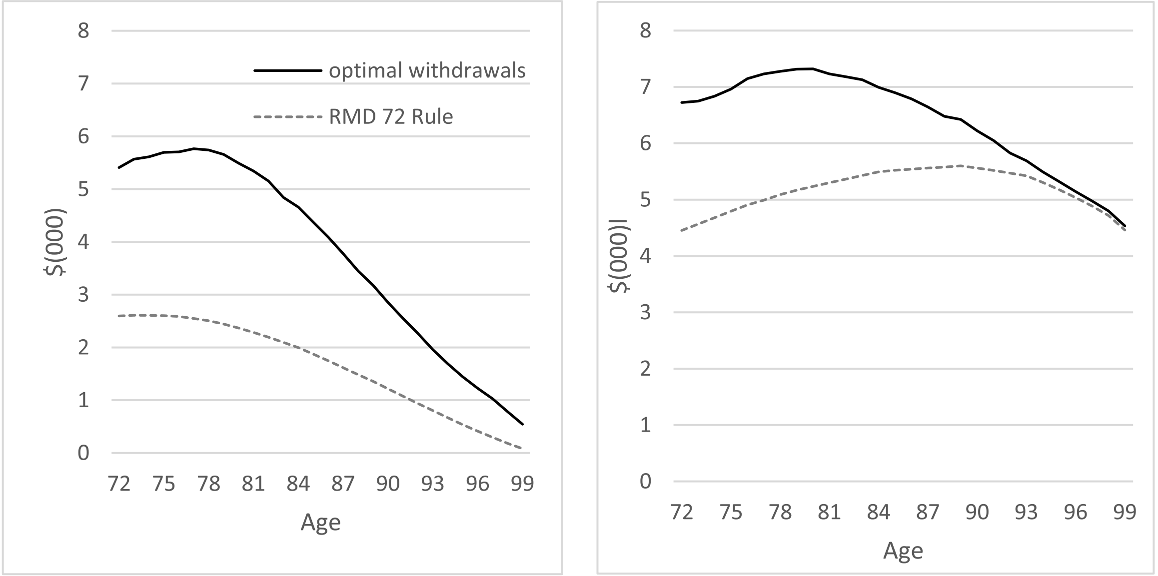
[13] Withdrawals prior to that age are small, mainly driven by workers having unexpectedly large negative income shocks (e.g. unemployment) and low savings outside their 401(k) plans. This accords with empirical evidence showing a modest rate and size of pre-retirement withdrawals from 401(k) plans (Poterba et al., 2000).

[14] For the total population, the average replacement ratio (average social security income divided by average labor income) is about 45%. Due to the progressivity of the social security formula, this replacement ratio is much higher for high school dropouts, and lower for those having the highest educational levels (Coll+).



Panel A: Life cycle profiles (w/o bequest)

Panel B: Life cycle profiles (with bequest)



Panel C: 401(k) withdrawals (w/o bequest)

Panel D: 401(k) withdrawals (with bequest)

Fig. 1. Expected life cycle pattern and withdrawals from 401(k) accounts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Panels A and B depict mean values for consumption, cash on hand, income (work, pension benefits from social security), and 401(k) assets generated by our life cycle models. Panels C and D compare optimal 401(k)-withdrawals vis-á-vis withdrawals according to the RMD_{72} rule with a 50% penalty tax. The right (left) columns show households with (without) a bequest motive. Mean values are calculated using 200,000 weighted simulated lifecycles paths based on optimal feedback controls by sex/education subgroups. Population outcomes use education weights for the female (male) populations: 61% +Coll; 28% HS; 11% <HS (57% +Coll; 30% HS; 13% <HS); weights for females (males) 49.28% (50.72%) of entire population. Preferences: risk aversion $\rho = 5$; time $\beta = 0.96$; leisure $\alpha = 1.5$; bequest $b = 3$ ($b = 0$ no bequest).

outside tax-qualified accounts for precautionary reasons, including to buffer uninsurable labor income risk. The hump in cash on hand between age 60–70 can be explained by the fact that some households reduce their working hours considerably yet defer claiming their social security benefits. Therefore, they use liquid assets during this period to finance consumption.

Up to age 70, the life cycle profiles for individuals without (Panel A) and with a bequest motive (Panel B) are quite similar, although the latter group does accumulate more wealth in 401(k) plans even during their work lives. This is mainly due to the fact that these households work more hours per week (3 h more) and retire about 0.4 years later, compared to those without a bequest motive. At older ages, however, stronger differences emerge. In particular, those lacking a bequest motive completely deplete their 401(k) accounts at older ages. By contrast, those with a bequest motive continue to hold substantial amounts in their 401(k) accounts, so as to transfer them to their heirs when they die. Furthermore, they hold rising levels of cash on hand from age 80 onwards, indicating that the RMD regulations become increasingly restrictive for this group the older it gets. To avoid the significant 50% penalty tax on under-withdrawals, households take out sufficient funds from their retirement plans, pay income tax on them, and then invest the assets in non-tax-qualified accounts to finance consumption and bequests. Hence these households with a bequest motive pay for transfers to the next generation from assets held both inside and outside their 401(k) accounts.

Optimal versus required withdrawals: Further insights into the extent of the restrictiveness of the RMD rules are evident in the bottom row of Fig. 1. Here we compare expected optimal (solid line) and required (dotted line) RMD withdrawals for households without (Panel C) and with a bequest motive (Panel D).

For those unconcerned about their heirs (Panel C), optimal withdrawals first rise slightly between ages 72–78 (from $5500 to 5800), and then they fall steadily. These retirees spend more of their accounts than the expected investment returns on assets, hence their 401(k) balances decline with age. The required withdrawals curve under the RMD_{72} rule also declines with age. This is because, although the tax-relevant percentage withdrawal rates according to the IRS uniform table rise with age, 401(k) assets remaining fall faster due to households' high withdrawals. Evidently such individuals will optimally withdraw substantially more from their DC accounts than what the RMD rules requires during retirement. The gap between the two curves also shrinks with age, due to shrinking 401(k) plan assets.

Panel D of Fig. 1 compares optimal and RMD withdrawals for retirees with a bequest motive. Again, expected optimal withdrawals again exceed those under the age-based RMD_{72} rules, and the gap declines with age. But compared to the no bequest case, optimal withdrawals are now higher and fall much less with age. Furthermore, the difference between optimal and RMD withdrawals is much smaller than without bequests, and the withdrawal differentials converge to zero from age 90 onward. For example, for a retiree with no (with) bequest motive under the RMD_{72} rule, her first optimal withdrawal exceeds the minimum by $5400 - $2600 = $2800 ($6700 – $4500 = $1800). At age 95, the withdrawal differential is $1300 ($200). This arises because people with an inheritance motive accumulate more in their 401(k) plans by the end of their working lives, and from these assets, they optimally withdraw only slightly more than the investment returns generated. Consequently, 401(k) assets decline less by age compared to the case with no bequest. This, in turn, leads to the RMD amounts increasing to age 90.

3.2. Probability distribution of withdrawal rates

A more granular look is available by reviewing the probability distribution of optimal withdrawals as a fraction of retirement balances generated from 200,000 simulated lifecycle patterns. For retirees without and with a bequest motive, the top row of Fig. 2 illustrates, the required withdrawal ratios according to the RMD rules (red line), and a probability band (10–90% quantile in blue) for their optimal withdrawal rates. The figure clearly shows that retirees with no bequest motive are not at all constrained by the RMD rules, whereas persons having a bequest motive are much more likely to find the RMD requirement a binding constraint. The bottom row of Fig. 2 reports the relative frequencies of optimal withdrawals as a fraction (in 0.5% increments) of retirement account balances for retirees at ages 75, 85, and 95, still assuming the RMD_{72} rules. Table 1 provides summary statistics for these frequency distributions, for both the total population and for the three education subgroups.

The bottom left panel in of Fig. 2 depicts results for households with no bequest motive, where we observe that for all scenarios, the probability mass is broadly distributed over the entire spectrum of possible withdrawal ratios. To avoid the 50% penalty tax, only very few ($< 0.05\%$) of the simulated retirees take out less than the RMD rules require. Essentially, these are the small number of cases where people seek to avoid boosting their taxable incomes in retirement above exemption thresholds, by making the full RMD withdrawals. Such tax exemption limits are relevant, for example, when calculating how much of peoples' social security benefits must be included in taxable income.[15] In these few cases, it is better to accept a penalty tax for a small under-withdrawal than to go over the exemption limit and pay more income taxes.

By contrast, households lacking a bequest motive generally wish to avoid the 50% penalty, so they take at least as much as the RMD rules require. Moreover, many retirees seek to withdraw much more than the RMD rule prescribes (reflected by the arrows). For example, the rule requires a 75-year-old retiree to withdraw 4.4% from her retirement account. There is only a moderate peak in the probability mass of 1.8% around this withdrawal rate, while the mode of the distribution shows a much higher withdrawal rate of 7.5%. As can be seen in Table 1, the mean (13.6%) and the median (12.6%) are also far above the RMD_{72} withdrawal rate. This effect is larger among the older retirees: by age 85 (95), the RMD rule requires a withdrawal of 6.8% (11.6%) of the account, while the distribution's modal withdrawal rate is around 18% (25%). Furthermore, the dispersion of the distribution continues to increase, as mean and median values are even further away from the RMD rules. A look at results for the three education subgroups in Table 1 provides a similar conclusion. The distributions show a high dispersion with mean and median values far above the required withdrawal levels. Overall, then, we conclude that the RMD rules do not bind for retirees lacking a bequest motive.

A completely different picture emerges when retirees do have a bequest motive (see bottom right panel of Fig. 2 and Table 1). Here, the modal payout ratio corresponds to the required RMD fraction, and the probability mass increases significantly with age. Mean and median values are only slightly larger than the required minimum distributions, and the dispersion of the distribution is low. For example, at age 75, about 20% of retirees withdraw the required minimum asset share of 4.4%. The mean (median) is only about 1.3 (0.6) percentage points higher, and the standard deviation is only a quarter of that for those lacking a bequest preference. Hence, we conclude that the RMD regulations are far more restrictive for this population subgroup. Among retirees surviving to age 85 (95), about 40% (85%) follow the RMD payout rule. This underscores the fact that they prefer to withdraw less than the required minimum fractions, yet the high penalty tax prevents them from doing so. In this regime, few retirees take out less than required, and those who withdraw more, do so at a moderate rate. This can be explained by the exemption limits and nonlinearities in the tax system. Accordingly, our theoretical result confirms Mortenson et al.'s (2019) empirical finding that the RMD rule proves to be a binding constraint for an important group of retirees. The finding that our theoretical results match up with evidence on real-world retirement plan participants' withdrawal patterns can therefore be interpreted as evidence that many retirees' planned payout patterns are consistent with them having a bequest motive.[16]

Accordingly, we conclude that the regulatory minimum RMD withdrawal rules are not particularly restrictive for retirees lacking a bequest motive. These individuals intend to spend all of their assets by the time they pass away so as to smooth lifetime utility stream from consumption, and the best way to achieve this is to withdraw enough along the way. Any remaining assets transferred to the next generation are therefore random, depending on whether retirees die early or late. By contrast, households having

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[15] This depends on the so-called Combined Income, whereby only half of social security benefits but all withdrawals from 401(k) plans are taken into account for tax purposes (US SSA, nd_c).

[16] Additional factors explaining the high correspondence between empirical and regulatory minimum withdrawal rates might include behavioral (non-expected utility) preferences or optimization constraints, but such factors are beyond the framework of our model.

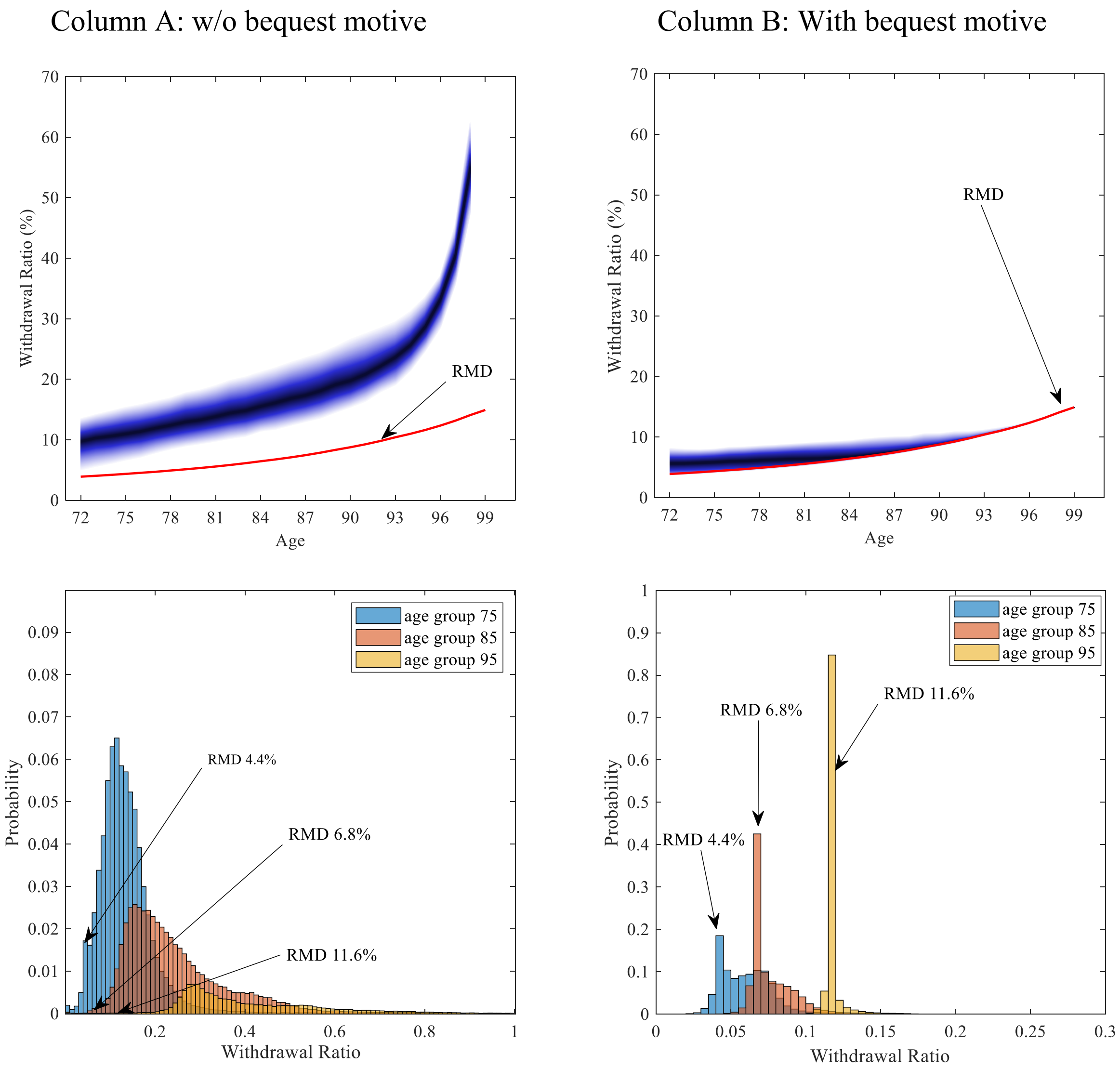

Fig. 2. Optimal withdrawal ratios from 401(k) accounts for the RMD_{72} rule. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
The figures in the first row illustrates the probability distribution (90%; 10% quantile) of optimal withdrawal rates as a fraction of retirement account assets for 200,000 simulated lifecycles of individuals without a bequest motive (column A) and with a bequest motive (column B). Darker areas represent higher probability mass. The solid red line represent the required withdrawal rates according to the RMD-rules. The figures in the second row depict the predicted probability distribution of optimal withdrawals as fraction of retirement assets (withdrawal ratio) taken by retirees at ages 75 (blue bars), 85 (orange bars), and 95 (yellow bars). Relative frequencies by withdrawal ratios are reported in 0.5% steps. The arrows reflect the RMDs as per uniform table 2018 for those in the corresponding age group, as per the IRS uniform table 2018. Population outcomes are generated using 200,000 weighted simulation paths based on optimal feedback controls from the lifecycle models by six sex/education subgroup. Paths with 401(k) assets equal to zero ($<$ \$2000) without (with) bequests were eliminated from the sample. For additional information on parameters and calibrations see Figure 1.

a bequest motive are those most likely to be constrained by the RMD_{72} rules; they do their best to use tax-advantaged retirement accounts, not only for old age consumption, but also to fund their gifts to the next generation.

3.3. Sensitivity analysis for medical shocks

Thus far we have not modelled medical risks explicitly, as this substantially reduces the computational intensity of the problem we solve. Yet a question might arise as to whether the risk of healthcare costs could alter our conclusions thus far. At least two possibilities suggest themselves. First, being in poor health can increase mortality rates and reduce the retiree's remaining life expectancy. Second, poor health is frequently accompanied by unexpected out-of-pocket medical expenses not covered by insurance, and it may also generate additional (persistent) expenditures for long term care expenses.[17]

We therefore conduct sensitivity analysis in which we also model health shocks. To do so, we first include an i.i.d. lognormal distributed transitory shock of retiree out-of-pocket medical shocks.[18] Not surprisingly, findings are consistent with results reported above. Second, we analyze the impact of a permanent reduction in disposable retirement income due to the costs associated with a permanent deterioration in health (e.g. to cover long-term medical costs). We model this as a homogeneous two-dimensional Markov chain with two states, where state 1 reflects

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[17] See Love and Smith (2010) and De Nardi et al. (2010).

[18] Specifically, we use a transitory shock variance of 0.0767 (0.0784) for people with a Coll+ (HS and <HS) education as reported in Love (2010).

Table 1
Optimal 401(k) withdrawal ratios at different ages, w/o and with bequest motive.

	Panel A: w/o bequest motive			*Panel B: with bequest motive*		
Subgroup	Mean	Median	Std.	Mean	Median	Std.
Age 75 (RMD = 4.4%)						
<HS	0.165	0.159	0.060	0.057	0.050	0.025
HS	0.153	0.150	0.071	0.058	0.054	0.018
Coll+	0.127	0.116	0.070	0.062	0.062	0.017
Population	0.136	0.126	0.071	0.060	0.058	0.018
Age 85 (RMD = 6.8%)						
<HS	0.300	0.290	0.122	0.074	0.068	0.015
HS	0.299	0.264	0.149	0.074	0.068	0.015
Coll+	0.232	0.203	0.106	0.079	0.073	0.017
Population	0.247	0.216	0.119	0.077	0.070	0.016
Age 95 (RMD = 11.6%)						
<HS	0.420	0.428	0.159	0.117	0.116	0.003
HS	0.428	0.383	0.180	0.117	0.116	0.006
Coll+	0.405	0.355	0.155	0.118	0.116	0.011
Population	0.407	0.358	0.158	0.118	0.116	0.009

Note: This table reports the mean, median, and standard-deviation of optimal withdrawal ratios from 401(k) retirement plans at different ages for the overall population and three educational subgroups: <HS, HS, or Coll+. The model embeds the RMD$_{72}$ and 50% penalty tax on remaining retirement asset at death. Results in Column A (B) represent patterns for individuals without (with) a bequest motive. Outcomes are generated using 200,000 weighted simulation paths based on optimal feedback controls by sex/education subgroup. For additional information on parameters and calibrations see Fig. 1.

normal health, and the absorbing state 2 reflects bad health. Transition probabilities between the states are assumed to be $p_{11} = 0.95$, $p_{12} = 0.05$, $p_{22} = 1$, and $p_{21} = 0$; in other words there is a 5% transition probability (from age 70 onwards) to switch from normal health to the absorbing state of poor health, and poor health is associated with a permanent 20% reduction in retirement income. Furthermore, if such an event occurs, the retiree's survival probabilities are reduced by 20%.[19]

Interestingly, we find no systematic differences compared to our previously reported results (see Table E1 in Appendix E). For households lacking a bequest motive, the rate of asset withdrawal is somewhat slower initially, due to precautionary saving against lingering health shocks. Thereafter, withdrawal rates rise with age, partly to pay for long-term-care expenditures and partly because life expectancy is reduced. Nevertheless, withdrawal rates from retirement plans are always well above those required by the RMD rules. Furthermore, for persons having a bequest motive, optimal withdrawals from 401(k) accounts are still highly concentrated at the RMD rates. This confirms that RMDs are highly restrictive for households with bequest motive, even given medical shocks.

4. What would delaying the RMD age do?

Next we compare the expected optimal outcomes from the lifecycle model for several different variants of the RMD rules. We focus only on persons with an inheritance motive, as we have shown in the previous section that the RMD rules are restrictive only for them. As in Section 3, we next solve for the optimal lifecycle policies and generate simulated optimal outcomes for the same heterogeneous six subgroups of households, but now for the alternative RMD rules of key interest. Simulated lifecycle outcomes (consumption, income, work hours, retirement ages, 401(k)-contributions/withdrawals/wealth, cash on hand, tax payments) of these groups vis a vis the RMD$_{72}$ (control) group are the basis for comparisons in the policy analyses. Table 2 reports results.

Our first set of results adopts a RMD start age of 70 (RMD$_{70}$), in effect until 2019.[20] The second analysis implements the new start age of 72 (RMD$_{72}$) implemented in 2020; the third assumes that the RMD begins at age 75 and keeps the penalty tax at 50%; the fourth posits a (not yet legislated) RMD$_{75}$ age only applied to retirement accounts holding assets over $100,000 (RMD$_{75}$ & W > 100 K); in setting five, the start age is raised to 73 and the penalty tax is cut to 25% (25%-RMD$_{73}$) as stipulated for 2023 in the SECURE 2.0 Act; in the sixth case, the required RMD start age rises to age 75 (RMD$_{75}$) with a penalty tax of 25% (consistent with the SECURE 2.0 Act as of 2023). In case seven (not yet legislated), we analyze the consequences of eliminating the RMD rule during live but paired with a 25% tax (along the SECURE Act 2.0 penalty tax) due on peoples' remaining 401(k) assets at death. Our final case eight (also not yet legislated) eliminates the RMD rule altogether.

In Table 2, we report average outcomes for the overall population in terms of social security claiming ages, work hours, 401(k) assets, assets in non-qualified accounts, and consumption over the life cycle. Panel A shows the results assuming a 50% penalty tax for under-withdrawals, and Panel B for a 25% penalty tax. These results demonstrate that average claiming ages, work hours, consumption, and assets held outside tax-qualified plans, are virtually unchanged during the worklife, across the various RMD designs. That is, the average social security claiming age remains at age 64.7, work hours average around 34 per week, and average yearly consumption holds at around $24,600. In addition, asset accumulation is very similar across RMD rules, with 401(k) plan assets between $100,000 and $103,000, and other assets averaging $14,600-$17,000. This means that for the working-age population, the RMD constraints are so far in the future that these have practically no influence on work and financial decisions. Although this result is not surprising, it is important to confirm intuition using our model.

Table 2 further shows that shifting the RMD start age from 70 to 72 or 75 has little impact on expected wealth patterns even in retirement, regardless of whether the penalty tax is 25% or 50%.

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[19] This approach to modelling deteriorating health is a simplified version of the approach proposed by Ameriks et al., 2011.

[20] The pre-SECURE Act age was in fact 70.5, but we solve the model in round years. In some situations, the RMD rules have been suspended, as in the case of the Coronavirus Aid, Relief, and Economic Security (CARES) Act (2020).

Table 2
Model-generated outcomes under alternative RMD designs.

	Panel A: 50% penalty tax				*Panel B: 25% penalty tax*			
	RMD$_{70}$ (1)	RMD$_{72}$ (2)	RMD$_{75}$ (3)	RMD$_{75}$ & W>$100K (4)	RMD$_{73}$ (5)	RMD$_{75}$ (6)	w/o RMD PT at death (7)	w/o RMD no PT (8)
Average claiming age								
Age 62–70	64.7	64.7	64.6	64.7	64.7	64.7	64.67	64.6
Average Work Hours per week								
Age 25–61	34.1	34.2	34.2	34.1	34.1	34.1	34.1	34.1
Average 401(k) assets ($000)								
Age 25–61	102.1	102.7	100.3	103.8	102.9	104.7	102.8	103.2
Age 62–90	98.3	98.6	100.0	101.9	99.0	100.1	74.3	103.1
Age 91–100	39.2	39.5	40.0	57.0	40.6	40.9	12.9	60.1
Average Non-qualified assets ($000)								
Age 25–61	15.4	15.1	17.0	14.6	15.1	13.7	16.4	15.3
Age 62–90	13.9	13.7	12.9	11.3	13.3	12.7	38.1	10.6
Age 91–100	22.0	21.8	21.2	6.8	20.9	20.5	50.1	4.5
Average Consumption ($000)								
Age 25–61	24.6	24.6	24.6	24.6	24.6	24.5	24.5	24.6
Age 62–90	22.6	22.6	22.5	22.6	22.5	22.5	22.6	22.5
Age 91–100	19.8	19.8	19.8	19.9	19.9	19.8	19.9	20.6

Note: This Table reports average outcomes for various penalty taxes (50% in Panel A versus 25% in Panel B) and starting RMD ages: RMD$_{70}$; RMD$_{72}$; RMD$_{73}$; RMD$_{75}$; and the progressive RMD rule (RMD$_{75}$ & W > $100 K). Column (7) shows results for no RMDs but with a penalty tax of 25% on any remaining 401(k) assets when the account owner dies. Colum (8) reports the case with RMD and no penalty tax at all. Averages are derived from 200,000 simulated lifecycles for individuals with a bequest motive based on optimal feedback controls from the life cycle model using income profiles by sex/education subgroup. For additional information on parameters and calibrations see Fig. 1.

Asset accumulation changes only slightly: retirees age 62–90 have on average $1500 more in their 401(k) accounts with the RMD$_{75}$ and a 25% penalty tax, versus the RMD$_{72}$ and the higher penalty tax of 50%. This difference shrinks to $1000 for retirees surviving to ages 91–100. Also, no major changes are identified for assets held in non-qualified accounts: under the RMD$_{72}$ rule, retirees hold $1000 more than with the RMD$_{75}$ and penalty tax of 25%. Average consumer spending also does not change much due to the shift in the RMD start age. Overall, we conclude that delaying the RMD start age and even reducing the penalty tax does not materially change the appeal of retirement savings. That is, our results show that even for those having a bequest motive, people would neither accumulate more wealth nor boost retirement consumption dramatically.

By contrast, implementing a progressive RMD rule would substantially increase average assets in retirement accounts late in life (age 92–100), to about $57,000, or 45% above those in the RMD$_{72}$ case. Assets in non-qualified accounts would also be much lower in later life, by about $15,000 (70%). Accordingly, retirees with a bequest motive would hold on to more assets in their 401(k) accounts if the progressive RMD rule were in place, since their tax-qualified retirement accounts are now a more effective instrument to finance bequests than are non-qualified accounts. This occurs for two reasons. First, the 401(k) buildup represents a tax-free transfer of assets to the next generation, and second, retirement account assets accumulate free of tax. Accordingly, these retirees spend more of their non-qualified assets to finance late-life consumption, which for the progressive RMD case generates essentially the same consumption as do the other rules. Eliminating RMD rules altogether (see column 8) would reinforce this effect. In this case, an average of $60,000 is still retained in the retirement plan at ages 91–100.

A very different set of outcomes obtains if the RMD rules were eliminated but the 25% penalty tax were levied on remaining 401(k) assets at the death of the account owner. Now, using the 401(k) plan as an instrument to bequeath financial assets to the next generation is clearly much less attractive. Instead, retirees shift their assets from 401(k) plans to non-qualified plans early on. Between age 62–90, an average of only $74,300 is retained there, nearly a quarter less than under the RMD$_{72}$ rules. By contrast, non-qualified assets triple, from $13,700 to $38,100. Clearly, in this case it is less expensive, on average, to withdraw 401(k) assets, pay income taxes, and accept a lower after-tax return on the non-qualified assets, than it would be to pay 25% tax on the remaining 401(k) plan assets at death. Interestingly, the different RMD start ages do not produce major changes in expected consumption in retirement. In sum, this policy mainly causes people to alter the optimal asset location for bequeathing assets to the next generation to non-qualified accounts.

Table 3
Optimal 401(k) withdrawal ratios for two alternative RMD rules and two tax regimes under RMD elimination.

Subgroup	*Mean*	*Median*	*Std.*
Age 75 (RMD = 4.4%)			
RMD$_{75}$ & 25% PT	0.061	0.060	0.019
RMD$_{75}$ & W>100K	0.050	0.055	0.030
w/o RMD & 25% PT at death	0.210	0.110	0.239
w/o RMD	0.049	0.053	0.031
Age 85 (RMD = 6.8%)			
RMD$_{75}$ & 25% PT	0.076	0.069	0.015
RMD$_{75}$ & W>100K	0.055	0.059	0.037
w/o RMD 25% at death	0.322	0.201	0.279
w/o RMD	0.055	0.058	0.036
Age 95 (RMD = 11.6%)			
RMD$_{75}$ & 25% PT	0.117	0.116	0.008
RMD$_{75}$ & W>100K	0.051	0.043	0.045
w/o RMD & 25% PT at death	0.417	0.317	0.297
w/o RMD	0.048	0.040	0.043

Note: This Table reports the mean, median, and standard deviation of optimal 401(k) withdrawal ratios for three RMD start ages of 75, 85, and 95 and two tax regimes. Outcomes are generated using 200,000 weighted simulation paths based on optimal feedback controls for individuals with a bequest motive. For additional information on parameters and calibrations see Fig. 1.

Fig. 3 and Table 3 report how the alternative withdrawal rules influence the probability distribution of assets for retirees age 75, 85 and 95. The histogram of optimal withdrawal rates with an RMD start age of 75 and the lower penalty tax of 25% (Panel A) hardly differs from that with RMD$_{72}$ and a 50% penalty tax (see Fig. 2 Panel B). Moreover, the means, medians, and standard devi-

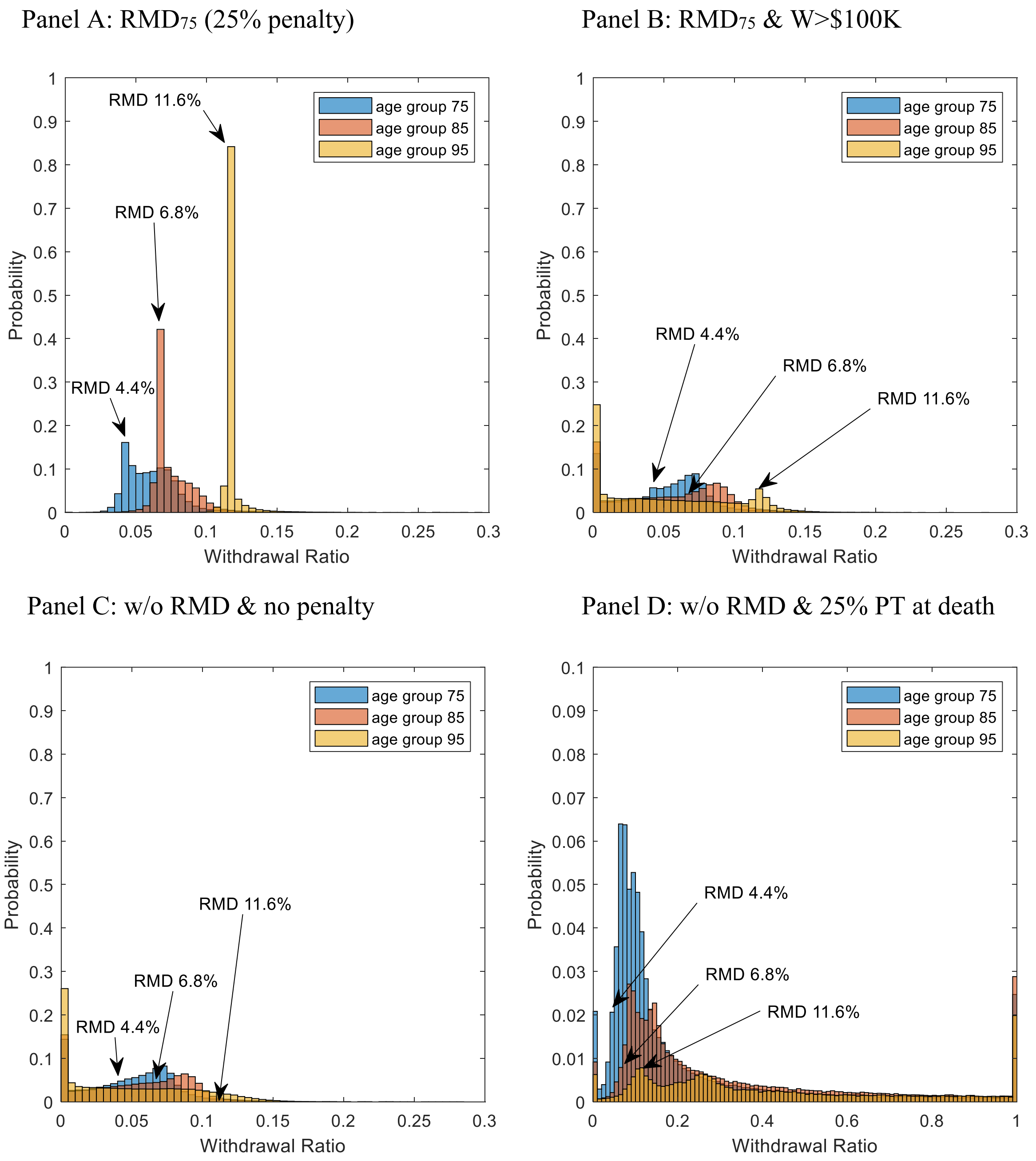

Fig. 3. Optimal withdrawal ratios from 401(k) accounts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
The figures depict the predicted probability distribution of optimal withdrawals as fraction of retirement assets (withdrawal ratio) taken by retirees at ages 75 (blue bars), 85 (orange bars), and 95 (yellow bars). Relative frequencies by withdrawal ratios are reported in 0.5% steps. The arrows reflect the RMD for those in the corresponding age group. Panel A illustrates the RMD_{75} rules using a 25% penalty, Panel B the progressive RMD_{75} rule ($W > \$100$ K), Panel C has no RMD or penalty tax, and Panel D has no RMD but does impose a 25% penalty on remaining 401(k) assets when the account holder dies. Population outcomes are generated using 200,000 weighted simulation paths based on optimal feedback controls for individuals with a bequest motive by sex/education subgroup. For additional information on parameters and calibrations see Fig. 1.

ations are also very close. By contrast, eliminating RMD start ages completely or applying them only to 401(k) assets over $100,000 changes the distributions markedly (see Panels B and C). To preserve inheritances in the 401(k) accounts, the modal value of optimal withdrawals falls to zero rather than following a minimum RMD withdrawal rate.

We also see that when there are no minimum withdrawal ages but retirement assets over $100,000 are subject to a 25% tax at the retiree's death, the histogram is similar to the case with no bequests (Fig. 1, Panel A). Optimal withdrawal rates are much more heterogeneous, ranging from 24% at age 75, to 30% at age 95. Means and medians are also quite a bit higher than those under the other RMD rules, for all ages considered, and the probability mass concentrated at 0% and 100% withdrawal rates is striking. Especially early in retirement, it may make sense for some households not to withdraw at all from their 401(k)s, so as to let them continue to grow tax-free. As the probability of mortality rises with age, households increasingly shift retirement assets into nonqualified accounts, with the aim of avoiding the 25% penalty tax at death on retirement plan accruals.

To sum up, we document that people having a bequest motive retain relatively more assets in their 401(k) plans to finance these bequests, and raising RMD start ages or lowering the penalty tax does not fundamentally alter this story. A progressive RMD rule (or the complete elimination of RMDs) would allow for this more flexibly, compared to simply delaying the RMD start age. By contrast, most households would massively increase withdrawals from their 401(k) plans if the RMD rule were eliminated but remaining retirement assets at death were taxed at a 25% rate.

5. Implications for lifetime tax payments

5.1. Tax payments over time

We next explore the potential impact of alternative RMD rules for household tax payments over the lifecycle. This is important since RMDs [were intended] "to generate taxable income from these distributions, it probably won't help the federal deficit if they push the age back" (Malito, 2018: n.p.). Additionally, the US Joint Committee on Taxation (JCT 2019) estimated that federal tax revenue would fall by \$8.9 billion over the period 2019–2029, as a result of simply raising the RMD from age 70.5 to 72. Our quantitative results regarding tax revenues must be interpreted with caution, of course, since the microeconomic lifecycle model does not take into account potential macroeconomic effects that could arise in overlapping generations. Moreover, our model does not endogenize the impact of changes in RMD rules on the labor, financial, and goods markets. Nevertheless, since individual behaviors transfer to the macroeconomic level, our results *mutatis mutandis* can inform us about how changing RMD rules could affect the federal budget. Moreover, to simultaneously demonstrate the impact of actual and potential RMD policy changes on key household behaviors including consumption, work hours, saving, labor input, and benefits claiming, is a valuable contribution.[21]

To this end, we focus only households having a bequest motive and narrow our examination to the window between age 70 ($t = 46$) and the maximum age of 100 ($T = 76$). Using the weighted simulated optimal lifecycles profiles for the six subgroups (males/females in each of the education groups <HS, HS, Coll+), we calculate for each individual i the tax payments $IT_{i,t}$ at time t. Whether an individual pays taxes depends on her state of life. Income taxes and penalty taxes are paid only upon survival. An exception is the RMD_{75} & 25% PT rule, in which taxes on remaining assets in the 401(k) plan are levied at a 25% rate only in the year of the retiree's death. To reflect mortality risk, we multiply tax payments by an indicator variable $1_{i,t}$ equal to 1 if the individual must pay taxes at time t and zero otherwise. The transition probabilities of this indicator variable are derived from the mortality tables for males and females. Formally, this is defined as:

$$Tax^{pop}_{i,t} = 1_{i,t} \cdot IT_{i,t}. \tag{7}$$

This reflects the probability distribution of annual tax payments per individual i at each age t. To evaluate the implications of the different RMD rules for tax payments, we calculate the (cross-sectional) mean value for the total population, as well as the mean value at each age for the 99%th quantile (the top 1% of taxpayers). The curves in Fig. 4, Column A (left side), compare expected tax payments for the RMD_{72} (black dashed line) and the higher starting age of RMD_{75} in effect since 2023, with either a 50% penalty tax (green line) or a 25% penalty tax (red line). Column B (right side) compares the RMD_{75} (green line) with the progressive RMD_{75} rule (dashed green line).

Expected tax payments appear in the top row of the Figure. In all cases, tax revenues increase initially to age 80, and then they decline due to rising mortality. Furthermore, no differences in tax payments under the alternative RMD rules is detected for ages 70 and 71; instead, these become apparent only from age 72 onwards. On the left, compared to the traditional RMD_{72} (black dashed line) approach, tax payments are lower between ages 72 and 75 under the RMD_{75} rule (green line), as retirees make fewer withdrawals from their 401(k) accounts. But from age 75, tax payments under the RMD_{75} rule rise somewhat. This "catch-up" effect arises because, as more assets remain in the 401(k) plan to age 75, withdrawals and hence tax payments are higher when the RMD_{75} rule takes effect. In other words, tax payments between age 72–75 are postponed under the later RMD start age. Actual income tax shortfalls occur only when the retiree dies in the meantime. At age 75, the black and green black lines intersect; thereafter, retirees pay more taxes until age 85, on average, under the RMD_{75} than under the RMD_{72} rule. In fact, the differences between the two lines indicate that the RMD_{75} scenario actually generates more tax revenue over the lifecycle, compared to the old RMD_{72} rule.

This catch-up effect also occurs, albeit mitigated, when the penalty tax falls to 25%, as is evident from the red line in Fig. 4. Now, the red line (RMD_{75}) does not intersect the black dashed line (RMD_{72}) at age 75, and it remains below it until about age 85. The red line also remains below the black line (RMD_{72}) between ages 72 and 75, implying less tax is paid on average during this period. Around age 76, the two curves almost coincide, but there is no catch-up effect with the penalty tax of 25%. By comparison, as can be seen in the right panel of Column B, top row, there is also no catchup effect under the progressive RMD approach. That is, retirees having a bequest motive use the \$100,000 exemption limit to leave assets in their 401(k) plans to their heirs, without fear of penalty taxes; this results in lower tax payments at all ages.

The second row of Fig. 4 (left) illustrates the effects for the 1% of people who pay the highest income tax. Now the catch-up effect is even clearer: both the green and red lines intersect the black line (RMD_{72}) at age 75 and slightly remain above it until about age 80. The catch-up effect again disappears for the progressive RMD_{75} rule (right panel), as lower taxes are paid at all ages.

5.2. Present value of tax payments

To investigate whether the catch-up effect fully compensates for the initial tax losses resulting from postponing the RMD starting age, over the remaining lifetime (age 70–100). To this end, we calculate for each individual the present value (at age 70) of all her tax payments between age 70 and 100 (using the risk free interest rate of 1%):

$$PV\_Tax_{70,i} = \sum_{t=70}^{100} \frac{Tax^{pop}_{i,t}}{\left(1 + R_f\right)^{t-70}}. \tag{8}$$

From this probability distribution for the overall population, we calculate the mean, median and the three quantiles Q-99%, Q-95% and Q-75% which represent the 1%, 5%, and 25% highest present value of tax payments. Using these metrics, we evaluate the resulting effects on tax payments for the eight alternative RMD and tax approaches under consideration. Results appear in Table 4.

A first finding is that the catch-up effect is more or less sufficient to compensate for initial tax losses resulting from delaying the RMD start age from 70 to later. Both the means and quantile values of the distribution of present values of tax payments between age 70 and 100 are generally equal to, or only slightly below, the corresponding numbers under the RMD_{70} rule. Moreover, this is true even with a reduced penalty tax of 25% on underwithdrawals. Also, tax revenues actually increase slightly when the

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[21] Our model also posits rational households, even though in practice they sometimes are not. We leave this extension to future research, as there is no consensus regarding which behavioral aspects should be implemented in normative models and how.

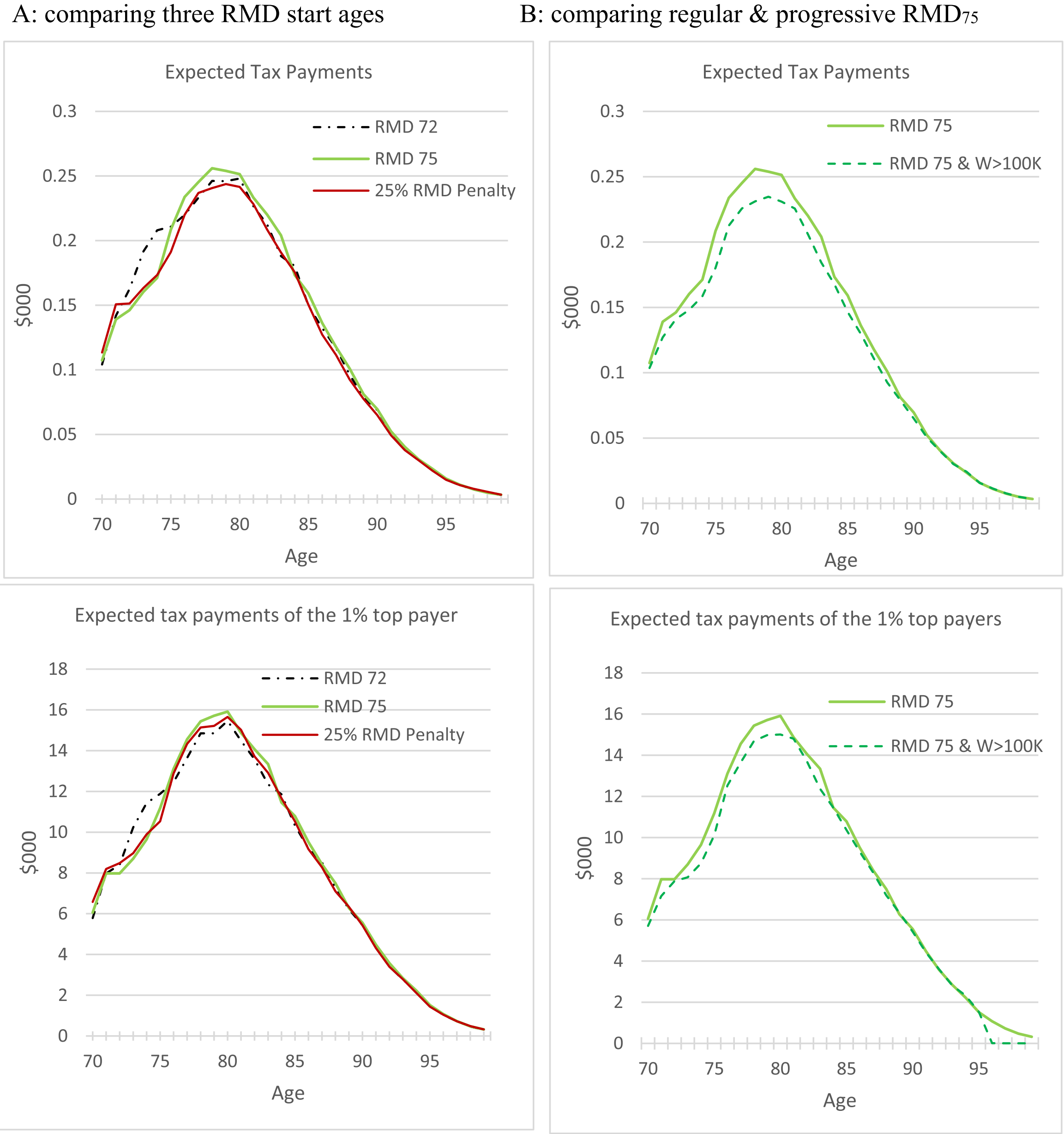

Fig. 4. Expected tax payments under alternative RMD rules for retirees with a bequest motive. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
This Figure reports summary statistics of tax payments (including penalty taxes) for retirees with a bequest motive from age 70–100, under alternative RMD rules. The top row refers to overall means, while the lower row refer to the (conditional) mean of the 1% highest taxpayers. Column A illustrates the effect of changing the RMD start age from 72 to 75 with a penalty tax of 50% (25%), while Column B illustrates the impact of the progressive RMD_{75} approach versus the progressive RMD_{75} for account values over \$100,000. Population outcomes are generated using 200,000 weighted simulation paths based on optimal feedback controls by sex/education subgroup (see text and weights in Table 1).

Table 4
Present value of tax payments age 70–100 under alternative RMD rules for individuals with a bequest motive (\$000).

	Penalty tax 50%				*Penalty tax 25%*			
	RMD_{70} (1)	RMD_{72} (2)	RMD_{75} (3)	RMD_{75} & W>\$100K (4)	RMD_{73} (5)	RMD_{75} (6)	w/o RMD & PT at death (7)	w/o RMD no PT (8)
Mean	3.58	3.45	3.50	3.25	3.37	3.39	13.35	3.25
Median	0.16	0.13	0.10	0.00	0.06	0.05	1.40	0.00
Q-75%	0.53	0.47	0.42	0.07	0.25	0.23	11.05	0.05
Q-95%	12.13	11.51	11.90	11.25	11.31	11.58	64.41	11.50
Q-99%	77.39	75.38	77.29	71.78	77.89	76.48	157.77	72.69

Note: This Table reports summary statistics (mean, median, quantiles) for the present value of total taxes paid by individuals between age 70–100 for alternative RMD and penalty tax (PT) scenarios. Results are based on 200,000 simulated optimal lifecycles by sex/education subgroup for individuals with a bequest motive. Tax payments are discounted to age 70 at the risk-free rate of 1%. For other parameters and calibrations, see Fig. 1.

RMD age shifts from 72 (Column 2) to 75 (Column 3), though the differences are slight (both the mean and 99%th quantile are only 1.5% higher). When the penalty tax falls to 25% at the same time (Column 6), the catch-up effect is no longer sufficient in expectation to compensate for the initial lower tax payments. Nevertheless, the differences are again modest.

As noted above, it has been suggested that overall tax revenue would fall as a result of deferring the RMD start age and penalty tax (JCT 2019). Our results imply a more nuanced impact, since the delay in tax payments is then offset by the catchup effect from the new RMD age onward.

If the RMD rule were to be completely eliminated, or if the progressive RMD were to be instituted (Columns 7 and 8), this would result in tax revenue losses, as those wishing to leave a bequest would defer 401(k) withdrawals, leaving more to the next generation. In particular, people in the highest taxpaying quintile (Q99%) would leave their 401(k) accounts to their heirs, and consequently, tax payments would fall by about 7.5% relative to taxes collected under the old RMD_{70} rule (=71.78/77.39–1).

By far the most significant impact on tax revenues would result if no minimum withdrawals were required during retirees' lifetimes and assets remaining in the retirement plan at death were taxed at 25% (the new penalty tax rate after Secure Act 2.0). In this case, the expected present value of tax revenues would almost quadruple compared to the traditional RMD_{70} rule (14.72/3.93 -1). This is due to two effects. First, wealthy households in particular would withdraw relatively heavily from their 401(k) plans. As these withdrawals would be part of taxable income, this would boost income tax payments to the govenrment. Secondly, any remaining 401(k) plan assets upon the retiree's death would be taxed at 25. This would result in higher tax payments especially for those who passed away soon after retirement.

6. Conclusions

The RMD rule was embedded in the US tax code to encourage retirement account owners to pay income tax on their tax-free accumulated assets prior to their deaths, so as to "prevent the individual retirement plan from being used to postpone taxes indefinitely" (Feuer, 2021: 181). Specifically, the purpose of RMDs was to limit the cost of tax subsidies designed to encourage retirement saving, without adversely impacting their intended effect which is to enhance old age security of private households through the accumulation and decumulation of retirement assets (Mortenson et al., 2019). To explore how alternative RMD rules shape saving, social security claiming ages, and withdrawals from retirees' tax-qualified retirement accounts, we build and calibrate a lifecycle consumption and portfolio choice model embodying realistic institutional considerations. We compared results under the initial RMD_{70} start age rule, as well as later start ages of 72, 73 and 75, and we also examined the impact of eliminating RMDs for retirees having retirement asset values below $100,000, known as the progressive RMD approach, as well as the complete abolition of the RMD.

Overall, our model shows that delaying the RMD age would have little impact on peoples' financial behavior during their work lives, including for expected savings both inside and outside tax-qualified retirement accounts. Additionally, social security claiming behavior would be almost unaffected. Nevertheless, more notable changes would occur during the retirement period, depending on whether retirees have a bequest motive or not. For those without a bequest motive, even eliminating RMD start ages would change very little. By contrast, for households having a bequest motive, the former RMD_{70} start age rule was quite restrictive, since such a household would prefer to make fewer withdrawals than required and use the 401(k) plans as a tool to transfer financial wealth to the next generation. Raising the RMD start age to 72 permits such households to postpone account withdrawals and defer taxes for two years. We also show that delaying the RMD start age from 70 to 72 or even age 75 alters the timing of tax payments, but it hardly changes overall tax payments over the remaining lifecycle. This is due to a catch-up effect, where lower tax payments early in retirement are offset by higher tax payments later, due to higher 401(k) values and larger taxable withdrawals. Under a progressive RMD plan, households intending to leave a bequest end up paying less tax over their lifetimes. Instead, they would use the $100,000 exemption to transfer wealth to the next generation without fear of penalty taxes. This produces lower lifetime tax payments, especially for the 1% highest taxpayers. A substantial boost in tax revenue would result if all assets remaining in the retirement plan at death were taxed at 25% and no minimum 401(k) withdrawals were required in retirement. In such a case, households would have a strong incentive to make substantial 401(k) withdrawals, partly to cover their consumption expenses but mainly to protect these assets from the 25% penalty tax at death.

Our contribution to the literature is thus to illustrate using an economic model of rational decision-makers how peoples' behavior under alternative RMD rules depends on the extent to which they desire to leave money to their heirs, taking into account the centrally important tax and other constraints facing retirees. Our work implies that financial institutions such as insurance companies and mutual funds offering retirement plans and investment advice would benefit from ascertaining their clients' bequest intentions, before advising them about RMD strategies. Our conclusions will also be of interest to professional financial planners guiding clients as they make retirement payout choices. Moreover, our results should inform policymakers considering legislation to raise and/or eliminate RMDs as well as penalty taxes for 401(k) plan payouts.

CRediT authorship contribution statement

Vanya Horneff: Methodology, Software, Formal analysis, Visualization, Writing – review & editing. **Raimond Maurer:** Conceptualization, Methodology, Validation, Resources, Writing – original draft. **Olivia S. Mitchell:** Conceptualization, Methodology, Visualization, Writing – review & editing, Funding acquisition.

Data availability

Data will be made available on request.

Appendix A. Wage rate estimation

We calibrate the wage rate process using the waves from Panel Study of Income Dynamics (PSID) 1975–2015 from age 25 to 69. Extreme observations for wages below $5 per hour and above the 99th percentile are dropped. The wage rate values are expressed in $2015. 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 $\ln(U_t) \sim N(-0.5\sigma_u^2,\ \sigma_u^2)$. These are estimated separately by sex and three educational levels: less than High School (<HS), High School graduate (HS), and with at least some college (Coll+). We use a second order polynomial in age and dummies for employment status to estimate the deterministic component using the regression function:

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

Table A1

Regression results for the wage rate process.

Coefficient	Male <HS	Male HS	Male +Coll	Female <HS	Female HS	Female +Coll
Deterministic						
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)
Age^2/10,000	-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

Note: Regression results for the natural logarithm of wage rates (in $2015) are based on the Panel Study of Income Dynamics (PSID) for persons age 25–69 in waves 1975–2015. Independent variables include age and age-squared, and dummies for part time work ($\leq$20 h per week) and overtime work ($\geq$ 40 h per week). Robust standard errors in parentheses. Deterministic and Permanent defined in Appendix A. ***: p > .01. Source: Horneff, Maurer, and Mitchell (2022).

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 ($\leq$ 20 hours), full-time worker ($<$ 20 & $\leq$ 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 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:

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

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

$$\nu_{id} = \beta_1 \cdot d + \beta_2 \cdot 2 + e_{id}, \tag{A3}$$

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

Appendix B. Modeling taxes

We embed a US-type tax system for workers having access to a qualified tax-deferred retirement account (TDA). All values are in $2018 and relevant amounts are inflation adjusted yearly. The worker pays federal income taxes on taxable income which is a complex function on labor income (minus housing costs), Social Security benefits and returns from investments in bonds and stocks.[22] Contributions A_t (up to D_t = $18,500) to the TDA reduce and withdrawals W_t from the TDA increase taxable income. For taxation of Social Security (Y_{t+1}) benefits after retirement, we use the following rules: when the retiree's combined income is between $25,000 and $34,000 (over $34,000), 50% (85%) of benefits are part of taxable income. Combined income is sum of adjusted gross income and half of Social Security benefits (US SSA nd). Negative returns from equity investments held in non-tax-qualified accounts are up to $3000 offset against other sources of income. Finally, a general standardized deduction GD = $12,000) reduces the worker's taxable income, which is given by:

$$\begin{aligned} Y_{t+1}^{tax} = {} & \max\Big[\max\left(S_t\left(R_{t+1}-1\right); -3000\ \right) + B_t\Big(R_f - 1\Big) \\ & + Y_{t+1}(1-h_t) + \ W_t - \min\left(A_t; D_t\right) - GD; 0\Big]. \end{aligned} \tag{B1}$$

In line with US federal income tax, our progressive tax system has $i = 1, \ \ldots, 7$ brackets (IRS 2018) 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 $9525, 12% from $9225 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 income taxes payable is given by:

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

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[22] For simplicity, we do not distinguish between different taxation of dividends and capital gains on stocks; rather, we assume that all investment earnings (if positive) are part of taxable income at the source. This is consistent with the assumption that equity investments are held in mutual funds (or ETFs), which due to tax requirements must distribute their income (dividends, realized capital gains) to their shareholders at least once a year. Here we assume that the investment funds have only short-term capital gains (SEC 2016).

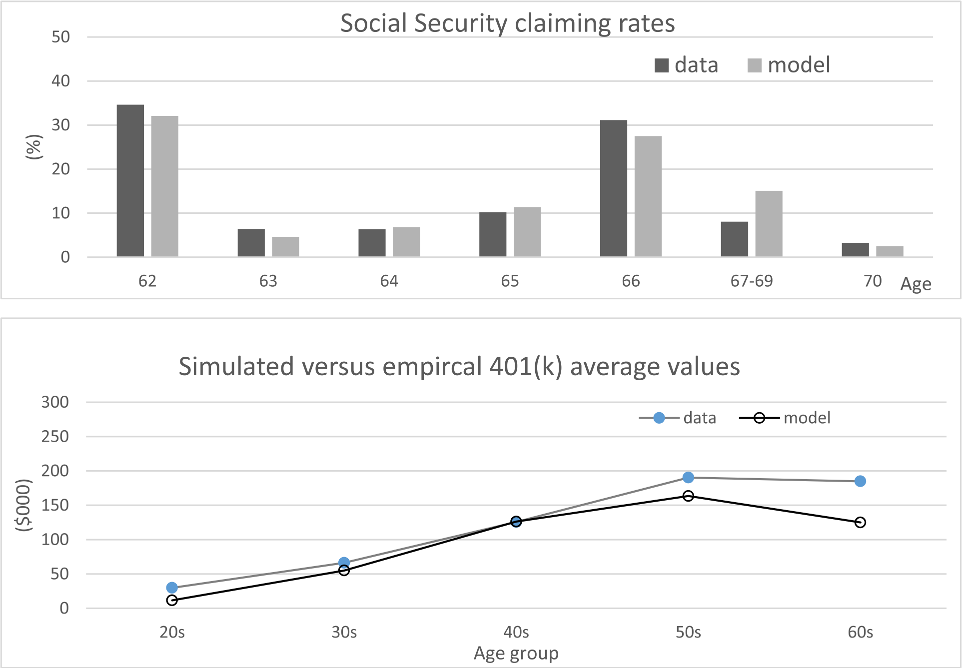

Fig. C1. Social security claiming patterns and wealth in 401(k) accounts. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The top panel compare expected 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). The lower panel compares expected account balances generated by the life cycle model versus empirical 401(k) account balances across the US population. Empirical account balance data are from the Employee Benefit Research Institute (2017); age groups referred to as 20 s, 30 s, 40 s, 50 s, and 60 s denote average values for persons age 20–29, 30–39, 40–49, 50–59, and 60–69. Expected values are calculated from 200,000 simulated lifecycles based on optimal feedback controls for each of six subgroups. Results for the entire female (male) population are computed using income profile three education levels: 61% +Coll; 28% HS; 11% <HS (57% +Coll; 30% HS; 13%<HS); weights for females (males) 49.28% (50.72%) of entire population. Parameters used for the baseline calibration are as follows: risk aversion $\rho = 5$; time preference $\beta = 0.96$; leisure preference $\alpha = 1.5$; bequest $b = 3$; 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 (IRS 2015); tax rules for 401(k) plans are as of 2015. The risk premium for stocks returns is 5% and return volatility 18%; the risk-free rate is 1%.

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

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

Additionally, before retirement ($t = \mathrm{K}$) the worker pays payroll taxes proportional to labor income: the tax rate for social security is 6.2% (up to a limit of 128,400); the Medicare tax rate is 1.45%; and city/state tax rate is 4% (without limit). Overall payroll taxes are modelled as $PayT_t^{tax} = 6.2\% \cdot \max(Y_t, 128,400) + 5.45\% \cdot Y_t$ before retirement, and $PT_t^{tax} = 5.45\% \cdot Y_t$ after retirement $(t \geq K)$. Finally, penalty taxes are 10% on early retirement account withdrawals prior to age 59 ½ ($t = 36$), and 50% (or 25% depending on the case) for non-compliant RMD withdrawals from 401(k) accounts.

Appendix C. Calibration of preference parameters

We believe it is important to calibrate such a rich lifecycle model to both financial and non-financial data. Accordingly, calibration of preference parameters (assumed unique for each of the six sex/education subgroups) follows the procedure in Horneff et al. (2022). We aim to ensure that the model outcomes simultaneously match empirical claiming rates reported by the US Social Security Administration (US SSA 2015), as well as average assets in 401(k) plans reported for 7.3 million plan participants for five age groups (20–29; 30–39, 40–49, 50–59 and 60–69) from EBRI (2017). The high computational intensity required to solve our life cycle model does not allow us to perform an exhaustive grid search procedure at fine intervals for all parameters $(\alpha, \beta, \rho,\ b)$. To limit the computational effort, we instead use values reported in the literature for comparable life cycle models (e.g. Chai et al., 2011; Cocco and Gomes 2012; Gomes et al., 2008; Hubener et al., 2016), and we perform further variations based on these initial values.[23] For a given set of preference parameters, we solve the lifecycle model's policy functions under the tax regime and social security rules in place in 2018 (i.e., using RMD_{70}) for each of the six sex/education subgroups. Next we generate 200,000 simulated independent lifecycles with respect to three exogenous random variables (stock returns, and permanent and transitory income shocks) using optimal feedback controls with respect to the control variables (consumption, leisure, investments in stocks and bonds, 401(k) contributions/withdrawals, social security claiming age). The number of simulations run for each subgroup varies with NCSE (2016) population weights by sex and education, generating a representative distribution of outcomes for the overall population.[24]

The simulation outcomes for the six subgroups are then aggregated to obtain population mean values on claiming rates and 401(k) wealth. Next we calculate for each set of preference parameter the distance function θ_{SMM}, which is defined as the sum of squared percentage deviation of the difference of simulated model

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[23] Specifically, we test the following values: $\alpha = (0.9;\ 1.1, ;\ 1.3;\ 1.5;\ 1.7)$, $ß = (0.9;\ 0.92, ;\ 0.94;\ 0.96;\ 0.98)$, $\rho = (3; 4; 5; 6; 7)$ and $b = (0; 1; 2; 3; 4; 5)$.

[24] 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); see NCES (2016).

moments from the data moments:

$$\theta_{SMM} = \min_{\alpha,\ \beta,\ \rho,\ b} \left(\sum_{i=1}^{6} \left(\frac{x_i^{model} - x_i^{data}}{x_i^{data}} \right)^2 + \sum_{j=1}^{5} \left(\frac{y_j^{model} - y_j^{data}}{y_j^{data}} \right)^2 \right) \tag{C1}$$

Here x_i^{model} (x_i^{data}) is the percentage of individuals in the model (data) claiming social security benefits at age $i = 62, 63, \ldots, 70$ and y_i^{model} (y_i^{data}) the average wealth in 401(k) accounts in the model (data) in in the $i = 1, 2, \ldots 5$ age groups. In the next step we repeat this procedure for a certain set of preference parameters. The parameter constellation that leads to the lowest value of the distance function generates a coefficient of relative risk aversion $\rho = 5$, time discount rate $\beta = 0.96$, leisure parameter $\alpha = 1.5$, and bequest parameter $b = 3$. The $\theta_{SMM} = 1.4463$. As Fig. C1 show this set of parameters closely match simulated model outcomes as well as empirical evidence on both average assets in tax-qualified retirement accounts and Social Security claiming ages. Specifically, the model generates a large peak at the earliest claiming age of 62, along with a second peak at the (system-defined) Full Retirement Age. Our model also matches the current distribution of average 401(k) wealth by age rather nicely, yet it underestimates wealth at higher ages.

Appendix D. Numerical solution of the life cycle model

The numerical procedure used to generate the optimal policy functions for each of the six subgroups in each period assumes a four-dimensional discrete state space grid 40(X)×20(F)×10(P)×9(K), with X being cash on hand, F referring to 401(k) assets, P permanent income, and K the nine possible ages to claim social security benefits. In the case with medical shocks the current health status is an additional discrete state variable. Since the model is using non-linear functions for taxes, contribution matches and other absolute cutoffs in non-linear functions it is not possible to reduce the dimensionality of the problem by normalization of other variables by permanent income (see e.g., Cocco et al., 2005). We use an equidistant logarithmic grid for the continuous state variables X, F and P. This means that we have more and closer points for the low values since the policy and value functions are especially sensitive in this area of the state space. The multiple integrals of the expected utility function is computed by resorting to Gaussian quadrature integration and the optimization is done by numerical constrained maximization routines using fmincom in MATAB. The values of the policy functions lying between the grid points of the continuous state variables P, F, and X are computed by cubic-spline interpolation. In order to obtain stable results, it is particularly important to select the range (minimum and maximum values) of the continuous state variables appropriately. It should be noted that the achievable permanent income differs between the six education groups. We therefore chose different ranges for the respective grid sizes. Specifically, we used the following minimum and maximum values for the permanent income (P), for males and females with education levels <HS = (min 0.1/max = 7); HS = (min 0.1 / max = 10), and Coll+ = (min 0.1/max = 10).

This choice of grid points ensures that households' simulated life cycle patterns with optimal feedback controls cover the core of possible realizations. At the same time, very high possible realizations are also covered, but very view values exceed the upper limit of the grid. A detailed diagnosis of the generated simulation paths for permanent income shows that for each of the six subgroups, fewer than 0.01% of the realizations lie outside the grid. In this tiny number of cases, the grid was extrapolated using cubic interpolation. We also tested other extrapolation methods (quadratic splines, not considering values outside the grid) that did not affect the reported results. The choice of these grid points generates sufficiently smooth policy functions without implausible discontinuities (such as jumps, valleys, or mountains). The following examples in Fig. D1 show policy functions on (1) optimal withdrawals from 401(k) plans with respect to age 70+ and 401(k) wealth, and (2) consumption as a function of age and cash on hand.

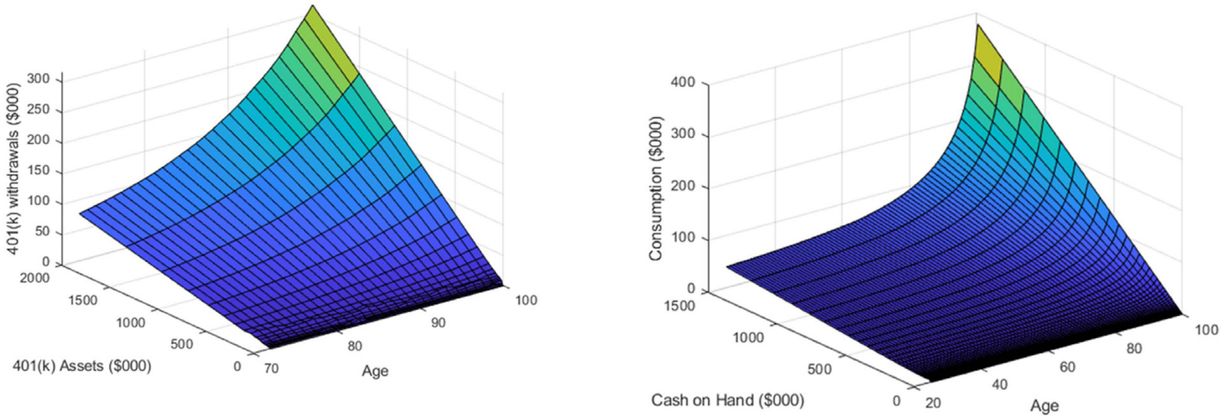

Fig. D1. Policy function for college females with a bequest motive. The left panel shows policy function on age, 401(k) assets, and 401(k) withdrawals. The right panel shows age, cash-on-hand, and 401(k) withdrawals. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Appendix E. Results assuming persistent medical shocks in retirement

Table E1
Optimal 401(k) withdrawal rates for RMD_{72} rule, w/o and with medical shocks.

	Panel A: no uncertain medical expenses			*Panel B:With uncertain medical expenses*		
Subgroup	Mean	Median	Std.	Mean	Median	Std.
Age 75 (RMD = 4.4%)						
with bequest	0.060	0.058	0.018	0.074	0.070	0.030
w/o bequest	0.136	0.126	0.071	0.224	0.184	0.138
Age 85 (RMD = 6.8%)						
with bequest	0.077	0.070	0.016	0.080	0.070	0.022
w/o bequest	0.247	0.216	0.119	0.323	0.276	0.171
Age 95 (RMD = 11.6%)						
with bequest	0.118	0.116	0.009	0.117	0.116	0.007
w/o bequest	0.407	0.358	0.158	0.468	0.426	0.183

Note: This table reports mean, median, and standard deviations of optimal 401(k) withdrawal ratios at different ages for the total population generated by our life cycle models. In the first (second) row for each panel, households have (lack) a bequest motive. Panel A reports results without uncertain medical expenses; Panel B includes persistent medical shocks. The absorbing probability of switching to bad health status is 5%. Bad health results in 20% reduction of retirement income and 20% increase in remaining mortality rates. For more information see Fig. E1.

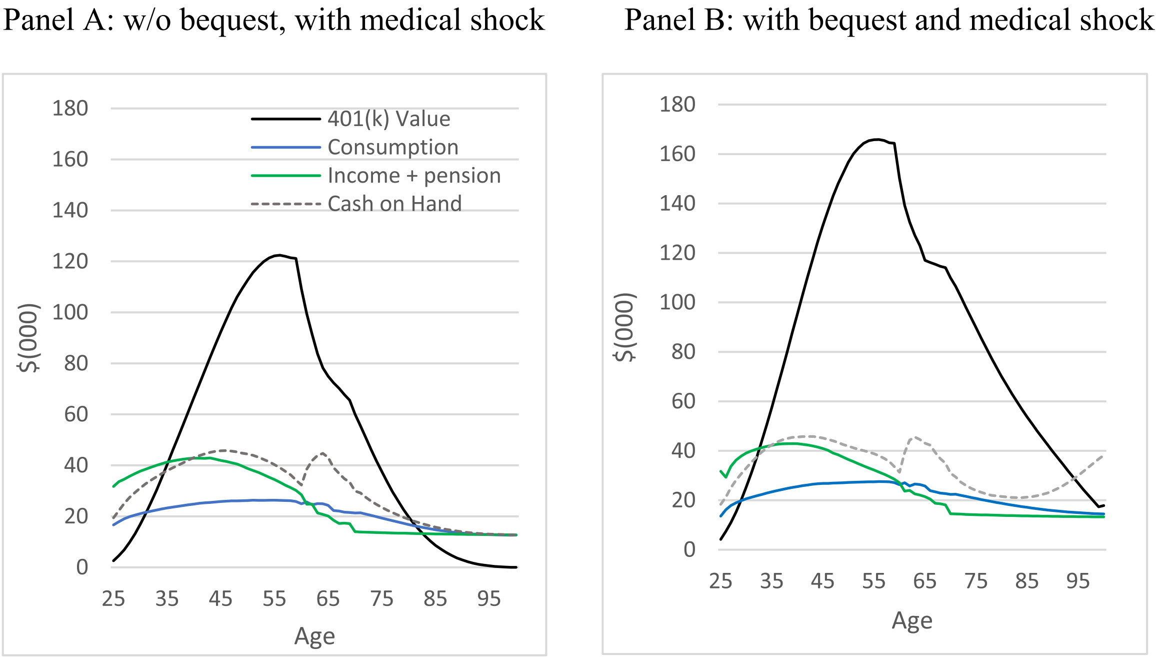

Fig. E1. This Figure shows expected values for consumption, cash on hand, income (work, social security benefits), and 401(k) assets generated by our life cycle model (for the RMD_{72} rule) with persistent medical shocks. In Panel A (B), individuals lack (have) a bequest motive. The absorbing probability of bad health status is 5% from age 70 onwards. Bad health results in 20% permanent reduction of retirement income and remaining survival probabilities. Expected values are calculated using 200,000 weighted simulated lifecycle paths based on optimal feedback controls for individuals in each of the six subgroups. Population averages use education weights for the female (male) population: 61% +Coll; 28% HS; 11% <HS (57% +Coll; 30% HS; 13%<HS); weights for females (males) 49.28% (50.72%) of entire population. The preference parameters are as follows: risk aversion $\rho = 5$; time $\beta = 0.96$; leisure $\alpha = 1.5$; bequest $b = 3$ ($b = 0$ no bequest). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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